Lecture Notes on Data Engineering and Communications Technologies 157

Igor Ilin
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Digital Technologies in Logistics and Infrastructure

Springer

Lecture Notes on Data Engineering and Communications Technologies

Volume 157

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Digital Technologies in Logistics and Infrastructure

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ISSN 2367-4512 ISSN 2367-4520 (electronic)
Lecture Notes on Data Engineering and Communications Technologies
ISBN 978-3-031-24433-9 ISBN 978-3-031-24434-6 (eBook)
https://doi.org/10.1007/978-3-031-24434-6

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

The active development of communications (cargo flows, financial flows, data flows) and the parallel development of digital technologies have made it possible to implement fundamentally new business models, implement new devices, and create new communication networks. The combination of logistics and digital technologies is of particular interest to researchers as the integration of material and information flows. Spheres related to the infrastructure support of states, regions, and industries (logistics, health care, banking, etc.) have changed their glare significantly with the introduction of digital technologies.

The conference "Digital Technologies in Logistics and Infrastructure" (ICDT-2021) is dedicated to promoting dialogue between industrial, academic, and research society in the field of maritime, transport, warehouse logistics, the digital transformation and information technologies in logistics, as well as the digital transformation of infrastructure industries.

The ICDT-2021 conference is the third one, and during the past three years, it has become an attractive discussion event that attracts attention of the international logistic- and infrastructure-oriented researchers and practitioners.

The proceedings of the ICDT-2021 highlight different aspects, challenges, and solutions in logistics and digitalization from both theoretical and practical points of view. The papers collected show that professionals and researchers from different countries and industries are dealing with very similar and also very different problems for which science can offer promising solutions. At the conference, the widest range of issues of digitalization of the logistics sector was discussed: enterprise architecture approach in developing effective solutions for maritime and transport logistics; digital platforms; cases of different industries digitalization (oil and gas and refineries, health care, railway transport, multimodal logistics, etc.). The authors of the conference are representatives of large companies, as well as researchers and scientists from Russia, Hungary, Armenia, Kazakhstan, Thailand, the Netherlands, and Finland.

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Methods of Recognition and Classification of Objects in Digital Logistics

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Abstract. The actual problem of digital logistics of recognition and classification of objects – vehicles from video cameras of the road network is considered. The purpose of recognition and classification is to detect trucks and cars for solving the logistic problem of analyzing the density of freight traffic from video cameras. To solve the problem in the work, we analyzed the classical methods of machine learning: "neural differential equations", "decision tree", "gradient amplification trees", "logistic regression", "Markov model", "naive Bayesian", "nearest neighbors", "random forest", "machine support vectors". The authors proposed a new method of autonomization of neural differential equations, which allows to increase the accuracy and productivity of recognition and classification. For recognition and classification methods, the accuracy, computation time, training time, memory size for training, and computation speed are examined. Comparative analysis of the methods is carried out based on a computational experiment for datasets of nine hundred objects. The computational experiment shows an increase in the speed of learning and computations for neural differential equations using the autonomization method. The "neural differential equations" method, using the autonomization method presented by the authors, can reduce the training time of the neural network and the memory size for the classifier compared to other traditional methods. Application of the autonomization method for the "neural differential equations" in recognition and classification problems is optimal from the point of view of speed and accuracy of calculations in digital logistics.

Keywords: Digital logistics · Recognition methods · Classification methods · Neural differential equations · Autonomization method

1 Introduction

The paper deals with the actual problem of object recognition used in digital logistics. The problem of digital logistics of recognition and classification of objects – vehicles from video cameras of the road network is considered. The purpose of recognition and classification is to detect trucks and cars for solving the logistic problem of analyzing the flow density of freight vehicles from video recording cameras. To solve the problem

I. Ilin et al. (Eds.): ICDT 2021, LNDECT 157, pp. 1–14, 2023.
https://doi.org/10.1007/978-3-031-24434-6_1

in the work, we analyzed the classical methods of machine learning: "neural differential equations", "decision tree", "gradient amplification trees", "logistic regression", "Markov model", "naive Bayesian", "nearest neighbors", "random forest", "machine support vectors". The authors proposed a new method of autonomization of neural differential equations, which allows to increase the accuracy and productivity of recognition and classification.

The accuracy of computer analysis of video information is growing all the time and the use of digital logistics can provide great cost savings along with improved quality. The recognition problem in machine learning should be considered as a matter of assigning an object to a predefined class according to a formalized attribute. At the same time, each of the objects in the task at hand is shown as a vector in an N-dimensional space, the dimensions of which are descriptions of one of the object's attributes. It should be mentioned, that the training of the classifier is carried out using a set of objects with predefined classes. The set is called a training sample, the markup is done manually, with the involvement of specialists in this subject area.

Many methods and their implementation in computer programs for object recognition and classification are known. Many scientific works are devoted to the problems of digital logistics and intelligent transport systems [1–5].

The method of decision tree [6] is used for recognition and classification. Classification is also performed using an ensemble of trees trained with gradient boosting [7]. In the logistic regression method, the probabilities of linear combinations of characteristics are used [8]. Markov models for a sequence of features are used for classification [9]. Classification is widely used, which assumes the probabilistic independence of features [10] and classification by examples of the nearest neighbor [11]. Classification using ensembles of Breiman-Cutler decision trees [12] and classification using support vector machine [13] are applied. To solve the classification issue in artificial neural networks, an innovative approach of neural differential equations is used [14].

In this work, the authors present a new method of autonomization for neural differential equations, conduct a comparative experiment for various applied classification methods. The "neural differential equations" method, using the autonomization method presented by the authors, can reduce the training time of the neural network and the memory size for the classifier compared to other traditional methods. Also, in terms of accuracy and calculation speed, the "Neural differential equations" method with integrated autonomization is comparable to the "Logistic Regression" method. For the numerical solution of the neural network, the authors presented a new scheme of the third-order Runge-Kutta method, which makes it possible to increase the speed of computations.

In digital logistics, you can specify several basic methods used for object recognition and classification. In the study, we will carry out a comparative analysis of the following methods: "decision tree" [15], "gradient boosted trees" [16], "logistic regression" [17], "Markov model" [18], "naive Bayes" [19], "nearest neighbors" [20], "random forest" [21], "support vector machine" [22], "neural differential equations" [23]. But not all methods are optimal in terms of accuracy and computation time.

For each method, several limitations determine the area of application. For example, the "support vector machine" method is noise sensitive and relies on data standardization.

For the "naive Bayes" method, it is necessary to transform the original data on an interval scale to avoid the loss of meaningful information.

One of the most urgent problems used in digital logistics is object classification. The "decision tree" method [15] classifies using a decision tree. Modeling the likelihood of classes using a decision tree based on the CART algorithm is carried out by the decision tree regression classifier. The gradient boosted trees method [16] classifies using an ensemble of trees trained with gradient boosting. By iteratively training a sequence of decision trees of the training data and combining them, a gradient boosted tree predictor predicts values and labels. The "logistic regression" method [17] is classified using the probabilities of linear combinations of characteristics. In a statistical logistic regression model, predicting the occurrence of an event is done by fitting the data to a logistic curve. Using the parameters of a set of characteristic features for predicting the probability of occurrence of events, it is possible to use this method.

Using logistic functions of linear combinations of features, the logistic regression classifier models class probabilities. This, in turn, can be defined as a linear model, maximum entropy classifier, or softmax regression.

The "Markov model" method [18] classifies using the Markov model according to the sequence of features. It has been observed, that statistical hidden Markov methods or models have been studied already in the 1960s and 1970s. However, it has gained popularity and widespread distribution only in the last decade. The recent popularity of these methods can be attributed to the following two factors. The first reason to be mentioned is the mathematically rich structure of the Markov model. Consequently, it is possible to formalize the theoretical basis for a wide and varied range of issues. Secondly, the practical application of hidden Markov models allows one to obtain very high results. We can say that the Markov model refers to statistical methods that are very significant in the classification of the observed data sequences. It should be remembered that to use the Markov model in real applications, there are three main tasks to pay attention to evaluation, decoding, and training. To predict the class in the Markov classifier of order 0, Bayes' theorem is applied. It is assumed that in the Markov classifier, tokens are generated independently for a given class. For this, there is a definition of a naive Bayesian model or unigram.

The "naive Bayes" method [19] classifies, assuming the probabilistic independence of features. The naive Bayesian classifier also uses Bayes' theorem to predict the class, and features are generated independently of the class [24]. There are systems for detecting objects in images based on the "naïve" Bayesian method. This method builds the empirical probability density of classes for the training sample. The method is based on the assumption that the components of the feature vector should be independent. The problem of weak conditioning is solved by choosing a compact representation of the feature vector. This approach is an approximation of the method of maximum posterior probability and therefore does not have the optimal overall risk. It should be noted that the method depends on the selected transformation module. As a rule, features are rather complex characteristics of an image of an object of interest, selected heuristically. Practical results show that about 91% of correct detections and about 0.2% of false positives in the classification task.

The algorithm for constructing a "naïve" Bayesian classifier is prone to overfitting. It should be noted, that the algorithm for constructing a "naive" Bayesian classifier is sensitive to noise since based on empirical distribution density functions. The speed of the classifier itself is extremely high; the main time may be occupied by the calculation of the feature vector. Bayesian networks (trust networks) are an approach to classification based on a combination of the Bayesian approach and graph theory. A graph is built, each vertex of which corresponds to some component of the feature vector, arcs denote a causal relationship. The construction of the network can be carried out automatically by analyzing the correlation of the components of the feature vector. Such an approach does not require such strong assumptions, as the principle of maximum a posteriori probability, however, it does not have theoretical attractiveness, that is, in the absence of a priori data, the constructed network will not deliver a minimum of the overall risk. Bad conditioning, however, is also a problem for a Bayesian network, since the large dimension of the feature vector makes the link graph very difficult to construct and analyze. The computational complexity also increases dramatically. There is a known solution to the issue – the possibility of reducing the dimension of the vector of features, but it should be noted, that this option reduces the generalizing.

If we consider Bayesian networks in relation to the problem of object classification in images, then the following results can be mentioned:

– 90% correct detections with 0.4% errors of the second kind for the problem of face classification;
– Bayesian networks are said to be sufficiently sensitive to noise. However, there has been no deeper research into this issue;
– It is claimed that the method is resistant to overfitting;
– Computational complexity linearly depends on the dimension of the feature vector.

Speed data for real systems are not published. It is also possible to note the good efficiency of the method based on "naïve" Bayesian learning and careful selection of the representation of feature vectors for a specific task.

The "nearest neighbors" method [20] classifies by example the nearest neighbor. The class of the new example is found by the "nearest neighbors" classifier using the analysis of the nearest neighbors in the feature space. This classifier, in its simplest form, chooses the most general class from the k-nearest neighbors. It should be emphasized that the implementation of the algorithm for the k-nearest neighbor's classification method is relatively simple. This makes it possible to compare the classification results of other algorithms with the k-NN algorithm [25].

It should be added that the metric classification algorithm (k-nearest neighbors method) is based on the analysis of the similarity of objects.

The "random forest" method [21] classified using ensembles of Breiman-Cutler decision trees. The random forest classifier performs class prediction using an ensemble of decision trees. Each decision tree applies only a random subset of functions already trained and prepared on a random subset of the training set. Random Forest - an ensemble of decision trees built according to special rules.

The following stages of model training can be distinguished:

- Selection from the initial training set of objects of a random subset with repetitions, the number of objects is equal to the number of objects in the original set (bootstrap). This subset is used to train a single decision tree.
- Building a decision tree by the CART algorithm, but at each step, not all variables are considered, but only a small randomly selected part of them (tuning parameter of the model).
- N trees are built up to the maximum depth.

Since the models are resistant to overfitting, adding trees to the ensemble does not reduce the predictive power. In most cases, 500 trees are sufficient. The choice of the number of variables that are considered when constructing each node of the tree has the greatest impact on the final model. Empirical studies suggest that for regression problems the optimal number of variables is N/3 for the classification sqrt(N).

The advantages of the method, inherited from decision trees, include the following:

- nonlinear nonparametric method,
- does not require selection of variables,
- able to work with numeric and nominal variables.

Own advantages:

- resistance to retraining,
- resistance to changes in input data,
- fast learning process.

Disadvantages of the "random forest" method:

- impossibility of extrapolation.
- complexity, and often impossibility of interpretation.

The "support vector machine" method [22] classifies using a support vector machine. The "support vector machine" method can be used to split training data into two classes using a hyperplane with maximum margin. Support Vector Machines are a family of binary classification algorithms based on supervised learning that uses linear division of the feature space using a hyperplane. Supervised learning is a line of machine learning that combines algorithms and methods for constructing models based on a set of examples containing known input – known output pairs. Thus, for the algorithm to be related to supervised learning, it must work with examples that contain not only a vector of independent variables (attributes, features) but also the value that the model must produce after training (such a value is called the target value). The main idea of the method is to map the vectors of the feature space, representing the classified objects, into a space of a higher dimension. This is due to the fact that in a space of higher dimension the linear separability of the set turns out to be higher than in a space of lower dimension. The reasons for this are intuitive: the more features are used for object classification, the higher the expected classification quality. It is possible to map the original feature space to a higher dimension to improve linear separability. The multiclass classification question is converted into a set of binary classification problems.

The “neural differential equations” method [23] classifies using an artificial neural network using differential equations. Layers of artificial neural units make up neural networks. In turn, the unit calculates its value as a function of the unit values at the previous level. You should process the information layer by layer from the feature layer to the output layer to determine the probability of the class. It is defined as a feed-forward neural network or multilayer perceptron.

Differential equations in neural networks are used to solve the problem of damped gradients when training deep neural networks. This minimizes the problem of fading gradients and provides the desired accuracy and training time. The authors proposed to apply the autonomization method for neural differential equations based on polynomial transformations.

2 Materials and Methods

This section discusses the method of autonomization for neural differential equations. Let’s present an autonomization method for solving neural differential equations. The method has high accuracy with low computational complexity of the algorithm. In accordance with the method, the system is reduced to normal form, a linear transformation and a polynomial transformation are performed.

Here are the main stages of the autonomization method presented by the authors. The implementation of the autonomy method in neural differential equations allows an order of magnitude to increase the speed of the neural network during training.

The neural differential equations dataset is fitted with a polynomial of a given degree to provide the required accuracy. As a result of the approximation, the nonlinear function of neural differential equations can be represented by a high degree polynomial.

At the first stage of the method, the system is reduced to normal form. Let’s write the investigated differential equations in normal form:

$$S' = CS + \sum_{|\nu|=2}^{n} k_\nu \prod_{i=1}^{m} s_i^{\nu_i} \tag{1}$$

where S – the required vector of states for neural differential equations, C – square matrix of constants of the linear part of the system, k – constant coefficients of the nonlinear part of the system. The nonlinear part is represented by a polynomial of degree n.

From the neural differential equations, the transition to Eq. (1) occurs by means of polynomial approximation, as a result of which, from the coefficients of the polynomial, we obtain the coefficients c of the linear part and k for the nonlinear part.

Here, the notation uses the vector index and the norm:

$$\nu = (\nu_1 \nu_2 \nu_3 ... \nu_m),\ |\nu| = \nu_1 + \nu_2 + \nu_3 + ... + \nu_m,\ 0 \le \nu_i \le n. \tag{2}$$

In the second step of the method we carry out a linear transformation of the system:

$$X = LS \tag{3}$$

Defining a non-degenerate matrix L.

As a result of linear transformation (3), the original system (1) is transformed to the form with a diagonal linear part.

$$X' = \Lambda X + \sum_{|\nu|=2}^{n} l_\nu \prod_{i=1}^{m} x_i^{\nu_i} \tag{4}$$

where X is the new required vector of states for neural differential equations, Λ – the square diagonal matrix of the roots of the linear part of the system $\Lambda = diag[\lambda_1, ..., \lambda_m]$, l – constant coefficients of the nonlinear part of the system after linear transformation.

At the third stage of the method we carry out a polynomial transformation of the form:

$$x_S = y_s + \sum_{|\nu|=2}^{n} a_\nu^s \prod_{i=1}^{m} y_i^{\nu_i} \tag{5}$$

where a_ν^S – transformation coefficients.

As a result of the polynomial transformation (5), we obtain a system with a diagonal linear part:

$$Y' = \Lambda Y + \sum_{|\nu|=2}^{n} q_\nu^S \prod_{i=1}^{m} y_i^{\nu_i} \tag{6}$$

where q_ν^S – the coefficients of the transformed system.

Y – the transformed desired vector of states for neural differential equations.

The coefficients q_ν^s and a_ν^s are found by the iterative formula:

$$\sum_{|\nu|=2}^{n} q_\nu^S \prod_{j=1}^{k} y_j^{\nu_j} + \sum_{|\nu|=2}^{n} \left(a_\nu^S \prod_{j=1}^{k} y_j^{\nu_j} \left(\sum_{i=1}^{k} \lambda_i \nu_i - \lambda_S \right) \right) +$$
$$\sum_{i=1}^{k} \left(\sum_{|\nu|=2}^{n} a_\nu^S \prod_{j=1}^{k} y_j^{\nu_j} \nu_i y_i^{-1} \sum_{|\mu|=2}^{n} q_\mu^i \prod_{j=1}^{k} y_j^{\mu_j} \right) \sum_{|\nu|=2}^{n} r_\nu^S \prod_{j=1}^{k} y_j^{\nu_j}.$$

The transformed system (6) is autonomous and much simpler than the original (1) and contains an order of magnitude fewer nonlinear components in the polynomial, which greatly simplifies its solution and the computational complexity of calculating the right-hand sides of the equations.

For the numerical solution of the simplified transformed system (5), the scheme of the numerical Runge-Kutta method with an adaptive step is used.

For the next stage of the method, the authors proposed a new scheme of the third-order Runge-Kutta method, which makes it possible to increase the speed of calculations. The formulas of the third-order Runge-Kutta method have the following form:

$$Y' = F(t, y),\ t_{n+1} = t_n + h_n,\ y_{n+1} = y_n + k_1/6 + k_2/3 + k_3/2,$$
$$k_1 = h_n F(t_n, y_n),\ k_2 = h_n F(t_n + h_n/2, y_n + k_1/2),\ k_3 = h_n F(t_n + 3h_n/4, y_n + 3k_2/4)$$

The adaptive step is determined by the formula:

$$h_{n+1} = h_n/(max|k_1/18 - k_3/18|)^{-0.2}$$

The presented method makes it possible, without decreasing the accuracy, to reduce the number of polynomial components by a hundred times and to efficiently solve the neural differential equations. The autonomization method allows you to lower the degree of the polynomial and reduce the computation time several times. As a result, the solution of a system of nonlinear differential equations in the neural differential equations is obtained.

3 Results

This section presents a description of the computational experiment. A computational experiment for the recognition and classification of trucks and cars is carried out on a set of 900 images from a road video camera. Examples of images are shown in Fig. 1.

Fig. 1. Traffic camera images for recognition and classification.

Figure 2 shows the dependences of the classification accuracy as a percentage of the number of training examples constructed by the following methods: "decision tree", "gradient boosted trees", "logistic regression", "Markov model", "random forest", "naive Bayes", "nearest neighbors", "support vector machine", "neural differential equations".

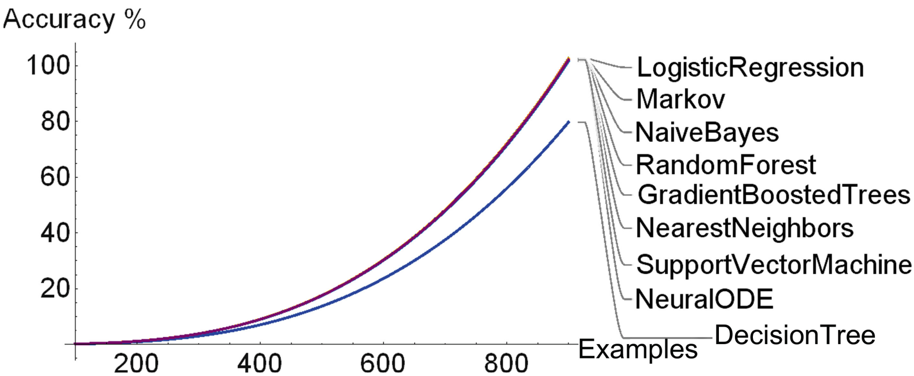

Fig. 2. Dependences of the classification accuracy.

Figure 3 shows the dependence of the training time in seconds on the number of examples constructed by the methods. The shortest time for the methods: "neural differential equations".

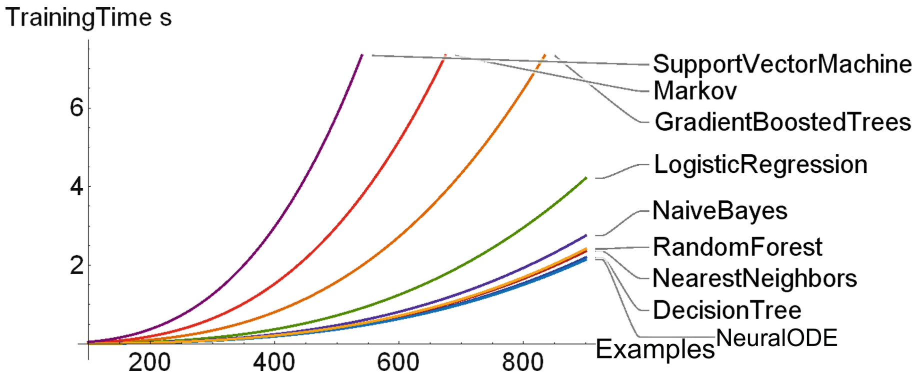

Fig. 3. Dependences of the training time in seconds on the number of examples.

Figure 4 shows the dependences of the evaluation time in milliseconds per example by the considered methods. The fastest evaluation time per example for methods: "Gradient Boosted Trees", "Support Vector Machine".

The evaluation time for the "neural differential equations" method is similar to the time for "logistic regression".

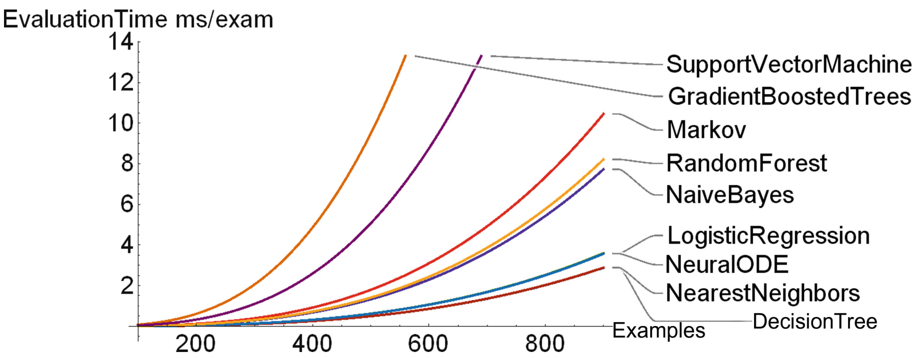

Fig. 4. Dependencies of evaluation time in milliseconds per example.

Figure 5 shows the dependence of the memory for the classifier on the number of examples constructed by the methods.

The smallest amount of memory for a classifier in methods "Gradient Boosted Trees" and "neural differential equations".

Figure 6 shows the dependence of the maximum memory used during training on the number of examples.

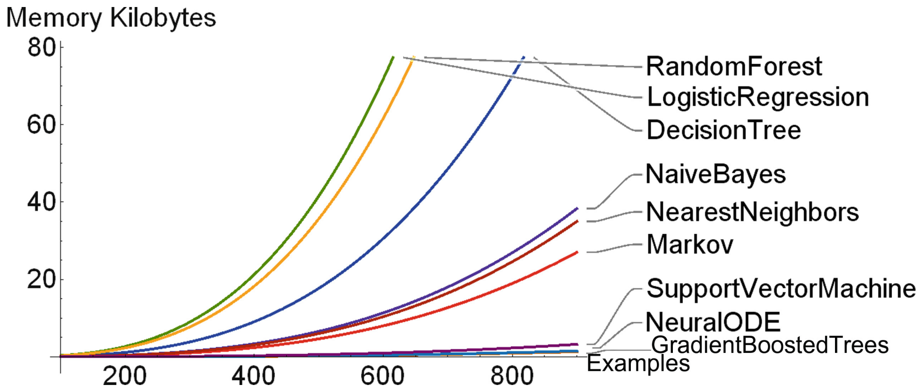

Fig. 5. Dependences of the memory for the classifier on the number of examples.

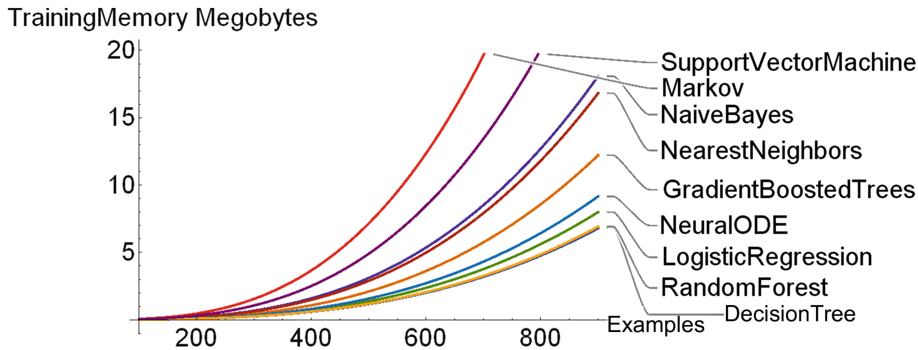

Fig. 6. Dependences of the maximum memory used during training on the number of examples.

The maximum memory used during training is the smallest for methods: "neural differential equations", "logistic regression", "Random Forest", "Decision Tree".

4 Discussion

As a result of a computational experiment, two classes of objects appear for the analyzed image: cars and trucks. After performing recognition and classification of objects, we have a set of objects for each image (Fig. 7). To calculate the flow density, it is necessary to track the events of the entry and exit of cars and trucks into the image frame.

Table 1 shows the results of a computational experiment - estimated accuracy of the classifier in %.

Comparative analysis of the data in Table 1 shows the best similar accuracy for the methods "logistic regression", "Markov", "naive Bayes", "neural differential equations".

Table 2 shows the results of a computational experiment – batch evaluation speed.

Comparative analysis of the data in the table shows the highest speed of batch calculations for the methods: "Logistic Regression", "Nearest Neighbors", "Neural differential

Fig. 7. Object definitions for classification.

Table 1. Accuracy.

Method	Accuracy %
"Decision Tree"	79.97
"Gradient Boosted Trees"	93.60
"Logistic Regression"	98.52
"Nearest Neighbors"	92.37
"Markov"	98.52
"Naive Bayes"	97.12
"Neural differential equations"	97.55
"Random Forest"	96.47
"Support Vector Machine"	85.40

Table 2. Batch evaluation speed.

Method	Batch evaluation speed examples/milliseconds
"Decision Tree"	4.29
"Gradient Boosted Trees"	3.56
"Logistic Regression"	4.67
"Markov"	3.61
"Naive Bayes"	3.06
"Nearest Neighbors"	4.23
"Neural differential equations"	3.75
"Random Forest"	2.63
"Support Vector Machine"	2.15

equations", "Decision Tree". The obtained results of the computational experiment agree with the asymptotic estimates of the computational complexity of the methods.

Thus, the "Neural differential equations" method with the implementation of the autonomization method presented by the authors can reduce the training time of the neural network and the memory size for the classifier compared to other traditional methods.

Also, in terms of accuracy and speed of calculation, the "Neural differential equations" method with embedded autonomization is similar to the "Logistic Regression" method.

5 Conclusion

The actual problem of digital logistics of recognition and classification of objects – vehicles from video cameras of the road network is considered. The purpose of recognition and classification is to detect trucks and cars for solving the logistic problem of analyzing the density of freight traffic from video cameras. To solve the problem in the work, we analyzed the classical methods of machine learning: "neural differential equations", "decision tree", "gradient amplification trees", "logistic regression", "Markov model", "naive Bayesian", "nearest neighbors", "random forest", "machine support vectors". The authors have proposed a new method for autonomization of neural differential equations, which allows to increase the accuracy and productivity of recognition and classification.

For the recognition and classification methods under consideration, the accuracy, computation and training time, memory volume for training, and computation speed are assessed. Comparative analysis of the methods is performed based on a computational experiment for datasets of nine hundred objects.

The results of the experiment show an increase in the speed of learning and computation when applying the method of autonomization in the "neural differential equations".

The "neural differential equations" method, using the autonomization method presented by the authors, can reduce the training time of the neural network and the memory size for the classifier compared to other traditional methods. In terms of accuracy and speed of calculation, the "Neural differential equations" method with embedded autonomization is similar to the "Logistic Regression" method.

The presented autonomization method makes it possible, without decreasing the accuracy, to reduce the number of polynomial components by a hundred times and to efficiently solve the neural differential equations. The autonomization method allows you to lower the degree of the polynomial and reduce the computation time several times. The method has high accuracy with low computational complexity of the algorithm.

The application of the "neural differential equations" method with the implemented autonomization method is the most optimal from the point of view of speed and accuracy of calculations for object recognition and classification problems.

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Prospects and Opportunities for Green Logistics Development in Russia

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Abstract. The article presents the results of the research on the specifics of green logistics development and its impact on the environment. A study of approaches to define the term "green logistics" has been conducted, its importance and need for development at the current stage of economic development has been determined. The problems and prospects for green logistics development in Russia are identified through the lens of its key functional areas: supply, production, transportation, warehousing and distribution. The key reasons for applying green logistics fundamentals in managing logistics supply chains for the state, society and people involved in the logistics supply chain are also outlined. Implementing the actions to develop green logistics in Russia which were defined in the article should form the base for the strategic goal to ensure the domestic logistics industry competitiveness and has the capacity to guide legislative initiatives, create economic and organizational environment, and introduce best practices and innovative solutions into environmental logistics management. The article determines that the compliance of the Russian logistics system with international environmental requirements and standards will not only ensure its competitive edge in the international trade, but will also give an opportunity to become a fully entitled partner in Europe-Asia supply chains due to separate link efficiency, including international transport corridors.

Keywords: Green logistics · Ecologistics · Ecologization · Environment · Transport logistics · Supply chains

1 Introduction

In modern economies that are known to worsen environmental impact and increase pollution, introducing fundamentally new approaches to production processes is extremely urgent. Environmental pressures come against the backdrop of aggravated competition for markets, increasingly more natural resources involved in production, which leads to their gradual depletion.

Russian producers' entry into foreign markets is associated with closer relations with international counterparties, intensified international transportation business and a subsequent environmental pressure. Many scientists assert that pollution is one of the major challenges mankind face. According to the study held by the American publication

I. Ilin et al. (Eds.): ICDT 2021, LNDECT 157, pp. 15–24, 2023.
https://doi.org/10.1007/978-3-031-24434-6_2

Lancet, an increase in environmental pollution entails more victims than wars, violence, disease, hunger, or natural disasters [1].

Thus, the authors state that one in six deaths across the globe is caused by toxic environmental effects. The estimate is rough, since not all countries take environmental monitoring measures. That is why there is the need to introduce fundamentally new approaches to economic operations related to sustainable production and sale processes. One of the innovative tools to ensure this is green logistics that will reduce the environmental burden, logistics costs and increase business profitability and competitiveness.

The importance and the need to develop green logistics is driven by its globalization features that were outlined in the World Economic Forum in Davos one of the conclusions of which recommended to reduce logistics costs that account for about 5.5% of carbon emissions.

Over the last years, a large number of domestic and foreign scientists have devoted their research to develop green logistics mechanism and introduce it into business management. Scientists note that green logistics is one of the key tools to ensure the sustainable development model, capable to implement the mechanisms of sustainable development in practice and will develop into a reliable way of environmental protection.

Thus, F.G. Adams, S.B. Gabler and V.M. Landers note that "environmentally-focused business logistics has formed ecologistics – a system forming and managing logistics processes (transportation, warehousing, production movement, recycling) in order to limit negative environmental impacts. To be effective in current conditions, logistics is to be consistent with environmental strategies" [2].

S. Loutra, D. Garg and A. Halim determined that ecologistics practices can effectively reduce negative environmental impacts and support or improve cost reductions, energy conservation and competitiveness [3].

T.V. Kobylinskaya suggests using two green logistics proxy variables, such as Logistics CO2 (LCI) and Ecologistics Performance Index (ELPI) severity, to assess green logistics effectiveness. The researcher emphasizes that the use of ecologistics performance indices and their improvement will help to improve international competitiveness factors, such as improving infrastructure, assistance in improving the quality of logistics services and intensifying the use of modern information technologies to improve customs and logistics tracking efficiency [4].

However, though significant improvements in logistics and ecologistics have been made, the potential for ecologistics to develop in Russia is understudied in the context of sustainable development.

The aim of the article is to study peculiarities of ecologistics and determine the potential for its development in the current Russian economy development.

2 Materials and Methods

2.1 Research Methodology

To achieve the aim of the article, a number general scientific and special approaches were used. In particular, when studying modern views on the green logistics concept, the following methods were applied: a systemic approach, analysis and synthesis, clustering.

To ensure strategic development for green logistics, an inductive and deductive method, modeling and formalization methods were used. Tabular and graphical presentation was used to visualize data. The research works by leading foreign and domestic scientists and experts devoted to green logistics and logistics ecologization were used as the theoretical basis for the stud.

2.2 Theoretical Fundamentals

In contemporary practice, "green logistics" has many definitions. Originated in English, "green logistics" implies measures related to optimal solutions in collecting, storing, recycling and managing recycling or environmentally and socially non-pressing disposing various types of waste [5]. The term was developed as a result of raising public awareness in environmental issues. Common approaches to understanding green logistics are based on innovations and latest technologies in logistics, with regards to the minimum environmental impact.

According to the definition given by the Russian scientist N. Verstina, "green logistics" is a fairly wide and comprehensive concept that includes measures to assess and reduce the CO2 impact on natural and man-made environment resulted from business logistics, developing a system for environmentally friendly goods transportation and vehicle managing by using alternative fuels, changing the design of transport means in order to reduce the negative environmental impacts, routing logistics flows to reduce fuel and operating costs, etc. [6].

According to P. Shi, M. Oseve and A. Liu, green logistics is an environmentally friendly and efficient transport distribution system as the cost-saving strategy which logistics operators pursue tends to contradict to environment protection fundamentals and not consider ecological costs. In addition, the authors argue that green logistics focuses on loading and unloading operations, waste management, transportation and packaging [7]. More definitions of the term are presented in Table 1 that provides interpretations given by different authors and used by theorists and practitioners in green logistics ecologization.

Thus, one of the most common and comprehensive definitions of green logistics is the definition that researchers H. Dzvigol, N. Trushkin and A. Kwilinsky give. They believe that green logistics is a science that involves modern logistics techniques; a set of actions aimed to reduce the environmental impact produced by logistics [15]. Such a definition brings together the issues of production economic efficiency and environmental safety, contributes to increased competitiveness among industrial businesses, and will also be used in further research.

Green logistics is aimed to reduce the harmful environmental impacts to minimum and reduce or minimize non-renewable natural resource consumption. With that, harmful impacting implies not only exhaust gas emissions, noise and vibration produced by cars and trains, fuel and lubricant waste, packaging and spoiled products that need to be disposed of also penetrate into the ground and water [16].

Thus, the analysis of different approaches to interpret green logistics showed that when introducing green logistics fundamentals into business practices, most authors

Table 1. Green logistics interpretations.

№	Author	Interpretations
1	L.A. Cesarino, D.B. Tavares, T.B. Teisheira [8]	Planning, executing and monitoring the flow of goods and data from the place of their origin to consumption place in order to meet the needs of all stakeholders, starting with sustainable development built on social responsibility for protecting the environment and its cost-effectiveness
2	S. Khan, Yu. Zhang [9]	An example of a sustainable logistics process, which ensures a balance between environmental protection and economic profitability growth
3	T. Grühmann [10]	Managing environmental, economic and social impacts produced by the logistics system, which involves activities in key areas such as sustainable procurement, sustainable transport, sustainable development, reliable warehousing, green packaging and sustainable reverse logistics
4	S.M. Kurbatova, L.Yu. Eisner, V.Yu. Mazurov [11]	Holistic transformation in logistic strategies, processes and systems in businesses and corporate networks to create environmental and resource-intensive logistic processes which are to reduce the harmful environmental impacts and reduce the use of non-recoverable resources
5	L.Yu. Alexandrova, O.F. Kireeva, S.V. Timofeev [12]	Studying the impact on the external environment for all activities related to transportation, storage and processing of goods as they move across supply chains both forward and backwards
6	H. Nguyen, V. Pham [13]	Shifting from environmentally adverse modes of transport to environmentally friendly transport
7	P. Richnak [14]	Research and practice aimed to optimize and efficiently manage forward and reverse goods and co-current (data, financial, waste flows, harmful emissions, various natural resources and energy) flows in order to reduce the negative environmental impact to the minimum

emphasize the need to prioritize transport logistics ecologization. Other scientists consider green logistics as part of the integrated logistics management, including production, warehousing, transportation, waste management. Summarizing the above, we would define two functional areas in green logistics: reverse good flow logistics and reverse waste flow logistics (recycling logistics, logistics of waste processing and waste management, secondary business management logistics).

3 Results

Studying the literary sources and experience in logistics development in Russia and foreign countries showed that logistics is one of the most harmful activities for the ecosystem. In this regard, we believe that the range of tools to develop green logistics in Russia should consider the extent of the environmental and destructive impact that various logistics chain links produce, namely supplies (supply logistics), production (production logistics), transportation (transport logistics), warehousing (warehouse logistics), distribution (sales logistics) and innovations each link uses (see Fig. 1). Each of these produces different environmental impacts of different intensity.

Among all logistics areas, transport logistics produces the greatest impact. Harmful vehicle emissions, the use of cheap fuels, noise pollution, carbon emissions cause climate change and determine transport logistics as one of the most environmentally destructive areas. Carbon monoxide emissions dominate in the total emission pattern. It is a major challenge today that causes a climate change and is a top priority to solve globally.

Green logistics helps to solve the problem since it takes into account transport ecological safety – in particular, rail or water transport is most often used, which optimizes the delivery links and reduces pollution. Noteworthy, Russia has the developed railway transportation, its network is one of the largest in the world. In addition, geographical location is the reason for intense involvement of water transport in transport. Thus, green logistics has a fairly high potential for development. However, in order to fully utilize the water and rail transport system, the major focus must be laid on improving the quality of transport infrastructure, which involves creating favorable conditions to develop logistics companies, raise capital to replace obsolete fixed assets, improve the regulation and control system in order to optimize interaction and mutual agreement among different modes of transport, build an effective system based on new environmental management that will mitigate negative external impacts.

Transport logistics solutions such as optimizing transportation routes, reducing the number of transport operations by ensuring full loading and loading on-the-way, consolidating goods, using vehicles with more environmentally friendly engines, high-quality fuel, etc., can also be effective.

Introducing the intelligent systems for cargo management and tracking at all transportation stages, which not only optimizes routes but ensures an increase in revenues and a decrease in logistics costs as well, can play a significant role in transport logistics ecologization [17]. Currently, digitalization has a tremendous influence on transport logistics. Internet of Things technology is widely used in transport logistics, but its capabilities are nowhere near exhausted. Unmanned vehicles can also be widely used in the future. The survey showed that only 28% of transport and logistics businesses estimate

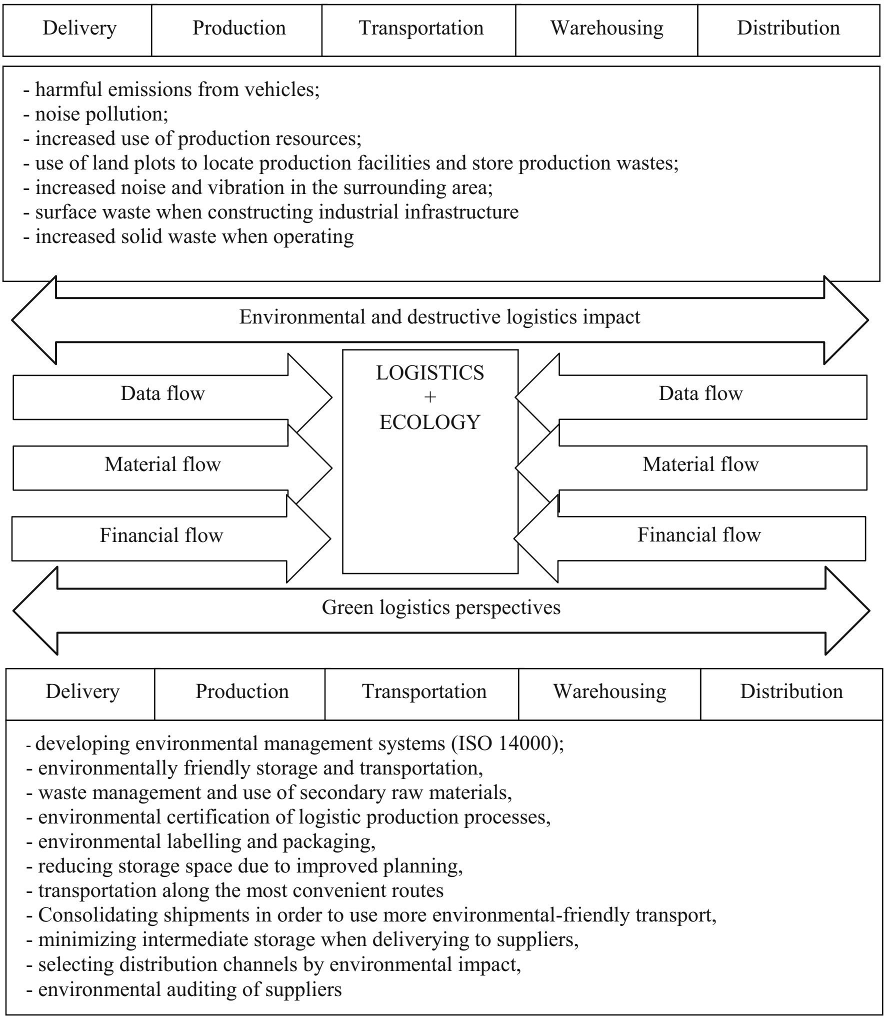

Fig. 1. Challenges and prospects for green logistics in Russia.

their digital development as "advanced" [18]. According to [19], the use of Big Data technology optimizes complex distribution systems, logistics, and production networks, resulting in 20 to 30% reduction in inventory costs.

The second largest impact on the environment is produced by production logistics, which leads to an increase in the use of production resources; use of land plots to locate production facilities and store production wastes; increased noise and vibration in the surrounding area; surface waste when constructing industrial infrastructure. Production logistics can be eclogized by introducing an environmental management system into a business which is based on ISO 14000 standards, using modern green technologies in production, ensuring resource saving and energy saving, using raw materials to full advantage, reducing production waste to minimum. In addition, comfortable and environmentally friendly working conditions must be ensured.

Sales logistics produces its impact on environment with increased solid waste when operating; spills, leaks, evaporation of goods through poor-quality packaging. Recent research held by scientists and practitioners has formed the basis for the latest approach to waste management. In particular, a focus was announced to build a closed-loop economy instead of the traditional linear one, which provides for the rational use of resources to reduce the negative impact on the environment [20]. There is also a five-stage hierarchy to waste management, which includes preventing waste generation, creating opportunities to reuse it or recycle if impossible, other types of waste management, and waste burial in designated places in compliance with environmental standards. The approach requires a set of successive steps to achieve the goal by both the state and civil society. These include the least volume of materials put in landfill, packaging, transition to reuse of things and materials, compost organic waste, reduce the waste toxicity and hazards. This is the baseline minimum to waste preventive measures. Obviously, most proposals are aimed to resolve the secondary resource use. One of the examples to use green logistics mechanism is introducing waste management and a recycling system, which involve sorting waste in order to determine its qualitative and quantitative composition.

Environmental challenges in warehousing logistics caused by warehousing facilities that consume energy and water resources emit greenhouse gases as a result of warehouse transport operation, and affect the area surface. However, the packaging system has the greatest negative warehousing effect on the natural environment. The following prospects for green logistics to develop in the warehousing system are considered today: the use of energy-saving technologies (warehouse winterization, the use of wind turbines and solar panels); inventory optimization; the use of environmentally friendly package; establishing the system when they are returned, sorted and processed.

In distribution logistics, when estimating an environmental impact and environment friendliness, distribution channels are analysed because they are closely related to marketing. Thus, market conditions are investigated to establish a rational distribution channel. Consumers have formed their ecological culture, that is why it is necessary now to take into account consumer's environmental needs regarding the capacity to reuse and process packaging, create channels for inverse product flow.

An important role in the further green logistics development in Russia is played by the incentives for logistics supply chain members (see Fig. 2).

Studying the incentives for logistics greenification and the key benefits that companies receive not only indicates their focus on image, but is also aimed to improve the efficiency of business processes and reduce costs. In this regard, a new concept and a new corporate social responsibility of a business, its ecologization and greenification, due the latest logistics concepts introduced mainly, can be considered. Such social responsibility is peculiar to and can be implemented mainly in large companies that have great financial resources to apply these changes.

Substantial costs to implement environmental concepts can be cited as a deterrent to introducing green logistics approaches in supply chain management. This naturally leads to an increase in the price for the end product for consumers. On the contrary, logistics costs are often even reduced due to the use of environmentally friendly technologies.

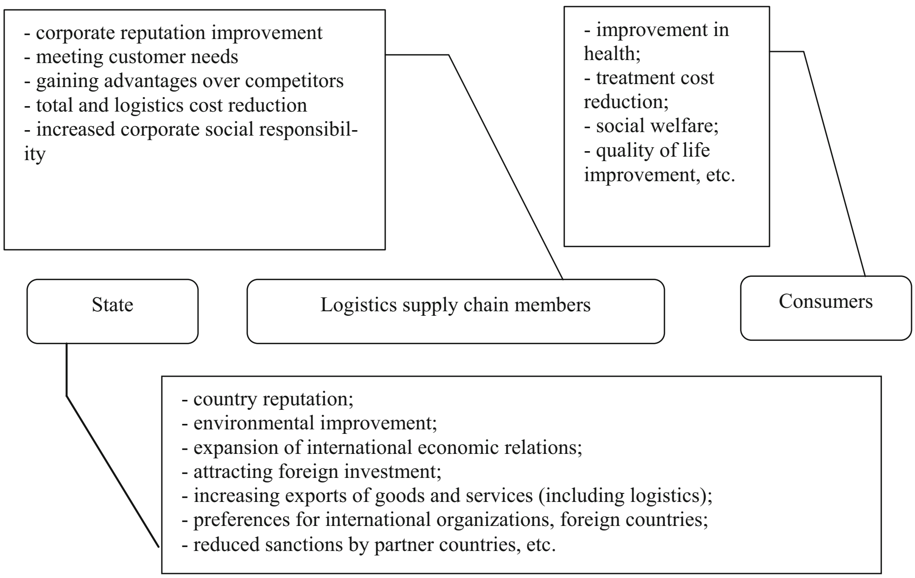

Fig. 2. Incentives to apply green logistics mechanisms in supply chain management.

Thus, environmental factors in logistics today cannot ignore either individual supply chains members, or the state when developing its logistics system. Quality service leads to competitive advantages, consumers' commitment to products produced by a business, building reputation and improving business financials, which is the ultimate goal of business logistics.

4 Discussion

Thus, the study showed that green logistics includes a wide range of business activities in all its functional areas. Implementing the actions to develop green logistics in Russia which were defined in the article should form the base for the strategic goal to ensure the domestic logistics industry competitiveness and has the capacity to guide legislative initiatives, create economic and organizational environment, and introduce best practices and innovative solutions into environmental logistics management. The study identified the following potential for further development: (1) analyzing the costs to implement ecologizing measures in business logistics in the context of the total logistics costs of a business; 2) studying ecologizing measures that can be applied in business logistics processes and justifying implementation financial efficiency.

5 Conclusions

Strengthening economic relations in the domestic and foreign markets will lead to intensified production, logistics is no exception. As a result, the volume of products produced increases, which leads to an increase in emissions and waste products. All this requires developing fundamentally new approaches to economic activity, one of which is the use of green logistics.

The following conclusions can be drawn about the studies carried out in the article:

1. Environmental focus of business logistics has led to the emerged green logistics – a system forming and managing logistics processes (transportation, warehousing, production movement, recycling) in order to limit negative environmental impacts. To be effective in current conditions, logistics is to be consistent with environmental strategies.
2. Green logistics tackles the issue of carbon dioxide emissions, as it directly deals with the choice of transport and a carrier, determines the optimal patterns and routes for goods delivery, and the like. Potential reserves to improve environmental friendliness when using road transport can include: correct vehicle choice, full load, estimating shortest routes, associated loads, use of high-quality fuel and its savings due to high driver proficiency
3. Waste management reduces energy consumption, reduces pollutant emissions and saves raw materials. In addition, firms improve their competitiveness and financial performance. In the near future, suppliers will be evaluated in the light of environmental factors. Decrease in energy consumption is significant for saving and results from implementing green supply chain solutions. When dealing with household waste, ecologizing principles should be used, and secondary raw materials should be referred to as goods necessary for new product manufacturing.
4. Prospects for green logistics development in the Russian economy involve the use of appropriate products and raw materials, which in the future will provide for processing or disposal with the least harmful impact on the environment; balanced approaches to warehouse planning and management, which contributes to reducing waste; optimizing routes when transporting goods; increase in the railway transport, using water transport, reducing delivery time, reducing vehicle empty run, using environmentally friendly packaging.

Creating the logistics system, logistics market members should be mindful of the environmental impacts they produce, thus facilitating implementation of a wider range of measures to achieve long-term perspectives.

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Ice Reconnaissance Data Processing Under Low Quality Source Images

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Abstract. The ice reconnaissance task is extremely important for maritime logistics in high latitudes as the results of its solution are the basis for the development of rational ship routes in high latitudes areas. The intermediate result of ice reconnaissance is a huge corpus of aerial survey data of poor quality. Since the amount of aerial survey data is extremely high, it is necessary to ensure the maximum efficiency of its data processing under low quality source images. The paper considers the issues of highly efficient automation of ice reconnaissance data processing based on the use of machine learning methods. In particular, the problem of automatic classification of the sea-ice floe size distribution (FSD) type for a three-class model based on aerial survey data is solved. The case of low-quality images is considered, which a usual situation is for meteorological conditions of the Far North. We have proposed a new classification method of FSD type based on aerial survey data processing using machine learning methods which is quite effective for low quality images processing. Also, an original feature space, which ensured the efficiency of this classification method, was proposed. The method has shown its high efficiency in testing it on Data Set, compiled from real low quality images (high blurriness, fuzziness, presence of meteorological disturbances). The developed algorithm is based on multi-class SVM and is extremely undemanding to computing resources, so it can be placed onboard an ice reconnaissance UAV.

Keywords: Sea-ice floe size distribution · Ice reconnaissance · Image classification · Multi-class SVM · Image histogram · Blurry images · Sea-ice type classification

1 Introduction

Shipping routes in the Northern latitudes, including the Northern Sea Route, do not have a permanent geographical reference and are formed based on a set of hydro-meteorological information, which comes to the ship. As a rule, the total length of the route, in this case, is a variable value, since throughout the route the vessel is affected by different from each other ice conditions. In this case, the tortuosity coefficient always exceeds unity, and additional increase in route length of the route in old ice due to their circumvention is 10–30% [1]. When laying routes in the Northern latitudes, the concept of a rational

I. Ilin et al. (Eds.): ICDT 2021, LNDECT 157, pp. 25–34, 2023.
https://doi.org/10.1007/978-3-031-24434-6_3

route, which best meets some formal criterion (for example: route length, travel time along the route, fuel economy and others) plays an important role [2]. The main criterion used when constructing a rational route in the Northern latitudes is the total time spent on its passage time. A rational route is usually laid through the zones where: total ice cohesion is minimal, young ice forms prevail, and ice torsion is minimal. All this information can be obtained operatively only from ice reconnaissance data. Thus, without taking into account hydro-meteorological information, which is mainly the result of ice reconnaissance, the construction of a rational route is fundamentally impossible. Therefore, the role of ice reconnaissance in the set of tasks for providing logistics in northern latitudes is extremely important. The main navigational characteristic to be monitored during ice reconnaissance is the "ice cohesion" characteristic. Ice cohesion is the ratio of the area of ice in area *X* to the total area of this area, expressed in fractions or scores [3]. Let us denote this parameter by the symbol *S(X)*. It is the parameter *S(X)* that cardinally affects the ability to navigate in a particular area of the sea [3]. More precisely: the resistance of broken ice increases in proportion to the value of $(2 - S(X)) \cdot S^2(X)$ [3]. Somewhat differently, but close in meaning, ice cohesion can be described by the concept of "floe size distribution" (FSD) [4]. There are many papers devoted to the study of FSD, e.g., [4–11], from which it follows that this FSD is well approximated by the power law. At the same time, some works consider more complex models, such as mix of power law and gaussian law or the mix of two power laws with different parameters. Depending on the type of FSD, the ice is classified into classes according to the N point system. That is, solid ice gets the maximum number of points (N), and sparse ice gets the minimum number of points. Different applications of the FSD concept imply different values of N. For example, in [12] N = 10, and in [4] N = 3. From a practical point of view, it is the ice cohesion score assigned to a particular area Ξ_i of the sea surface with an ice cohesion value $S[\Xi_i]$ that is important. Let's denote this value by γ_i, $\gamma_i = \{1, ...N\}$. In practice, the value of γ_i is calculated using the processing (manual or automatic) of some image $I(\Xi_i)$ of the surface area Ξ_i. The image $I(\Xi_i)$ can be made in one or another spectral range, this image can be obtained by one or another means of aerial photography. The data processing procedure D, which calculates the value γ_i based on $I(\Xi_i)$, , in fact, maps the set of all possible images of different parts of the sea surface (which form the set Ξ), onto the set $\{1, ...N\}$. That is:

$$\Xi \xrightarrow{\mathrm{D}} \{1, ...N\}.$$
$$\gamma = \mathrm{D}(I(\Xi_i)) \in \{1, ...N\}, I(\Xi_i) \in \Xi.$$

In fact, D is a classifier. Depending on the value of γ_i, the decision is made to include or not to include the section Ξ_i in the ship's route. It follows from this definition that γ_i is a discrete (otherwise coarse) descriptor of the value $S[\Xi_i]$.

The efficiency of D classifier implementation directly affects the correctness of determining the value of γ, and consequently, the efficiency of ice reconnaissance data implementation. Many works are devoted to methods of construction of the classifier D, for example [13–25]. Different methods of image processing are traditionally used, but the main accent is made on studying the boundaries of elements of a scene, which represents an image. In this direction, considerable progress has been made, including the use of the fashionable concept of Deep Learning [19]. In this work, Deep Convolutional Neural Network is successfully used to process ice reconnaissance data.

Against the background of huge recent achievements in the field of ice reconnaissance data, the problem remains the construction of such a classifier D, which would be able to work with images of very low quality. Namely, low-quality ice images are not uncommon when operating in the High Latitudes using UAVs equipped with visible range sensors, which is due to the chronically difficult weather conditions of this region. The images practically used to determine γ are often very blurry and highly noisy. As a rule, traditional image processing methods based on the analysis of image element boundaries (in fact: local contrast gradients and hessians) prove ineffective when processing blurred images [26]. In addition, developers are often faced with the problem of a training corpus of small volume. Also relevant is the task of ensuring the processing of ice reconnaissance data directly on board the UAV, which imposes additional requirements for optimizing the computational complexity of the algorithms for determining γ.

Therefore, the main goal of this paper is to develop a classifier D that would be operable for low-quality image processing, remain operable for training on a small volume image body, and be adaptable for implementation in the onboard complex of a small UAV.

2 Materials and Methods

2.1 Description of the Features Space Used

For automatic classification of images, explicitly or implicitly, some numerical characteristics of the image are calculated, which informatively characterize the image. Ideally, they are invariant to scale, rotation and illumination, and also have a significantly smaller dimensionality than the original image. These features are called features. Typical examples of features are: histograms, image pixel intensity, contrast gradient, contrast hessian, SIFT-descriptors (spatial histogram of the image gradients), HOG (histogram of oriented gradients) and so on. The main idea underlying the proposed method is to form such features that characterize large fragments of the analyzed image, avoiding the use of features that characterize small details. We will call the feature of the first type – global and the feature of the second type – local. The main task of ice reconnaissance is to estimate the FSD type for quite large fragments of sea surface. This problem can be solved by different methods, which allow the use of both global and local features. For example, in [8, 11, 21] both types of features are considered, and in [4, 19, 24] preference is given to the study of local features. For the case of blurred, noisy images considered in this paper, the use of fine details of the image, for example, based on the calculation of contrast gradients and hessians, is problematic. In other words, in this case, computing local features involves unacceptable errors. Local features computed in this way are uninformative and therefore unsuitable for solving the problem of FSD classification or other concepts characterizing FSD, in particular, for determining the parameter γ. On the other hand, global features are less dependent on the parameters of image blurring (although there is such dependence). The stability of global features is largely determined by the radius of correlation of the image: the larger this value is, the more stable the global features are to the effects of blurring and noisiness factor.

That is why this paper focuses on the use of global features. Initially, a fairly wide set of features was considered: more than thirty. At subsequent stages, this set was reasonably narrowed down by selecting the most informative features. Several methods were used, including three so-called "filtering" methods: chi-square, Pearson correlation and analysis of variance (ANOVA), as well as adaptive method of backward elimination. As a result, the following set of features was obtained:

$$f_{\Xi} = (\mathbf{E}[I(\Xi)], |\Xi|, ST[I(\Xi)], H_m[I(\Xi)], r_{\Xi}, E(A_{\Xi}|x \geq r_{\Xi}), st(A_{\Xi}|x \geq r_{\Xi}))$$

Here:

- $I(\Xi) = \left\{ i_x | x \in X_{I(\Xi)} \right\}$- image of Ξ, x-coordinates, $X_{I(\Xi)}$- image $I(\Xi)$ coordinate set, i_x- intensity in image point with coordinates x;
- $\mathbf{E}[I(\Xi)] = \sum_{x \in X_{I(\Xi)}} i_x |I(\Xi)|^{-1}$, hereinafter, the entry $|B|$ denotes the power of the set B;
- $|I(\Xi)| = \max\limits_{x \in X_{I(\Xi)}} (i_x) - \min\limits_{x \in X_{I(\Xi)}} (i_x)$;
- $ST(\Xi) = \sqrt{\sum_{x \in X_{I(\Xi)}} (i_x - \mathbf{E}[I(\Xi)])^2 |X_{I(\Xi)}|^{-1}}$;
- $H_m(\Xi)$- histogram of $I(\Xi)$ with m bins;
- $A_{\Xi}(l)$-autocorrelation function of the $I(\Xi)$ (averaged over different slices),$l \in (0, d)$-pixel shift; d is determined by the size of the $I(\Xi)$;
- r_{Ξ} - radius correlation of $I(\Xi)$(averaged over different slices);
- $E(A_{\Xi}(l)|l \in (r_{\Xi}, d) = \sum_{l \geq r_{\Xi}} A_{\Xi}(l)(d - r_{\Xi})^{-1}$;
- $st(A_{\Xi}|x \geq r_{\Xi}) = \sqrt{\sum_{l \geq r_{\Xi}} (A_{\Xi}(l) - E(A_{\Xi}(l)|l \geq r_{\Xi}))^2 ((d - r_{\Xi})(d - r_{\Xi} - 1))^{-1}}$.

In numerical studies it was assumed that m = 14. The features f_{Ξ} are defined in the corresponding feature space **F,** consisting of real vectors of length 20.

2.2 Description of the Data Set Used

To set up and test the proposed classifier, we used a Data Set specially created for this purpose. This Data Set included, according to the classification from [4], images of three FSD distribution classes, namely: "Pack Ice", "Marginal Ice Zone" and "Open Ocean" (Fig. 1). At statement of the problem the variant of use, so-called, "background" class was quite consciously excluded. Images of all three classes were collected from open sources. Then, in order to simulate the influence of a complex meteorological situation, the images were subjected to the procedure of artificial noising by spatially correlated noise and smoothing by a Gaussian filter.

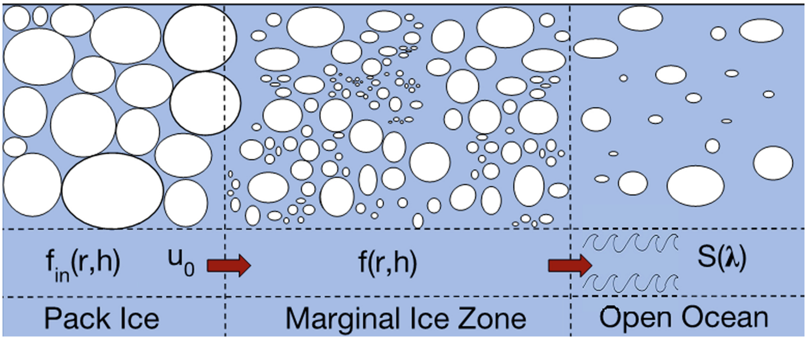

Fig. 1. FSD types used in this study. This figure is taken from the article

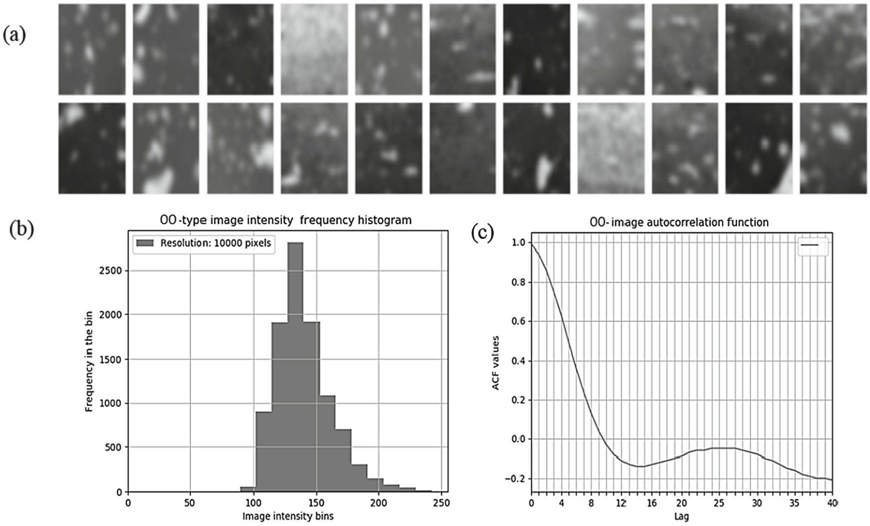

Fig. 2. Class "Open Ocean" (OO). (a) Typical sample images from the OO class. (b) Intensity histogram plotted over the entire typical image from the OO class. (c) Typical autocorrelation function of an OO- image (averaged over different slices)

Data Set was obtained, in which class PI ("Pack Ice") corresponds to 96 samples, class MIZ ("Marginal Ice Zone") corresponds to 76 samples, class OO ("Open Ocean") corresponds to 192 samples. Figure 2 shows the information on the class "Open Ocean". Figure 3 shows information on class "Marginal Ice Zone", and Fig. 4 shows information on class "Pack Ice". It can be seen from the figures that the video material is of very low quality: ice edges are very blurred, contrast is low. But it is images of such quality that are typical when using small UAVs in the difficult meteorological conditions of the High Latitudes.

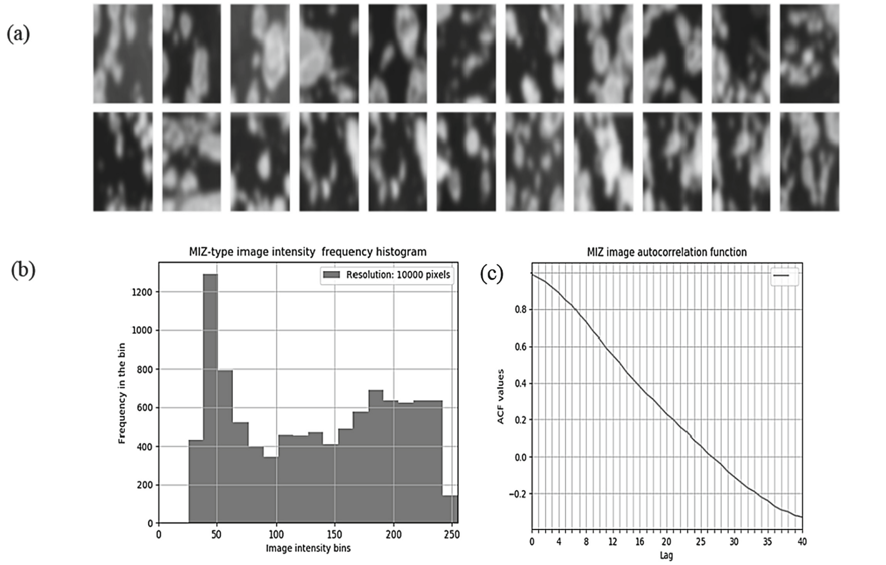

Fig. 3. Class “Marginal Ice Zone” (MIZ). (a) Typical sample images from the MIZ class. (b) Intensity histogram plotted over the entire typical image from the MIZ class. (c) Typical autocorrelation function of MIZ- image (averaged over different slices).

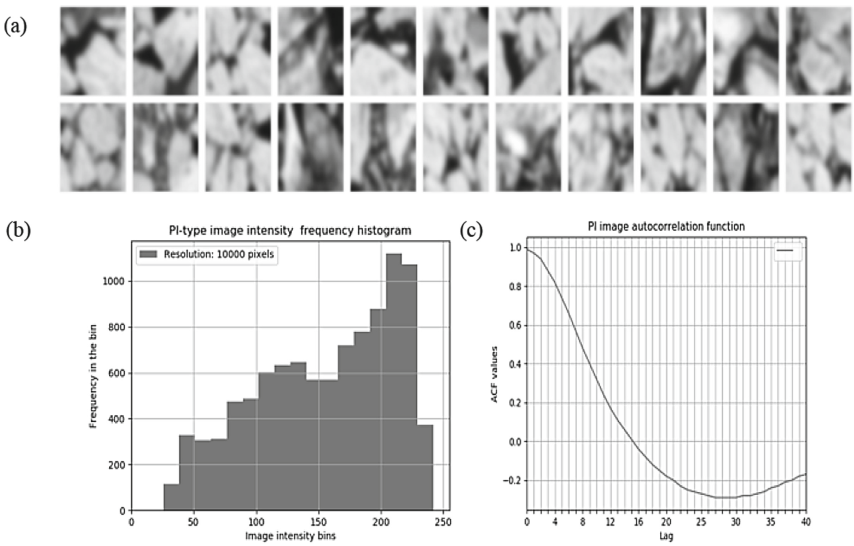

Fig. 4. Class “Pack Ice” (PI). (a) Typical sample images from the PI-class. (b) Intensity histogram plotted over the entire typical image from the PI-class. (c) Typical autocorrelation function of PI-image (averaged over different slices).

2.3 Description of the D-Classificator Used

In practice, the amount of power available to developers and researchers for training Data Set with aerial survey data is affected by legal restrictions. In particular, special licenses are usually required to use high-resolution remote sensing data. A significant number of modern airborne video sensors fall under this limitation. Thus, the Data Set with aerial imagery data available to a particular developer-researcher may by no means always be of significant (more than a thousand samples per class) power. In the present work, we assume that for training classifier D, researchers have access to a Data Set of relatively small power. Since the dimensionality of feature space is relatively small, and the images in Data Set have a relatively large correlation radius (8 or more pixels), the samples of the same class will relatively "smoothly" differ from each other by the metric of **F**-space. Under these conditions, it is logical to use a conventional and very computationally economical multi-class SVM (MC-SVM) as a D-classifier [27]. For comparison, a DL-classifier was also used: ResNet20 [28]. During training, in order to ensure control of the generalization ability of the classifiers, the standard Cross Validation scheme was used, in the LOO (leave-one-out) variant. For the MC SVM classifier, given the multiclass formulation of the problem, a one-vs-rest strategy was used.

3 Results

The results of the numerical studies are summarized in Tables 1–3. The main information is contained in Table 1. Here we accumulate the results, which were shown on the test Data Set by classifiers based on MC SVM and Resnet20. A standard set of metrics was used to evaluate the classification results: precision, recall, and f1-score. The table shows that in the experiments, exactly 24 samples from each class were used at the test stage.

Table 1. The basic metrics values on the test Data Set.

Image class	Method	Precision	Recall	f1-score	Support
Open space (OS)	SVM	1.0	0.96	0.98	24
	Resnet20	0.96	1.00	0.98	24
Marginal ice zone (MIZ)	SVM	0.96	1.00	0.98	24
	Resnet20	0.92	1.00	0.96	24
Pack ice (PI)	SVM	1.00	1.00	1.00	43
	Resnet20	1.00	0.93	0.96	43

Tables 2 and 3 contain the so-called confusion matrix for classifier implementations by MS SVM and Resnet20 schemes, respectively. In general, the classification results are quite good. A more detailed analysis of the results is given in the Discussion section.

Table 2. Confusion matrix for MC-SVM.

Image class	OS	MIZ	PI
Open space (OS)	23	0	1
Marginal ice zone (MIZ)	0	24	0
Pack ice (PI)	0	0	42

Table 3. Confusion matrix for ResNet20.

Image class	OS	MIZ	PI
Open space (OS)	24	0	0
Marginal ice zone(MIZ)	0	24	0
Pack ice (PI)	1	2	40

4 Discussion

As follows from Tables 1–3, the classifiers built according to different schemes, taking into account the low power of the Data Set, showed very decent results. At the same time, the classifier based on MC SVM is slightly superior in all parameters to the classifier based on ResNet20. This is due to the insufficient power of the Data Set to provide full training of the DL-classifier, in this case, ResNet20. It is known that the training of DL-classifiers, for example based on Deep Convolutional Neural Network, requires a Data Set of considerable power (more than 1000 instances for each class). This is due to the fact that DL-classifier is a very complex model, which depends on tens of thousands (and more) parameters. It follows from machine learning theory [29] that model complexity should grow "slowly" as the size of the training Data Set increases. Therefore, on small Data Sets, the DL-classifier simply does not have time to be trained, due to the mismatch in the complexity of the classifier and the Data Set. Analysis of confusion matrixes shows that MC SVM made only 1 mistake, confusing classes PI and OO. This is probably due to the fact that these classes, despite their many differences, have in common: a significant part of the surface, in both cases, may occupy a coherent, texturally homogeneous array: a water surface (OO-class) or a solid ice slab (PI-class). The ResNet20-based classifier made three errors. All errors are related to incorrect classification of samples from the PI-class. The reason for the errors: insufficient capacity of the Data Set to fully train the ResNet20-based classifier.

5 Conclusions

The paper suggests a new method for classifying the sea-ice floe size distribution type based on the use of low-quality video footage. Low quality of video footage is quite typical for high latitude conditions, where most of the year a set of complex meteorological factors negatively affects the quality of aerial photography. That is why ice reconnaissance data processing should be able to compensate the negative influence of meteorological factors on the quality of ice surface imagery. In other words, ice reconnaissance data processing should be able to estimate with high reliability the sea-ice floe size distribution type, because this estimation is one of the main results of ice reconnaissance. The sea-ice floe size distribution type classification method proposed in the article has high robustness to noises and distortions of the source video material, which makes it an effective means of overcoming the negative influence of a complex high latitude meteorological environment. The simulation results showed high reliability in solving the task of estimating the sea-ice floe size distribution type, which the proposed method provides under the condition of highly noisy and distorted source data. The proposed method is economical in the computational sense and, therefore, it can be implemented in software on a medium- and low-power computing platform placed on board a small-sized ice reconnaissance UAV.

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Assessment of the Impact of the Level of Railway Tariffs on the Evolution of Cargo Supply Chains

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Abstract. The objective of the paper is to quantify the impact of rail tariff levels on the evolution of freight supply chains. The following methods were used: econometric modeling, comparative method, analysis, statistical method, systemic method. Using econometric modeling and comparative calculation, a quantitative assessment was made of the impact of the level of freight railway tariffs on the evolution of supply chains in terms of changing one mode of transport to another on the example of transportation of oil cargo and coal in the Russian Federation; additional comments were formulated to the conclusions of the obtained assessment; recommendations for further refinement of the results of the econometric assessment have been developed. The results of the research can be used to optimize tariffs for rail transport in the face of constrained supply chains of goods, as well as for further research in the field of the evolution of supply chains of goods and pricing in rail transport.

Keywords: Cargo supply chains · Rail tariffs · Pricing · Evolution · Oil cargo · Coal

1 Introduction

Trends in cargo supply chains i.e. the evolution (transformation) of cargo supply chains is influenced by a variety of factors. For example, in terms of changing one mode of transport to another in the cargo supply chains, factors contributing to such a change include: the availability of the ability to transport large consignments of cargo, the availability of the possibility of exporting cargo in full, the presence of a developed transport infrastructure, the availability of the ability to carry out transportation in the near future after submitting an application for transportation, the timing of the vehicle's submission for loading, the availability of the ability to track the cargo along the route, the degree of safety of the cargo during transportation, compliance with the delivery time of the cargo, the delivery time of the cargo, the cost of transportation, the degree of flexibility in pricing for transport services, the ability to carry out door-to-door cargo transportation, the speed of response to customer requests, the ease of interaction with the carrier regarding the application for transportation, the level of development of

I. Ilin et al. (Eds.): ICDT 2021, LNDECT 157, pp. 35–45, 2023.
https://doi.org/10.1007/978-3-031-24434-6_4

transport and logistics centers, the quality of preparation of the vehicle for transportation, assortment t of the services offered by the carrier and other factors.

One of the most important of these factors is the cost of transportation, which is confirmed by the results of surveys of cargo owners, owners of rolling stock, representatives of transport and logistics companies, owners or operators of infrastructure. At the same time, the cost of transportation is determined by the level of transport tariffs applied for specific goods by various modes of transport. A particular case of the influence of the factor of the cost of transportation of goods on the transformation of supply chains in terms of changing one mode of transport to another is the case of freight rail tariffs.

Note that the problem of assessing the impact of the level of railway tariffs on the evolution (transformation) of freight supply chains is, including in terms of changing one mode of transport to another, a problem not only of a theoretical, but also of an important practical nature. Thus, the growth / value of the level of freight railway tariffs for the transportation of oil cargoes and coal in the Russian Federation (Fig. 1), a number of researchers name among the main factors of the transition of part of oil cargo from railway to pipeline transport and part of loading coal from railway to road transport in 2010–2020 (Fig. 2).

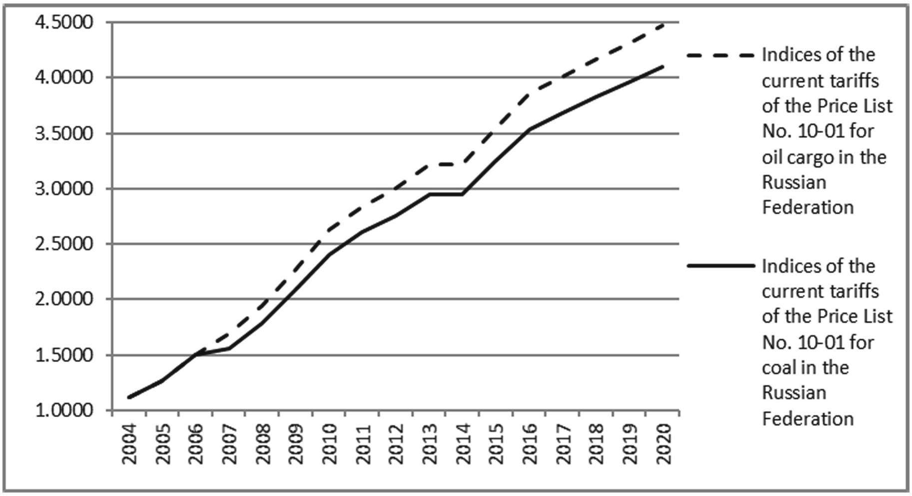

Fig. 1. Indices of the current tariffs of the Price List No. 10–01 for oil cargo and coal in the Russian Federation in 2004–2020. (according to Rosstat data [1]).

In 2020, the railway transport of the Russian Federation accounted for about 20% of the loading of coal in the domestic traffic, about 40% of the loading of coal for export, about 16% of the loading of oil cargo in the domestic traffic and about 20% of the loading of oil cargo for export [1]. Therefore, even a partial transfer of these cargoes from rail to other types of transport results in the loss of multibillion-dollar income for Russian Railways and rolling stock operators.

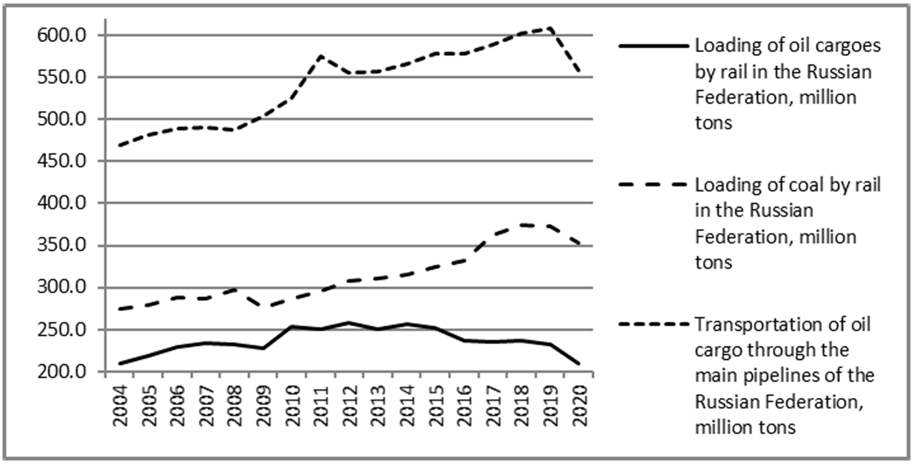

Fig. 2. Volumes of loading oil cargoes and coal by railway transport of the Russian Federation and transportation of oil cargoes through main pipelines of the Russian Federation in 2004–2020. (according to Rosstat data [1]).

Recent work on trends in cargo supply chains and drivers of these trends include publications by Macioszek et al. [2], Antún [3], Carlan et al. [4], Perboli et al. [5], Runhaar and van der Heijden [6], Taniguchi et al. [7], Schniederjans et al. [8]. In the field of theory and methodology of freight railroad tariffs, recent publications include the works of Pittman [9], Poliak et al. [10], Serfas et al. [11], Wilson and Wolak [12], Brewin et al. [13], MacDonald [14], Alises et al. [15], Boyer [16]. Also indirectly, the studied problem is affected by the works of Chechenova et al. [17], Guliy et al. [18], Tretyak et al. [19].

Recognizing the depth and thoroughness of the studies carried out on the problem under consideration, some of their limitations should be noted:

1. studies of the influence of the level of railway tariffs on the evolution (transformation) of freight supply chains are, as a rule, mainly of a qualitative nature; an exception is the work of Brewin et al. [13], in which an attempt was made to quantify the consequences of the abolition of the maximum tariff for the carriage of grain by rail in Canada on the grain supply chains in the country;
2. the researchers for the most part do not analyze the influence of the level of railway tariffs on the evolution of freight supply chains in terms of changing one mode of transport to another.

The foregoing substantiates the relevance of this research, and helps to formulate its objective: to quantify the impact of rail tariff levels on the evolution of freight supply chains.

2 Materials and Methods

2.1 Research Methodology

To quantify the impact of the level of railway tariffs on the evolution of cargo supply chains (for example, the transition of oil cargo and coal from railway transport to other modes of transport), a first-order autoregressive model of the following type is used:

$$y_t = a + b_0 * x_t + c_1 * y_{t-1} + \varepsilon_t, \tag{1}$$

where y_t – the resulting variable (volumes of cargo transportation by rail and pipeline) at time t;

y_{t-1} – resulting variable at time t−1;

x_t – indicators of the level of the current tariffs of railway transport (indices of the current tariffs of the Price List No. 10–01) at time t;

$b0, c1$– model coefficients;

ε_t – residual term of autoregressive model.

This instrumental variable is defined using the view model:

The estimation of the coefficients of model 1 is carried out in 2 steps using the instrumental variable $\widehat{y_{t-1}}$, which is substituted into model 1 instead of the lag variable y_{t-1}. This instrumental variable is defined using a model of the form:

$$y_{t-1} = d_0 + d_1 * x_{t-1} + u_t, \tag{2}$$

where u_t – residual term of regression model 2;

x_{t-1} – indicators of the level of the current tariffs of railway transport (indices of the current tariffs of the Price List No. 10–01) at time t−1;

$d0, d1$ – coefficients of regression model 2 estimated using classical least squares method.

The assessment of the statistical significance of model 1 is carried out using the Fisher criterion, the assessment of the statistical significance of the coefficients of model 1 - using the student's test. Testing of model 1 for the presence of auto-correlation of residuals (if necessary) is carried out using the Darbin h test.

Also, the study uses a comparative method, analysis, statistical method, systemic method. These methods are used to generalize the provisions of published works on the problem under study, when conducting econometric modeling and for a comprehensive interpretation of the results of this modeling, to construct and interpret a comparative calculation of the average growth rates of indicators of the level of railway tariffs and transportation of goods by rail and pipeline transport, to generalize the - research results.

2.2 Theoretical Fundamentals

The autoregression model (in this study, the first-order autoregression model is used) was first applied for econometric analysis by Yule [20] and Slutzky [21] in the 1920s and 1930s. XX century Comparative method, analysis, statistical method, systemic method are general scientific methods used for scientific research since ancient times.

3 Results

The assessment of the influence of the level of railway tariffs on the evolution of freight delivery chains was carried out using the autoregressive model 1 on the example of the transportation of oil cargo and coal by rail and pipelines in the Russian Federation during 2003–2020 (the phenomenon of the transition of oil cargo and coal from railway transport to other modes of transport).

Table 1 presents the results of the assessment of model 1 of autoregression of the influence of the level of the current tariffs of Price List No. 10–01 for oil cargoes in the Russian Federation transported by rail (separately for the time intervals 2004–2020 and 2010–2020).

Table 1. The results of the assessment of model 1 of the autoregression of the influence of the level of the current tariffs of the Price List No. 10–01 for oil cargo in the Russian Federation (railway transport, the significance level $\alpha = 0.05$, estimated by the author on the basis of Rosstat data [1])

Resulting variable y_t	Statistical significance of model 1	Statistical significance of the coefficient b_0 of model 1	Statistical significance of the coefficient c_1 of model 1	Estimation of the coefficient b_0 of model 1	Estimation of the coefficient c_1 of model 1
Oil cargo handling (2004–2020), million tons	Insignificant	Insignificant	Insignificant	10,78	−1,37
Oil cargo handling (2010–2020), million tons	Significant	Insignificant	Insignificant	−26,78	−0,30

Table 2 shows the results of the assessment of model 1 of autoregression of the influence of the level of the current tariffs of Price List No. 10–01 for oil cargo and oil in the Russian Federation on the volumes of these cargoes transported by main pipeline transport in 2004–2020.

Table 2. The results of the assessment of model 1 of the autoregression of the influence of the level of the current tariffs of the Price List No. 10–01 for oil cargo and oil in the Russian Federation in 2004–2020. (pipeline transport, significance level $\alpha = 0.05$, estimated by the author on the basis of Rosstat data [1])

Resulting variable y_t	Statistical significance of model 1	Statistical significance of the coefficient b_0 of model 1	Statistical significance of the coefficient c_1 of model 1	Estimation of the coefficient b_0 of model 1	Estimation of the coefficient c_1 of model 1
Oil cargo transportation, million tons	Significant	Insignificant	Insignificant	5,44	0,75
Oil transportation, million tons	Significant	Insignificant	Insignificant	4,33	0,75

Table 3 presents the results of the assessment of model 1 of autoregression of the influence of the level of the current tariffs of Price List No. 10–01 for coal in the Russian Federation transported by rail in 2004–2020.

Table 3. The results of the assessment of model 1 of the autoregression of the influence of the level of the existing tariffs of the Price List No. 10–01 for coal in the Russian Federation in 2004–2020. (railway transport, significance level $\alpha = 0.05$, estimated by the author on the basis of Rosstat data [1])

Resulting variable y_t	Statistical significance of model 1	Statistical significance of the coefficient b_0 of model 1	Statistical significance of the coefficient c_1 of model 1	Estimation of the coefficient b_0 of model 1	Estimation of the coefficient c_1 of model 1
Loading of coal, million tons	Significant	Insignificant	Insignificant	−33,42	2,04

In addition to the results of the estimates of model 1 (Tables 1, 2 and 3), Table 4 presents a comparative calculation of the average chain growth rates of the indicators of the level of the current tariffs of the Price List No. 10–01 and the indicators of transportation of goods by rail and pipeline transport in the Russian Federation (for oil cargo and coal).

Table 4. Average chain growth rates of indicators of the level of the current tariffs of the Price List No. 10–01 and indicators of cargo transportation by rail and pipelines in the Russian Federation (for oil cargo and coal, calculated by the author on the basis of Rosstat data [1])

Indicator	Average chain growth rate of the indicator in 2005–2020, %	Average chain growth rate of the indicator in 2010–2020, %
Indices of the current tariffs of the Price List No. 10–01 for oil cargo in the Russian Federation	9,2	6,4
Indices of the current tariffs of the Price List No. 10–01 for coal in the Russian Federation	8,6	6,4
Loading of oil cargoes by railroad transport of the Russian Federation, million tons	0,1	−0,7
Transportation of oil cargo through the main pipelines of the Russian Federation, million tons	1,2	1,0
Loading of coal by railway transport of the Russian Federation, million tons	1,7	2,3

4 Discussion

An econometric assessment of the impact of the level of the current tariffs of Price List No. 10–01 for oil cargoes in the Russian Federation transported by rail did not reveal a statistically significant effect in terms of the coefficients of the model and the model itself as a whole for the time interval 2004–2020. (row 2 of Table 1). This influence was revealed for the interval 2010–2020. only in part of the model as a whole, but the coefficients of the model are still insignificant, Durbin's h test is not applicable for testing the autocorrelation of the model residuals (row 3 of Table 1). That is, according to the results of the assessment of model 1, the growth of tariffs for the transportation of oil cargo in the Russian Federation by rail did not have a statistically significant effect on the volume of transportation of these goods by rail both in 2004–2020 and in 2010–2020.

An econometric assessment of the influence of the level of the current tariffs of Price List No. 10–01 for oil cargoes and oil in the Russian Federation on the volumes of these cargoes transported by pipeline transport revealed a statistically significant effect in terms of the model as a whole for the time interval 2004–2020. (Table 2). However, the coefficients of the model are statistically insignificant and Darbin's h test is not applicable for testing the autocorrelation of the model residuals. Thus, according to the results of the assessment, the growth of tariffs for the transportation of oil cargo and oil in the Russian Federation by rail did not have a statistically significant effect on the volume of transportation of these goods by pipeline in 2004–2020.

An econometric assessment of the impact of the level of the existing tariffs of Pricekurant No. 10–01 for coal in the Russian Federation transported by rail has revealed a statistically significant effect in terms of the model as a whole for the time interval 2004–2020. (Table 3). However, the coefficients of the model are statistically insignificant and Darbin's h test is not applicable for testing the autocorrelation of the model residuals. Consequently, according to the results of the assessment, the growth of tariffs for the transportation of coal in the Russian Federation by rail did not have a statistically significant effect on the volume of transportation of these goods by rail in 2004–2020.

Thus, if we take into account only the results of econometric modeling, then the change in tariffs for railway transportation in 2004–2020. for oil cargo and coal (and in 2010–2020 for oil cargo) did not statistically significantly contribute to the partial transition of these cargoes from railway transport to other types of transport (pipeline, road) with a change in supply chains.

However, according to the results of a comparative calculation of the average chain growth rates of the indicators of the level of the current tariffs of Price List No. 10–01 and the indicators of cargo transportation by rail and pipeline transport in the Russian Federation (for oil cargo and coal), such an influence was still present at least for oil cargo (Table 4). Growth of the current tariffs index of Price List No. 10–01 for oil cargo in the Russian Federation by an average of 9.2% in 2005–2020. was accompanied by an almost zero average growth in the loading of oil cargo by rail (0.1%) and an average growth of 1.2% in the transportation of oil cargo via trunk pipelines. And the growth of the current tariffs index of Price List No. 10–01 for oil cargo in the Russian Federation by an average of 6.4% in 2010–2020. was accompanied by a negative average decrease in the loading of oil cargo by rail (−0.7%) and an average growth of 1.0% in the transportation of oil cargo via trunk pipelines.

Such dynamics of changes in oil supply chains is clearly visible in Figs. 1 and 3: after 2010, the base rate of growth in the loading of oil cargo by rail begins to gradually decline simultaneously with an increase in tariffs for the transportation of oil cargo by rail and an increase in the base rate of growth in the transportation of oil cargo by pipeline. This leads to a change in the structure of the oil cargo supply chains: if in 2010 railway transport accounted for 32.5% of the transportation of these cargoes, then in 2020 this figure dropped to 27.2% (Fig. 4).

Note that such a picture was not observed for coal (the increase in tariffs was accompanied by an increase in loading on railway transport, Table 4), but this does not prove the thesis that the change in freight railway tariffs did not / does not have any effect on the supply chains of coal in the Russian Federation.

The statistical insignificance of the results of econometric modeling in Tables 1 and 2 against the background of the coincidence of the dynamics of the partial transition of oil cargo from railway transport to pipeline transport (Table 4, Figs. 1, 3, 4) can be explained by the complexity of a set of factors in the evolution of supply chains. The level of tariffs is an important factor in this population, which is recognized by researchers and participants in the transport market (based on surveys), but this level is not the only important factor. Also, the very evolution of supply chains is not limited

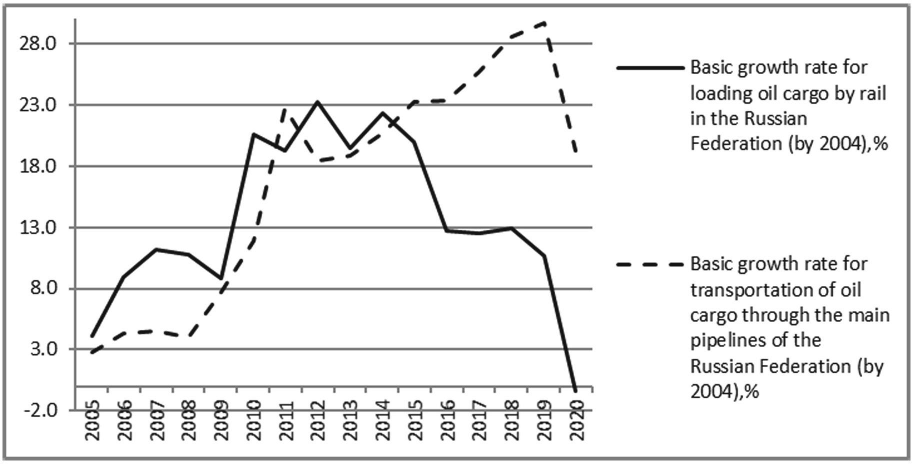

Fig. 3. Basic growth rates of oil cargo loading by rail in the Russian Federation and basic growth rates of oil cargo transportation via main pipelines of the RF in 2004–2020. (by 2004) (calculated by the author based on Rosstat data [1]).

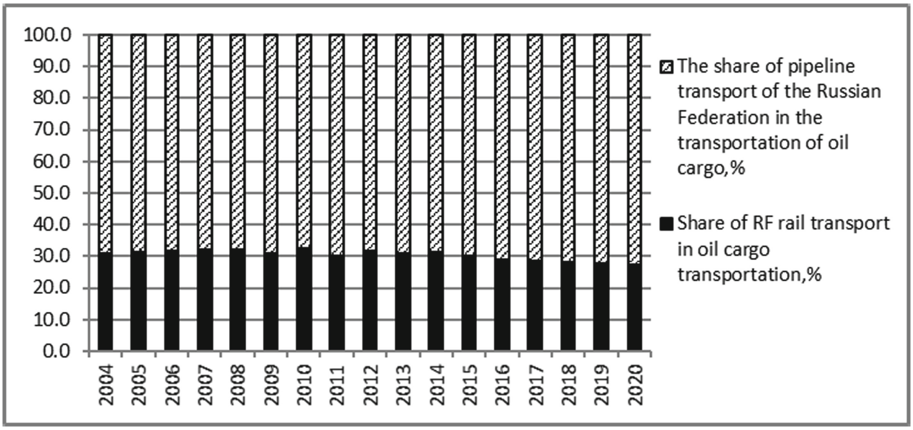

Fig. 4. Shares of pipeline and rail transport in the transportation of oil cargo in the Russian Federation in 2004–2020. (calculated by the author based on Rosstat data [1]).

to the replacement of one mode of transport for another. Therefore, on the basis of the first-order autoregressive model 1, it is impossible to obtain a complete assessment of the picture of the influence of a complex of sometimes interrelated factors on the evolution of supply chains. To obtain such estimates in the future, it is necessary to use more complex econometric models (for example, a vector autoregression model) and use them to evaluate the influence of the whole complex of influencing factors simultaneously on a number of different indicators of the evolution of supply chains.

5 Conclusions

According to the results of the conducted econometric modeling using the first-order autoregressive model, the change in tariffs for railway transportation in the Russian Federation in 2004–2020. for oil cargo and coal (in 2010–2020 for oil cargo) did not statistically significantly contribute to the partial transition of these cargoes from railway transport to other types of transport (pipeline, road) with the transformation of the supply chains of these goods. However, according to the results of a comparative calculation of the average chain growth rates of the indicators of the level of existing freight railway tariffs and indicators of the transportation of these goods by rail and pipeline transport, such an influence was still present at least for oil cargo: an increase in the index of existing tariffs for oil cargo by an average of 9, 2% in 2005–2020 was accompanied by an almost zero average growth in the loading of oil cargo by rail and an average growth of 1.2% in the transportation of oil cargo via trunk pipelines (similar quantitative estimates were obtained for the period 2010–2020).

To clarify the results of quantitative econometric assessments of the effect of the level of railway tariffs on the evolution of freight supply chains in the future, it is necessary to use more complex econometric models (for example, a vector autoregression model), taking into account the need to simultaneously assess the entire range of influencing factors, and also taking into account a number of different indicators of the evolution of supply chains.

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Stochastic Operational Logic for Berths Throughput Modelling of Export Coal Terminal

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Abstract. The commercial stability and competitiveness of marine terminals largely depends on the correct choice of the input values of technological parameters, the calculation of which should be carried out by new methods with such tools as flexible probabilistic calculations and simulation technologies. For marine side of export coal terminals the functional logic and operations in numbers are described. Data mining and analysis approaches make it possible to form a holistic picture for shiploading operations and downtime, which are taken into account within the "ignorance" coefficients in the Russian regulatory framework for the technological design of seaports. For marine terminals, is the value in deep understanding of the operational factors, which are hidden in coefficients. The considered detalisation of the processes can be used as a tool for creating more accurate methods for calculating the throughput for marine side, using mathematical modelling. That allow to achieve the transparency in the relationships "client – contractor" and form the results in terms of the most probable values of throughput and the potential to increase the cargo turnover.

Keywords: Marine ports and terminals operations · Port planning · Port performance · Stochastic processes · Benchmarking

1 Introduction

The existing regulatory framework for the technological design of Russian seaports SP 350.1326000.2018 "Standards for the technological design of seaports" [1] was updated in 2018, but did not get rid of significant shortcomings, which were relocated from the previous editions of the standards RD 31.3.05–97 and RD 31.3 .01.01–93. In accordance with [1], the result of calculations of the throughput of the marine side is fixed by a dete rministic value (one numerical value). The result obtained in this form often greatly underestimates the capabilities by 50–60% for export coal terminals, which provokes the emergence of mutual mistrust between the research-design community (client) and industrial corporations (client). This is largely due to the need to use the coefficients of "technical ignorance" [2]: berth idle time due to meteorological factors (K_{meteo}), transition from technical to operational productivity ($K_{efficiency}$), berth occupancy by handling vessels ($K_{occupancy}$).

I. Ilin et al. (Eds.): ICDT 2021, LNDECT 157, pp. 46–58, 2023.
https://doi.org/10.1007/978-3-031-24434-6_5

The annual volume of cargo transshipment is the main commercial indicator for the terminal, in this regard, planning and achieving high values of cargo turnover is the most important task for the client. Operators of modern coal export terminals using conveyor mechanization own high-performance equipment that is used in situations of uncertainty. On the one hand, there is significant market uncertainty (uneven supply of coal grades by rail, the need for uniform contracting of bulk carriers for ship calls, the formation of a sufficient number of ship lots in the warehouse area), on the other hand, operational difficulties arise (synchronization of conveyor routes, minimization of operations downtime).

The main scientific contribution related to the activities of coal terminals was made by: V. H. Barros [3], T. A. Robenek [4] and N. Umang [5] about berth allocation problem; U. S. Bugaric [6] about bulk cargo unloading; T. A. Van Vianen [7, 8] about stockyards and operations of stacker-reclaimers; A. J. A Kleinheerenbrink [9] about heuristic calculations of dry bulk terminals; G. C. Menezes [10], N. Boland [11] and O. Unsal [12] about integrated scheduling and planning problem on export terminals of ore and coal. Several chapters of marine ports handbooks by H. Ligteringen [13] and C. A. Thorensen [14] are devoted to the matters of technological operations of bulk terminals and vessels. Contemporary guidelines for planning, site selection, design, vessel handling, operations, hazard management, storage facilities, transshipment, maintenance and environmental considerations of specialized bulk terminals were issued by PIANC in 2019 [15].

Among the works of Russian scientists, there is a limited number of studies about bulk terminals. The studies by Y. Spassky [16] and A. Kuznetsov [17] are focused on increasing the efficiency of handling equipment at marine side of coal export terminal using dynamic simulation of weather conditions and ship calls. Most of the Russian scientific research works are devoted to the modeling of maritime container terminals, these are the studies by S. Pavlenko [18], V. Pogodin [19] and A. Kuznetsov [20], whose findings can be partially used for bulk coal terminals.

For marine terminals, an independent value is the identification, deep understanding and management of the factors hidden within the specified coefficients. Identification of the functional structure of the marine side operational processes allows to plan and operate the terminal more efficient, reduce the range of uncertainties, increase the throughput.

2 Materials and Methods

In the study, a stochastic processes model was developed for the probabilistic assessment of the throughput of marine part of a coal export terminal using power driven conveyors. The following methods were used:

- collection of operational statistics;
- data mining of equipment and vessels characteristics;
- establishment of probability distributions.

The boundaries of the study are limited by the marine side of a coal export terminal (see Fig. 1), according to modern port planning and designs of such terminals. Generally, coal is delivered from storage to berths by conveyors, where it is loaded onto bulk carriers by shiploaders.

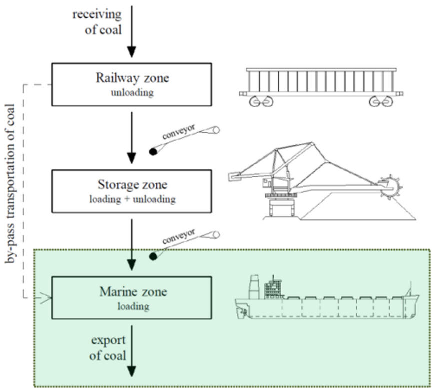

Fig. 1. Boundaries of study.

Simplified process flow diagram of the marine side was set with following characteristics (Fig. 2):

- technical productivity of conveyor equipment 3500 t/h (conveyors, ship-loading machines);
- 2 berths for mooring of vessels;
- 2 shiploaders;
- deadweight of vessels 25,000 – 185,000 t.

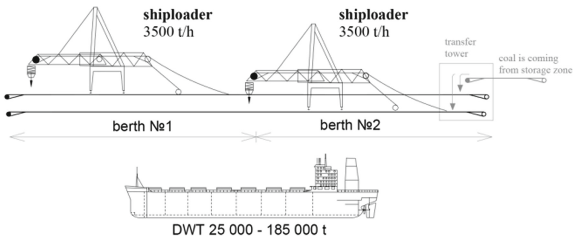

Fig. 2. Process flow diagram of the marine side of coal export terminal.

This process flow diagram can be named typical for coal export terminals in the Russian Federation. It is used at the existing operating terminals Rosterminalugol (port Ust-Luga) and Daltransugol (port Vanino). The use of this type of diagram in the research offers the benefit of verifying stochastic results versus actual cargo turnover.

In modern market conditions, operation of the terminal should be based on the cost efficiency principle. Terminal operators and designers need to understand the sequence and duration of operating processes so that shiploading operations are carried out without exceeding lay time in order to avoid additional payments. Coal export terminal Daltransugol located in the port of Vanino was chosen as the basis for the study. The structure of process operations and time losses for the processing of bulk carriers at this terminal was outlined in detail and became the basis for the stochastic modeling. Data mining was used to collect the data sets and statistics from different sources: equipment documentation, vessels design documentation of terminal, operational statistics and vessel timesheets. Collected data was plotted on a typical shiploading cycle (Table 1).

Table 1. Typical shiploading cycle of export bulk terminal

#	Operations	Average duration, h
1	Pilotage (approach to the berth)	0.6–1.0
2	Mooring	0.3–0.6
3	Measuring the draught (unladen)	0.8–1.2
4	Shiploading: • coal loading (normal speed, trimming) • transitions of shiploaders between holds (shutdown of conveyors, detachment and movement of shiploaders) • operator-dependent downtime (shift changes, lunch) • special cases (discharge of ballast for ships with outdated slow pumping systems, emergency repairs, unscheduled stoppages of conveyors, overheating of magnetic separators, cleaning from ice, slipping of coal in the warehouse, excessive dusting of coal, absence of coal in the warehouse, etc.) • downtime due to weather conditions	calculated value
5	Measuring the draught (laden)	0.8–1.2
6	Registration of cargo and commercial documents: calculation of berth occupancy time, cargo plan, navigator's receipt, bill of lading, cargo manifest	0.8–1.2
7	Unmooring	0.3–0.6
8	Pilotage (departure from the berth)	0.1–0.2

To establish the model's calculation algorithm, a deterministic model was prepared as the first step, which incorporates the calculation logic and the sequence of operations and takes into account every possible factor. Next, the deterministic model is used as background for building the stochastic model that takes into account the distributions of parameters. The stochastic model later will be divided into 3 modules:

- worktime fund of the marine side,
- berth available time,
- fleet.

The logic operations in "Worktime fund of marine side" module is shown on Fig. 3.

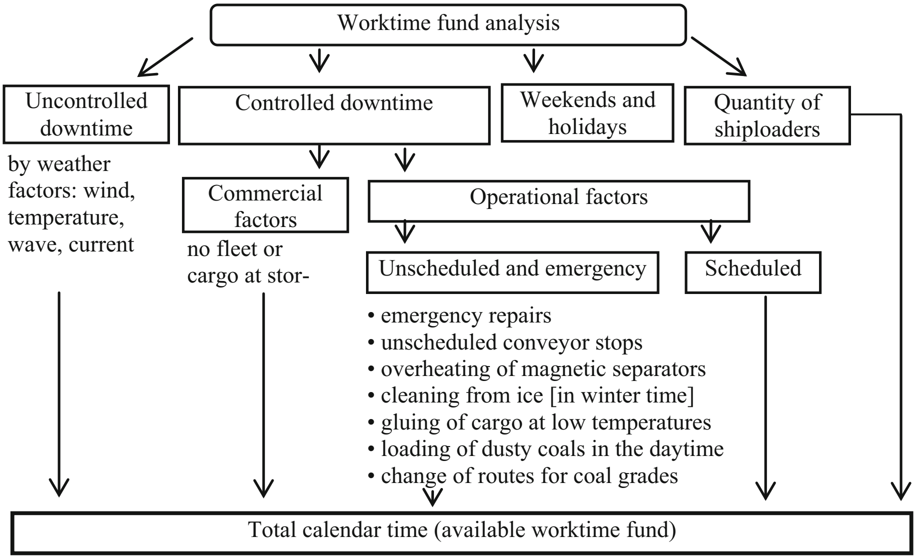

Fig. 3. The logic of "Worktime fund of marine side" module

The logic operations in "Berth available time" module is shown on Fig. 4.

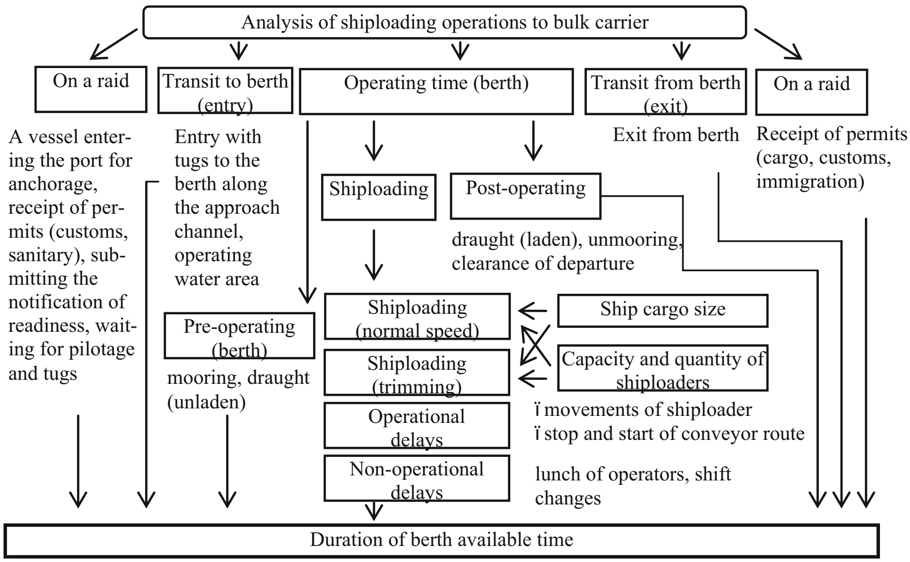

Fig. 4. The logic of module "Berth available time".

The logic operations in "Fleet" module is shown on Fig. 5.

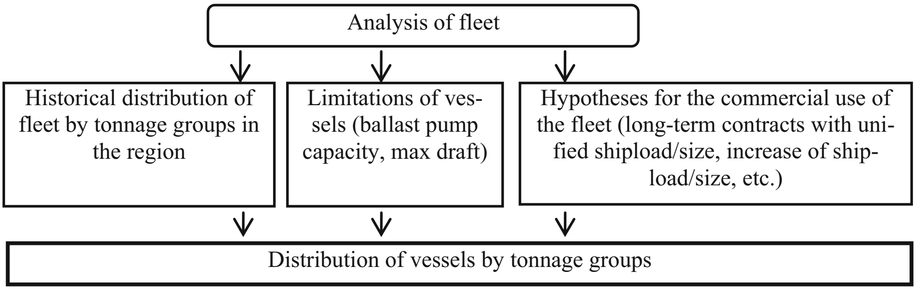

Fig. 5. The logic of module "Fleet".

3 Results

A bulk of statistical data has been analyzed and processed: berth downtime, distribution of vessel calls by tonnage groups, exported cargo capacity by each tonnage group of vessels, distribution between vessels with normal and limited hold capacity. Thus, the functional essence of the processes and downtime has been prepared for a mathematical description in the modeling. Assumptions were made based on the probability distributions of initial data. Operational statistics processing results were then used to estimate the minimum, average and maximum values of each parameter. Five criteria were used to verify proper selection of distributions: Akaike information criterion, Bayes information criterion, chi-square statistics, Kolmogorov-Smirnov statistics, and Anderson-Darling statistics. As a result, for most of the initial data, a triangular or PERT distribution was chosen, which is related, among other things, to the available statistical dataset.

The "Worktime fund of marine side" module is used to determine the probabilistic range of available hours of operation of the sea cargo front during the year. It is influenced by the following initial data: uncontrolled downtime due to weather factors, controlled downtime, non-working days, and the number of shiploading machines. The value is determined as the maximum theoretically possible worktime fund minus total shiploaders' downtime due to various factors (detailed breakdown of data and stochastic distributions are provided in Table 2).

Table 2. Input and variables of module "Worktime fund of marine side" [cells with probabilistic ranges and title of distribution are indicated in grey]

#	Title of input	Multiplier	Min	Avrg	Max	Distribution
1	Uncontrolled downtime					
a	Weather downtime (summer-spring)	6 months ×	0	76	155	triangular
b	Weather downtime (winter)	6 months ×	0	133	313	triangular

(*continued*)

Table 2. (*continued*)

#	Title of input	Multiplier	Min	Avrg	Max	Distribution
2	Controlled downtime					
2.1	Commercial factors					
a	No fleet (summer-spring)	6 months ×	36	83	173	triangular
b	No fleet (winter)	6 months ×	54	226	397	triangular
c	No cargo at storage	12 months ×	2	178	337	triangular
2.2	Operational factors					
2.2.1	Scheduled					
a	Scheduled repairs (shiploaders, conveyors)	5 months ×	125	139	453	triangular
b	Scheduled maintenance	7 months ×	116	122	124	triangular
2.2.2	Unscheduled and emergency					
a	Emergency repairs (shiploaders, conveyors)	yes/no ×	13	27	40	triangular
b	Unscheduled conveyor shutdown (incorrect belt run, overheating, belt skew, traction cord)	12 months ×	3	10	19	triangular
c	Overheating of magnetic separators	7 months ×	0	1	9	triangular
d	Cleaning from ice [in winter time]	6 months ×	58	61	62	triangular
e	Creep of coal at low temperatures	4 months ×	100	110	120	triangular
f	Loading of dusty coals in the daytime (summer-spring-autumn)	8 months ×	9	10	11	triangular
g	Loading of dusty coals in the daytime (winter)	4 months ×	80	95	100	triangular
Quantity of shiploaders (Q_{sl}), pcs		2 shiploaders ×				
Total calendar time ($T_{calendar}$), h/year		Q_{sl} * 8760 - Σdowntime				

The "Berth available time" module is used to determine the probabilistic time ranges for the cycles of shiploading operations for each tonnage group of bulk carriers. The cycle is influenced by shunting operations in the port's water area, operations at the berth (mooring, loading of coal in normal and trimming modes, shiploader movements), and release of registration documents and permits. The most time is spent on shiploading onto the vessel performed in the normal and trimming modes, when shiploading capacity decreases during movements of shiploader between holds and operator-dependent downtime (lunch, shift changes). Shiploading operations duration, detailed breakdown of data and stochastic distributions are provided in Table 3 and Table 4.

Table 3. Input and variables for bulk carriers in module "Berth available time" [cells with probabilistic ranges and title of distribution are indicated in grey]

Characteristics of bulk carrier	DWT 10–25k		DWT 25–50k		DWT 50–80k		DWT 80–120k		DWT 120–185k	
	Normal	Limited draught (LD)	Norm.	LD	Norm.	LD	Norm.	LD	Norm.	LD
Deadweight (D), t	–	[19000; 22800; 25000] Triang	–	[25000; 44000; 50000] Triang	–	[50000; 63500; 80000] Triang	–	[80000; 86300; 120000] Triang	–	[170000; 175500; 185000] Triang
Length overall (LOA), m	159	159	185	159	215	159	230	159	270	159
Length over holds (LOH), m	132	132	154	132	178	132	191	132	224	132
Holds quantity, pcs	5	5	5	5	7	7	7	7	9	9
Length between holds (LBH), m	33	33	38	33	30	22	32	22	28	16
Shipload size (SLS), t	[17900; 18800; 19300] PERT	D*HOL	[31800; 32900; 34800] PERT	D*HOL	[61300; 63700; 65400] PERT	D*HOL	[77600; 80540; 82500] PERT	D*HOL	[133900; 146100; 158500] PERT	D*HOL
Hold occupancy for limited ships (HOL), %	–	[0,77; 0,80; 0,83] Triang	–	[0,70; 0,81; 0,85] Triang	–	[0,72; 0,80; 0,85] Triang	–	[0,71; 0,78; 0,84] Triang	–	[0,78; 0,80; 0,82] Triang

The "Fleet" module is used to determine the distribution of vessels by tonnage groups. Fleet distribution depends on the technical limitations of vessels and commercial factors. According to the statistical data analysis results, an increase in the share of bigger vessels (Panamax and larger) is observed each year. Detailed breakdown of data and stochastic distributions are in Table 5.

Table 4. Input and variables for operations in module "Berth available time" [zero input means no impact on berth available time; cells with probabilistic ranges and title of distribution are indicated in grey]

Characteristics of bulk carrier	Data inputs
1. On a raid	
Call of the vessel to the port to the anchorage, h	0
Receipt of permits (customs, sanitary), h	0
Submitting a notice of readiness and waiting for the pilot / tugs, h	0
2. Transit to berth entry (TENT), h	[0,4; 0,5; 0,6] PERT
3. Pre-operating (berth)	
Mooring (MOOR), h	[0,4; 0,5; 0,6] PERT
Measurement of draught unladen (MDU), h	[0,9; 1,0; 1,1] PERT
4. Operating time (berth)	
4.1 Shiploading	
4.1.1 Normal mode	
Shiploading capacity in normal mode (N), t/h	[3400; 3450; 3500] PERT
% of cargo is going to normal mode (PN)	from 80% to 97% depends on deadweight (25 000–185 000 t)
Shipload size in normal mode (SLN), t	SLS*PN
Shipload size on each shiploader [2 items] (SN), t	SLN / 2
Duration of shiploading in normal mode (DN), h	SN / N
4.1.2 Trimming mode	
Shiploading capacity in trimming mode (T), t/h	0,1 * N
% of cargo is going to trimming mode (PT)	from 3% to 5% for normal vessels, about 20% for vessels with limited draught
Shipload size in trimming mode (SLT), t	SLS*PT
Shipload size on each shiploader [2 items] (ST), t	SLT / 2
Duration of shiploading in normal mode (DT), h	ST / T
4.1.3 Movements between holds	

(*continued*)

Table 4. (*continued*)

Characteristics of bulk carrier	Data inputs
Number of approaches to each hold (NA), pcs	3
Number of holds for each shiploader (NH), pcs	2,5 for vessels with deadweight 10 000–50 000 t 3,5 for vessels with deadweight 50 000–120 000 t 4,5 for vessels with deadweight 120 000–185 000 t
Shiploader movement speed between holds (SMS), m / min	[10; 15; 20] PERT
Stop of the conveyor route (STOC), min	[6; 7; 8] PERT
Time for one unclamping of shiploader (US), min	[0,5; 1,0; 1,5] PERT
Time for one movement between holds (OM), min	S * LBH
Time for one clamping of shiploader (CS), min	[0,5; 1,0; 1,5] PERT
Start of the conveyor route (STAC), min	[6; 7; 8] PERT
Total movements time (TMT), h	NA * NH * (SMS + STOC + US + OM + CS + STAC) / 60
4.1.4 Lunch of shiploader operators (~30 min, 2 times per day)	
Quantity of lunches (QL), pcs	(TENT + MOOR + MDU + DN + DT + TMT) / 12
Duration of lunches (DL), h	QL * [25; 30, 35 PERT] / 60
4.1.5 Shift changes of shiploader operators (~30 min, 2 times per day)	
Quantity of shifts (QS), pcs	(TENT + MOOR + MDU + DN + DT + TMT) / 12
Duration of lunches (DS), h	QS * [25; 30, 35 PERT] / 60
5. Post-operating	
Measurement of draught laden (MDL), h	[0,9; 1,0; 1,1] PERT
Mooring (UNMOOR), h	[0,4; 0,5; 0,6] PERT
Registration of exit by port supervision, h	[0,9; 1,0; 1,1] PERT
6. Transit from berth (exit) (TEXIT), h	[0,4; 0,5; 0,6] PERT
7. On a raid (cargo documents issuing and clearance, customs, immigration)	0

(*continued*)

Table 4. (*continued*)

Characteristics of bulk carrier	Data inputs
8. Total berth available time (TBAT), h	TENT + MOOR + MDU + DN + DT + TMT + DL + MDL + UNMOOR + TEXIT

Table 5. Input and variables for operations in module "Fleet" [cells with probabilistic ranges and title of distribution are indicated in grey]

Tonnage groups of bulk carriers	By	Share of vessels inside tonnage group (S_V), %	Share of vessels by normal and limited draught (S_{Vg}), %		T_{year}, t/ear
			Normal	Limited draught	
DWT 10–25k	$T_{percentage}$, %	[0%; 1%; 2%] Triangular	72,5%	27,5%	
	T_{tonnes}, t/year		$S_V * T_{calendar} * T_{percentage} / TBAT_j$		Svgj *SLN + Svgj *SLT
DWT 25–50k	$T_{percentage}$, %	[4%; 8%; 11%] Triangular	70,0%	30,0%	
	T_{tonnes}, t/year		$S_V * T_{calendar} * T_{percentage} / TBAT_j$		Svgj *SLN + Svgj *SLT
DWT 50–80k	$T_{percentage}$, %	[40%; 42%; 47%] Triangular	75,0%	25,0%	
	T_{tonnes}, t/year		$S_V * T_{calendar} * T_{percentage} / TBAT_j$		Svgj *SLN + Svgj *SLT
DWT 80–120k	$T_{percentage}$, %	[38%; 38%; 42%] Triangular	77,5%	22,5%	
	T_{tonnes}, t/year		$S_V * T_{calendar} * T_{percentage} / TBAT_j$		Svgj *SLN + Svgj *SLT
DWT 120–185k	$T_{percentage}$, %	[8%; 10%; 12%] Triangular	90,0%	10,0%	
	T_{tonnes}, t/year		$S_V * T_{calendar} * T_{percentage} / TBAT_j$		Svgj *SLN + Svgj *SLT
Marine side throughput, t /year					ΣT_{year}

The logical algorithm and stochastic dataset of marine side operations for the coal export terminal have been established.

4 Discussion

The commercial stability and competitiveness of marine terminals largely depends on the correct choice of the input values of technological parameters, the calculation of which should be carried out by new methods with such tools as flexible probabilistic calculations and simulation technologies.

The considered detalisation of the processes can be used as a tool for creating more accurate methods for calculating the throughput for marine side, using mathematical modelling. That allow to achieve the transparency in the relationships "client - contractor" and form the results in terms of the most probable values of throughput and the potential to increase the cargo turnover.

Interpretation of the final results of technological design requires the Client to change their attitude to the results of calculations, and from designers - to change the calculations principles. Creation of parametric models allows obtaining transparent results of the most likely attainable values of throughput (no the only one number), comparison of which with actual operating results can allow evolutionary realisation of the throughput potential with the help of more efficient planning, implementation of modern technological solutions, and elimination of downtime.

5 Conclusions

Key highlight of the article that the structure of marine coal export terminal operations is detailed, including downtime due to weather conditions in severe winter climate. This is the basis for the implementation of stochastic modeling.

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New Approaches to the Economic Assessment of Transport Projects in the Context of Changing Urban Mobility

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Abstract. Nowadays, significant changes are taking place in urban transport systems. They are connected, on the one hand, with the growing demand of the population for transportation, on the other hand, with the change in the structure of the supply of transport services, the emergence of new forms of urban mobility, new business models of transport companies. In addition, digital technologies are developing rapidly, and the scope of their application in transport is expanding. Under these conditions, traditional methods of the economic assessment of transport projects are losing relevance. At the same time, most of these projects are implemented using various forms of public-private partnership. This leads to the need for a cost assessment of the social effects and benefits resulting from the implementation of transport projects. The article substantiates the need to supplement the existing methods of economic assessment of transport projects. The authors systematized the social effects in transport projects and analyzed the available methods of their assessment. It is proved that there is a problem of accounting for some social effects due to the lack of an adequate methodology or the impossibility of valuation. As an example, the assessment of social effects in the project of construction of a transport hub is given. Taking into account the social effects, the structure of the sources of financing of the project implemented with the use of public-private partnership is proposed.

Keywords: Population mobility · Urban mobility · Social benefit · Transport projects · Economic assessment · Public-private partnership

1 Introduction

Nowadays, the process of urbanization continues, leading to the concentration of the population in large cities. New forms of settlement are being formed - agglomerations, megacities, conurbations, megalopolises. Territorial specialization of agglomeration leads to the need to manage significant passenger and transport flows. Not only the demand of the population for transportation is changing, but also the requirements for the quality of transport services: the speed of transportation, the comfort during the

I. Ilin et al. (Eds.): ICDT 2021, LNDECT 157, pp. 59–67, 2023.
https://doi.org/10.1007/978-3-031-24434-6_6

trip. Passengers highly appreciate the opportunity to use free wi-fi during the trip, additional services at transfer points. New forms of urban mobility are emerging, such as joint consumption of vehicles (carsharing is the most common), joint trips using special applications.

The features of new forms of urban mobility are considered in different works by both domestic and foreign scientists. Thus, Wruk, D. et al. [1] consider the issues of quantitative assessment of the segment of joint consumption. Duan, Q. et al. not only note the socio-economic efficiency of carsharing, but also pose the problem of determining the future demand for this service in Chinese megacities by dividing the factors affecting it and their subsequent quantitative assessment [2]. Bellini, F. et al. classify business models of joint mobility and identify their key characteristics, as well as describe the prospects for solving existing problems in the field of urban mobility [3]. Some researchers note that all the existing business models of joint mobility are changing urban transport markets by increasing competition and opportunities for product differentiation [4].

Some studies are devoted to the forms and methods of pricing in the carsharing and carpooling markets. Thus, Farajallah et al. note the uniqueness of the new segment of the transport market, which is manifested, among other things, in the development of new methods for setting prices [5].

Nevertheless, passenger transport management in megacities is often inefficient, which leads to some problems. Among them are traffic jams caused by a high level of motorization, aggravating the environmental situation in megacities; an increase in the number of accidents, low level of transport accessibility of remote and new residential areas, a lack of rail transport routes (including metro). New forms of urban mobility also give rise to new problems of transport functioning. Laa and Emberger, Link et al. highlight the main problems and barriers faced by new segments of the transport market. Among them are administrative (political and legal) barriers and the lack of adequate methods of state regulation [6]. The problem of the development of bike-sharing in Vienna is also confirmed in the study of Link, C. et al. [7]. The listed problems are usually considered as a single "transport problem".

As a rule, the reason for the so-called "transport problem" of agglomerations lies in the fact that population growth significantly exceeds the rate of development of transport infrastructure. In some cases, there are also infrastructural limitations due to the impossibility of developing the historical center of the city, existing planning decisions, dead-end schemes for the development of previously built transport routes. In addition, the development of transport infrastructure requires significant capital investments, which also hinders the implementation of infrastructure projects.

Partial removal of infrastructural restrictions in the urban transport system is possible under the condition of effective passenger and transport flows management, improvement of pricing and transport planning. For example, in the case of carsharing and other forms of joint mobility, identification of factors influencing consumer choice plays an important role. Thus, in the article of Hahn, R. et al. the results of quantitative research and surveys of focus groups of carsharing users in one of the German universities are presented. The authors concluded that the success of carsharing development is determined by the compatibility of the lifestyle and habits of users, on the one hand, and the parameters of the service provided, on the other hand [8]. Papu Carrone et al. prove that the key factors determining the willingness to use carsharing services are the availability of parking and convenient access to vehicles [9]. In the article of Aguilera-García, Á. et al. a model has been developed that includes factors influencing the frequency of scooter sharing among the population of Spanish cities. Such factors include age, level of education and other socio-demographic characteristics that determine the choice of a passenger trip option [11]. Some authors, for example, Hartl et al., prove that financial benefits are the key factor of choice for consumers [12].

In addition, less capital-intensive projects solving the "transport problem" are aimed at improving the efficiency of elements of the transport system. Such projects include the development of transport hubs [13, 14], the introduction of "smart" traffic regulation systems, "smart" stops, the development and implementation of a unified fare payment system, etc. It can be noted that the interest of Russian researchers in the methods of solving the transport problem in megacities is growing, which is reflected in the publications of Zhuravleva N.A. and Shavshukov V.M. [15], Kazanskaya L.F. and Proskuryakova E.A. [16]. Some works emphasize the transformation of the Russian market of urban transport [17] and the development of intelligent technologies in transport [18–20]. The emphasis is placed on the fact that for the sustainable development of urban transport systems, new forms of interaction of market entities are needed [21], which include effective resources management based on "smart" solutions [22], and the emergence of new forms of urban mobility.

Despite many methods of improving the efficiency of the urban transport system are considered, the problems of their economic assessment, considering features of the development of technologies, new forms of mobility, are not fully disclosed. In this regard, the development of new methods of economic assessment of urban transport projects becomes relevant.

This article is aimed at systematization of social effects arising in urban transport projects and analysis of available methods of their assessment.

2 Materials and Methods

The theoretical basis for the research is the scientific works of domestic and foreign researchers in the field of city logistics, transport economics, the economy of shared consumption, and market analysis. To conduct the research, such general scientific methods as analysis and synthesis, induction and deduction, generalization, analogy were used. To assess social benefits in case study, we use some special methods developed by Evreinova N.Yu (Russian University of Transport, Moscow) in her thesis connected with the economic assessment of functioning of transport hubs.

For this article, we use data from open sources containing data on urban transport system and transport development projects in St. Petersburg, Russia. For the case study, we use data from the official website of the Committee for the development of transport infrastructure (St. Petersburg) about transport hubs projects. We use the description of Devyatkino transport hub to identify social benefits of the project. We also get data for calculating the effects from simulation modeling and using expert assessments.

3 Results

Based on the analysis of open sources data and scientific publications, it can be concluded that most urban transport projects generate not only commercial benefits, but also public effects. That is why many transport projects are implemented on the initiative and with the support of the state. At the same time, one of the options for combining commercial and public effects in the project is its implementation based on public-private partnership (PPP).

Public-private partnership is a combination of state financing and private capital in the project; there are different forms of PPP, for example, a concession agreement. In any case, when using PPP, the question of the funding structure, the ratio of the shares of the state and the private investor is relevant. We believe that the share of each party should correspond to the amount of benefits (effects) it receives from the implementation of the project. This presupposes the need for full and accurate accounting of social effects, the recipient of which is the state. To solve this problem, it is necessary to systematize the social effects generated by transport projects considering the growing need of the population for fast comfortable transportation, the emergence of new forms of urban mobility. Based on the materials of open sources, we concluded that the main social effect of such projects is reducing travel time. It is also advisable to specify which component of the total travel time is being reduced - driving time, waiting time for transport vehicle, time for a transfer, taking into account the specifics of a particular project. The second significant social effect is environmental. It consists in reducing carbon emissions, noise pollution of the environment by redistributing passenger traffic by transport modes, reducing the level of motorization, and increasing the intensity of use of public transport. The third effect is a reduction in the number of road accidents. It is also a consequence of a decrease in motorization and congestion on highways. An important effect for society is cost savings for passengers, which is typical for new forms of joint mobility, for example, for carsharing. Some researchers also identify such an effect as more comfortable trip. This effect, on the one hand, contributes to an increase in demand for public transport, and on the other hand, reduces transport fatigue, which can also affect labor productivity indicators.

The listed effects manifest themselves in different ways, considering the specifics of the project being implemented. Table 1 shows an attempt to systematize them depending on the content and focus of the project.

In addition to description of social effects, their cost assessment is necessary to substantiate the structure of funding. As an example, let us consider a project for the development of a passenger transport hub, which include an intercity and international bus station, a railway station and a metro station, as well as business infrastructure facilities, pedestrian crossings and parking (Fig. 1).

The project is supposed to be implemented in the form of a public-private partnership (a concession agreement for a period of 40 years).

The social effects in transport hub projects reflect the interests of passengers, as well as car owners and the city (region) on whose territory the facility is being built. The most important externalities include:

– reduction of passengers' travel time on the territory of the city.

Table 1. The main social effects generated by urban transport development projects.

Focus (content) of the project	Main social effects
Smart traffic regulation	Reduction of driving time (by reducing waiting for a traffic light signal), reduction of transport fatigue, reduction of accidents
Passenger transport hub development projects	Reduced transfer time, increased demand for public transport services
Projects for the development of forms of joint mobility	Saving passengers' costs, reducing the level of motorization, environmental effect
Smart stops and stopping points	Reducing the waiting time of the vehicle, increasing the level of comfort, increasing demand for public transport services
High-speed urban transport development projects	Reduced driving time (due to increased speed), increased comfort level, increased demand for public transport services, environmental effect, reduced accident rate
Multimodality development projects	Reduction of waiting time and transfers, increase in comfort level, increase in demand for public transport services, environmental effect, reduction of accidents

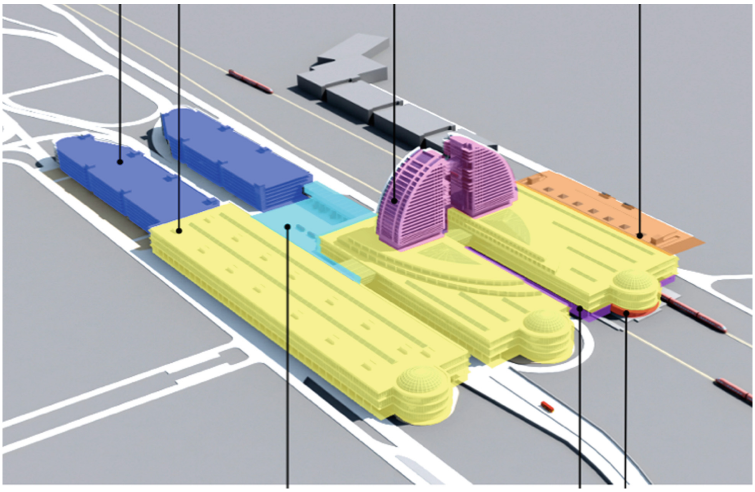

Fig. 1. Layout of passenger transport hub

– unloading of the road network because of the growing attractiveness of public passenger transport.

To carry out a quantitative assessment of these effects, we will use the methodology proposed by Evreinova N.Yu. The assessment of the social effect of reducing the time of passengers on the road, rubles per year (E_{pass}^{year}), is carried out according to the formula:

$$E_{pass}^{year} = 288 * P_{day} * GRPp * \frac{\Delta t}{60}, \quad (1)$$

where P_{day}– is the daily passenger turnover of the considered transport hub (passengers per day);

GRPp– gross regional product created by a passenger per hour (rubles per hour);

t – saving passengers' transfer time (minutes).

The GRP created by the passenger per hour is calculated by the formula:

$$GRPp = GRP/(365 * 24 * N), \quad (2)$$

where *GRP* – the value of the annual GRP of the region in question (rubles);

N– the number of economically active population of the region (people).

To assess this effect, we used data from official state statistics, as well as the results of simulation modeling of the transport hub functioning in a situation "with a project" and "without a project". The data for the calculation are presented in Table 2.

Table 2. Data for calculation the public effect of reducing passengers' travel time.

Indicator	Unit of measurement	Indicator value	
		min	max
Total passenger traffic	thousand people	2 185, 509	2 185, 509
Saving passengers' time spent on transfer	minutes	5	9
Daily passenger turnover in the transport hub	pass/day	70000	85000
GRP	billion rubles	3 742	
Number of economically active population	thousand people	2 980,90	

According to Table 2, the social effect of reducing the travel time of passengers according to the maximum option will be from 240.7 to 526.2 million rubles per year.

Unloading of the road network because of the use of the transport hub is provided by transferring some motorists to public transport. This social effect E_{road}^{year}, rubles per year, can be estimated using data on the cost of mileage of cars according to the following formula:

$$E_{road}^{year} = 365 * \Delta N_{day}^{cars} * S_{km} * l_{avr}^{route}, \quad (3)$$

where ΔN_{day}^{cars} – reduction of daily traffic intensity at the entrance to the city and at the entrance to the city center, cars per day.

S_{km} – average cost of 1 km of passenger car mileage, rubles.

l_{avr}^{route} – average length of a route, km.

Table 3. Data for calculating the public effect of unloading of the roads.

Indicator	Unit of measurement	Indicator value
Reduction of daily traffic intensity at the entrance to the city and at the entrance to the city center	cars per day	5 000
Average cost of 1 km of passenger car mileage	rubles	9,57
Average length of a route	km	29

Data for calculating the effect were also got from simulation modeling and using expert assessments. They are presented in Table 3.

According to Table 3, the economic effect of unloading the road network because of using the transport hub will amount to 506.5 million rubles per year. Thus, according to our preliminary calculations, the social effects in the transport hub development project can range from 0.75 to 1.03 billion rubles per year.

4 Discussion

The cost assessment of social effects obtained in the example above can serve as a basis for determining the structure of funding for the development of a transport passenger hub. In this case, the shares of the state and the private investor should be proportional to the effects they receive.

At the same time, the assessment of social effects in some cases is difficult or impossible for several reasons. First, there are effects that cannot be quantified. Thus, the following effects cannot be correctly estimated: an increase in the level of comfort; convenience; reduction of transport fatigue. These effects describe the new quality of urban transport, increase its level of development, therefore, when evaluating investments in relevant projects, they cannot be ignored. However, the question of its assessment and the impact on the structure of funding of the project remains open.

Secondly, when trying to assess some effects, difficulties may arise, consisting in the availability of alternative approaches to evaluation, the impossibility to consider all the components of these effects, or the difficulty of assessing the impact of the project on the dynamics of macroeconomic indicators. For example, when assessing the effect of reducing travel time, the average salary of a passenger can be the basis of a cost assessment. An alternative approach to assessing the effect of reducing travel time involves using the value of the gross regional product per capita created in the region per hour as the cost equivalent of the time saved. However, this approach ignores the fact that the released time can be spent not only on work, but also on rest. In addition, it is not possible to assess the impact of the projects on the growth of macroeconomic indicators, an increase in tax revenues that occur under the influence of many factors.

Thirdly, the problem of assessing social effects lies in the varying degree of objectivity of the proposed approaches based on conditional indicators and assumptions. Thus, the available methods for assessing the environmental effect and reducing accidents are based on stochastic methods and expert assessments, which casts doubt on the cost indicators obtained.

5 Conclusion

Summing up the results of the study, we can draw the following conclusions.

At first, new forms of urban mobility led to the emerging of new business models, new methods of pricing, and gave rise to new problems of transport functioning.

Secondly, problems of economic assessment of transport projects, considering features of the development of technologies and new forms of mobility, are not fully disclosed.

Thirdly, most urban transport projects generate not only commercial benefits, but also public effects. When using PPP, the question of the funding structure is relevant. This presupposes the need for full and accurate accounting of social effects, the recipient of which is the state.

Finally, it is important to identify and assess social benefits of particular transport project, taking into account its features and the scope.

Thus, the assessment of social effects in transport projects is a complex task, connected with some problems. However, it is obvious that the projects under consideration bring the urban transport system to a new level of development. Therefore, it can be concluded that such projects require the fullest possible identification of social effects and further refinement of methods for their cost assessment.

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Digitalization and Data Driven Logistics at Dutch Logistic SMEs

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Abstract. Dutch logistic Small and Medium Size companies (SMEs) are lagging behind on the field of digitalization. They concentrate on operational processes, which are obstructed by the increasing influx of data, that they have trouble processing, especially if there are disruptions, such as the consequences of the COVID-19 pandemics. This paper contains a brief literature review on the topics digitalization in logistics and data driven logistics providing definitions and an exploration of the field. The paper concludes that the notion data driven logistics does not exist in the literature. The papers treating data driven applications in logistics contain analyses on a high abstraction level, which are not suitable for SMEs. Based on the literature it is concluded that digitalization both starts and ends with the definition of a digital strategy, which means that it should have a circular model. Further, the paper proposes an applied research methodology to explore the problem of lack of digitalization at SMEs by performing a scan of Heeroma et al [1], the Digiscan of evofenedex and searching for solution at the platform Datagids. These sources are found in the gray literature. The author poses a question on how to proceed with the research when digitalization is to be assessed instead of the company level on the supply chain level, which should be a subject of future research.

Keywords: Digitalization · SMEs · Data driven logistics · Industry 4.0 · Scans

1 Introduction

The shift towards digitalization and data driven logistics are developments that the Dutch Small and Medium Enterprises (SME's) cannot afford to ignore. It may be possible for companies to use outdated digital technology at the moment, but in the long run, they will lose their competitive position against major global players, which digitalize fast and harvest the advantages of data driven logistics. The COVID-19 pandemic has shown how important resilience is for companies that can be enhanced by digital means.

There is definitively a gap to close. From the Dutch 100 top logistics companies, 20% is seriously involved in digitalization and only 5% uses digitalization to its full potential. In general, the smaller the company, the less likely it is to digitalize [2]. Numerous SME's in the logistic sector lag behind on the field of chain digitalization and data communication, and they are not yet fully informed about the possibilities

I. Ilin et al. (Eds.): ICDT 2021, LNDECT 157, pp. 68–78, 2023.
https://doi.org/10.1007/978-3-031-24434-6_7

that data driven logistics offers for increasing their added value. The added value can be efficiency, supply chain integration and a better business model. The problems with digitalization are mostly caused by priority on operational processes and the lack of time. The problems with data communication are mostly caused by the lack of trust between companies, which makes them reluctant to share data. The lack of applying data driven solutions on its turn is caused by the lack of knowledge.

At the moment, companies are mostly offered help in digitalization in a technology driven manner., however, companies are more interested in and benefit more from an approach that starts from their (digital) strategy, bottlenecks in their operational processes and their digital maturity [2].

This paper describes a project proposal for enhancing digitalization, data communication and data driven logistics at Dutch logistic SMEs. The project proposal: *Data Driven Logistics Plug and Play Readiness* aims to be a starting point for preparing SMEs in the Netherlands to shift towards digitalization and data driven logistics. This is well-aligned with the aim of The Netherlands, as part of European Union, to use innovation such as application of technologies, in order to achieve competitiveness and sustainable performance in logistics [3–5]. Therefor, the central research question of this paper is, which methods are there in the literature that help SMEs digitalize and how should they be used?

After this introduction, Section 2 presents the status quo in the academic literature about digitalization data communications and data driven logistics. Section 3 explores a scan from the grey literature and two practical approaches. Section 4 provides a discussion on the feasibility of the project after which the conclusions are presented.

2 Materials and Methods

In order to answer the central research question in this paper first a comprehensive exploratory literature review is performed in the academic literature on digitalization and data driven logistics. The search procedure, terms and the results are described in Sect. 2. As the literature review has delivered only contextual results, the search was continued in the gray literature and among practical solutions, which is described in Sect. 3 Here the choice was made eclectically and practically, which is suitable for applied research. The advised methodology is a synthesis of the found tools, that is to be tested in the proposed research project empirically.

This section contains a concise literature review on two topics, digitalization and data driven logistics. The third subject, data communication in logistics, has delivered too many hits for a comprehensive literature review about them, and as it overlaps with the other two topics, it is not discussed here separately.

2.1 Digitalization in Logistics

The search "digitalization" and "logistics", "peer reviewed" publications "from the last 5 years", in "English" has delivered 87 hits, which after removing the duplicates, editorials, too specific, geographical, application of industry related articles, left nine relevant items.

First of all digitalization needs to be defined. Heilig et al. define digitalization as a sociotechnical process, which implements digital tools in a broader social and institutional context, as opposed to digitization, which is merely translating analog sources into digital information. The authors specify digital transformation as a broader process of transformation on among others, strategy, governance and leadership, which use enablers, digital technologies and concepts. As enablers they list cloud computing, Internet of Things, cyber-physical systems, blockchain, real time data science, such as big data and machine learning.

Heilig et al. define five levels on which the changes take place. The first three levels relate to the changes within the company, while the fourth and fifth levels refer to supply chain level. On the first, localized level, there are minor changes by the implementations of production planning and inventory management systems. On the second level internal technical and organizational integration takes place, facilitating cross functional integration and connecting internal data silo's by implementing ERP systems and data warehouses. On level three there is a complete business process redesign, to increase the integration achieved on level two. Further integration between processes enables more streamlining, coordination, and monitoring. Level four moves outside the organization and helps redesign interorganizational networks. On this level data exchange standards, such as EDI is applied and it could include collaborative planning, management, collaboration and data exchange. At the last, fifth level the revision of the business model and strategy takes place, such as restructuring or outsourcing the activities, including new products and services and change long standing alliances and practices [6]. Figure 1 shows these levels of digitization in logistics including examples of enablers of technologies used for each level.

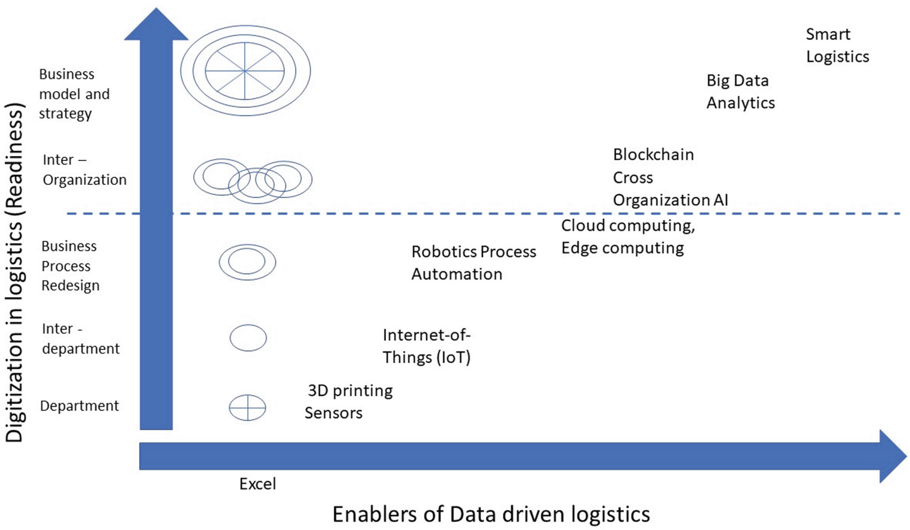

Fig. 1. A framework summarizing the levels of digitization in logistics and various technological enablers for each level.

Heilig et al. also define three dimensions of digital transformation, scope, scale and speed. Scope can be seen as trans-functional, as they overlap different business processes. The scale tackles problems with upscaling the infrastructure and possible information overload. Speed refers to competitiveness, which requires fast action, supply chain control by joint access to data, inter organizational network forming by digital innovation – all sources of value creation [6]. For this research it is important to consider the levels and dimensions of digital transformations as they can be different at companies at different digital maturity levels.

Zouari uses the definition of digital tools of Frank et al. digital tools as technologies that provide intelligence and connectivity [1, 7]. Heilig et al.'s definition indicates that next to the technical aspects of digitalization the social and institutional context is equally important. Correspondingly Mathauer & Hofman emphasize the importance of technology acceptance for digitalization [8].

The importance of digitalization is pinpointed in the literature on different logistic fields, for example for process planning logic in manufacturing [9], estimation of product availability in retail networks [10] and transparent demand forecasting of spare parts [11]. The resilience of logistics service providers is also a major topic in the literature. Herold et al. mention the enforcement of digitalization and data management as one of the five strategies that has helped logistic service providers to survive the Covid 19 pandemics. They claim that there is a demand on the logistics field for example for better prediction, and digital measurement of packages. Better use of data could make better tracking of products possible, which could be used for slow steaming to apply ships as floating warehouses. However, according to the authors, numerous companies, especially the smaller ones, lag behind in digitalization, because companies often resist innovation and they are unwilling to change [12]. Bergström especially recommends digitalization to third party providers, who are according to him "stuck in the middle", they lost their competitive advantage in performing customer servitization and cannot produce economies of scales to compensate for it [13]. According to Herold et al., there is an urgency in digitalization, as Amazon and Alibaba have already patented anticipatory shipping, which allows them to ship the products, before they were even ordered and store them in local warehouses, close to the customers. The volume of data that these major companies possess, allows them to make reliable predictions [12].

Pan et al. explore the interoperability of digitals systems with the Physical Internet, which promise to interconnect and coordinate logistics system worldwide. They conclude that there are four challenges on this field: (1) the data sharing format, which is a question of standardization, (2) open communication, which is related to the trust issue between companies, (3) privacy, security and access restrictions, and finally (4) the combining product and order related data [14]. Table 1 gives an overview of the topics articles in digitalization in logistics.

Concludingly it can be stated that the recent literature defines digitalization as a broader process, which includes next to the technical aspects, strategy, leadership, a social and institutional context and technology acceptance. The technical aspects are comprised by enablers, the concrete technologies. On the field of technology Pan et al, treat the interoperability of digital technologies with the Physical internet and defines four bottlenecks [14]. The literature emphasizes the urgency of digitalization, especially

Table 1. An overview of the topics of the articles on digitalization in logistics

Topic	Authors
Definitions	
Digitalization	Heilig et al.
Digital tools	Zouari, Frank et al.
Technology acceptance	Mathauer & Hofman
Classifications	
5 levels, 3 dimensions	Heilig et al.
Importance of digitalization	
Process planning logic in manufacturing	Xu et al.
Estimation of product availability in retail networks	Xu et al.
	Derhami et al.
Transparent demand forecasting of spare parts	Andersson & Jonsson
Resilience of logistics service providers	Herold et al. (2021), Bergström
Interoperability of digitals systems	Pan et al.

to small parties, i.e. logistic providers, to enhance their resilience and supply chain integration. The literature distinguishes different levels of digitalization. At the highest level there is a change in the strategy and business model.

2.2 Data Driven Logistics

The literature search for "data driven logistics" and "peer reviewed" and "English" has delivered ten thousands of hits, while an additional restriction: "publications from the last 5 years" has led to thousands. In order to reduce further the number of articles to a feasible amount, only the publications from 2021 are considered, which delivers 21 hits. After a similar selection as described in the previous paragraph, 14 articles were selected. In this section, after a discussion on the definition of data driven logistics the 14 articles are reviewed.

Conspicuously, none of the thousands of articles have data driven logistics in their title, instead, they address a data driven topic in a certain logistic area. This produces a doubt whether such a notion as "data driven logistics" actually exists in the literature. Consequently, there is no definition of data driven logistics found in the articles. Thus, in this paper, a working definition of data driven logistics is created based on the analogy of the definition of digital transformation by Heilig et al. as applying enablers, digital technologies to enhance the business performance of companies or networks of companies, using data [6]. These enablers are according to Davis et al. are Internet of Things, artificial intelligence, cloud infrastructure, big data analytics, nano-technology, advanced robotics/robotic process automation, sensors, blockchain, 3D printing, augmented reality, quantum and edge computing [15].

The majority of the articles address optimization based on big data analytics in physical distribution. Two of them propose routing systems, such as Wang et al on the field of inventory [16] and Zunic et al. for city distribution [17]. Another two articles focus on location optimalization, such as Nguyen et al. in dry ports [18] and Lv et al. (2020) in steel logistic parks [19]. Chenhao et al. use data analytics for the efficient sorting of e-commerce packages [20] and Gutierrez-Franco et al. intend to to optimize last mile operations of forward- and reverse logistics [21]. Two articles apply risk analysis, Xu et al. on the field of the efficiency of e-commerce logistics [22] and Wu et al. for cargo loss [23]. All these articles use quantitative analysis on a high abstraction level, creating calculation algorithms, combining different methods. Table 2 gives an overview of the literature on data driven logistics. The approach proposed in these articles is not suitable for this research as the companies involved in it are on a too low digitalization maturity level to implement these data driven applications.

Table 2. An overview of the literature on data driven logistics

Topic	Logistics application	Authors
Definitions		
Enablers		Davis et al.
Optimization based on big data analytics in physical distribution		
Routing systems	Inventory management	Wang et al.
	City distribution	Zunic et al.
Location optimization	Dry Ports	Nguyen et al.
	Steel logistics	Lv et al.
E-commerce efficiency	Sorting packages	Chenhao et al.
	Last mile	Gutierrez-Franco et al.
Risk analysis	E-commerce logistics, cargo loss	Xu et al.
	Cargo loss	Wu et al.
Supply chain capabilities and financial performance		Yu et al.
The impact of industry 4.0 applications.		Davis et al., Keane et al., Shaw et al., Sheares

An exception is the paper of Yu et al., which analyzes the effect of big data analytics on supply chain capabilities and financial performance. They address four supply chain capabilities – information exchange, coordination, activity integration and responsiveness. They conclude that especially coordination and responsiveness increase financial performance [24].

A separate category of articles are the four publications on the applications of industry 4.0 of the journal Economics Management and Financial Markets. These articles are based on data of diverse consultants and interviews conducted by the authors with professionals from the industry and their opinions about the impact of industry 4.0 applications. These articles can be useful for the research as a comparison of the results [15, 25–27].

Concludingly it can be stated that the literature on digitalization treats definitions, classification, the importance of digitalization in different domains of logistics, next to the definition of enablers on Optimization based on big data analytics in physical distribution. One article analyses the effects of data driven logistics on financial and supply chain performance. A series of articles inventories the expectations of professionals from the industry 4.0 applications. The literature on digitalization helps to formulate a working definition of digitalization and data driven logistics as a process of transformation of strategy, governance and leadership, which use enablers, digital technologies and concepts. However, except for the framework of Heilig et al. and the work of Yu et al. the academic literature does not provide much help in finding a methodology to perform the research for Dutch SMEs to explore the possibilities of digitalization, data communication and Data driven logistics for them. In order to find a methodology the search is extended to the grey literature and practical solutions.

3 Results

In this section a number of other methods and sources are discussed, about which have not been published in the academic literature (yet). The selection method of these is practical, they are developed by parties from the consortium of the project proposal. This section treats the following topics, firstly the blockchain feasibility scan of Heeroma et al., secondly the digital maturity scan of Evofenedex and thirdly the platform Datagids.

3.1 Blockchain Feasibility Scan

From the literature review it became clear that digitalization needs to be connected to strategy. Heeroma et al. developed a business scan for the applicability of blockchain to logistic SMEs. They examine the added value of the company from a strategic point of view, followed by exploring the power relations in the supply chain and the critical processes of the company. Lastly, they analyze the critical processes further, in order to assess the applicability of blockchain technology. They have selected from the academic literature research methods and tools on strategic, tactical and operational level and combined them. The proposed tools and methods are the SWOT analysis together with a confrontation matrix, SCOR metrics, Business Process Notation (BPMN or swimming lane analysis), RACI or RASCI that explores the responsibilities of employees in the processes within the organization, and finally the Olson criteria are used for the assessment of information quality [28]. This scan was originally intended for research on the application of blockchain, nevertheless it is also useful for a problem driven approach to digitalization and data driven logistics. However, it is necessary to include a scan that is specifically meant for digital maturity, which is discussed in the next section.

3.2 Digiscan of Evofenedex

Evofenedex is the Dutch organization of shippers, which, in order to help its member to digitalize, has developed a digital maturity scan [28]. For the scan companies need to answer 260 questions on 18 topics. The topics include, next to the technical issues, company culture and (human resources) strategy. Based on the results the scan calculates on which digital maturity level a company is situated. It is possible that companies are at different maturity levels based on different aspects. There are four maturity levels described, digital core, connectivity, digitalization and disruption. The levels are comparable to the levels of Heilig et al. although de Digiscan as one level less.

There is a common denominator in the scans of Heeroma et al., evofenedex and the levels of change of Heilig et al. that digitalization starts with a digital strategy and ends with the change in the strategy, a new business model or a disruption. Given the fact that it is expected that digitalization and data driven logistics will develop further and that there is no end to technological development, the model that frames this development should be circular, see Fig. 2.

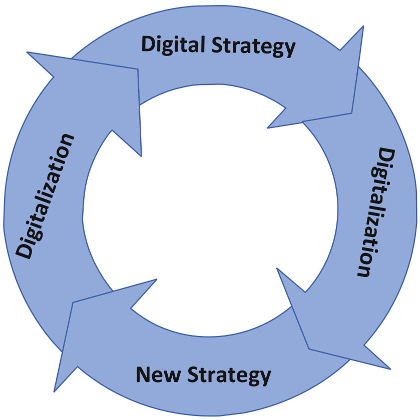

Fig. 2. A circular model of strategy and digitalization.

The goal of the Digiscan is to give advice to companies about what the next steps are for them in digitalization based on their digital maturity level. For example, for a company that is on level one, the digital core, some steps should be taken before it can start initiating a blockchain implementation. Next to Digiscan, there is another tool that can advise companies about their advancement in digitalization based on a decision tree, which is introduced in the next section.

3.3 Platform Datagids

Poort8 is a startup consultancy company, which specializes in data sharing solutions in logistics [29]. It has developed Datagids, a platform for companies looking for the next step in digitalization. Companies need to fill in a decision tree which starts from their motivation, goals and the obstacles that they experience in digitalization in order to guide them to the solution. When based on the questions it becomes clear what the company exactly wants, the company is provided with the data of the parties that can provide the solution. Basically, it is a matching platform for problems and solutions and the parties that can help. For this research it is a relevant tool as it contains solutions that are accumulated by years of research. The way how this platform can be integrated into the research is discussed in the next paragraph.

4 Discussion

This paper provides an explanation of a research proposal on digitalization and the introduction of data driven logistics in Dutch logistic SMEs, consisting of a review of the academic literature and some practical sources from outside of it. The paper proposes a methodology as follows: the participating companies are firstly scanned by the scan of Heeroma et al. which is used in this case for a more general purpose, than it was originally meant for. This scan will deliver the connection between the company's strategy and the possible added value of digitalization, and the practical use of digitalization in its critical processes. The next step is to perform the Digiscan, to establish the digital maturity level of the company. From the digital maturity level it can be derived what the next steps are that the company can take to digitalize more and strive towards data driven logistics. The solutions can be sought for in the decision tree of Datagids. This step validates the database and eventually found solutions can enrich it further, thus improving this tool to help SMEs to digitalize. Up till now the research has a linear flow, parting from a digital strategy towards data driven methods. However, as the outcome of digitalization changes the business model and that the technological development is endless, the model of the research is supposed to be circular.

This approach does have a bottleneck. The research focuses on individual companies, while according to both Heilig et al. from phase 4 and according to the Digiscan from phase 2 digitalization takes place between companies by means of data communication. In order to tackle this problem, the research is conducted as much as possible with companies that are supply chain partners or clients of each other's. This, however, poses the problem of confidentiality and the fear for data sharing. The project aims to prove to the participating companies that data sharing offers advantages by exploring its added value. However, there may be a need for this of a maturity scan for data sharing.

5 Conclusions

This paper started by a short review of the academic literature on digitalization and data driven logistics combined with the discussion of a source from the grey literature, a Digiscan and a matching platform between problems with digitalization, solution and parties who can provide it. The paper proposes a methodology of combining two scans, that of Heeroma et al. and the Digiscan of Evofenedex together with applying the decision three of Datagids. The research is advised to use a circular model, instead of a linear one for digitalization. The assessment of digitalization after level 4 of Heilig et al. and level 2 of the Digiscan become problematic as from that point more parties are involved in the supply chain. This poses the problem of confidentiality and it is likely that for this part of the project additional methodology is needed.

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Conventional and Digital Technologies Convergence as an Additional Advantage in Ensuring of Supply Chain Counterparties Economic Growth

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Abstract. Hybrid business models of digitalization are relevant for most companies at the stage of digital transition, since digitization of business models occurs partially, digitalization projects are implemented in close connection with traditional technologies, previous ways of providing consumers with a value proposition, and it is often impossible to implement digital projects in isolation from traditional ways of organizing the provision of services. Business faces not a full-fledged digitization of business, but a partial or so-called hybrid model. The article proposes the definition of a hybrid model of digitalization, substantiates the economic advantages, as well as the risks and threats of additional losses during the introduction of hybrid digitalization models, offers a combined matrix-scheme of the effects of digital transformation projects of the Russian Railways Holding and the parameter "degree of project hybridization". Based on the method of analyzing hierarchies for a separate sample of projects, the technology of ranking them according to the multicriteria principle, taking into account the degree of hybridization parameter, is shown. The methods of descriptive diagnostics, content analysis, hierarchy analysis and a number of others were used. The results are useful for companies' management to understand the essence of transitional – hybrid models within the framework of corporate digitalization projects and programs.

Keywords: Hybrid models · Hybrid digitalization · Digital technologies · Hierarchy analysis method

1 Introduction

A hybrid business model of digitalization means the simultaneous application of a traditional business model (previously existing traditional technologies, methods of organizing sales and management tools that work not on a digital basis) and an innovative business model (involving the digitization of both internal processes and the creation of digital channels, platforms, consumer interaction services, as well as the introduction of cyber-physical assets into the production process).

I. Ilin et al. (Eds.): ICDT 2021, LNDECT 157, pp. 79–87, 2023.
https://doi.org/10.1007/978-3-031-24434-6_8

The hybridization process combines various elements of two business models into one hybrid model, which is considered as a special form of the management object at the stage of the digital transition of companies. The hybrid form of synthesis of digital and non-digital technologies, market channels for the sale of products and services, the specific structure of the cost budget, combining the former items of expenditure with new digitization projects ultimately lead to competitive advantages that companies receive at the stage of digital transition of their business and the environment. On the one hand, there is a business model based on the traditional mechanism of rendering (in our case) transport services. Currently, we are witnessing a movement towards a hybrid market, characterized by a transition from the simple coexistence of two markets (traditional and virtual-digital) to a hybrid one. An example of the difference between a traditional market and a hybrid one is the basis, as a rule, a digital platform, where in addition to basic services, additional services are offered: related, potentially in-demand services, the purchase of which on a digital platform becomes more convenient and economical.

2 Materials and Methods

The information base of the study consists of statistical indicators included in the databases of international and Russian statistics, public reporting data on the Russian Railways Holding and its individual companies, open sources and analytical reviews providing information on the research topic. At the level of the Federal State Statistics Service of Russia (Rosstat), the indicators «Information on the use of information and communication technologies and the production of computer equipment, software and services in these areas» were used; «Information on the development and use of advanced manufacturing technologies».

Representatives of the foreign scientific community are mostly showing great interest in the study of hybrid business models today. Among the most informative works, we note the works of the authors: Cavalieri A., Saisse M. [2], Endres H., Stoiber K., Wenzl N.M. [3], Estrada M.A.R. [4], Goldsby C., Hanisch M. [6], Jacoby M., Jovicic B., Stojanovic L., Stojanovic N. [8], Tabak E. [16], Tabares S. [17]. The significant research potential and practical significance of the studied area predetermine its great prospects in Russia. The basis for the study of hybrid models of transport and logistics business is laid in the works of the authors: Bozhko L., Sapanova R., Shtykova I., Wijayanti F. [1], Fedorenko R.V., Khramtsova E.R., Pokrovskaya O.D. [5], Green L., Zhuravleva N. [7], Kazanskaya L., Proskuryakova E. [9], Pokrovskaya O., Fedorenko R. [11].

3 Results

3.1 Features of Hybrid Models of Digitalization

The introduction of hybrid business models, the essence of which consists in the coexistence of two complementary technological spheres: traditional methods of production and implementation, the creation of a value proposition for the consumer and digital transformations, in particular, electronic channels of interaction, digital services, platform solutions, new cyber-physical systems, represents a new scientific and practical problem. Hybrid models of digitalization also include such methods of describing business processes, which are characterized by additions of non-improvised traditional technologies with separate fragments of digital technological innovations. For example, digital projects are not implemented throughout the company, but only in a limited part of divisions, in a narrow segment of the main technological process, have the character of partial selective digital additions and minor transformations.

Hybrid models of digitalization will be in great demand, because in conditions of a limited budget of companies, hybridization undoubtedly contributes to companies obtaining an additional effect, greater added value, better orients their attention to the increasing demands of consumers in terms of the speed of operations, transparency and visibility of technological and logistics processes.

But the development of hybrid business models of digitalization is fraught with obvious risks and problems, in particular:

- hybridization leads to the duality of ensuring the operability of two convergent forms within one hybrid, performing operations, repairs and maintenance, updating digital and non-digital equipment and other assets (for example, servicing both ticket sales equipment at ticket offices and online information and communication devices);
- often, the digital form of a hybrid cannot function normally and smoothly in isolation from the traditional non-digital form: for example, errors that occur, failures in digital systems must be corrected and eliminated by employees (the probability of high costs here is high), and cyber-physical systems themselves are not able to do this;
- the work of cyber-physical devices, platforms, Internet of Things, etc. takes place under mandatory external supervision, the presence of a person;
- there are threats caused by possible cyber attacks, interference, hacking, information leakage;
- the limitations of the hybrid model, the impossibility of its full application at the request of customers due to the fragmented, point-based nature of the implementation of digital projects only in certain areas, divisions, decorative content, when individual technological solutions are implemented not to build a real business model on a digital basis, but to create a formal appearance of digitalization;
- the risks of reducing the investment budget after the launch of projects or the initial underfunding of large-scale events, which will lead not to real economic results, but to partial digital improvements and additions that create minimal effect.

In the Russian Railways holding, digital transition projects also have signs of a hybrid. Some of the projects are most practically feasible and low-risk within the hybrid model (dynamic pricing within the framework of the customer experience management platform; predictive analytics of technical condition based on mobile diagnostics data; predictive analysis of the technical condition of freight cars; management of customer experience and minimizing customer churn in CRM services). Individual projects, such as the introduction of a system of motorists on mountain locomotives; the system of assistance to the driver when driving due to technical vision; automatic disbanding of wagons on sorting slides, are characterized by increased risks within the framework of the hybrid digitalization model for many of the reasons outlined above.

Despite the risks, the hybrid digitalization model has great advantages in terms of generating additional effects.

The obvious advantage is the creation of additional competitive advantages in the hybrid model due to the differentiation of the offer. Various products and services are combined with digital services and additional services. Multi-channel sales options, both offline and online, increase the reach and flow of consumers.

Customer orientation in hybrid models is ensured, among other things, thanks to the close digital exchange and cooperation of companies, often competing. In digital environments, the consumer is provided with a variety of choices, a fast speed of obtaining information, and an additional value of multi-channel access is created.

Another significant positive effect of the hybrid business model is saving transaction costs, reducing unproductive losses and time costs that do not lead to the creation of value and value. We also note the economies of scale, the possibility of savings for both the company and its consumers (for example, in mobility services as a service, last-mile delivery services).

All this will lead to an increase in operating profit, an additional increase in the return on investment in hybrid digitalization projects.

Using a single example - the project of unmanned railway traffic - we will show that along with the advantages in the hybrid digitalization model, there are risks and a number of unresolved problems.

The introduction of unmanned technologies in railway transport will ensure the optimization of train traffic, high accuracy of the process without the participation of the driver, the release of human labor when performing routine operations, a significantly higher degree of awareness of dispatchers and, in general, traffic management information content, a greater level of safety and predictability of the system.

But the problems of autopilot rail traffic can arise over long distances (not within the agglomeration, but between regions). For example, the probability of a system failure when entering the path of an animal, a person, the appearance of foreign objects, snow debris, etc.

The occurrence of failures in the operation of systems will lead to the need for human intervention, the direction of a group of workers to the place of occurrence of the situation, will cause downtime and disruption of the arrival and delivery of goods in a certain direction.

With the transition to automation, the information load on the operator, the central dispatcher for the control of unmanned vehicles increases (for example, false alarms, erroneous warnings, etc.).

Catastrophic risks are also possible, which can lead to software failures, possible cyber attacks and hacking of control systems.

Therefore, hybrid digitalization business models should be implemented with very serious crash testing and performing a large number of technical and economic calculations.

3.2 Using the Hierarchy Analysis Method in the Study of Hybrid Models of Digitalization

In conditions of high risks of investing in hybrid digitalization projects, existing financial constraints on the implementation of large and large-scale investment projects, business investors need a high reliability of evaluation of the results and effectiveness of investments. Fragmentation, conditionality, multivariance, and the probability of achieving effects in hybrid digitalization models determine the importance of improving and deepening the methods of their assessment.

One of the tools here is matrix analysis, as well as multi-criteria analysis taking into account the hierarchy of evaluation indicators.

For the empirical evaluation of hybrid digitalization projects based on matrix analysis, we propose a specific analytical tool - a combined matrix-scheme of the effects of digital transformation projects of the Russian Railways holding and the degree of their hybridization. The matrix scheme is based on existing studies of elements of the corporate strategy of digital transformation of the Russian Railways holding until 2025, additional expert assessments based on the results of meetings and project presentations [10].

We introduce the concept of "relative degree of hybridization of the project" - a conditional value showing the combination, the ratio in the project of the critical mass of basic digital technological innovations and traditional non-digital technological units. In our study, we propose to differentiate the parameter by levels:

- absent hybridization – the project is completely based on full-fledged digital transformations, the processes of creating and implementing a product, services are fully implemented on the basis of digital technologies;
- weak hybridization – the project is mainly associated with a digital technological basis, and the addition of traditional technologies is insignificant;
- moderate hybridization - the project is associated with two forms of technologies in approximately equal proportions, digital solutions and traditional non-digital means of production are synchronized in importance, the contribution of each form to the creation of added value of a product, service is approximately the same;
- significant hybridization - the digital component in the project is of the nature of improvement, improves the basic form; the creation and implementation of products and services are effective even in the absence of digitization of business processes; the project is difficult to implement without traditional technologies;
- strong hybridization – the project is extremely slightly digitalized, the digital basis included in it is characterized by insignificant and barely noticeable influence; or the implementation of the project is impossible in isolation from traditional technologies.

Table 1 shows the formed empirical matrix-scheme of effects on a sample of projects of digital transformation of the Russian Railways holding and the degree of their hybridization.

A mathematical tool, the use of which is promising for further analysis of hybrid models of digitalization, is the method of hierarchy analysis. Its use does not lead to obtaining any single correct solution for the investor, but allows in a ranked sequence

Table 1. Empirical matrix-scheme of effects on a sample of projects of digital transformation of the Russian Railways holding and the degree of their hybridization

Evaluation parameter	Effect - cost reduction of:	Effect - additional income by (from):	Degree of hybridization
Project name			
1. Integrated system of interaction with customers participating in the freight transportation market (CRM)	Transactional costs, including for act-claim work	Cargo transit in international traffic, responding to customer requests	Moderate
2. Unified digital service - blockchain of smart contracting and interaction of freight transport participants	Transaction costs, losses from waiting times during paperwork	Monetization at the expense of additional services, due to the growth of cargo turnover with a decrease in the turnover time of wagons	Significant (complexity of full coverage)
3. Digital paperless transportation using Intertran technology	Losses from downtime and fines	Growth of the transit flow of goods	Weak
4. MaaS ticket solutions for passengers (basic and related services)		Generation of commission income, promotion of services in related industries, a single value proposition	Moderate (difficulty of full coverage)
5. Customer experience management platform «digital passenger footprint»	Individual unproductive costs and losses	Mobile response to demand, flexible tariff schemes	Weak
6. Predictive analysis of the technical condition of freight cars	Maintenance and repair costs, losses from unplanned downtime		Moderate
7. Artificial intelligence («unmanned locomotive», «traffic controller», etc.)	Cost reduction due to downtime of wagons, due to accurate compliance with the schedule, reduction of staffing		Strong (the value of constant convergence with traditional technologies)

Source: compiled by the author using data [19]

of alternatives to find an option that best fits with the understanding of the problem and the tasks at hand.

Table 2 shows the calculations of matrices and vectors performed by us using the hierarchy analysis method, which build a list of projects in a hierarchical sequence (determine the priority of projects) by synthesizing two criteria: "degree of hybridization" and "potential effect".

Table 2. Coordinated calculations and the final solution of hierarchical prioritization of the considered projects, found using the hierarchy analysis method

Project	Matrix of paired comparisons for the parameter «degree of project hybridization»							Approximate value of the main eigenvector	Matrix of paired comparisons for the «potential effect» parameter							Approximate value of the main eigenvector	Hierarchical synthesis vector - priority vector
Project 1*	1	3	1/3	1	1/3	1	5	0.126	1	3	1	3	5	5	5	0.282	**0.2430**
Project 2	1/3	1	1/5	1/3	1/5	1/3	3	0.058	1/3	1	1/3	1	3	3	3	0.143	0.1218
Project 3	3	5	1	3	1	3	9	0.270	1	3	1	3	5	5	5	0.282	**0.2790**
Project 4	1	3	1/3	1	1/3	1	5	0.126	1/3	1	1/3	1	3	3	3	0.143	0.1388
Project 5	3	5	1	3	1	3	9	0.270	1/5	1/3	1/5	1/3	1	1	1	0.050	0.1049
Project 6	1	3	1/3	1	1/3	1	5	0.126	1/5	1/3	1/5	1/3	1	1	1	0.050	0.0689
Project 7	1/5	1/3	1/9	1/5	1/9	1/5	1	0.023	1/5	1/3	1/5	1/3	1	1	1	0.050	0.0433

* Note: the numbering of the projects corresponds to the first table.
Source: developed by the author.

When using the hierarchy analysis method, we took into account two levels of hierarchy: the degree of hybridization and the possible effect for the company (medium, significant, high). Based on the results of calculations of the matrix of the hierarchy analysis method, the best solution according to the criteria: «income maximization/minimization of the «degree of hybridization» parameter are the projects: «integrated system of interaction with customers participating in the freight transportation market (CRM)» and «digital paperless transportation using INTERTRAN technology».

4 Discussion

Along with the obvious certainty and evidence of the results of the study, we can assess its limitation in terms of the lack of a set of statistical data to predict the effects and assess economic growth due to projects of specific technologies of the fourth industrial revolution: industrial Internet of things, big data analytics, distributed ledger platforms, artificial intelligence, etc.

The available statistical data arrays of «Russian statistical agency» and international statistics only allow ranking information on the use of individual technologies. Following the trend of new trajectories and problems of digitalization, relying on the experience of [12–15] we described not only the dialectical relationships between digital and traditional business models, but also formed matrix calculations using the hierarchy analysis method, which ranked the list of projects of digital transformation of «Russian railways» company in a hierarchical sequence, taking into account two criteria: «degree of hybridization» and «generated potential effect».

We can assess the limitations of our research in terms of the lack of procedures for predicting the effects of hybrid digitalization in transport using Big Data and artificial intelligence. This important direction of increasing the reliability of the results of the introduction of hybrid digitalization is used by a number of authors, in particular [10, 18, 20], and is the most important direction for further research.

5 Conclusions

Hybrid business models of digitalization have unconditional advantages, but at the same time their implementation is fraught with many risks and difficulties. The risks of hybrid digitalization are associated with fragmentation, the inability of the cyber-physical system to correct errors and eliminate their consequences, additional investment burden on businesses using a hybrid of traditional and digital factors for creating goods and services.

Hybrid business models of digitalization are a promising object of analysis, one of the tools of which is the matrix of the ratio of parameters: effects, degree of hybridization, priority in the portfolio of projects, investment costs, the value of return on investment.

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Development of Rail Container Transportation Based on Mobility and Logistics Efficiency

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Abstract. Increasing the level of containerization in Russia is a source of competitiveness growth, since it focuses on increasing the efficiency of nationally oriented logistics and integration into global logistics chains, ensures transparency and productivity of the transport and logistics sector. The negative consequences caused by COVID-19 have affected freight transportation by all modes of transport. The reaction of carriers to the existing challenges largely determines the trajectory of development not only of railway container transportation, but also the format of the development of Russian cargo traffic for the coming years or even decades. The purpose of this study is to develop measures to increase the mobility of container cargo turnover on Russian railways and indicative designation of possible effects from their implementation. We prove that the development of infrastructure, stabilization of tariff policy, optimization of operational activities, expansion of the digital platform significantly affects the qualitative and quantitative development of rail container transportation based on mobility and logistics efficiency. The methodology of the study is based on the analysis of the target indicators of containerization of Russian railways for 2010–2020, the main product line of container transportation and competitors of the railway by means of transport. As a result of the study, trends in the growth of the share of container cargo turn-over on the Russian railway network are determined, the support of digital tools is justified in order to increase the mobility of container cargo turnover, a set of mechanisms for supporting and developing railway container transportation based on mobility and logistics efficiency is proposed.

Keywords: Container transportation · Rail transport · Cargo mobility

1 Introduction

Changes in the current economic situation in the global cargo transportation market associated with the coronavirus pandemic have significantly affected the current state of the transport and logistics system, have made it possible to differentiate and identify a number of significant shortcomings of the logistics business, have outlined long-term development priorities in accordance with international quality standards and consumer preferences. The negative consequences caused by COVID-19 have affected freight transportation by all modes of transport. However, today there is an adaptation of transport companies to the limitation of activities and the restoration of transport activity.

I. Ilin et al. (Eds.): ICDT 2021, LNDECT 157, pp. 88–101, 2023.
https://doi.org/10.1007/978-3-031-24434-6_9

Railway container transportation showed the greatest stability and ability to adapt to new conditions. Despite the current conditions of uncertainty and interruptions in supply chains, there is an upward trend in the growth of container transportation volumes by rail (Fig. 1).

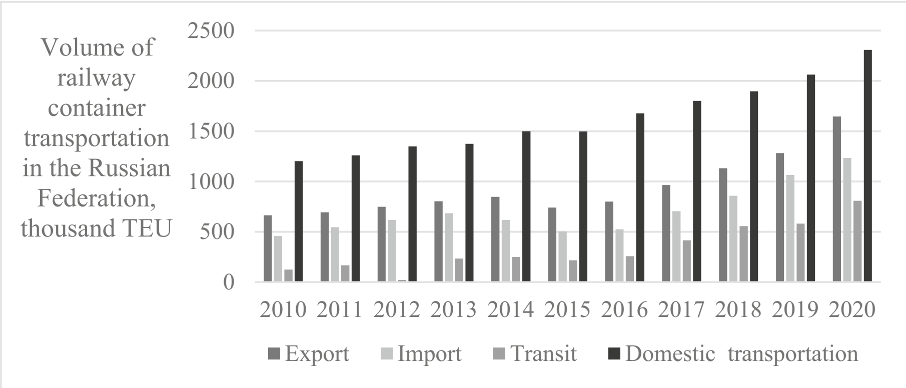

Fig. 1. Dynamics of rail container transportation in the Russian Federation, th. TEU.

As can be seen, by the end of 2020, the maximum indicators for the volume of container traffic were set – transit increased by 37%, imports by 16%, exports by 14%, while the share of domestic traffic decreased by 41%. Thus, containers have remained the fastest growing and most promising segment of transportation for Russian railways in recent years.

Nevertheless, there is a significant lag between Russia in terms of container cargo transportation by rail from developed and developing countries due to underutilization of the main geographical opportunities for overland transit routing between Europe and Asia, despite the fact that in September 2020 there is a rapid increase in export cargo transportation from China to the United States, along with a critical shortage of containers in China [1]. All this led to an increase in the container market by 15% compared to the same period in 2019 and an increase in tariffs for routes from China.

The total scale of the container world turnover is more than 50% of the total volume of cargo transportation, and part of the port infrastructure of Europe is more than 90% working under container cargo turnover. It is necessary to understand that increasing the level of containerization in Russia is a source of competitiveness growth, since it focuses on increasing the efficiency of nationally oriented logistics and integration into global logistics chains, ensures transparency and productivity of the transport and logistics sector through the use of innovative supply chain management technologies, optimizes "green" development trends by reducing the hydrocarbon footprint due to a decrease in the share of road transport.

Thus, it is possible to identify promising tasks in order to improve the quality of container cargo turnover for Russian railways, namely, the expansion of the internal network of container cargo transportation, the development of the transit segment, taking into account its high profitability (ensuring an increase in margin profit) and the growth of export-import turnover with a shift in emphasis to the European market, since the Far Eastern direction is almost completely covered by the introduction of the "Transsib service in 7 days".

The existing scientific base of research in the container transportation industry is mainly reduced to the analytical designation of possible and expected economic effects [2, 3], as well as individual expert judgments on the impact of the current economic situation on the future of the container business in Russia [4–8]. At the same time, at the moment, science has not sufficiently worked out the issues of increasing the mobility of container cargo turnover in the crisis conditions of the economy, which is key for container carriers. The aim of the study is to develop measures to increase the mobility of container cargo turnover on Russian railways and indicative designation of possible effects from their implementation. To achieve this goal, a set of mechanisms for the support and development of railway container transportation has been proposed, which will allow the Holding to reach a new level in the business of railway cargo transportation.

2 Materials and Methods

According to the results of the last 10 years, the average annual growth rate of the railway container cargo turnover of the Russian Federation is about 8%. It should be noted a difficult period for containers in 2015, when there was a decline in traffic by 8% due to the difficult economic and geopolitical situation. Starting from 2016, the situation is stabilizing, and over the next 2 years, the growth rate reaches the level of 19% (Fig. 2).

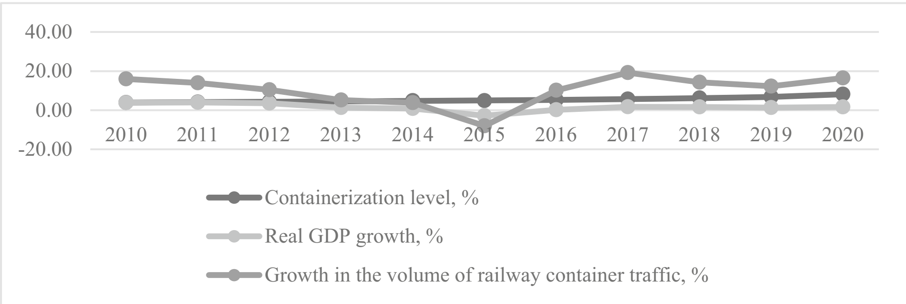

Fig. 2. Graphical relationship between the level of containerization, real GDP growth and railway container cargo turnover in dynamics.

At the present time, taking into account the impact of epidemiological restrictions on the economy, increasing or maintaining the volume of rail traffic is possible solely through transit. The volumes of export, import and domestic traffic have a slight downward trend, which correlates with the contraction of the economy. Nevertheless, COVID-19 has had a positive impact on the growth of the mobility of the transportation process, since digitalization and automation of container transportation has a stable growth trend. Most of the employees were transferred to remote operation, but due to the developed IT infrastructure, changes in the working format did not affect the stability and quality of transportation services. Some organizations are implementing pilot projects based on new digital tools. Thus, PJSC TransContainer, together with PJSC SIBUR Holding, has commissioned a pilot project for the integration of transport management systems (TMS) to organize a single end-to-end planning process and control over the execution of multimodal transportation.

The dynamics of the main target indicators of containerization of Russian railways also shows a positive development trend (Fig. 3):

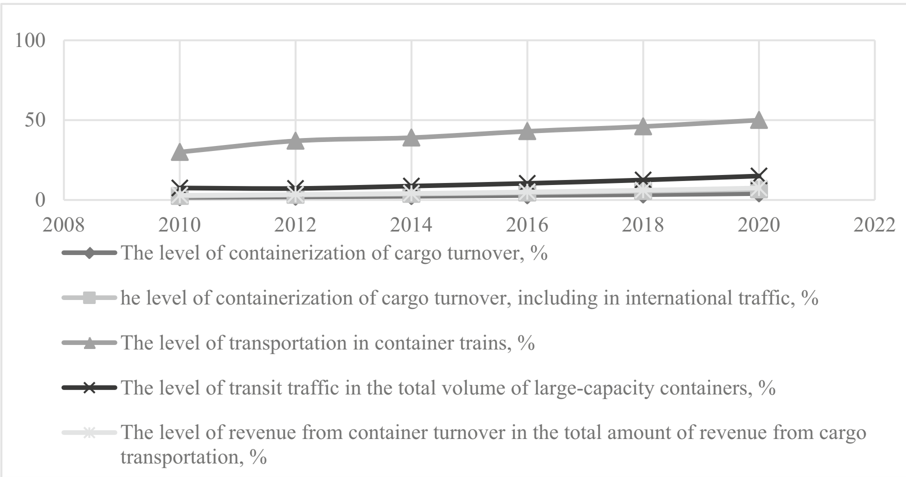

Fig. 3. The main indicators of the level of containerization of Russian railways.

The main product line of container transportation of Russian railways is represented by the following types of transport goods:

– single and group container shipping on all stations of the route of 75–450 speed km/day;
– transportation to container trains between stations equipped with container terminals with a Shuttle bus speed of 800–900 km/day;
– "Transsib in 7 days" – accelerated container train in the message «Find Red» route speeds of up to 1362 km/day;
– accompanying services – terminal handling of containers, motor transport delivery «to the door» of the customer, customs services (registration, temporary storage warehouse), forwarding services.

Despite epidemiological restrictions, there is an increase in international trade in 2020, which has a positive effect on export-import indicators. Export container turnover through the Russian Railways network in 2020 increased by more than 20%, while the share of loaded containers increased by 2.5% compared to 2019 and the share of empty container turnover decreased by 2.6%. The share of loaded containers in import traffic decreased by 3.8%, the increase in empty container turnover was 8.9%.

The structure of transportation in export-import traffic with grouping by type of goods is shown in Figs. 4–5.

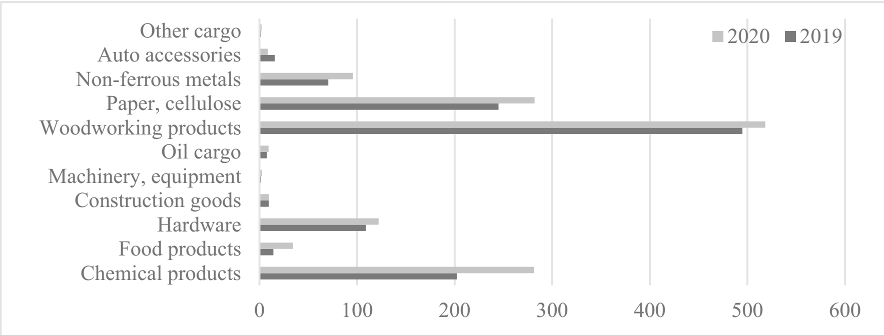

Fig. 4. Volumes of export container traffic on the Russian railway network, th. TEU.

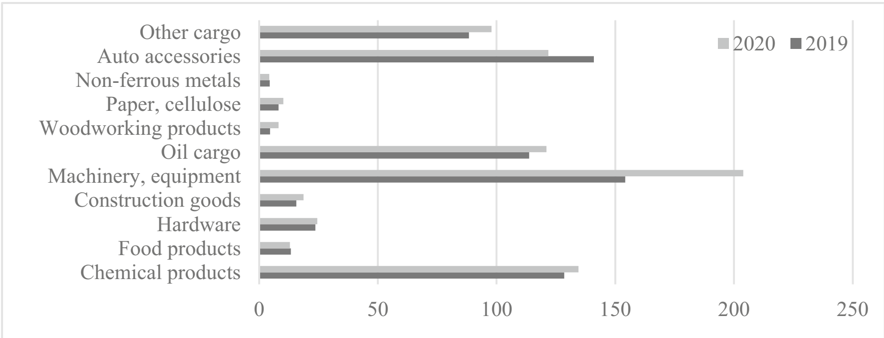

Fig. 5. Volumes of import container traffic on the network of Russian railways, th. TEU.

There is a significant increase in container transit cargo turnover of Russian railways – in comparison with 2019, volumes increased by almost 40% due to the introduction of a new route "Korea-Europe" and increased transit on the route "China-Europe-China" – an increase of 60% compared to the previous year. In domestic traffic, the route "Center of Russia-Siberia" works for the most part, the chemical industry goods and the food group of goods occupy the largest share in the cargo (Figs. 6–7).

The railway's competitors in container transportation are:

– cargo transportation by road, the route speed of which is more than 500 km/day, as well as the presence of advantages in cargo security services, door-to-door delivery and transportation costs up to 2000 km. – tariffs are lower than those declared by JSC "Russian Railways";

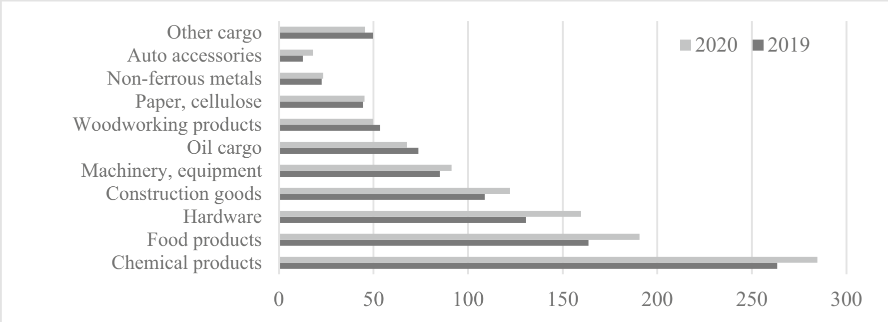

Fig. 6. Volumes of domestic container traffic on the network of Russian railways, th. TEU.

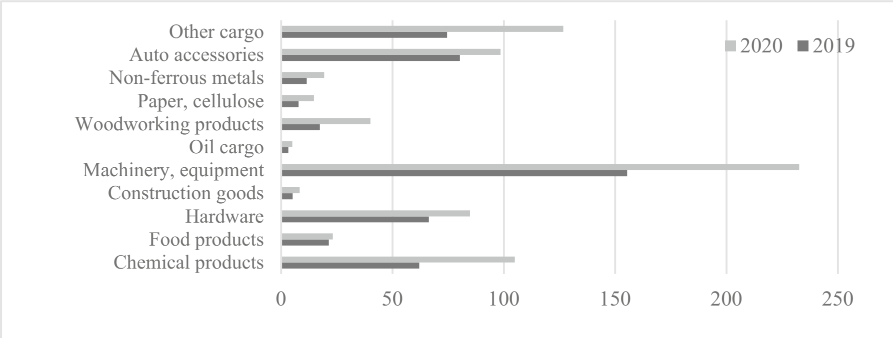

Fig. 7. Volumes of transit container traffic on the network of Russian railways, th. TEU.

– cargo transportation by sea with a route speed of up to 550 km/day, a range of transportation exceeding 2–3 times railway cargo transportation, as well as a tariff up to 2 times lower than that declared by Russian railways.

The research materials were accounting documents and studies of logistics companies and leading container operators – JSC "Russian Railways Logistics", "DHL Russia", PJSC "TransContainer", LLC "Tank-container Petrochemical Company", LLC "RG-Trans", "FM Logistic", JSC "United Transport and Logistics Company – Eurasian Railway Alliance" (OTLK EPA), TLC "Major Cargo Service", etc. The criteria of the Concept of integrated development of container business in the Russian Railways Holding are taken as a basis [9].

3 Results

3.1 Prospects for Increasing the Share of Container Cargo Turnover on the Russian Railway Network have been Established

According to the analysis of the container turnover market on the Russian railway network, transit traffic accounts for a significant increase in 2020. A significant contribution to the development of this direction is the subsidization of business and the introduction of preferential tariffs for container transit traffic on routes connecting the port stations of the Pacific Basin with the Baltic and Black Seas, as well as with checkpoints on the border with Finland, the Republic of Belarus, Poland and Azerbaijan, with compensation to Russian Railways for the loss of income [10].

Another significant factor in favor of increasing transit turnover is the creation of transport and logistics centers and parks with the introduction of container business units. So, in 2020, a pilot project was launched to develop its own high-margin cargo base based on the Bely Rast transport and logistics center. For Russian Railways, this is the optimal opportunity to transform from a monopolist into a global multifunctional logistics business unit. This is confirmed by the project figures: the completion of the first stage will allow processing up to 300 thousand. TEU, the import of the final stage will increase the volume of processing to 725 thousand TEU, with an average volume of container transportation by Russian railways – about 5 million. DFE per year.

It should also be noted that other major projects for the development of transport and logistics centers are the Vorsino TLC, the investor of which is Transcontainer Freight Village Kaluga with a terminal capacity of 350 thousand. TEU per year and the prospect of increasing to 500 thousand; launched in 2014 TLC "Khovrino" in Moscow (2.5 million tons per year); launched in 2018 TLC "Vostochny" (200 thousand TEU) in the Moscow region and TLC "Kaliningrad" (450 thousand TEU) in the Kaliningrad region [11].

The next promising solution is the creation of terminals for cargo handling, since the lack of infrastructure for the organization of a highly efficient linear service leads to a low share of container cargo turnover on the railway network in comparison with road transport. By the end of 2020, it was noted that the delivery of more than 70% of cargo over distances of more than 500 km. From the ports of Russia to customers occurs by means of motor transport, that is, the share of the railway accounts for about 32%.

The Russian stevedoring market tends to reduce turnover, which is explained by an excess of capacity – in the Northwestern Federal District more than 60%, especially the Large Port of St. Petersburg, in the Southern Federal District – more than 30%, as well as an investment load with a high level of risk due to the fact that investments can collapse the market both from the setting of tariffs and from the expected income of market participants.

It should be noted that the crisis phenomena in the economy may affect the timing of the implementation of some measures in the field of railway transport and lead to minor adjustments in the amount of funding. The implementation of investors' plans depends on the situation in the markets of those goods that should ensure the loading of existing and under construction container terminals. Based on this, Russian Railways will be forced to revise the parameters of projects as the cargo flow changes. However, we do not expect a "freeze" or cancellation of projects, since they are important in terms of increasing the volume of export-import operations.

3.2 The Support of Digital Tools is Justified in Order to Increase the Mobility of Container Cargo Turnover

It is proposed to systematize digital services of Russian Railways by categories depending on the destination or recipient of the service for a more visual perception of digital technologies and the effect of their use in order to increase the mobility of container cargo turnover (Table 1).

Table 1. T digital services of Russian railways.

Types	Application	Effects
Digital services based on artificial intelligence technologies		
Natural language processing	Speech services: receiving voice calls, speech synthesis Rolling stock: predictive diagnostics, maintenance and repair	Reduction of the average downtime of a transit car by more than 20% Reducing the amount of investment in the technical development of the production capacities of marshalling yards Investing the released funds in other critical areas
Intelligent decision support	Railway infrastructure: predictive diagnostics of infrastructure facilities Transportation management: digital assistant dispatcher (based on innovative technologies of artificial neural networks)	
Software robots	Automation of routine operations: technical support, reporting, maintenance of regulatory and reference information	
Digital services with a focus on the customer – shippers and partners		
Electronic trading platform “Cargo transportation”	Provision of comprehensive transportation services in 10 min: online registration – 3 min, online order – 7 min	Reduction of the total time for the provision of services Growth of the electronic trading sector during the pandemic period – more than 80%
“RZD-Market”	Online search for the necessary goods, comparison of suppliers, delivery order	Reduction of the transport component in the service Time reduction due to electronic transaction processing and online order tracking

(*continued*)

Table 1. (*continued*)

Types	Application	Effects
"Electronic Pretensionist"	Automation of the main processes for interaction between users of railway services and the carrier within the framework of claim work through the client's personal account	Reduction of time for preparation of claim materials and processing of primary documents
Designer of personalized services for the client	Customization of services for the client in cargo transportation: creation of a digital portrait of the shipper due to a single customer base and management of their requests; formation of a portfolio of services for transportation by request unification of a set of services of the holding with uniform parameters	The accumulated effect of the program until 2025 is more than 50 mlrd. Rubles
Electronic seals	Development of a system for tracking the transportation of goods and the use of electronic navigation seals	Acceleration of the clearance of goods transportation. Optimization of customs procedures without reducing their effectiveness. Minimizing the time and financial costs of shippers
Digital services with a focus on improving transit mobility		
"INTERTRAN" Project	International intermodal transportation, issued by paperless technology In 2020, the route was mastered: Ningbo (China) – Vladivostok (Russia) – Kolyadichi (Belarus)	Reduction of the total transportation time by 4 days on the route: Yokohama Port-VMTP-railway station "Vlahdivostok-Moscow" – container terminal
Smart contracts in TLC – blockchain-Hyperledger Fabric solution – for creating closed corporate-level blockchain networks	Pilot implementation: October Railway, Great Port of Saint Petersburg, "Modul" Freight Forwarding Company In 2021, the expansion of the project participants and the coverage of the cargo transportation process	Transparency of the transportation process. Reduction of document preparation time; Reduction of the volume of act-claim work. Growth of container cargo transportation on the railway network in this segment by 13% in 2020
Unified information space	Cargo transit control with the use of navigation seals in order to ensure data registration: deviations from the route; about cargo opening; about artificial damage to the seal	The growth of the volume of international cargo transportation in Russia by more than 10%. Reduction of the length and delivery time compared to sea routes

Thus, one of the target indicators for increasing container cargo turnover is an innovation-oriented model of industry development, which involves increasing mobility and the level of safety of railway transport, which is achieved through the use of digital tools. All this undoubtedly justifies the volume of investments and payback periods, since the result is increased transparency, online interaction of transportation participants, the formation and end-to-end use of information resources at all stages of the transport process.

3.3 A Set of Mechanisms has been Developed to Support and Develop Rail Container Transportation Based on Mobility and Logistics Efficiency

In the first quarter of 2021, there is an increase in the transit of containers through the network of JSC "Russian Railways" by almost 2 times – almost 1000 thousand were transported in all types of communication. DFE of loaded and empty containers. In order to effectively master such rapid growth, a set of mechanisms has been developed to support and develop rail container transportation based on mobility and logistics efficiency (Fig. 8).

Infrastructure development

- development of public container infrastructure;
- development of container infrastructure of industrial enterprises, commercial infrastructure at the points of origin of the cargo base;
- containerization of raw materials;
- development of the capacity of border crossings.

Optimization of operational activities

- reduction of bottlenecks arising due to current speed limits on a number of crossings;
- reduction of bottlenecks caused by trains passing through station necks on the main track;
- elimination of delays associated with the need to change traction at the junctions of sections with alternating and direct current.

Digital platform expansion

- bringing the digital ecosystem of transport logistics mobility to uniform national standards to unify the procedures for tracking the supply chain of products from the moment of shipment, border crossing to commissioning.

Tariff policy stabilization

- long-term tariff formation using the inflation minus method in domestic, export-import traffic;
- approval of long-term transit tariffs;
- fixing fees required for the implementation of the transportation process, using the inflation minus method;
- simplification of tariff decision-making within price limits;
- change of fare in the composition of a container train;
- subsidizing new internal intermodal routes/transit routes until the target schedule density is reached, allowing to compete with road and sea transport.

Fig. 8. Mechanisms for the support and development of rail container transportation based on mobility and logistics efficiency.

It should be noted that China is the main competitor manufacturer of containers for Russia: Based on statistical data, it is safe to say that China has a 95% share in the global container production market. The difference between the cost is more than 120 thousand rubles, which is explained by subsidizing Chinese manufacturers, easy taxation conditions, cheap raw materials [12, 13].

Another problem is the imbalance of trade turnover with China – the excess of imports over exports, which leads to loading container terminals with empty wagons.

In 2020, 4 billion rubles of state support were requested to support the transit container sector. In particular, JSC "Russian Railways" planned to finance a program for the development of trunk infrastructure and container transportation at the expense of the federal budget in the amount of 202.3 billion rubles, but this event was not implemented.

4 Discussion

A new vision of the economic consequences of increasing the mobility of container cargo turnover appeared in 2019 during the global global crisis, when transport companies were forced to adapt to the restriction, and then recovery and intensification of activities. Currently, it is necessary to think about attracting high-yield goods to the railway. The relevance of the issue under study is also confirmed by the fact that despite the negative dynamics of loading as a result of the pandemic crisis, the level of containerization of cargo is steadily increasing.

The main discussion on the current state and development trends, shown by Olli-Pekka Hilmola, confirms that over the past decade the trade turnover between Europe and China has been steadily growing, which has led to an increase in container traffic. At the same time, the importance of container transportation by the Russian Railway and the Trans-Siberian Land Bridge is emphasized against the background of the COVID-19 crisis in 2020 [13].

In continuation of this question, a comparative analysis of long-distance transportation based on trade relations between central and eastern China and Poland, carried out by the authors [14], should be noted. On the basis of a multi-criteria analysis, the author's method of determining the order of preference for cargo transportation by similarity with the ideal solution method (TOPSIS) is proposed. Transportation time, cost, maximum number of containers and environmental index were taken as the analysis criteria.

We are interested in the work [15], which explores not only the mobility of cargo transportation, but also the safety of a high-speed freight train in combination with various conditions for loading cargo passing a sharp curve at a speed of 350 km/h. This study will provide theoretical assistance in ensuring the safety of the newly designed high-speed freight train, since it takes into account two key indicators – the condition of the cargo in the container and the level of its filling.

In recent years, China has continued to work on the restructuring of multimodal transportation in the country and is actively developing the infrastructure of high-speed railways to improve transportation efficiency. The authors [16] recorded operational data on 59 stations and 200 railway connections to assess qualitative and quantitative data on cargo transportation. The article fills an important research gap, since the results of a comparative analysis of indicators indicate a significant impact of the construction of high-speed highways on rail freight transportation.

The consequences of container terminal transportation in terms of the relative competitiveness of various terminals and their suitability for movement are investigated in [17]. The paper presents a mathematical model for calculating the aggregate costs resulting from the transportation of containers from several locations in a geographical region to various container terminals serving this region. The practical significance of the study lies in the application of the model during the construction of a new terminal in the port and the closure of the existing one.

Ways of compromise solutions between the priorities for the placement of terminal and logistics centers are proposed in [18]. The authors propose a hybrid model of analysis, the use of which can be useful when choosing the location of a TLC, since it takes into account the geographical location, economic development and national policy of the region.

The study of the problem of distribution of containers transported by rail between two transport terminals in a synchronous transport network is another step forward in favor of cargo transportation mobility. The paper [19] presents a specific optimization model, the essence of which is to minimize the waiting time for container cargo at the destination, minimize the total travel time of the train, minimize the waiting time for container cargo at the point of arrival.

One of the key factors in the development of container cargo turnover is the use of innovative digital solutions. Thus, scientists [20] identified key technical problems in the cloud environment, such as application management, business information exchange and big data processing, at different levels of building a cloud platform for rail and water transport, then an experimental analysis of the corresponding models is carried out to verify the possibility of reconstructing the cloud platform. The results obtained have theoretical and practical significance, since they expand our understanding of intermodal informatization of railway and water transport modes.

The practical application of the intermodal rail and sea container transportation system planning model, taking into account the Arctic route, developed by scientists [21] will significantly reduce the cruising distance and save costs.

Our judgments regarding the effectiveness of subsidies are confirmed by the conclusions [13]. The author's system for assessing the effectiveness of the freight subsidy policy is based on a cost-benefit analysis with a wide range of elements. The results of the study substantiate the possible risks that arise during the development or revision of the subsidy policy.

Undoubtedly, the research topic is of interest to the scientific and business communities, since increasing the mobility of container cargo transportation is a guarantee of competitive and productive activities of transport companies.

5 Conclusions

The conducted research confirms that the implementation of the strategic opportunities of the industry, the support of the steadily growing demand for container cargo transportation by rail should be provided not only by investments in infrastructure, rolling stock and container fleet, but also by optimization of operational activities, the introduction of digital technologies, the development of "smart" solutions.

Undoubtedly, the shift in mobility stereotypes will lead to the modernization of the cargo transportation process, which, in turn, will affect the emergence of new business models of container operators and a change in the structure of the cost of transport services.

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Two-Level Algorithms as Part of Digital Logistics Platforms

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Abstract. Transfer of logistics to work in modern concept of digital transport corridors implies optimization of commodity flows processing process. Nodes play an important role in the network structure of logistics chains. From the condition of economic expediency, multi-stage or multi-level distribution subsystems are used for effective work today. The paper presents the results of a study aimed at developing mathematical models of complex multilevel nodes of logistics networks. Algorithms have been obtained that form the basis of the software of decision-making systems as part of digital platforms. Their application makes it possible to more accurately solve the problem of organizing a multi-level system of warehouse and distribution nodes of the logistics chain. Since conventional deterministic models are ineffective in the conditions of market uncertainty characteristic of modern commerce, more complex scientifically based methods are used. Methods of the theory of stochastic processes, simulation modeling, and theoretical optimization methods are used to find a solution. The relevance of the work is due to the formation of a large-scale segment of third-party logistics in the Industry 4.0 concept.

Keywords: Logistics · Digitalization · Algorithm · Commerce · Distribution · Warehouse

1 Introduction

The modern organization of logistics activity reflects the trend towards digitalization. The requirements of the transition to Industry 4.0 platforms quickly led to the formation of a separate segment of third-party logistics. Third Party Logistics providers are the most common. Since, thanks to digitalization, consolidation of various types of business and commerce into network entities is most economically advantageous, a transition to a higher level of logistics outsourcing 4PL is planned, which is integrated at the interface level with cargo owners and service customers [1]. This trend is particularly pronounced within the framework of globalization and among transnational network players in most segments of commerce, trade in goods and services [2, 3]. Starting from the 3PL level, the

I. Ilin et al. (Eds.): ICDT 2021, LNDECT 157, pp. 102–111, 2023.
https://doi.org/10.1007/978-3-031-24434-6_10

successful implementation of digital platforms has slowed down, as a serious problem has appeared caused by the lack of algorithms for managing the activities of logistics network nodes. Conventional deterministic models are ineffective in conditions of market uncertainty. The requirements of the transition to DDT (Demand-driven Techniques) technology focused on the current changeable demand force us to look for a solution based on mathematical models using the theory of stochastic processes. Additionally, it becomes possible to more accurately solve the problem of a two-level system of warehouse and distribution nodes of the logistics chain, characteristic of distribution systems [4]. Also, mathematical models and algorithms make it possible to use for practical purposes the possibilities of widely used methods of the theory of optimal solutions [5]. The criterion in this case is an integral functional, which includes in its composition, in addition to economic indicators, also the time spent on operational logistics activities. It is taking into account the loss of time for transportation, inter-operational, loading and unloading, customs procedures, intra-warehouse storage that allows you to balance logistics costs taking into account factors such as expire date and contract terms [6]. Implementation of software products for integration into digital logistics platforms at the management level of optimal distribution systems will combine the capabilities of M2M flow of information about the state of logistics and planning methods based on leading indicators [7, 8].

The goal of the work is the development of mathematical formalisms for modeling multi-stage or multi-level subsystems of distribution chains. First of all, this is caused by the need to plan the activities of transport and logistics hubs. The vast majority of existing logistics systems use a two-level structure. The upper level of DC (distribution center), locations outside large consumption zones, such as settlements, especially megacities, is distinguished. Such placement is due to the economic feasibility [9, 10] of the balance between the cost of the land area and the cost of delivery. The lower or local level SW (Store Warehouse) is located either in the consumer's building itself or on its territory. This is especially true for shopping malls [11] and super/hypermarkets. A distinctive feature of modern network consolidated business entities has become the load on one DC of numerous local SW. The interaction between these levels is subject to the speak-hub topology. In the presented work, the task of forming a scalable algorithm allowing an increase in the number of intermediate levels of movement of goods and cargo through the warehouse nodes of the logistics network is set.

2 Materials and Methods

According to the modern understanding of the Industry 4.0 article, the mathematical model [12] uses data flows about the state of the system, in our case of an economic property. We express them in a set of formalisms, which are the framework of the description. Note that the incoming data must either be completely or as much as possible processed by M2M inter-machine interaction systems. A whole range of devices and technologies has already been developed and widely available for logistics tasks [13] to implement this principle. These are barcode, RFID, QR encodings, glonass/GPS monitoring systems, smart contracts, as well as online payments and other systems [14]. Let ‘s define the basic formalisms:

w – current load level DC/SW.

v – the volume calculated in quanta of delivery, provided $v \geq 0$;

$r = w + v$ – total value;

z – reflects the market uncertainty of demand also in the supply quanta, $z \geq 0$;

$p(z)$ – the value distribution function obtained from statistical data z;

D – determined by the terms of transactions or contracts, the volume in quanta of delivery in a single planning period;

L – time costs for the execution of the purchase order;

D_L – the volume of market demand in quanta of supply, can be interpreted as the rationing of the market during the period L;

Accordingly, the condition is true: $D_L = D \cdot L$;

$TC(v)$ – total cost as a function with a calculable volume argument;

FC – fixed cost, limited $FC > 0$, integral indicator of overhead costs;

$\Phi(r)$ – the function whose argument is the current level, reflects the costs;

β – coefficient, when $\beta > 0$ is equal to the cost of the warehouse maintenance of the supply quantum; γ - coefficient, when $\gamma > 0$ is an integral indicator of losses caused by the under-delivery of agreed volumes, including reputational losses and lost profits;

Ω^* – the critical parameter calculated by the formula $\Omega^* = \frac{\gamma - c}{\gamma + \beta}$, enclosed in the range $0 < \Omega^* < 1$;

S – a characteristic value defined as minimum among the increasing integer values of the summation range in the expression $\Omega\ (S) = \sum_{z=0}^{S} p(z) \geq \Omega^*$;

$\varphi(r|w)$ – the function of averaging the costs of the volume of goods r in the presence of volume w at the beginning of the logistics operation.

Since real logistics activities are subject to market uncertainty, an EOQ (Economic Order Quantity) test is needed to assess the sustainability of solutions This will allow you to focus on the EOQ indicators known as Δ^* of calculated parameters [15]. From the formula for calculating the parameter $\Delta^* = \sqrt{\frac{2FC \cdot D}{\beta}}$ it can be concluded that the level of cost impact FC is always below the linear trend. In particular, with a doubling or the same decrease in the level of market demand, the indicator EOQ ranges up to 40% [16]. Further, analyzing the impact of costs β within the same limits, EOQ changes only by 30%. The assessment of the impact of demand uncertainty on the time interval between neighboring restockings T^* is carried out by calculations using the formula:

$$T^* = \frac{EOQ}{D} = \frac{\Delta^*}{D} = \sqrt{\frac{2FC}{\beta D}}.$$

Note that an increase in the standard D will lead to an increase of Δ^* on the one hand, and a reduction of T^* of the other. For practical activities, this means the need to replenish the emergent level at the distribution center more often.

The practical recommendation in this case is to choose a parameter $\widetilde{\Delta}$ as close as possible to the optimal value Δ^*. This is due to the delivery quantum formats, loading regulations, packaging, type of vehicle, restrictions on minimum and maximum delivery. The calculation acceptable for practical implementation is carried out according to the formula:

$$\widetilde{\Delta} = \tau\Delta^* = \tau\sqrt{2\,\mathrm{KM/h}},\ \text{provided}\ \tau > 0.$$

If we derive a dependency to determine the average costs AC:

$$AC = \frac{FC \cdot D}{\Delta} + cD + \frac{\beta\Delta}{2},$$

then variable costs are calculated [17] in the total composition according to the formula:

$$VC(\tau) = \frac{FC \cdot D}{\Delta^*} + \frac{\beta \cdot \Delta^*}{2} = \frac{FC \cdot D\sqrt{\beta}}{\tau\sqrt{2FC \cdot D}} + \frac{\beta r\sqrt{2FC \cdot D}}{2\sqrt{\beta}}.$$

In this expression, Δ^* is understood as a variation of the actual value EOQ reduced by volume cD, which is equivalent to the parameter Fixed Cost.

Finally, the analysis of the impact of market demand deviation is carried out using the formula: $\xi = VC(\tau)/VC(1) = \frac{(\tau^{-1}+\tau)}{2}$, which we will program on a computer. The result of calculating ξ as a function of τ is shown in Fig. 1.

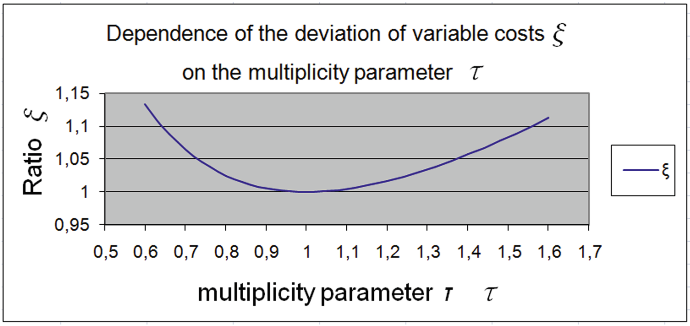

Fig. 1. Calculation of the dependence of ξ on the deviation of τ.

The analysis shows that there is a nonlinear dependence of ξ on the deviation of τ, which will satisfactorily affect logistics activities with small, up to 25% fluctuations in market demand. Even in the interval $0,\ 55 \leq \tau \leq 1,\ 6$ the spread ξ is below 10%. In the analysis, we introduce the notation and take into account the fact that the value of $\frac{VC(\tau)}{VC(1)}$ is invariant to the statements τ and τ'.

Next, it is necessary to consider an important property [17] of the process of organizing the movement of goods and cargo. This is the discreteness of both the volumes of the supply quantum and the time planning periods. In this formulation, the parameter D in the mathematical model will take the quantitative characteristic of demand as a planning unit. This scale will not violate the generality of the results in any way. Then the logistics costs of the DT supply quanta are accompanied by costs C_T, where $T = 1, 2, \ldots\ldots$ This is completely equivalent to C_T, as costs for T planning periods. Then the following is true:

$$C_T = FC + cDT + \frac{1}{2}\beta D(T-1)T.$$

Having determined the minimum value of C_T/T we get the optimal mode. Since $T = 1, 2, \ldots.$. This is formalized by finding the value of the expression:

$$\min_T \left[\frac{FC}{T} + cD + \frac{1}{2}\beta D(T-1)\right].$$

Having found the solution of the equation with relation to T for the zero value of the first derivative, we denote the result as T^*: $T^* = \sqrt{2FC/\beta D}$. Next, we get the parameter Δ^* necessary for EOQ from the calculation: $\Delta^* = D \cdot T^* = \sqrt{2FC \cdot D/\beta}$. We will take into account the discreteness by rounding T^*. We will get an economically significant result.

Having information about the frequency of receipt of indicators of logistics parameters DC, we will combine [18] data with the costs of placing goods and cargo In reality, DC operates with a contractual lag. The time difference is equal to $-s/\Delta$, where $s \leq 0$ is allowed, i.e. the critical level is below the demand The volume for a given period $(-s/2)$ of the delivery quantum. From here, the probable loss of the volume of market demand is calculated, for one period equal to $-s^2/2\Delta$.

Parameter γ (> 0), an integral indicator of losses caused by under-delivery of agreed volumes, including reputational losses and lost profits. Then we can write the formula for $\widetilde{AC}$ – the volume of average costs:

$$\widetilde{AC} = \frac{FC \cdot D}{\Delta} + cD + \frac{(\beta + \gamma)S^2}{2\Delta} - \gamma S + \frac{\gamma}{2}\Delta.$$

Acting similarly, with the difference that we differentiate $\widetilde{AC}$ by S. As a result, we calculate the optimal value for S^*:

$$S^* = \left(\frac{\gamma}{\beta + \gamma}\right)\Delta.$$

Then substituting S^* into the calculation of the optimal EOQ, we get a set of formulas acceptable for use in machine calculation algorithms Δ^*, S, s:

$$\Delta^* = \sqrt{2FC \cdot D\left(\frac{1}{\beta} + \frac{1}{\gamma}\right)}, S = \sqrt{2FC \cdot D\left(\frac{\gamma}{\beta(\beta + \gamma)}\right)}, s = -\sqrt{2FC \cdot D\left(\frac{\beta}{\gamma(\beta + \gamma)}\right)}$$

3 Results and Discussion

In logistics, the work of an outsourcing operator takes place within the framework of a very voluminous assortment matrix [19]. It should be taken into account that the costs

FC, as well as the costs of maintaining current stocks, are not deterministic parameters of the model. The value L of the time spent on delivery always corresponds to the inequality $L > 0$. We also additionally define z_L of the real demand for L. It's clear that the value z_L is stochastic. The ratio $z_L > s$ characterizes the presence of delayed delivery. The distribution function $p_L(z_L)$ fully describes the parameters of a random process. Since the statements about stationarity, ordinariness, as well as the absence of aftereffect are introduced a priori, $p_L(z_L)$, on the planning horizon T, can be formalized by an exponential law:

Note that in real commercial activity, the standard deviation may not be equal to the mathematical expectation. For a more correct mathematical description [20], an arbitrary character $p_L(z_L)$ is easily embedded in software applications, which increases the accuracy of management decisions.

Next, we define the components of the objective function. To do this, we will introduce implementation costs θ_S. Then by definition *EOQ* it is fair: $\theta_S = FC \cdot D/\Delta + cD$. We will also introduce into consideration the execution option $z_L < S$ and the opposite If we apply them to the previous arguments, then using a well-known function $p_L(z_L)$ we write:

$$= \sum_{z_L=0}^{s} \frac{1}{2}[s + (s - z_L)]p_L(z_L) + \sum_{z_L>s} \frac{1}{2}[s + 0]p_L(z_L) = \frac{1}{2}\left[s + \sum_{z_L=0}^{s} (s - z_L)p_L(z_L) \right]$$

M_L – Mathematical expectation M_L of the distribution $p_L(z_L)$ gives the average load level of terminals and DC:

$$\frac{1}{2}[(s - M_L + \Delta) + s] = \frac{1}{2}(2s - M_L + \Delta)$$

We will also add weight coefficients to the quality function. For the predicted DC load level, this will be the $\mu = M_L/\Delta$ parameter. We will take the average load with a coefficient $(1 - M_L/\Delta)$, which together with μ gives a complete set of data. As a result, we write down the calculation equation $\widetilde{r}$ - the average load level relative to a single time unit:

$$\widetilde{r} = \frac{M_L}{2\Delta}\left[-2s + M_L - \Delta + s + \sum_{z_L=0}^{s} (s - z_L)p_L(z_L) \right] + \frac{1}{2}(2s - M_L + \Delta)$$

Since for any kind of $p_L(z_L)$ it is fulfilled:

$\sum_{z_L=0}^{s} (s - z_L)p_L(z_L) = s - M_L - \sum_{z_L>s} (s - z_L)p_L(z_L)$, then using $p_L(z_L)$ we formalize the situation of a possible deficit: $\sum_{z_L>s} (s - z_L)p_L(z_L)$, and we use the coefficient D/Δ accordingly. This set of formalisms has led to an important result, namely, it is possible to put into the program the calculation of the costs of $\widetilde{\Phi}$ with work *DC* per unit of time:

$$\widetilde{\Phi} = \frac{FC \cdot D}{\Delta} + cD + \beta\left(\frac{\Delta}{2} - M_L + s\right) + \left(\frac{\beta M_L}{2\Delta} + \frac{D\gamma}{\Delta}\right) \sum_{z_L>s} (z_L - s)p_L(z_L)$$

After that, we apply the procedure for finding the extremum of $\widetilde{\Phi}$ by equating the partial derivative to zero $\frac{\partial E[AC]}{\partial \Delta} = 0$. Solving this equation for Δ, we get the result in the form of quadratures:

$$\Delta^* = \sqrt{\frac{2FC \cdot D}{\beta} + \left(M_L + \frac{2D\gamma}{\beta}\right) \sum_{z_L > s} (z_L - s) p_L(z_L)}$$

The integer condition is implemented by a discrete form of the function $\Omega_L(r) = \sum_{z_L=0}^{r} p_L(z_L)$. The result will be the optimal value s^* ($s^* > 0$) as an integer satisfying the inequality:

$$\Omega_L(s^*) > \Omega^*, \text{ where } \Omega^* = 1 - \frac{\beta \Delta}{\beta M_L/2 + D\gamma},$$

At the same time, $s^* = \inf_{\Omega_L(s^*) > \Omega^*} s^*$, which corresponds to the critical level for DC.

The minimum cost as an economically significant indicator is calculated as:

$$\min \widetilde{\Phi} = cD + \sqrt{2\beta \left[FC \cdot D + \left(\frac{\beta M_L}{2} + D\gamma \right) \sum_{z_L > s} (z_L - s^*) p_L(z_L) \right]} + \beta(s^* - M_L).$$

The set of obtained formulas is used in forecasting the economic feasibility of placing reserves on DC for each of the positions. The assortment matrix DC is usually very large and it's physically difficult to maintain the entire nomenclature. Considering the random nature of L is necessary for a number of reasons: it is the delivery of goods from various sites, cross-border deliveries, customs and control delays. Thanks to $p_L(z_L)$ it is possible to optimize not only storage costs, but also capital construction costs.

3.1 Example of Calculation

Within the framework of cooperation with the business incubator Universitat de Barcelona, the calculation was carried out according to the proposed mathematical model. The data is taken from the documents of The financial statements of The Barcelona Port Authority.

The port of Barcelona is the most important element of Spain's business infrastructure. It is the largest logistics hub receiving more than 10,000 ships and handles more than 53 million tons of cargo of all formats. The calculation according to the above model was carried out for the warehouse division of the port engaged in servicing incoming ships, both commercial and cruise. At the same time, before the pandemic, the share of cruise liners was about 12%, with an additional 4% of the volume accounted for by large ferry ships. The warehouse division provides a full set of services: refueling, loading of water, hygiene materials, medicines, provision of compressed air, electricity, steam, replacement of batteries, refueling with technical and chemical consumables, including maintenance of refrigerators, refueling with all kinds of lubricants, spare parts, etc., in total more than 20 thousand names and articles.

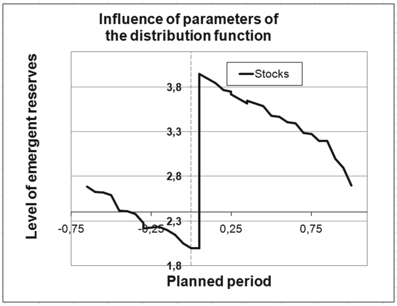

Fig. 2. Analysis of the distribution function.

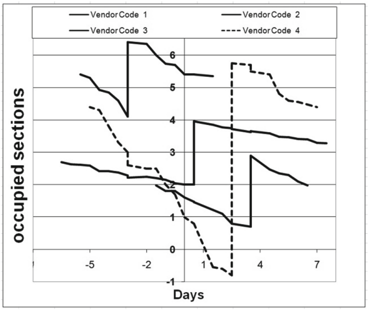

Fig. 3. Movement of DC stocks.

The results of calculating the dynamics of the movement of a monoproduct according to the presented mathematical model are shown in Fig. 2. For four articles in Fig. 3.

The analysis reflects the possible presence of a negative level as a result of the calculation. This situation is typical for reserving for deferred demand. It is explained by the time delay between the request for the cargo and the time of delivery. This is the main reserve for online or smart contact interaction, which provides operational opportunities to optimize the economic indicators of the distribution center, as well as reduce the costs of SW, both operational and capital.

4 Conclusions

The work of all levels of logistics has undergone a serious transformation over the past year in the conditions of COVID19. The load on the distribution centers of seaports did not decrease, but the resulting instability required a deeper scientific analysis of flows in such transport hubs. Such tests as traffic surges caused by the Ever given accident in the Suez Canal led to a one-time delay of more than 150 large and especially large vessels, including over 20 million barrels of oil. There were more than 20,000 FEU (Fourty-foot Equivalent Unit) on the stuck container ship alone. The analysis of the stability of mathematical models [21, 22] is devoted to this. The formation of digital transport corridors begins with optimizing the operation of logistics hubs, as the most capital-intensive and serving to dampen the instability of flows in logistics networks. Calculations based on the presented model allow us to identify resources for optimizing their performance indicators. It is the use of formalized mathematical models that provides the basis for the formation of programmatically implemented algorithms for managerial decision-making. At the same time, there is a natural transition to the next stage of attracting the capabilities of artificial intelligence in the management of such a complex business object as a distribution warehouse complex of a seaport.

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Digitalization of Oil Refining Process (Fuel Gas Flow Rate for Hydrotreatment)

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Abstract. Oil refining processes require large quantities of fuel gas. For rational consumption of fuel gas, digitalization of fuel gas consumption is required. The object of the study is the hydrotreating process. The subject of the study is digitalization of fuel gas consumption during hydrotreating. Main research methods: analysis, comparison, econometrics methods. The authors considered the process of hydrotreating diesel fuel. The authors applied reliable statistics from the refinery. Box-Jenkins methods were applied to the obtained time series of specific fuel gas consumption to construct a forecast model of fuel gas consumption during hydrotreatment. The obtained fuel gas flow model will allow predicting the fuel gas flow rate depending on the planned load of the hydrotreating unit. Fuel gas flow control will reduce the cost and price of diesel fuel. Accordingly, reducing the transport component will reduce the prices of goods for which transportation is needed. The further direction of the study is to draw up forecast models for fuel gas consumption at other plants of the enterprise.

Keywords: Fuel Gas · Hydrotreating · Stationary Row · Model Specification · Correlogram

1 Introduction

The refinery (hereinafter - refinery) consumes a large amount of fuel gas. Digitalization of fuel gas consumption will lead to resource savings. To do this, it is neccesary to create the fuel gas flow forecasting model. At refineries, many processes require fuel gas consumption. Consider the process of hydrotreating diesel fuel. Currently, more and more countries are imposing a requirement for diesel fuel – a minimum content of sulfur. This requirement is explained quite simply – minimizing the sulfur content reduces the release of sulfur oxides into the atmosphere SO2 and SO3, and thereby reduces the risks of acid rain. In addition, reducing the sulfur content of diesel fuel extends the life of the diesel engine.

The result of this requirement is the appearance on the market of ultrasulfuric diesel fuel (USDT). The process of removing sulfur, nitrogen, oxygen compounds

I. Ilin et al. (Eds.): ICDT 2021, LNDECT 157, pp. 112–120, 2023.
https://doi.org/10.1007/978-3-031-24434-6_11

occurs at a hydrogen plant under hydrogen pressure in the presence of a catalyst and is called hydrotreating. In particular, takes sulfur monoethanolamine. Nitrogen is removed because its oxides are capable of forming acids. Oxygen itself is a strong oxidant. The catalysts may contain elements such as Ni, Co, Mo. Hydrotreating also results in saturation of unsaturated hydrocarbons and reduction of polyaromatic hydrocarbons. Reducing polyaromatic hydrocarbons increases the cetane number of diesel fuel. It should be noted that not only diesel fuel is subjected to hydrotreatment, but also gasoline fractions, kerosene fractions and others.

Hydrotreating requires a lot of fuel gas, since a heated mixture of raw material and hydrogen-containing gas is subjected to the hydrotreating procedure. Hydrotreating takes place at temperature 613–673 K and pressure 2.5–4.0 MPa. The main technical elements of the process are the high pressure reactor unit and the low pressure fractionation section. If the mathematical model of hydrotreating in terms of fuel gas consumption is known, then this will reduce the cost of hydrotreating and the cost of diesel fuel itself. The potential for fuel economy is significant given the extent of hydrotreatment.

2 Background

The main chemical and technical aspects of diesel fuel hydrotreatment are considered in [1].

In [2], the inventors propose the use of multicomponent catalysts for diesel fuel purification processes. As a theoretical basis for the use of multicomponent catalysts, a corresponding mathematical model has been created.

In [3], the authors develop approaches to the construction of a mathematical model of catalytic hydroprocesses. The presence of such a model will optimize the hydrotreating process.

In [4], the authors create a scheme of chemical transformations in the process of vacuum hydrotreating. The presence of this scheme is a kind of road map for the hydrotreatment process.

In [5], the inventors describe the main transformations of diesel fraction hydrocarbons in the hydrodeparaffinization process. The hydrodeparaffinization process depends on the hydrotreatment prior thereto.

In [6], researchers compiled a computer model of diesel fuel production. The use of this computer model as a simulation model will make it possible to find optimal hydrotreating modes.

In [7], the authors develop approaches to building a computer model of catalytic hydroprocesses for the transformation of vacuum and atmospheric distillates.

In [8], the authors analyze the multi-component composition of diesel fuel and build the task of optimizing this composition, including by sulfur content. The solution of the constructed problem of optimizing the composition of diesel fuel will reduce the sulfur content in diesel fuel due to the hydrotreating process.

In [9], the authors propose to expand the raw material base for the production of diesel fuel due to heavy fractions. This poses new problems for the hydrotreating process, since in heavy fractions the content of sulfur and nitrogen is higher.

In [10], the authors use the mathematical modeling method to study the catalytic dewaxing process. In this mathematical model, there should be a place for the previous hydrotreating process.

In [11], the authors study the properties of straight-run diesel fuel after the use of various additives. In this case, the effect of sulphur left after hydrotreating on these additives must be taken into account.

In [12], the authors compiled an unstable mathematical model of catalytic dewaxing of diesel fuel. The instability element also contributes sulfur to the feedstock.

In [13], the authors considered the process of desulfurization of diesel fuel during hydrotreatment. The authors took quantum-chemical calculations as the basis of the study.

In [14], the researchers analyzed the effect of hydrogen pressure and mixture temperature on the hydrotreating desulfurization process. Here the task arises – to find a middle ground between the flow of fuel resources and the residual sulfur content in diesel fuel.

In [15], the authors investigated the effect of technological parameters on the output of diesel fuel after dewaxing. The prior hydrotreating process should also be taken into account here.

In [16], the authors proposed redistributing hydrogen-containing gas in order to intensify dehydrogenation and dewaxing.

In [17], the authors constructed a mathematical model to account for the effect of the catalyst on the dehydrogenation process.

In [18], the author applied mathematical modeling to study the synthesis of distillates freezing at low temperatures.

In [19], the authors investigate the quality control of diesel fuel production. In this case, hydrotreating issues are particularly important.

In [20], we analyze the possibilities of using platinum for the synthesis of branched hydrocarbons. Hydrotreating is also important here, since the platinum catalyst does not work well with an increased sulfur content.

In [21], the authors consider the possibility of increasing the input of light fractions in the catalytic cracking process. The presence of sulfur impairs the performance of the catalyst. Hydrotreating is very important.

The literary overview is not exhaustive, but it gives an idea of the main approaches to the process of hydrotreating diesel fuel.

1. possibility of constructing a mathematical model;
2. the possibility of building a computer model;
3. variation of process parameters (pressure, temperature);
4. using a catalyst or a multicomponent catalyst.

The main methods used in the study are analysis, comparison, econometrics methods.

3 Materials and Methods

The refinery regularly records data on fuel gas consumption at hydrotreating.

Currently, there is a database on fuel gas consumption. Digitalization means building a forecast model to control the subsequent flow of fuel gas according to the model. This will bring substantial savings. Let's look at the hourly data for the period from 0 h of October 1 2020 to November 23.00 30 2020, that is, for two months. In Excel, this is a table of 1464 rows, so we will only give the obtained statistics.

Let us schematically represent the first stage (mode No. 1) in Fig. 1.

The GRETL program is applicable.

Analysis Methodology:

1. checking the series Y (t) and the series of first differences dY (t) for stationary by the extended ADF test;
2. selection of ARIMA model specification;
3. testing the resulting model.

Diagram of the time series of specific fuel gas consumption at the hydrotreating unit is given in Fig. 1.

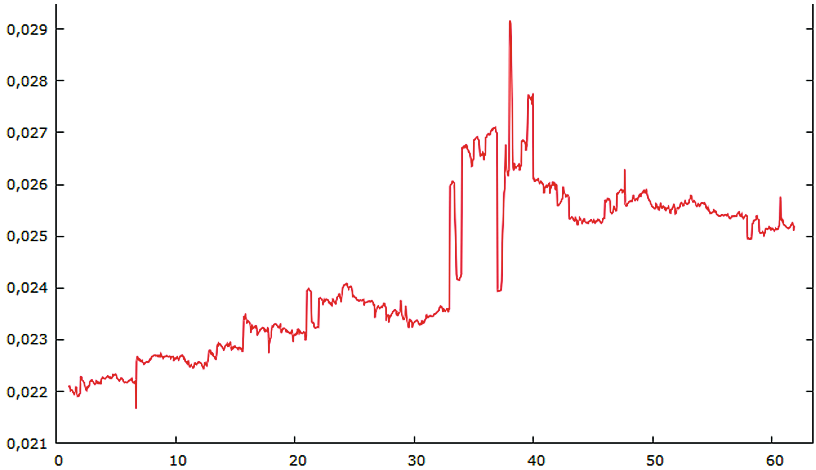

Fig. 1. Historigram Y(t).

We examine the time series Y (t) itself and the series of first differences dY (t) for stationary.

A number of first differences dY (t) without a constant is stationary. Since this is evidenced by the extended Dickie-Fuller test. The probability value of the null hypothesis (non-stationary series) is

$$p = 1,879e - 030.$$

According to the results of the test, the null hypothesis (the presence of a single root) is rejected, since the value of p is less than any reasonable level of significance.

We select the ARIMA model for the series dY (t). First consider variant AR (1), S (0), MA (1) with constant (Table 1). Independent variable: dY Standard errors are based on Hessian.

Table 1. Significance of Model No. 1 estimates.

№	Model element	Value	Standard error	z	Value P	Significance
1	const	2,11374e-06	4,93202e−06	0,4286	0,6682	No
2	phi_1	0,066256	0,0260868	1,728	0,0840	No
3	theta_1	−0,278295	0,204104	−1,363	0,1727	No

The coefficients have no significance. The model is inadequate.

Let's write the final model No. 6, obtained as a result of a long selection. All stages of the search do not allow limiting the scope of the article.

Select option AR = 0; S = 0; MA = 1 without constant. AR speaks of the order of autoregression. S reflects the presence of differences in the test series. MA informs about the moving average. Immediately give the table given by the GRETL program (Table 2). Dependent Variable: dY. Standard errors are based on Hessian.

Table 2. Significance of Model No. 6 estimates.

№	Model element	Value	Standard error	z	Value P	Significance
1	theta_1	0,0617215	0,0251673	2,452	0,0142	yes

The significance of the theta_1 factor here is 0.05 ($0{,}0142 < 0{,}05$).

Testing the model. Consider the distribution of residues. Null hypothesis – residues have a normal distribution. Chi-square = 27866.595.

Corresponding probability p = 0.00000. Residues have no normal distribution. For real processes, this is quite an acceptable phenomenon.

4 Results

As a result we suggest to examine the correlogram of residues: the smaller the emissions on the correlogram, the better our model. Since the absence of emissions makes it possible to consider the residues uncorrelated. Figure 2 shows the correlogram of residues.

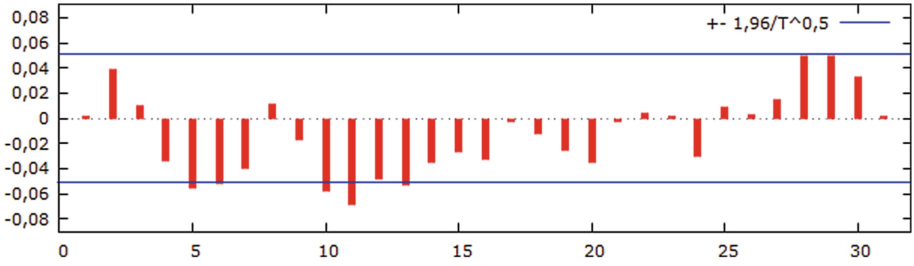

Fig. 2. Correlogram of residues ACF.

The figure shows that the first four coefficients of the autocorrelation function are not significant. It can be assumed that the remnants of model No. 6 are white noise (Table 3).

Table 3. Correlogram of Model No. 6 residues.

Lag	ACF	PACF	Q	p
1	0,0023	0,0023		
2	0,0391	0,0391	2,252	0,133
3	0,0097	0,0096	2,3912	0,303
4	−0,0343	−0,0359	4,1204	0,249
5	−0,0554	−0,0562	8,626	0,071
6	−0,0518	−0,0493	12,5712	0,028
7	−0,0396	−0,0348	14,8796	0,021
8	0,0116	0,0155	15,0772	0,035
9	−0,0177	−0,0176	15,54	0,049
10	−0,0575	−0,065	20,4145	0,016
11	−0,0684	−0,0771	27,3202	0,002
12	−0,0483	−0,0511	30,7602	0,001
13	−0,0527	−0,0518	37,8664	0
14	−0,0352	−0,039	36,6939	0
15	−0,0269	−0,0381	37,7614	0,001
16	−0,0328	−0,0532	39,3555	0,001
17	−0,003	−0,0261	39,3692	0,001
18	−0,0129	−0,0321	39,6149	0,001
19	−0,0262	−0,0463	40,6355	0,002
20	−0,0353	−0,0606	42,4895	0,002
21	−0,0031	−0,0296	42,5036	0,002

(*continued*)

Table 3. (*continued*)

Lag	ACF	PACF	Q	p
22	0,0044	−0,0215	42,5327	0,004
23	0,0016	−0,0279	42,5363	0,005
24	−0,0311	−0,0652	43,9726	0,005
25	0,0087	−0,0286	44,0861	0,007
26	0,0026	−0,0302	44,0963	0,011
27	0,0152	−0,0147	44,4393	0,014
28	0,0492	0,0228	48,0587	0,008
29	0,0492	0,0203	51,6813	0,004
30	0,0335	0,0013	53,3637	0,004
31	0,0018	−0,0282	53,3685	0,005

Accordingly, we consider the quality of model No. 6 satisfactory.

A time number of dY (t) represents MA (1) - process.

$$\begin{array}{c}\Delta\hat{Y}_t = 0,062\ \varepsilon_{t-1} \\ (0,025)\end{array} \tag{1}$$

Thus the statistics of the oil refinery on the fuel gas flow rate for hydrotreating have been processed. In the process of hydrotreating, the content of sulfur, nitrogen, oxygen in diesel fuel decreases. The hydrotreating process requires a high fuel gas flow rate. The presence of a forecast model of fuel gas consumption will significantly reduce fuel resource costs and reduce the cost of the final product – diesel fuel. The short-term period is considered – two months of operation of the hydrotreating plant (October, November 2020). Given that this is a short-term period, the Box-Jenkins method was applied.

In the process of searching for various specifications of the forecast model, it was decided to dwell on model No. 6. Model No. 6 interprets the time series “Specific fuel gas flow rate” as MA (1), moving average. The correlogram of residues (Fig. 2) shows that the model can be considered satisfactory. The final equation of the forecast model of specific fuel gas consumption is (1).

5 Conclusions

The authors formed a time series of hourly specific fuel gas consumption at the hydrotreating plant. Next, the original row was tested for stationary by the Dickie-Fuller test. After a negative response, the authors switched to a number of first differences and confirmed the stationary nature of a number of first differences.

The authors considered various specifications of the forecast model of specific fuel gas consumption. The authors consider the test for autocorrelation of residues to be a key test. Satisfactory fuel gas flow rate model – MA (1). The correlogram of residues confirms this.

The further direction of the study is to increase the number of levels of the series and consider the specific fuel gas consumption at the hydrotreating plant for the year. Apply neural networks to build a predictive model.

After receiving the result of the hydrotreating plant, build forecast models for fuel gas consumption at other refinery plants.

After the construction of forecast models for fuel gas consumption at the refinery plants, draw up forecast models for the consumption of other resources (steam, electricity) at the refinery plants.

Acknowledgement. The research was supported by the Ministry of Science and Higher Education of the Russian Federation (Agreement No. 075-15-2022-1136 dated 01.07.2022).

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Prospects of Multimodal Container Transportation in Russia

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Abstract. The article discusses the fundamental approaches of different countries and economic communities to the formation of the concept of multimodal transportation. The analysis made it possible to identify fundamental differences in the organization of technological systems for transporting goods in containers. The reasons for the slow containerization of domestic transportation on the territory of the Russian Federation are identified and proposals for the construction of new multimodal container transportation routes based on the use of medium-tonnage containers as a link in the technological process of transferring goods from inland transport to sea container lines are considered.

The paper presents mathematical dependencies connecting quantitatively the need for sea line containers and the need for medium-tonnage containers when expanding the hinterland boundaries of a sea container terminal. The solution of the famous scientific problem is demonstrated by the example of calculating the need for new means of enlargement to ensure an increase in the cargo flow of the sea line.

According to the results of calculations, it is emphasized that it is advisable to start expanding the boundaries of the application of the advantages of container technologies into the depths of the country by introducing new means of cargo consolidation with the development of the cargo flow of small (combined) shipments.

Keywords: Transportation modeling · Combined cargo · Container technologies · Multimodal transportation

1 Introduction

Container transportation occupies an increasing share of the global volume of cargo transported across the seas and oceans of the planet, and the cost of containerized cargo has already exceeded half of the total cost of goods [1]. Hence the special requirements of container systems for the simultaneous and coordinated development of rolling stock and infrastructure of the modes of transport involved in the transportation of containers.

Developing trade relations based on the use of large-sized containers, the countries entered into partnership relations mutually guaranteeing both interest and responsibility for the obligations assumed. The appearance of the idea itself was simply not enough.

I. Ilin et al. (Eds.): ICDT 2021, LNDECT 157, pp. 121–128, 2023.
https://doi.org/10.1007/978-3-031-24434-6_12

Someone had to take over the construction of ships, specialized ports, rolling stock of land transport and finally containers. The implementation of such projects requires both free working capital and motivation to achieve the goal [2].

At the first stage, the incentive for sending the first experimental batch of containers between US ports was a lot of various fees and weight restrictions in force in the states providing their territories for the transit of goods and complicating the process of organizing transportation. The idea was to be able to circumnavigate the borders of the states by sea transport, allowing to overcome considerable distances, with the subsequent delivery of goods from the port located inside the destination state by trucks [3]. The results exceeded expectations, the effect was achieved both in reducing the cost and in reducing the delivery time. The customer of the first ocean transportation, the US Army, quickly manifested itself, which was interested in the possibility of organizing the delivery of goods “door to door”, that is, the construction of the first multimodal routes by the carrier. And the carrier coped, and on the way back, the countries of the Asian-Pacific region offered their commercial goods to fill empty containers. Thus, the world trade network has begun to form production regions - China and Southeast Asia and consumption regions - the USA and Western Europe [4].

It would seem that everything worked out, the banks, feeling the benefits, provided financing for the creation of a container fleet, the construction of sea container ships and container terminals, the production of goods in regions with cheap labor received a powerful boost, the time of cargo delivery was reduced, the world economy grew three times, world trade grew almost 9 times (the effect of globalization), and container transportation - 23 times (the effect of containerization) [5].

But even today, the issues of containerization of international transportation, and in parallel with them, the issues of the development of multimodal transportation on their basis remain paramount in the state transport policy of the main exporters and importers in the world trade market [6].

2 Methods and Materials

Experts share approaches to the formation of concepts of multimodal container transportation, distinguishing them according to the degree of development of competition and the level of responsibility for transportation on a particular shoulder of transportation, participants in the cargo delivery process. At the present stage of containerization development, several fundamentally different approaches to the parrying and implementation of multimodal transportation concepts have been formulated [7–10].

The first approach was formulated and developed at the stage of the origin of the first container lines in North America (USA and Canada). Its essence boils down to the desire of container shipping operators to extend their influence on the inland (land) transport market. As a result, the largest container lines assumed the risks and obligations to accompany the container along the entire cargo route, including rail and road transportation and transshipment at transport hubs. In the course of fierce competition in the international container transportation market, the United States has experienced a rapid growth of multimodal transportation. Hence the possibility of using the transit potential between the west and east coasts of the United States in the construction of international transport corridors. And this is in the absence of more or less active participation of the state in the development of this area of business [11].

The second approach was developed in Western Europe. Despite the developed railway network and the nationalization of the main railways carried out in recent decades, in the countries of the European Union, road transport remains the main means of cargo delivery. At the same time, the resource of automobile communications, as well as the possibilities for increasing the carrying capacity, have already been practically exhausted [12–14]. Realizing this and due to fears of unforeseen disruptions in the system of road communications and possible disruption of road transport in Europe, they began to develop multimodal transport. The issues of integration of rail and sea transport into a single transport supply network are being considered, with a simultaneous decrease in the total share of road transport. At the stage of radical changes, logistics operators of Western Europe engaged in container cargo transportation received support from the state and the European Union [16].

While the transport policy of the USA and Western Europe is based on the implementation of plans for further containerization and the development of multimodal transportation in order to make full use of transport capacities, improve the transport infrastructure involved in transportation, reduce the negative impact on the environment and other challenges of our time, countries that find themselves outside the playing field of global containerization are solving the same issues, but in order to penetrate economic integration into the world economy, for the same purposes, territories are also provided for through transit of goods [17, 18]. As a result, another (third) alternative approach to the implementation of the concept of multimodal transportation is being implemented (Fig. 1).

In the Soviet Union, and later in the Russian Federation, the development of container transportation was not widespread enough [19].

Domestic cargo flows in Russia have very low containerization rates. If we leave out of the scope of this study the enumeration of all the reasons for the delayed reaction of the domestic market for the advantages of cargo transportation that the container brings to the overall technological process, then one question remains, to what extent is the internal container connected with international transport lines? After all, it breaks where it is thin.

Alas, sea container lines transport not only loaded, but also empty containers. It is the return of the container to the original port of shipment that closes the cycle of continuous transport technology. The same rules are set by the owners of the lines for the use of containers within the Hinterland borders. At the same time, an internal heavy-duty container that does not belong to the sea line, as a rule, does not get on board the vessel. The shipper is forced to deliver goods to the container terminal, which ensures the reception of goods from internal transport and their packing into containers.

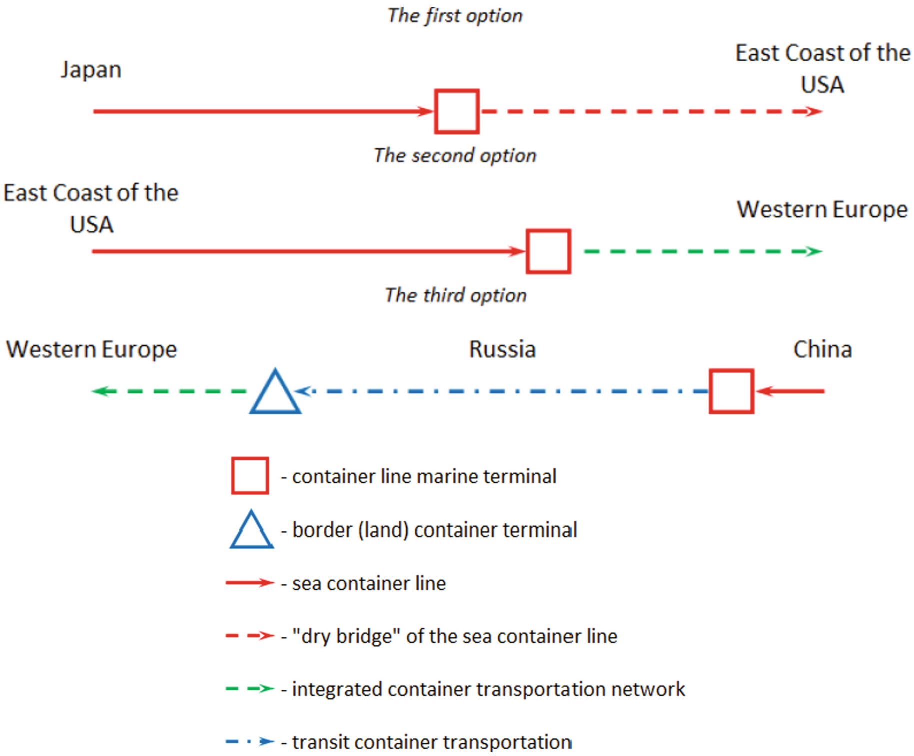

Fig. 1. Options for implementing the concept of multimodal transportation

Thus, the integrated container transportation network of the Russian Federation is not one, but two systems: the first ensures the transit of containers across the country, and the second transhipment of imported goods from containers to domestic modes of transport and packing of containers with export goods in the turnover zone of sea containers. The use of own heavy-duty containers for the delivery of transshipment to terminals is not an acceptable luxury, not to mention the technical complexity of such operations (Fig. 2). First of all, the transport infrastructure of modes of transport focused on working with medium-tonnage containers for decades earlier is not ready for the mass appearance of heavy-duty containers in the vastness of our country [16].

A new link is needed that can provide a technological link for the transportation of goods by internal modes of transport with sea container lines. In addition, the primary task of such a link is to ensure that the advantages of container technologies can be applied beyond the borders of the Hinterland of the seaport.

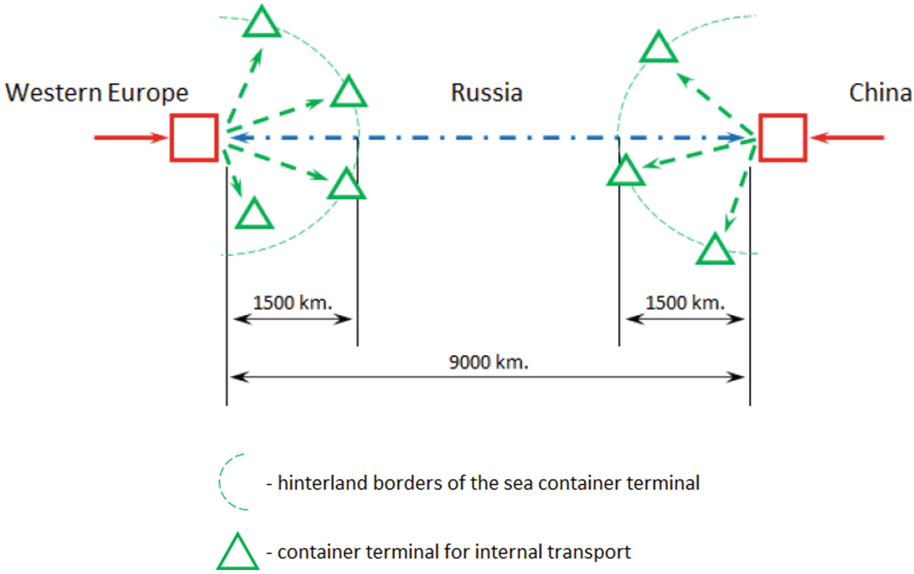

Fig. 2. Integrated container transportation network of the Russian Federation

A medium-tonnage, folding module, placed for transportation by sea in a heavy-duty container (2–3 units each), and providing transportation and transshipment of cargo placed in it by all types of land transport, can ensure the influx of cargo to sea terminals by reducing loading and unloading operations, convenience of placement and improving the safety of primarily small-sized piece-piece cargo with high cost [20]. Therefore, the owners of small shipments who prefer independent shipments in contrast to the existing practice of forming combined shipments are primarily interested in the introduction of new means of consolidation (Fig. 3).

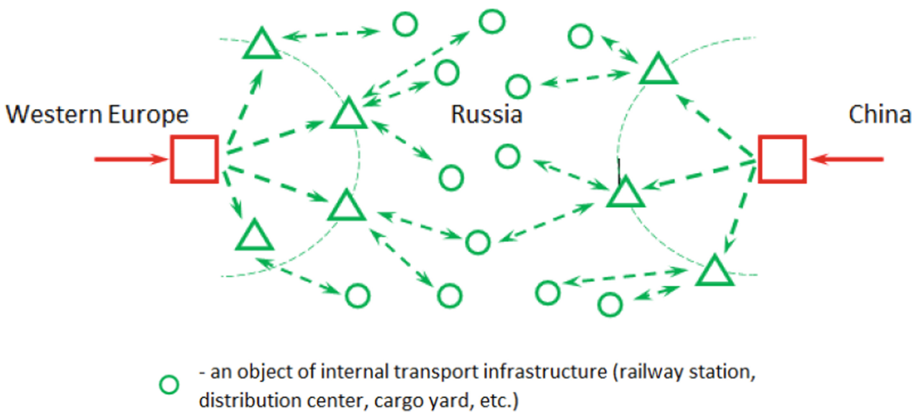

Fig. 3. Expansion of the integrated container transportation network of the Russian Federation

3 Results and Discussion

The main objective of the study is not to identify the management mechanisms of the integrated network of domestic container transportation, but to identify the possibility of introducing a new medium-tonnage means of cargo consolidation connected to the sea container line.

The organization of transportation of any cargo first of all requires calculating the need for rolling stock, containers for the sea line, and in our case, medium-tonnage containers.

The number of medium-tonnage containers is tied to the number of heavy-duty containers and the period of use of new means of consolidation outside the Hinterland.

The total number of containers included in the operation of the line can be calculated as the sum of all containers on board ships providing transportation in the direction of K_s and double the number of containers simultaneously located in the hinterlands of the ports of shipment and destination K_h.

$$\mathrm{K} = \mathrm{V}_{\mathrm{comt}}\mathrm{K}_{\mathrm{s}} + 2\mathrm{K}_{\mathrm{h}}$$

Number of vessels operating on the line K_s this is the ratio of the duration of the round trip T^{flight} to the interval of ship calls to the processing ports T^{int}.

$$\mathrm{K}_{\mathrm{s}} = \mathrm{T}^{\mathrm{flight}} / \mathrm{T}^{\mathrm{int}}$$

The number of containers simultaneously located in the hinterlands of the ports of shipment and destination K_h, this is the product of the vessel's capacity in containers V_{comt} and the relationship of the time of free use of containers in hinterland t^{use} to the interval of ship calls to the processing port T^{int}.

$$\mathrm{K}_{\mathrm{h}} = \mathrm{V}_{\mathrm{comt}} \cdot \mathrm{t}^{\mathrm{use}} / \mathrm{T}^{\mathrm{int}}$$

Hence, it can be concluded that with an increase in the time of free use of containers, their number in Hinterland increases, which will require the organization of their timely removal. Having accepted the circumstances dictating the factors of their behavior to the owners of container lines, it can be concluded that the reserve of possibilities for increasing the time spent by the container within the hinterlent lies in increasing the interval of the ship's arrival, and this is followed by a drop in container turnover. The second way is to increase the capacity of the vessel in containers, but the larger the vessel, the more expensive the port will cost for its maintenance and the longer the port capacity will be idle waiting for the next ship call.

The total number of medium-tonnage containers can be expressed by applying the modularity coefficient k^{module}, reflecting the percentage of cargo from the total cargo flow in need of new means of consolidation. For example, cutting of weeds at the beginning of the 21st century was 8%, by 2020 this figure was 10%, by 2025, according to experts, but against the background of rising prices of expensive goods, it can reach 12%.

It remains to take into account the time of free stay of medium-tonnage containers within the Hinterland and beyond through the ratio of the time of use of the module $t^{useModule}$ by the time the container is used t^{ucn}.

It should also be remembered that for each heavy-duty container there are 2 new means of cargo consolidation.

Then, the required number of medium-tonnage containers K_{module} will be equal to

$$\mathrm{K_{module}} = 2\,\mathrm{k^{module}V_{comt}K_s} + 2\,\mathrm{k^{module}V_{comt}} \cdot \mathrm{t^{useModule}} / \mathrm{t^{use}}$$

Here is an example of calculations. Let a container ship with a capacity of 6000 TEU work on the line, the duration of the voyage is 32 days, the interval between ship calls is 8 days, the free time of the container in Hinterland is 8 days:

$K = 6000 \cdot 32 / 8 + 2 \cdot 6000 \cdot 8 / 8 = 36000$ TEU,

the modularity coefficient is equal to 0.1, the time of use of the module $t^{useModule}$ – 24 days:

$K_{module} = 2 * 0{,}1 \cdot 6000 \cdot 32 / 8 + 2 \cdot 0{,}1 \cdot 6000 \cdot 24 / 8 = 8400$ modules.

The calculations are valid for a uniform demand for new means of enlarging cargo spaces and with the uniformity of the cargo flow itself. And as shown in Fig. 3, the transportation of small shipments outside the Hinterland can be characterized by an unpredictable variation in the volume of transportation and the timing of the return of medium-tonnage containers to the point of packing in sea containers. These variations will also affect the overall demand for medium-tonnage containers.

The above calculations are based so far only on the need to provide new means of consolidation of only small (combined) shipments. But it is from this segment that it seems most convenient to start implementing the proposed project on our vast territory.

4 Conclusions

These studies allow us to draw the following conclusions:

1. Further integration of the Russian transport network into the international container network requires the inclusion of a link between the country's internal transport and sea container lines based on medium-tonnage containers.
2. The inclusion of new means of cargo consolidation in the technological chain of containerization of cargo flows can contribute to the construction of new multimodal corridors on the territory of the country.
3. Expanding the boundaries of the application of the advantages of container technologies into the depths of the country by introducing new means of cargo consolidation, it is advisable to start with the development of the cargo flow of small shipments.
4. The principal dependencies given in the paper can be applied to assess the prospects for increasing the attraction of containerized cargo to transportation by container lines.

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Application of Digital Twins for Digital Transformation of Oil and Gas Enterprises

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Abstract. Currently, there is an active discussion around hydrocarbons as a source of energy. But taking into account the fact that at the moment the continuation of their use is not in doubt, it is important to improve the efficiency of energy companies - environmental, economic, etc. One way to do this is through the digital transformation of the enterprise. This article focuses on the use of digital twins in the oil and gas industry in order to improve the economic and environmental efficiency of oil production. The algorithm of application of the digital twin in the oil and gas enterprise is considered, its architecture is built taking into account the specifics of the task. The place of the digital twin in the models of technological and business processes is defined. Predictive analytics of equipment repairs, reconstruction, maintenance, modeling, remote maintenance, reduction of human factor influence allows to increase efficiency and safety of oil and gas production. The digital twin will make it possible to simulate various failure scenarios in operation, environmental impact, wear rate of parts, etc. Further research is expected to consider expanding the use of digital twins, both in oil production and in related areas, including hybrid scenarios for power systems.

Keywords: Oil and gas production · Hydrocarbons · Digital twin · Production efficiency

1 Introduction

The current technical trend is that companies are beginning to invest more money in smart equipment, reaping more benefits and remaining competitive through the possibilities of digitalization.

Responding to the demands of society and the global trend toward decarbonization, the global energy sector is also transforming. Digital and big data technologies will be important drivers of change in the energy sector. The goal of digital transformation: entering a new market, creating sales channels and revenue-generating solutions for the company. At the same time, digital transformation opens up opportunities to implement new strategies.

For economies such as Russia, Saudi Arabia, the United States, China and Canada, the oil and gas industry is very important. Oil and gas production has a significant impact

I. Ilin et al. (Eds.): ICDT 2021, LNDECT 157, pp. 129–137, 2023.
https://doi.org/10.1007/978-3-031-24434-6_13

on the micro and macro economies of countries [1, 2], although the pandemic situation due to COVID-19 has disrupted supply chains, slowed production and reduced global oil production [3, 4]. In this regard, investors are ready to invest in the introduction and adaptation of modern technologies, which in the near future will lead to the stabilization of production and help reduce costs.

In this regard, the urgent task is to increase the level of automation in the oil and gas industry, which will reduce the level of personnel involvement in the work of the enterprise, reduce the negative role of the human factor and increase the overall efficiency of production process management [5]. For example, geographically distributed sensors send data about the state of equipment, which allows less frequent full scheduled inspections and maintenance [6]. Digital twins are the hottest topic within industrial automation and Industry 4.0 in general, and in the oil and gas industry in particular [7].

The purpose of this study is to describe the application of the digital twin to maintain technical infrastructure in the oil and gas sector.

2 Material and Methods

The study applied a systematic approach. To perform the work, the method of deductive research is used. The theoretical structure is first studied, developed, and then tested by empirical observation, as such an observation, an example of the implementation of digital twins for equipment in the oil and gas sector is given.

Focusing on a deductive, qualitative approach to the topic under study, the research plan aims to review the literature on the research work related to the problem and then to analyze a specific situation.

Thus, the study identifies the following steps:

1. identification of the problem.
2. literature review.
3. theoretical framework.
4. description of the case of using digital twins in an oil and gas company.
5. formulation of results and conclusion.

The oil and gas industry is characterized by a fairly high degree of conservatism. The culture and established approaches to management that have evolved over the past decades in the industry determine, as a rule, a very cautious attitude towards the use of new technologies and tools, especially those whose implementation requires changes in enterprise management systems.

The industry is characterized by the complexity of decisions, high uncertainties, the level of cost risks, the danger and complexity of production, and the influence of the human factor [8]. However, it is already obvious that changes in the industry are inevitable, and the sooner companies change their approaches to strategic management, skills and technologies, the more successful they will be in this highly competitive market. At the World Economic Forum, the idea was presented that in the future much of the value will be determined by modern analytical models, the industry's ability to quickly adapt processes and digitalization, customer relationships, and innovation [9].

Four central directions for the digital transformation of the oil and gas sector in the coming years:

– Digital Asset Lifecycle Management. The emergence of new business models and structures through the use of modern technology with analytical data, which leads to the transformation of operations, helps to make strategic decisions and increase flexibility.
– Circular Collaborative Ecosystem. Digital twins are an integrator of systems that enable greater collaboration among their members and accelerate innovation and lower operating costs [10].
– Customer synergies provide flexibility and personalization, and open up opportunities for the oil and gas operator to increase revenues and bring new services to market [11].
– New Energy Induction. Digitalization promotes modern energy sources and supports energy complex marketing and equipment innovation.

The global energy industry is transforming in response to societal demands and climate change. In 2015, the UN adopted the 2030 Agenda for Sustainable Development [12]. The program consists of 17 global goals, including those related to energy. The International Energy Agency has noted the major changes that will need to be made to achieve these goals. The main vector of energy development for the next 2–3 decades will be aimed at reducing hydrocarbon emissions into the atmosphere in order to achieve zero emissions by 2070.

According to forecasts, in 2040, despite the growth of the global economy by an average of 3.4% per year, companies will see a significant decrease in demand for hydrocarbon energy: the oil market of 65–70 million barrels per day by 2040 will return to the level early 1990s At the same time, there will be a significant reallocation of investment from fossil fuels to renewable energy sources: investments in fossil fuels will decrease by almost 50%, while spending on renewable energy sources will increase by 250% [13].

In modern conditions, the prospects for the development of the oil and gas complex are closely related to the following key trends: adaptation to shocks in world markets, digitalization and challenges from alternative energy. These processes, combined with dynamic structural sectoral and market shifts in the global fuel and energy complex, increased competition for access to resources, require new scientific and practical solutions in the field of managing the oil and gas complex and its components.

The difference of the current stage is the complex and purposeful nature of the introduction of digital technologies in the production and economic practice of oil and gas companies. Large Russian companies have included the priorities and objectives of digital transformation in their development strategies and are creating their own centers of excellence. The pandemic and turmoil in the international oil and gas markets not only led to a reduction in the income of companies in the oil and gas sector, but also affected the speed of the spread of digital formats for organizing and controlling production processes.

Assessment of the state and development prospects of the oil and gas complex traditionally leads to an analysis of the dynamics of production, export of oil and gas, production of petroleum products, refining depth, specific multipliers (based on financial and specific indicators), and parameters of new projects [14]. The dynamics of these indicators is greatly influenced by both market and non-market factors (political, institutional, technical, etc.). Based on this, in the oil industry, the key barriers to technology development and digital transformation that need to be addressed are:

- insignificant amount of budget financing of scientific research;
- insufficient interaction between science and business;
- underdeveloped investment market and intellectual property legislation reduce the possibility of raising funds at the most risky stages of research and development;
- lack of support for small oilfield services companies reduces competition in the industry and, accordingly, the motivation to test new technologies;
- administrative barriers in the field of subsoil use and technical regulations encourage companies to buy ready-made technologies abroad, rather than create them.

In the short term, the digital transformation of the energy sector will be able to increase the company's revenue in the industry by 3–4% per year [15]. The main growth in revenue - in generation and distribution - will be achieved through the analysis of all available data, automation of business processes and local implementation of digital solutions at critical infrastructure facilities. It is important to note that digital transformation affects all sectors of the fuel and energy complex from oil and gas and electric power to coal.

The use of smart technologies in real time allows digital oil and gas companies to achieve the following goals [16]:

- expand the raw material base of the enterprise;
- increase the recovery factor and volumes of oil production;
- increase the productivity of enterprises;
- reduce the unit cost of oil production;
- reduce the number of accidents (including leaks and emissions).

Economic efficiency from the use of "smart" oil and gas production is achieved primarily by reducing the number of downtime of the oil well stock, reducing oil and gas losses during separation, and fully optimizing the oil production process.

3 Results

In this article, we will consider a case of implementing a digital twin when servicing equipment in an oil and gas company.

On-condition repair and preventive maintenance using the digital twin reduces the number of repairs performed, thereby reducing the labor costs for their implementation. And preventive maintenance helps plan scenarios to avoid further breakdowns and accidents. This opens up the possibility of reducing the number of workers to repair breakdowns and reduce overall costs.

The proposed solution, through the implementation of a digital twin, will allow simulating various scenarios of failures in operation, including operating modes of pumps, environmental impacts and varying degrees of wear of parts. The maintenance process will become much easier with the help of digital twins (Fig. 1).

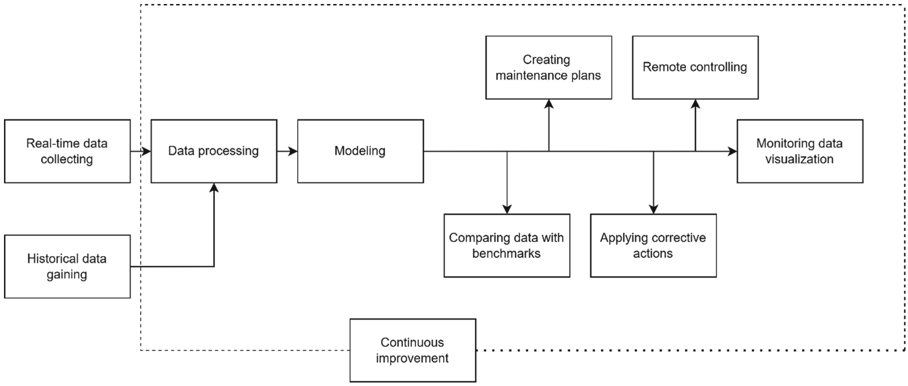

Fig. 1. Data process after applying Digital Twin

The digital twin optimizes the manufacturing process. First, remote control is possible. Often wells with pumps for oil and gas production are located in particularly hard-to-reach places. Thus, time is saved on the way to the objects and on the specialists who will do it. Secondly, digital technologies after data collection help to prepare models in various forms, not only to see the equipment and its condition in real time, but also to simulate various situations and propose preventive plans.

The digital twin improves the maintenance process. The pump algorithm needs parameters and data from sensors to determine which components or combinations of components may fail. After obtaining the necessary information, various analytical models will be created that will signal anomalies and corrective actions that need to be taken.

Let's summarize the opportunities that the well operator and management level will get from the digital twin (Table 1).

Table 1. Opportunities after digital twin implementation.

Monitoring of production indicators	Real-time assessment of overall equipment efficiency
Making recommendations to operators	Early detection of defects and prediction of their development
History by event and analysis of statistics	A single digital template for analyzing past events
Scheduling and dispatching	Consolidated and detailed indicators of the telecommunications operator's performance
Ability to connect to a wide range of equipment and IT systems	Unified connections to various types of equipment, engineering structures, automation circuits and IT systems
Prediction of breakdowns and deviations with a transparent cause-effect relationship	The digital twin provides a "what if" scenario analysis and troubleshoots the root causes of problems
Augmented reality for managers and engineers	Any analytical information can be presented in augmented reality mode along with expert recommendations and prescriptions "superimposed" on the real object
Unlimited scaling and easy setup	The modular architecture of the solution allows you to connect similar equipment and change the functional applications in the same way

The general algorithm of operation of the digital twin is as follows. Readings of physical sensors installed on the equipment are transmitted through the regular APCS to the digital twin, implemented as an industrial server or industrial controller. The mathematical model receives this data and continuously calculates the remaining process parameters, which are not physically measured. It provides the operator with this data in the form of virtual sensors and uses it to calculate technical and economic indicators, as well as to diagnose certain defects and make predictions.

The mathematical model is regularly calibrated according to the current state of the equipment. It also makes it possible to detect deviations at an early stage, since it can be used as a reference for comparing physical measurement data. The prediction is based on the extrapolation of deviation growth from diagnostic criteria and rules.

The top-level architecture of the digital twin is shown in Fig. 2.

In the above scheme, the coordination of goals and functional tasks by management levels is solved by developing adequate models of the company's technological and business processes for the purpose of their further optimization. Further, their interaction is ensured, as well as the consistency of the data used to develop control actions and make decisions. This is achieved through a single information resource - the "digital

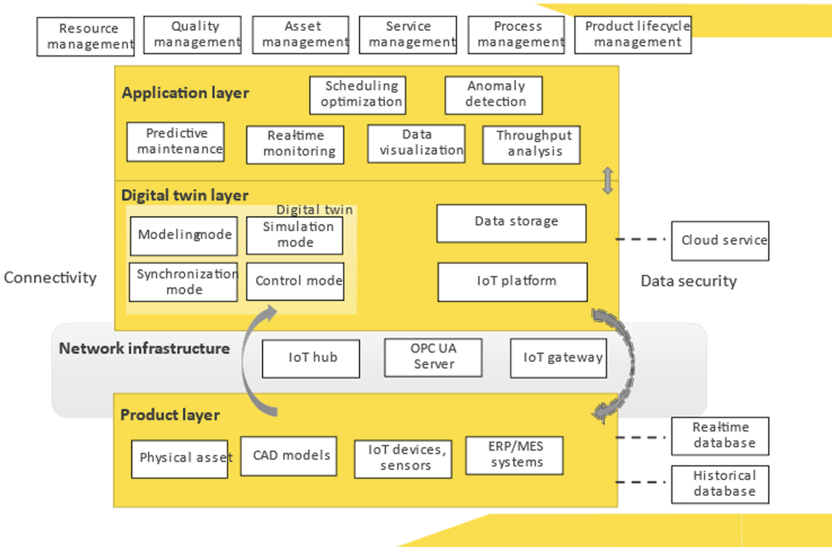

Fig. 2. Architecture of DT

twin". The architecture of the digital twin, taking into account the specifics of the task being solved, is a single integrated, constantly updated model used to optimize the technological and business processes of an enterprise. The purpose of creating a "digital twin" is to transfer an object to the digital space, simulate changes in the state of the object under the influence of various factors and possible control actions, determine and implement optimal control actions to achieve the target state of the object.

For their intended purpose, digital twins of service processes are used for modeling, predictive analysis, forecasting and optimization of oil production processes, and "digital twins" of assets are used to improve the coordination of activities to create assets, assess and predict their state at the stage of operation, scenario modeling and the formation of optimal plans for diagnostics, repair and reconstruction.

This case study demonstrates how the implementation of the digital twin can quickly increase efficiency and reduce costs while ensuring efficient and safe oil production. For the most rational extraction of hydrocarbons from the bowels, it is necessary to constantly improve the operation of equipment, carry out a large amount of measures to optimize the operation of wells, maintain optimal reservoir pressure, and automate production control.

The oil and gas industry is currently one of the leaders in using digital twins to improve production efficiency. This is facilitated by such factors as a variety of production processes (development of fields, construction of wells, artificial lift, transport and preparation of oil, processing of hydrocarbons), the availability of a large amount of production information and a high level of automation. In addition, digitalization provides a high return on investment (by increasing production volumes and reducing operating costs and capital investments).

4 Discussion

It is expected that over time the world will enter the era of renewable energy sources that will displace fossil fuels. There are prerequisites for an energy transition. This is both technological progress and a conscious policy of states to protect the environment and reduce carbon dioxide emissions into the atmosphere. The foundation for this transition will be digitalization, distributed energy, cheaper energy storage, renewable energy sources, hydrogen technologies.

Nevertheless, many researchers agree (for example, [17–20]) that the energy transition will not happen overnight, it will not be possible to quickly abandon hydrocarbons. At the same time, a relevant alternative at the moment is hybrid scenarios for energy systems, when the use of all available types of energy is combined - renewable energy sources, nuclear energy, hydrocarbon energy. In this case, the issues of minimizing and compensating for harm from the use of hydrocarbons continue to be relevant. A topic for future research, in particular, will be the possibility of a wider use of digital twins to improve the efficiency of an oil and gas enterprise, minimize energy losses, and pollutant emissions.

Also, as part of further research, it is planned to consider the expansion of the use of digital twins in related areas, including to improve the efficiency of energy supply using alternative energy sources. Decision-making systems based on digital twins will eventually relieve a person of the need to be in dangerous and aggressive zones. Industrial habitable objects will appear, where many processes will be controlled autonomously by digital twins - platforms in the field of mining, energy, agriculture.

5 Conclusion

Networking all equipment and creating a communication channel with higher-level systems, which just implies an integrated approach, allows you to centrally manage resources and production data. The use of a comprehensive data model containing all production information at all stages of the life cycle reduces the time to market for products, while increasing the flexibility and efficiency of the enterprise. As a result, companies that adopt this approach successfully adapt to the volatility and diversity of global markets, achieving higher productivity and more efficient use of energy and resources, thereby ensuring long-term competitiveness.

Increasing the efficiency of an oil and gas enterprise and reducing the negative impact of hydrocarbons, in particular, through the use of digital twins, will smooth out the process of a promising energy transition and make the use of hydrocarbons more gentle.

Acknowledgements. The research was supported by the Ministry of Science and Higher Education of the Russian Federation (Agreement No. 75-15-2022-1136 dated 01.07.2022).

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The Use of Unmanned Aerial Vehicles in Healthcare Logistic: Risks and Opportunities

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Abstract. In this paper, the authors analyze the application of unmanned vehicle technologies in various industries, including healthcare. The risks and possibilities of using such technologies are analyzed. The authors propose to consider the application of such technology from the point of view of key medical concepts such as the delivery of goods (medicines), organs. Also, paper Describes the world practice of introducing drones in the healthcare sector in countries such as the USA, China, Korea, Canada. The authors formulate a motivational expansion model for internal and external drivers necessary to understand the purpose of using unmanned aerial vehicle technologies.

Keywords: Healthcare · Unmanned aerial vehicles · Delivery · Organs

1 Introduction

Drones became massively available to ordinary people ten years ago, when DJI, a little-known company from the PRC, released a simple and reliable drone on the world market for the price of an amateur camera. These devices immediately began to conquer the world and a place in the backpacks of drone enthusiasts. The development of devices went rapidly - from rustic quadcopters, which could hardly broadcast a picture without stabilization from a height of 200 m, to devices that were perfect in terms of technology and design, showing a luxurious 2k video at a distance of 10 km in real time [1, 2].

By far one of the most trending uses of drones today is for logistics purposes, thereby creating a new competitive environment for automotive transport companies. Several main directions prevail here: courier, for the delivery of the “last mile”, air taxi for transporting people, and in-house, that is, warehouse drones capable of reading barcodes from packages and conducting technological inventory, as well as the field of medicine, which is especially relevant when transportation of medicines and organs, when time is a key factor in a person’s life [3, 4].

Using the example of the United States of America, you can see the distribution by industry where unmanned aerial vehicle technology is used (see Fig. 1).

I. Ilin et al. (Eds.): ICDT 2021, LNDECT 157, pp. 138–149, 2023.
https://doi.org/10.1007/978-3-031-24434-6_14

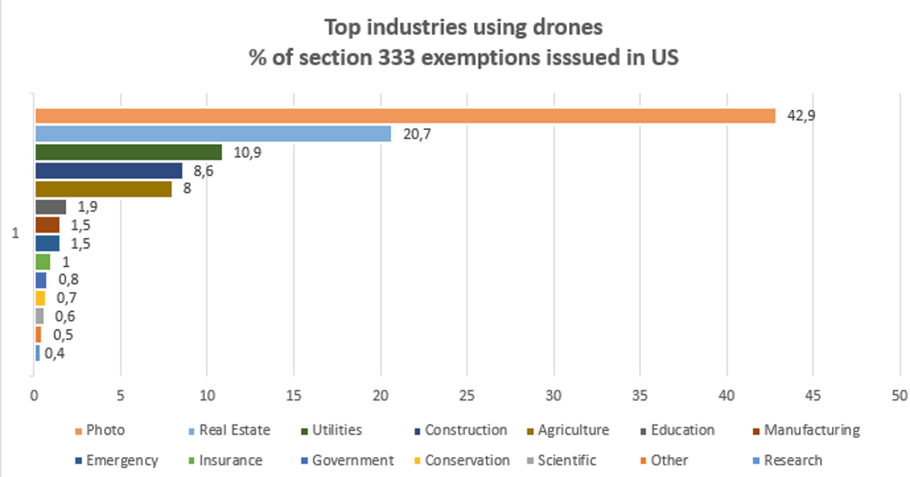

Fig. 1. The main uses of drones in healthcare [5]

It can be noted that the healthcare industry is no exception, despite the fact that drones are used primarily in the field of photography.

BI Intelligence predicts drone revenues to grow to $ 12 billion in 2021. The company's analysts estimate revenues from drone sales in 2015 at over $ 8 billion. Commercial drone shipments are expected to more than quadruple in the next 5 years. This will be driven by increased price competition and new technologies that make it easier for beginners to operate drones [6]. Commercial drone demand is set to grow faster than consumer demand, both in terms of shipments and revenues, once regulators open up opportunities for new drone applications in the US and Europe, these two potentially largest commercial markets drones.

2 Materials and Methods

For our study, of particular interest is the degree of study of the problem of the use of drones in healthcare in different countries. We have analyzed a number of publications devoted to this issue, starting in 2018.

The authors of the article [7] conducted a study to determine how drones are used for healthcare and healthcare-related services in North America, and how such applications account for factors related to human work and the design of machines. Using statistics, the authors showed that drones can represent a financially viable means of increasing the availability of health care and health-related services for those in hard-to-reach areas. According to the authors, further work is required to fully understand the costs of drones to medical organizations and communities.

In the source [8], the authors analyze the benefits of using unmanned aerial vehicles in AFRIC: faster response times during emergencies, which can save more lives; improvement of the environmental situation, as CO2 emissions are lower than with conventional delivery by trucks and cars. The authors believe drone technology has ushered in a new phase for the healthcare sector. To support these technological innovations in Africa, measures are needed to make the use of drones in healthcare widespread and safe:

- development of necessary policy frameworks with regulatory authorities,
- integration of drone technology with other health resources and technologies, such as telemedicine technologies;
- carrying out drone education on the usefulness of drones across the cultural background of rural communities;
- training of the necessary medical personnel to work with drones.

In the source [9] was described how a healthcare delivery drone can help developing countries overcome the challenges of not having the necessary traditional transportation infrastructure. Inaccessible roads will no longer obstruct the urgent delivery of blood, medicine, or other medical supplies. In this article, the authors examine the current state of innovative drone delivery, with a particular focus on healthcare.

In October 2021, the bioengineering company Unither Bioélectronique delivered lungs to a patient for the first time. It was a test flight that took six minutes. Transportation of cargo using traditional transport took about 15 min. The lungs were transported from Toronto West Hospital to the City General Hospital, where Dr. Shaf Keshawji, chief surgeon at the University Health Network of Canada, received the shipment at around 1am. He needed his lungs for a transplant, which he performed on the same day.

The researchers noted that the flight took 18 months to prepare. Moreover, organs have already been delivered using drones, but the lungs are especially sensitive to environmental changes during transportation, and most donor lungs become unusable due to insufficient oxygen saturation. Therefore, Unither Bioélectronique engineers have developed a special lightweight carbon fiber container that can withstand vibrations, changes in altitude and pressure in flight. The training included flight training and drop tests using lung simulators.

"This drone can improve the efficiency of organ transfer between donors and recipients, especially in congested urban areas," the company said. "Through this project, we have created an important stepping stone to the future of organ delivery that will ultimately open the door to the large-scale deployment of larger fully autonomous, electric, environmentally friendly transcontinental transplant drones."

The researchers added that every minute plays a role in organ transportation. The organ must be stored in special solutions so that it can be used later in transplantation. The human lungs and heart can usually withstand transportation for four to six hours, and the liver and kidneys up to several days. Therefore, it is better to use drones, not land transport or commercial flights, scientists say.

In the present study, to solve the set tasks, scientific research methods were used: system analysis, induction and deduction, comparative analysis.

3 Results

After analyzing various sources [10, 11] and identifying the main goals of using unmanned aerial vehicle technologies, the authors formed a motivational extension using the Arhimate enterprise architecture modeling language. The diagram presented in Fig. 2 reflects the key stakeholders, drivers, and the main goals of each stakeholder [12].

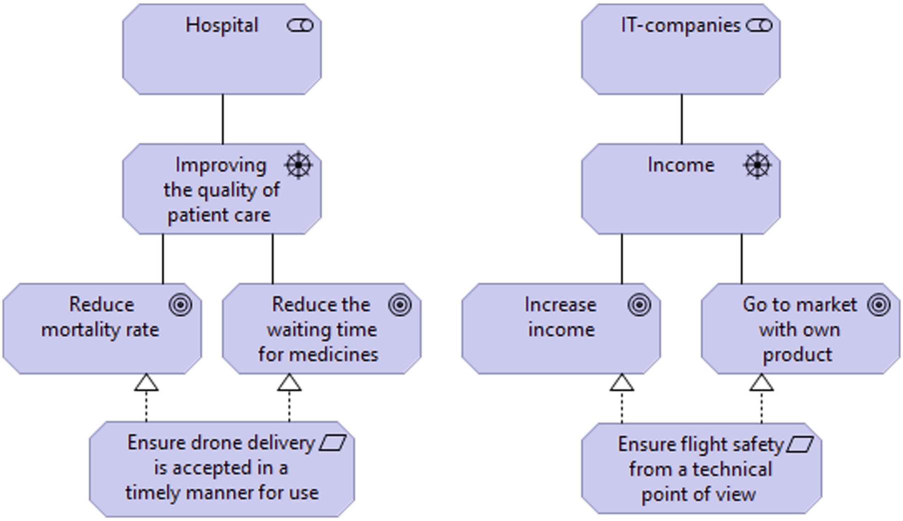

Fig. 2. The diagram of motivational extension

Table 1. The main limitations and possibilities of using unmanned aerial vehicles.

Limitations	Opportunities/necessary when using
Fly at a distance closer than 5 km from the borders of airfields, prohibited and dangerous zones	Need to know the main characteristics and capabilities when using UAV
Fly over moving vehicles to prevent distraction of drivers	Make sure the device is in good working order before use
Fly the craft over crowds during events	Fly in good visibility conditions and in the user's field of vision in good weather conditions
Fly over prohibited and dangerous areas and guarded objects	Respect privacy - keep the distance between other drones and people, animals, structures and property at least 50 m
Suspend and mount various objects on the apparatus that are not provided for by the design of the apparatus	Fly at an altitude of at least 100 m

3.1 Unmanned Aerial Vehicles: Limitations and Opportunities

The uncontrolled spread of the use of UAVs in the world, together with the corresponding risks associated with aircraft, other property, human life, privacy, violation of the boundaries of closed areas and security, require new regulation by legislators.

The Table 1 shows the main limitations and possibilities of using unmanned aerial vehicles.

3.2 Analysis of the UAV Using in Medicine: Best Practices

Flying drones are successfully used for operational delivery in medicine, when delivery is either technically difficult or maximum speed is required. For example, if some settlements are temporarily or permanently “cut off from civilization”, for example, due to floods, earthquakes, etc. Or to remote small settlements. The need for such an application of flying UAVs is indicated, for example, by the following statistics: “6.3 million children died in 2015 because there was no necessary medicine.” Samples of blood and tissue, blood supply for transfusions, antidotes, defibrillator, consumable medical supplies, instruments, etc. can be delivered [13].

Figure 3 provides an outline of the main directions in healthcare using drone technology.

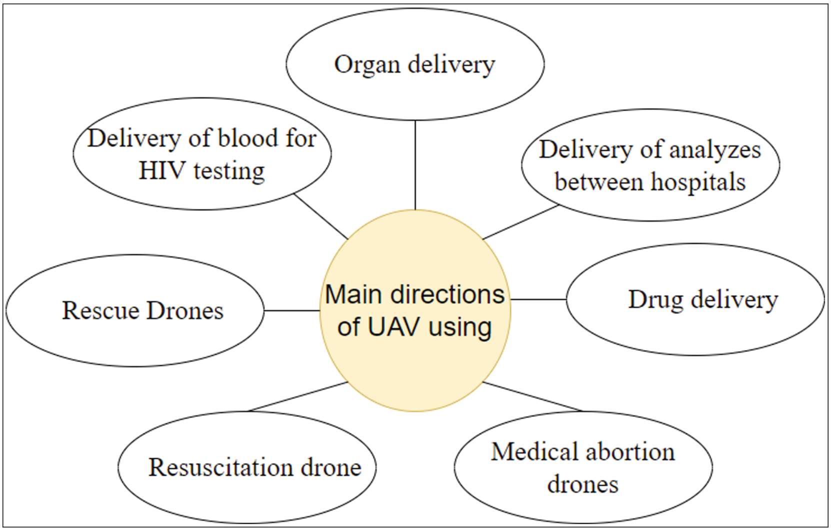

Fig. 3. The main uses of drones in healthcare [13]

Below are explanations of the main areas of UAV use in medicine and examples of their use [14]:

1. Drug delivery.
   The first drone for transporting drugs was tested by Flirtey. The delivery, which, incidentally, became the first officially permitted delivery of goods in the United States using a drone, was carried out from a pharmacy to a hospital. It took place in two stages. First, the drone transported 24 packages of drugs with a total weight of 4.5 kg to the airport, and then in several passes delivered them to a rural hospital in Virginia, covering the remaining distance. The load itself was lowered on a cable next to a medical facility. The duration of each flight was about three minutes.
2. Delivery of analyzes between hospitals.
   In Bern, Switzerland, in July 2017, drones for the delivery of laboratory tests and drugs will begin to be tested. The experiments are being carried out by the Swiss Post, a Swiss post that has been researching the commercial use of drones for several years. Drones with a diameter of 80 cm and a carrying capacity of up to 2 kg will carry out the delivery of medicines between hospitals belonging to the Insel Group. This will replace taxis that previously performed similar functions. The drone provides for the duplication of the autopilot and other important functions and provides for a parachute - in case the electronics fail. Earlier, the Swiss tested the delivery of biomaterials between two hospitals in the city of Lugano [15].
3. Delivery of blood for HIV testing
   A Zipline-like startup called Matternet, also from California, is testing blood shipment in East Africa, in the state of Malawi. The idea is that people in the country can quickly find out their HIV status and start treatment earlier. Now this procedure takes two months. The immunodeficiency virus in Malawi is colossal - it infects 10 to 15% of adults, and every year 10,000 children die from it.
4. Resuscitation drone
   In 2014, Alec Momon, a student at the University of Delft, Netherlands, proposed the idea of a drone designed to provide emergency care in cardiac arrest. The prototype he developed weighed only four kilograms and was equipped with a defibrillator. The drone is capable of reaching a speed of 100 km/h and operating within a radius of 12 km, while it can determine the location of the victim by the signal of the caller's mobile phone. Momon calculated that using a drone would increase the chances of surviving a heart attack from 8% to 80%. The idea of a drone defibrillator was developed. In particular, scientists from the Karolinska Institute in Sweden recently conducted a series of test flights. The drone was directed to the same points where earlier cases of cardiac arrest actually occurred. It turned out that the FlyPulse LifeDrone-AED multicopter was able to arrive on a call in an average of 5 min 21 s, while the ambulance arrived only after 22 min.
5. Rescue Drones
   The idea comes from Iran, which appeared in 2013 - drones that drop lifebuoys to drowning people. Scientists from the RTS laboratory in Tehran have thought about a similar drone called Pars in connection with the increased frequency of accidents in the Caspian Sea. The task of the drone was to search for people who were outside the ship and supply them with self-inflating circles and life jackets. The Pars prototype could carry only one lifebuoy on board, but the project planned to increase the carrying capacity to 3 laps, and in the "near future" to 15. It was also reported that

Pars drones will be equipped with a camera to search for drowning people will not be afraid of storm waves.

6. Medical abortion drones
   Another highly unusual use of drones for medical purposes was invented by the Dutch organization Women on Waves, which fights for women's rights bypassing the laws of different countries of the world. The fact is that some states prohibit women from having abortions, forcing them not only to violate the law, but also to take huge risks. For example, while traveling in Africa and Latin America, the founder of the organization, Rebecca Gomperts, noticed that many women die from the consequences of abortion, although the procedure is inherently safe. This is how the idea arose to help such women by providing assistance on a ship that, being in international waters, obeys the flag of its country and does not fall under the jurisdiction of another state. Due to the fact that not everyone can be reached by water, members of the organization came up with the idea to use a drone for delivery. The first experiment took place in June 2015, when a drone with drugs for medical abortion, dubbed the "Death Drone" by journalists, was sent from the German city of Frankfurt an der Oder, where abortion is allowed, to Poland, to the banned city of Slubice. Local authorities tried to stop the action, but could not legally prove that it was breaking the law - all drugs were prescribed by prescription, and since both countries are in the common Schengen area, the appointment was valid both in Germany and Poland.
7. Organ delivery
   Test flights were required before lungs could be sent for transplant in a refrigerator attached to a drone from hospital to hospital in downtown Toronto. In the middle of the night, the drone flew 1.2 km in less than ten minutes across the skies of the Canadian metropolis, taking off from Toronto Western Hospital and landing on the roof of a general hospital. The lungs were then successfully transplanted into a sixty-year-old patient with pulmonary fibrosis. The drone was transported through a refrigerated container "which maintains the thermal parameters of the organ" so that the latter is "suitable for transplantation. Overall, unmanned technology has enormous potential to become the standard in health care. The most important limitation for transporting organs is time. Experience shows that drone delivery technology already being used for packages purchased over the Internet in some countries can in fact be used to improve the existing organ transport system and reduce its cost [16].

3.3 New Use Cases of Drones During a Pandemic

Unmanned aerial vehicles can significantly improve the effectiveness of measures taken to reduce the spread of COVID-19 and find a large number of use cases [17]:

- prompt delivery of medical tests and medicines to medical institutions;
- notification of the population about antiviral measures;
- monitoring of crowded places, quarantine zones, vehicle traffic;
- antiseptic and disinfectant treatment of potentially contaminated areas;
- prompt contactless delivery of food and essential supplies to quarantine zones.

Any use case for drones during a pandemic has one big limitation - automated landing in urban environments. Existing UAV landing systems use GPS to navigate the drone as well as a vertical takeoff and landing trajectory. These features do not make it easy to land the device in dense urban areas, where the GPS signal is much worse than a similar signal in an open field, and also do not allow landing through a building window. In addition, UAVs require maintenance between flights (such as battery replacement), which also limits their use [18].

In Russia, a group of engineers from the Navigation Engineering project has developed a fully automated optoelectronic system for UAVs without the use of GPS and with a horizontal landing method, however, at the moment, the technology remains unclaimed.

The most vulnerable point of a drone is a person. The current generation of drones are unable to deliver a package of food or medicine to a balcony without a pilot. And in order to send the cargo, the drone must be taken out into an open area with a stable GPS signal. The developed landing system works on the principle of the classic course-glide path system used in aviation for aircraft landing. This approach makes it possible to choose a horizontal way of UAV landing, as well as to completely abandon the use of any GPS systems. In other words, it becomes possible to land the device in any building conditions and weather.

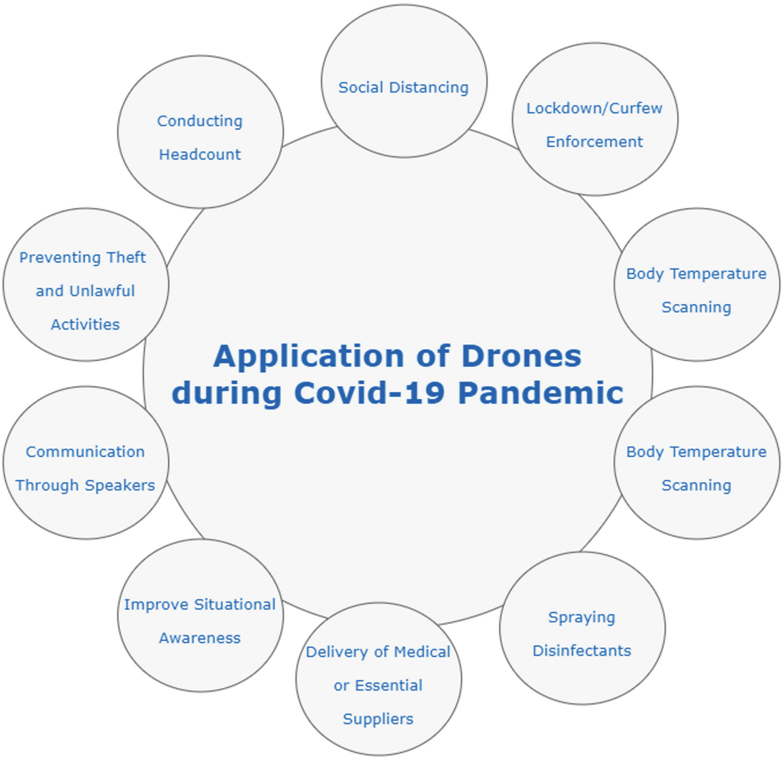

Fig. 4. Application of drones during Covid-19 pandemic [19]

During the pandemic, the demand for the use of drones has grown in many countries (see Fig. 4).

In China, drones have been used for disinfection, delivery of analyzes and cargo to isolated areas, and for patrolling. Drones, originally designed to spray pesticides in agriculture, have been adapted to spray disinfectant chemicals in some public places and vehicles. More than 2.6 thousand unmanned aerial vehicles were used for disinfection on an area of 902 million square meters. m in 20 provinces of China. The delivery of medical analyzes using drones can significantly speed up feedback for critical research. Delivery testing was done in early February 2020 - a drone with analyzes flew from the Xinchang County People's Hospital in Zhejiang Province to the Center for Disease Control and Prevention, located 3 km away. As a result, delivery, which would have taken 20 min by land transport, took only 6 min [20]. And already at its peak during the pandemic in China, the drone performed 20 flights daily. Delivery has been problematic in parts of China even before the virus emerged due to challenging landscapes such as the semi-isolated Anxin Islands. In order to bring the goods, three types of transport were usually required - the products were delivered to the pier, transported separately to each island, and then carried on foot. A car trip along a 100 km long narrow road on the peninsula can take more than two hours one way, but delivery by drones will take 10 min and at the same time may limit human contact.

In the South Korean city of Daegu, drones loaded with 9.5 L of disinfectant were used to spray 95,000 square meters. m in 10–12 min. In Spain, a military emergency response unit, an analogue of our EMERCOM service, also tested the use of agricultural drones by the Chinese company DJI during the pandemic to spray disinfectant in open areas and inside large vehicles.

At the end of April 2020, police in Westport, Connecticut, announced the use of "pandemic drones" that would measure people's temperature, heart rate and respiratory rate at a distance of up to 60 m, as well as detect sneezing and coughing. The drones are equipped with special sensors and computer vision technology and can detect the temperature, heart rate and respiration rate of people at a distance of 55 m. They can also recognize if a person is coughing or sneezing in a crowd, and measure the distance between people [21].

Police in the capital of Kazakhstan, Nur-Sultan, have armed themselves with drones from the local manufacturer Terra Drone to monitor the city during quarantine due to coronavirus. Using cameras with infrared sensors, UAVs make sure that quarantine is not violated. Also, the development of the exact coordinates of the objects led to the fact that the authorities discovered several bypass roads for penetrating the city and insights in the closed zone.

Researchers in Sweden have simulated Matternet drone delivery in a theoretical city of 100,000 with a COVID-19 outbreak. They estimate that 36 drones, each equipped with 100 tests, could visit every resident in such a city every four days. The researchers note that the main obstacle to the implementation of test deliveries based on UAVs is "lack of regulation of drone flights," without mentioning how Matternet drones will be able to visit self-isolated residents in dense urban areas [22].

In early February 2020, China launched special drones with loudspeakers to remind citizens of the safety rules that should be followed to contain the outbreak of the coronavirus. The microblogging platform Weibo shows a drone scanning passers-by for violations, such as missing a face shield. Upon detecting the intruder, the drone politely but firmly warns the person to put on a mask or go home. The footage published by the Global Times shows a drone publicly berating people without masks [23].

Based on the analysis of world experience in the use of unmanned aerial vehicles, it is possible to identify the main risks that can aggravate the situation with patients:

– improper transportation of organs, medicines in terms of temperature conditions;
– bad weather conditions;
– lack of sites for taking medicines/organs

Thus, it is impossible to exclude the traditional methods of delivery of medicines, organs, even with the availability of modern technologies that make it possible to reduce the delivery time, which is a vital moment in the healthcare sector.

4 Discussion

Today, drone technology in medical logistics is innovative. Studies and statistics obtained in different countries as a result of the use of drones indicate the prospects of their use for solving various problems of medical logistics: delivery of organs, medicines, monitoring an emergency, etc.

However, despite the positive experience described in our study, the relatively small number of experiments performed on the use of drones in medical logistics does not serve as a basis for guaranteeing the level of safety of this type of operation. Currently, we cannot yet talk about the large-scale use of this technology in healthcare logistics. It is obvious that the use of drones in healthcare logistics is possible as an additional support for ground medical transport in difficult situations. This does not require additional infrastructure or external services.

There are a number of constraints that must be taken into account when using this technology: weather conditions (e.g. strong winds), integration into dense urban airspace, standardization of procedures, regulations, staff readiness. All of these factors should ensure the appropriate level of maturity of the technology for using drones in medical logistics and make it possible to deploy it on a large scale.

5 Conclusion

In the study, we tried to summarize the experience of using UAVs in healthcare logistics. Conducted an analysis of the main areas of UAV use in medicine and examples of their use. The authors analyze the main limitations and possibilities of using unmanned aerial vehicles and consider possible ways of developing this technology.

The authors formulated the motivational extension model by using Arhimate tool, which helps to understand main stakeholders, their drivers and goals of using UAV technologies in healthcare sector.

The authors consider the sphere of application of drones during Covid-19 Pandemic. Finally, the authors consider the most important aspects of security when using with UAV technologies.

A further area of research can be the maturity levels of the medical company and urban infrastructure that allow the use of UAV for organ and drug delivery. Another important issue that requires further study is the issue of the effectiveness of the use of this technology.

Safety technologies and better regulation open up a new range of UAV applications in the commercial sector, including organ delivery, medicaments delivery.

Acknowledgement. The research was supported by the Ministry of Science and Higher Education of the Russian Federation (Agreement No. 075-15-2022-1136 dated 01.07.2022).

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Improvement of Information and Communication Activities of Participants in Supply Chains Using Corporate Portals

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Abstract. The article substantiates the expediency of using corporate portals to optimize the business processes of interaction between distributors and contractors. These systems allow increasing the level of sales by improving business processes, freeing up working time for employees, creating a new channel for interaction with partners and increasing customer loyalty. The authors identified the main directions of digitalization of economic entities in the pharmaceutical industry, identified trends in the development of communications for participants in supply chains in the modern economic environment and growing competition. The paper presents the results of a project for the development and implementation of a corporate portal for a distributor of the pharmaceutical market. Based on the analysis of business processes, the company's problems with interaction with counterparties were identified, a project management plan was drawn up, including the organizational structure of the project, a matrix of responsibility of its participants, a project communications management plan, and a register of risks. The analysis of the implementation results is carried out and recommendations for its practical implementation are given.

Keywords: Corporate portal · Relationships with contractors · Information and communication activities · Business process optimization · Supply chain participants

1 Introduction

Over the past years, the pharmaceutical industry in Russia has continued to grow steadily, and information technology is the primary factor in its transformation. The digitalization of economic entities in the pharmaceutical industry is currently the most important factor for maintaining competitiveness in the market; the following are automated: relationships with counterparties, drug promotion strategies, public procurement systems within the company, drug supply chains; systems of labeling, Big Data are being introduced to identify ineffective drugs and reduce the cost of developing new products; used by BI to improve the efficiency of production equipment [1, 2].

I. Ilin et al. (Eds.): ICDT 2021, LNDECT 157, pp. 150–162, 2023.
https://doi.org/10.1007/978-3-031-24434-6_15

Also, an indispensable factor for the successful functioning of enterprises is the correct organization of information and communication activities, which allows maintaining a high level of efficiency and reliability of information, accelerating the implementation of logistics business processes.

To automate relationships with contractors, b2b portals are widely used, which are web systems equipped with complex business functions. These systems are designed and developed exclusively for the business processes of a particular organization and allow increasing the level of sales by optimizing business processes, freeing up the working time of employees, creating a new channel for interaction with partners and increasing the loyalty of counterparties [3, 4].

The purpose of this study was to analyze possible areas of using corporate portals to optimize business processes of interaction with counterparties in the pharmaceutical industry supply chain.

The methodological basis of the study was the works [5–7], as well as research on the management of project activities of organizations [8, 9] and supply chain management [10–12]. The development of these concepts in the direction of methodological approaches to the implementation of information technology projects in business received in the research [13–15].

2 Material and Methods

The study used the PRINCE2 methodology to analyze the data and design the project.

Compared to other collections of best practices and project management techniques, PRINCE2 provides the following benefits:

- can be applied to any type of project;
- ensures the unity of terminology and approaches;
- easily integrates with other practices and with specific industry models and methodologies;
- focuses management efforts on the project product, which guarantees its creation in accordance with agreed quality standards;
- offers "deviation management", which ensures efficient use of managers' time;
- ensures continuous attention to ensuring the viability and feasibility of the project.

The seven principles guiding the PRINCE2 project are:

1. Ongoing Feasibility Assessment: Ensures the continuous alignment of the project with the organization's goals.
2. Considering previous experience.
3. Definition of roles and responsibilities.
4. Management by stages. Throughout the project, checkpoints are provided at key locations.
5. Deviation management: in PRINCE2 projects, for each management level, acceptable deviation limits are established within which they exercise their authority.

6. Focus on products: because successful projects are result oriented, not process oriented.
7. Adaptation to the environment of the project [16].

The research object was the pharmaceutical holding BSS LLC, one of the largest distributors of medicines and medical products in Russia.

A distributor is a company that acts as a reseller in organizing goods movement and distribution for a manufacturer of goods. The distribution link has always played an important role in the development of the Russian pharmaceutical market and has dominated the distribution chain. The main subjects of the pharmaceutical market are manufacturers, distributors and pharmacy organizations.

As a result of the study, the following trends in the development of distributors in the modern economic environment and growing competition were identified:

– growth and expansion of the assortment;
– development of our own retail networks;
– search for new forms of work with pharmacy organizations;
– various competitive technologies.

The distributor's quality system must ensure:

– Transfer of medicinal products to retail sale without any change in their properties.
– Compliance with all conditions of storage of medicinal products, including their transportation.
– Store medicines properly.
– Delivery of required items to appropriate addresses within a satisfactory time frame.
– Timely identification of any substandard drug.
– Creation of an effective methodology for countering the appearance of substandard or counterfeit products and their recall.

Holding LLC "BSS" carries out complex supplies of medicines and medical supplies to hospitals, pharmacies and pharmacy chains throughout the Russian Federation. Each client is the value of the company. The range of the company today includes more than 8 thousand items. Warehouses ship products around the clock. Customers have at their disposal a fleet of dozens of vehicles of various carrying capacities.

For the convenience of customers, BSS has 12 branches with their own warehouse complexes in cities such as: Bryansk; Kaliningrad; Kazan; Kostroma; Moscow (2); Murmansk; Rostov-on-Don; Orenburg; Yekaterinburg, Astrakhan. The central logistics center of the company is located in St. Petersburg.

The main advantages of the company are: stability in development, reputation of a reliable business partner, social responsibility, high professionalism of employees, European leadership style using modern management systems and supply technologies, the fight against counterfeit products, fair competition, impeccable quality of work.

An integral part of achieving business success is establishing and maintaining relationships with reliable counterparties: suppliers and buyers.

Suppliers include manufacturers of medicines and drugs, medical products from which the company purchases goods for resale, as well as other organizations that provide services or supply of goods necessary for the main activity of the company. Suppliers of medicines include such companies as: LLC Novartis Pharma, JSC Bayer, LLC Pharmsintez, LLC Pfizer and others. Communication with suppliers is carried out by the purchasing department.

Buyers include various business entities that purchase medicines and drugs, medical products from the company: government agencies - hospitals of various profiles, medical and prophylactic institutions; medical laboratories; charitable foundations; private medical clinics and offices; pharmacy chains and pharmacy points; any individuals and legal entities using medical products for their own purposes. Communication with customers is carried out by employees of sales departments.

Interaction with contractors is carried out through telecommunication networks; using legally significant electronic document management, as well as using ftp-servers and various external electronic platforms.

The main business process of the company is the distribution of medical products. Every day, the warehouse makes shipments of more than one and a half thousand orders to various customers. And not an exception is the emergence of a large number of claims from customers in connection with the detected production or logistic defects, deviations from the temperature regime during delivery, re-sorting of series, surplus of goods or underdelivery; mistakes of a client or manager when placing an order; often the return of goods is carried out in the event of federal rejection of drugs - withdrawal of a drug from circulation. Work with claims is carried out by managers of sales departments together with the department of claims and complaints, the department of certification. Based on the analysis carried out, it was calculated that one manager spends about 240 h a year to work on claims from clients, due to the fact that making a return is a very time-consuming process.

As a result of the analysis of the company's business processes for interaction the following problems were identified with counterparties:

1. High labor costs and time costs for working with claims for the delivery of goods: the process is not automated properly; managers manually create several documents of the same type (registration of claims and an application for a return); documents undergo long-term approval; managers spend a lot of time informing clients about the results of claims consideration.
2. Lack of service to provide customers with the necessary information. Clients need to upload the following data:

    a. Price lists: the process of setting up the unloading of catalogs to customers takes a long time, since it involves employees of various departments in its implementation - a sales manager, a head of the wholesale automation department, a programmer. In addition to the laboriousness of this business process, there may be cases of refusal to implement it due to the lack of interaction with the client's electronic platform, as a result of which the client may be lost by the company.

b. Quality documents: the majority of drugs and drugs are accompanied by certificates, registration certificates confirming the quality of the drug. Currently, a web-service (one-page site) for downloading certificates has been developed for clients. However, this service has frequent failures, and managers have to deal with uploading certificates manually: search for documents on the server, download them and send them to customers by e-mail. Managers spend about 10% of their working time on this process.
c. Data on federal rejection of drugs: in accordance with the legislation, Roszdravnadzor notifies companies about the detection of substandard, counterfeit drugs and about the withdrawal of drugs from circulation by means of "information letters". Next, it is necessary to inform customers about the rejected drugs they have purchased. At the moment, this process has not been implemented in the company.

3. Lack of a remote ordering program: the company works with many electronic platforms (on a commercial basis) that allow you to place electronic orders, which are transferred by exchanges to 1C UT for managers to work out, but its own service that allows customers to place an order on the basis of a price list. no company.

The solution to these problems can be the introduction of a corporate portal, which allows to optimize interaction with contractors [17, 18].

3 Results

Based on the requirements formed by the company, a comparative analysis of possible options for the implementation of the "Contractor's Portal" project was carried out and a decision was made to develop the portal independently by specialists from the company's information systems department.

The pre-project survey made it possible to build diagrams of business processes of interaction with the counterparties "AS IS" and "TO BE" [19]. As an example, Fig. 1 shows an algorithm for working with clients in terms of claims settlement after the implementation of this service.

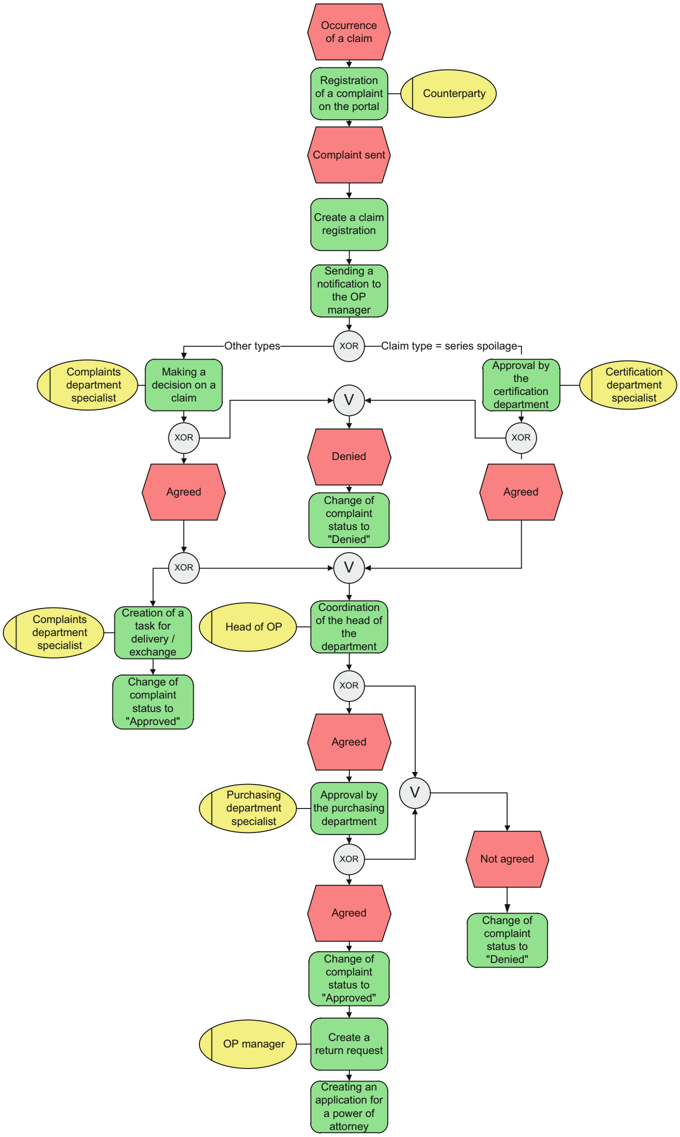

Fig. 1. Business process diagram for handling complaints "TO BE".

The project includes work on the creation of a contractor's portal and optimization of work with the company's clients in terms of: creating complaints; unloading invoices, quality documents, price lists; providing information about the All-Russian marriage. Integration of the portal with 1C UT. After the implementation of the portal within the framework of this project, its support is carried out. The main tasks and results of the project for the development and implementation of the portal are presented in Table 1.

Table 1. Objectives and results of the project.

Objectives of the project	Results of the project
Analysis of the work of managers of sales departments. Analysis of the business process for working with claims	Identification of bottlenecks. Schemes of business processes in the state "AS IS"
Analysis and formalization of Customer requirements	Generated requirements for the portal. Diagrams of business processes in the state of "TO BE"
Development of technical specifications for the implementation of the portal	Approved Terms of Reference for the development of the "Counterparty Portal"
Optimization of the current business process for working with claims	Optimized algorithm for working with documents "registration of claims" and "request for return"
Portal design, portal prototype development	Graphic layout of the portal
Portal development, programming of functional modules, testing	A functioning portal that meets all the requirements of the terms of reference is hosted on the hosting. Exchanges with 1C are configured
Development of operational and organizational and methodological documentation	Portal instructions for all roles and user types
Delivery of the portal to industrial operation	Clients are connected to the portal, familiarized with the instructions
Providing technical support and maintenance of operation	User support. Troubleshoot portal issues

To implement the project, a project management plan was drawn up, including: project charter, work structure, schedule and project milestones, project organizational structure, matrix of responsibility of its participants, project communications management plan and contract management plan, a project risk register (Table 3). The development and implementation costs of the corporate portal amounted to 837,900 rubles.

Responsibility for the implementation of the main project work in the ratio of roles is presented in the responsibility matrix (Table 2).

Table 2. Responsibility matrix

№	Stage name	DIS director	Analyst	1C programmers	Web-programmers
1	Initiation				
	Formation of the project team, assignment of roles and responsible persons	+			
	Formation of project documentation		+		
2	Pre-project inspection				
	Analysis of current business processes		+		
	Collecting requirements		+		
	Forming a vision of "how it should be"		+		
	Formation of the graphic layout of the portal		+		
3	Development of technical specifications				
	Formation of functional requirements for the portal		+		
	Defining style (portal design)		+		
	Development of technical specifications for programmers		+		
4	Realization				
	Realization of improvements 1C			+	
	Realization of web-portal				+
	Realization of design				

(*continued*)

Table 2. (*continued*)

№	Stage name	DIS director	Analyst	1C programmers	Web-programmers
	Setting up integration and exchanges 1C and the portal			+	+
5	Testing				
	Portal performance testing		+		
	1C testing		+		
	Functional testing		+		
	Interface testing		+		
	Compatibility testing		+		
	Performance testing		+		
	Security testing		+		
6	Writing instructions		+		
7	Commissioning		+		
8	User training				
	Manager training		+		
	Customer User Training		+		
9	Support		+	+	+

The main goals of testing are:

– Detection of the maximum possible number of defects that disrupt the normal functioning of the portal.
– Confirmation of the efficiency of the portal as a whole in accordance with the terms of reference.
– Confirmation of the operability of each developed portal module in accordance with the terms of reference.
– Confirmation of fault tolerance of the system and each individual module.
– Confirmation of the set performance parameters.

The study identified the qualitative and quantitative effects accompanying the implementation of the information system (Table 4) [20]. Thanks to the Counterparty Portal, customers will have the following opportunities:

– convenient service for creating complaints (claims);
– provision of quality documents (certificates, registration certificates);

Table 3. Risk register

№	Risk	Probability of occurrence (1–5)	Influence (1–5)	Level	Potential response actions
1	Refusal of customer employees to move to a new PSU work with claims	4	5	High	Training of clients' employees, demonstration of the advantages of working with the portal. Refusal to accept oral claims by sales managers
2	Refusal of customers from paid use of the portal	5	3	medium	Finalization of the portal in order to create material value for customers
3	Portal failures	2	3	Medium	Periodic control. Configuring notifications to managers about the documents being created
4	Dismissal of the programmers	1	2	Low	Replacing the contractor, contacting subcontractors
5	Increased implementation time due to difficulties in transferring information	3	4	Medium	Provide for the possibility of increasing the terms

– provision of price lists;
– provision of information on rejected drugs purchased by the client;
– convenient ordering service (remote ordering program).

Portal implementation will allow the company to:

– optimize the work of managers;
– automate routine processes and duplicate operations;
– to shorten the terms of rendering services;
– provide a convenient service to clients;
– increase customer loyalty;
– ensure an influx of new customers and increase sales.

Table 4. Changes in indicators after the introduction of the corporate portal

Index	Before implementation	After implementation
Time for processing claims by managers	20 h per month	5 h per month
Number of shipment orders	1500 orders per day	2500 orders per day
Time to upload quality documents	7 h per month	0
Time to unload price lists	10 h per month	0
Customer loyalty level	70%	85%
Profit	37 599833 RUB/month	39 479824 RUB/month

When a counterparty has an account on the portal, third-party organizations, intermediaries providing such data, are excluded from the value chain, which increases the level of security of the company's confidential information.

4 Discussion

The following aspect is debatable: when implementing such projects, it is necessary to make a decision about who will implement the project.

Currently, there are no ready-made solutions on the IT services market that meet the requirements of companies and fully take into account the specifics of their activities. The only alternative is the development of a B2B portal by the company independently or with the involvement of third-party organizations.

B2B-pore is an effective tool for automating routine work with partners, representing a flexible and functional system that allows you to take into account the subtleties and peculiarities of working with each of the clients. Projects for the development and implementation of this service by third-party organizations last on average from 4 to 8 months, and the average development cost varies from one and a half to three million rubles.

When deciding on the implementation of corporate portals, the following factors should be considered:

- Extremely high cost of development by external contractors.
- When using contractors, long terms of pre-project survey: immersion in all business processes of the company and the nuance of its work is necessary.
- After the implementation of the system, it may be necessary to refine the functionality: if implemented by external contractors, the revision of the system will require an additional budget.
- Third-party contractors, as a rule, use "template" development of b2b systems, which does not guarantee that they will not find practically identical services from competitors.
- Implementation of maintenance and support of the portal by external organizations is impossible according to the rules of information security of the company, since the portal is integrated with the accounting financial system.

The decision to independently implement such projects should be made as a result of a thorough analysis of opportunities and threats, as well as the availability of the necessary human resources for each organization individually.

5 Conclusion

The introduction of such portals will allow companies to reach a new level of work with counterparties, providing a convenient, flexible and multifunctional system that provides the ability to select the necessary "options" of work.

Thanks to the B2B portal, the company has the opportunity to automate most of the routine work with partners. A well-designed system will take into account all the previously specified features of working with each individual counterparty. By providing up-to-date and relevant information around the clock, the implementation of the portal will make the client autonomous, as a result of which the working time of managers will be freed up, and, as a result, the level of sales will increase.

The portal, developed and implemented by the holding's specialists, can be finalized and updated in connection with the emerging needs for the implementation of business processes and business functions at any time as needed, which increases the value and significance of the product for the business.

The results of this study can be used by organizations involved in supply chains when deciding on the development and implementation of corporate portals.

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Decision Aid Digital Instrument Within Arctic Maritime Logistics During Polar Night

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Abstract. In the article, there are considered decision aid digital instrument development results for arctic maritime logistics during polar night under climate change and COVID-19 pandemic within Industry 4.0 era. In research, there are used risk management, situational analysis, web technologies and building database methods in distributed networks. As the research result, it is proposed the using of geodata from the active remote sensing and supercomputer modelling to increase the efficiency and reliability of arctic maritime logistics during polar night within the global environmental economics. As the decision aid digital instrument, it is proposed to use modular decision aid system, which integrate the heterogeneous hardware and the software resources in distributed networks. As the research results, there are demonstrated examples for arctic maritime logistics in central and eastern Russian Arctic during polar night. Presented in this paper study results have scientific novelty and can be used by the different players, including energy export sector, insurance business and institutional investors.

Keywords: Maritime logistics · Arctic · Polar night · Digitalization · Decision aid · Climate change

1 Introduction

Currently, arctic maritime logistics (AML) is year round activity within global environmental economics and part of year it is going during polar night (PN). Now, there is a need to digitalize AML during PN under climate change (CC) and COVID-19 pandemic in accordance with the concept of Industry 4.0. Last time, a lot of organizations plan and implement whole range of information technologies [1–5] that leads to information technological changes in their activity [6, 7], including decision support [8–10], natural risks management (NRM) [11–14], and learning [15].

I. Ilin et al. (Eds.): ICDT 2021, LNDECT 157, pp. 163–170, 2023.
https://doi.org/10.1007/978-3-031-24434-6_16

This research purpose is to develop decision aid digital instrument (DADI) for AML during PN under CC and COVID-19 pandemic within Industry 4.0 concept. In paper, we present the DADI development results for AML during PN within geo-information management (GIM) paradigm [16–21], in large environmental projects ([22–25] within environmental economics [26, 27]. We give attention to aspects of climate change [5, 11] and COVID-19 pandemic [2, 14], including the issues of information collection and processing with big data [28–30].

2 Materials and Methods

In research, we used risk management, situational analysis, web-technologies and building database methods. Also, we used Internet of things, machine learning and big data technologies [3, 28–30] for remote sensing and supercomputer modelling geodata processing. For study, we used geodata from different geoinformation digital online platforms (GIDOPs) with open access.

3 Results

We conducted situational analysis and, as its result, we believe that AML during PN is the high-risk and tough business, especially in severe icy area of central and eastern Russian Arctic with very low temperature and strong winds. Sometimes and maybe too often, such activity is going with very slight rescue support and without insurance. As a significant result of research we developed DADI for AML during PN under CC and COVID-19 pandemic in the form of the modular decision aid system (MDAS). As modules within MDAS for AML during PN we proposed to use different geoinformation digital online platforms (GIDOPs) with open access.

The developed MDAS for AML during PN allows to track ships in icy arctic waters and dangerous weather risk factors, as well as to implement business investigation functions in the event of major incidents and disasters related to natural risk factors, including ice risks. Within MDAS for AML during PN, we use as the active remote sensing geodata from Sentinel-1 satellite with synthesized aperture radar (SAR) and supercomputer modelling data.

Let's go to research result, to illustrate the work of developed MDAS for AML during PN in the icy waters of the central and eastern Russian Arctic.

For AML during PN, it is very important to know different weather fields, including their mutual viewing. In Fig. 1, we present wind and air temperature fields for Russian Arctic modelled with supercomputers and visualized with GIDOP Earth on November 16, 2021, when PN of 2021 began in this area.

When PN begin, the ice covers huge area, as a rule. In Fig. 2, we show wind and ice fields for Russian Arctic modelled with supercomputers and visualized with GIDOP Earth on November 16, 2021.

In Fig. 3, we show the screen with the transit and cabotage ships within the central and eastern Russian Arctic, including ships in Ob Gulf and Yenisei river, visualized with GIDOP Marine Traffic on November 16, 2021.

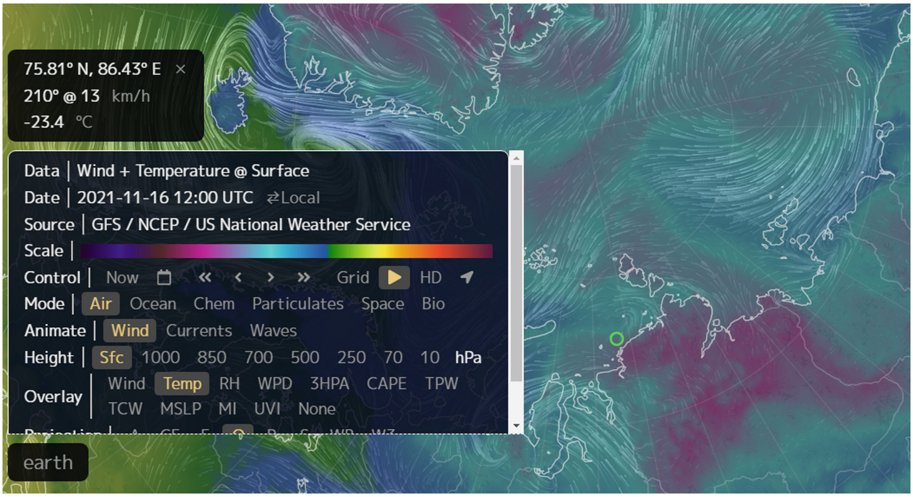

Fig. 1. Modelled with supercomputers wind and air temperature fields for Russian Arctic visualized with GIDOP Earth on November 16, 2021.

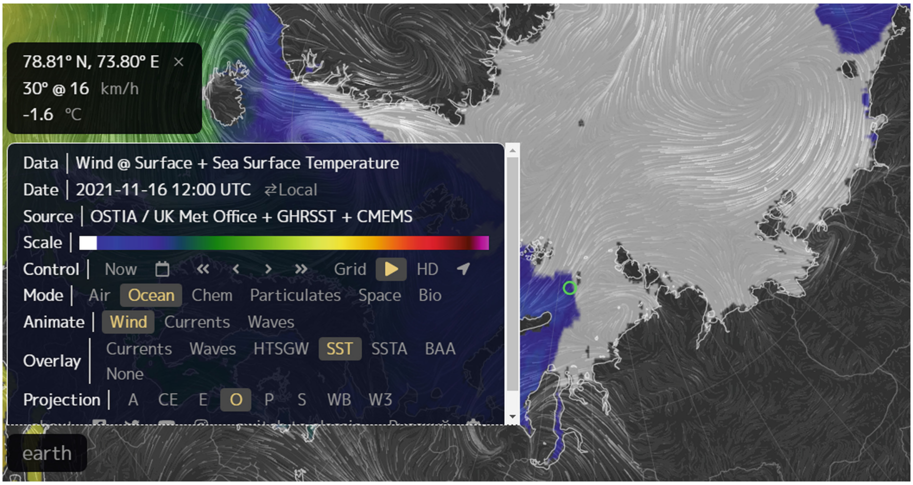

Fig. 2. Modelled with supercomputers wind and ice fields for Russian Arctic visualized with GIDOP Earth on November 16, 2021.

From comparison of Figs. 1, 2 and 3, it is obvious, that a lot of different unmoving ships are in icy trap in central and eastern Russian Arctic. It is very dangerous situation and the ships badly need rescue with icebreaker support. But in Fig. 3, there is no icebreaker and ships will have to wait it in severe weather conditions only to begin rescue operation of great scale. In Fig. 4, we present Sentinel-1 space image of ice field with spot signatures from trapped ships the ice channels in central Russian Arctic on December 13, 2021, scale 3 km.

Fig. 3. Screen with the transit and cabotage ships within the central and eastern Russian Arctic, visualized with GIDOP Marine Traffic on November 16, 2021, 14:12 UTC.

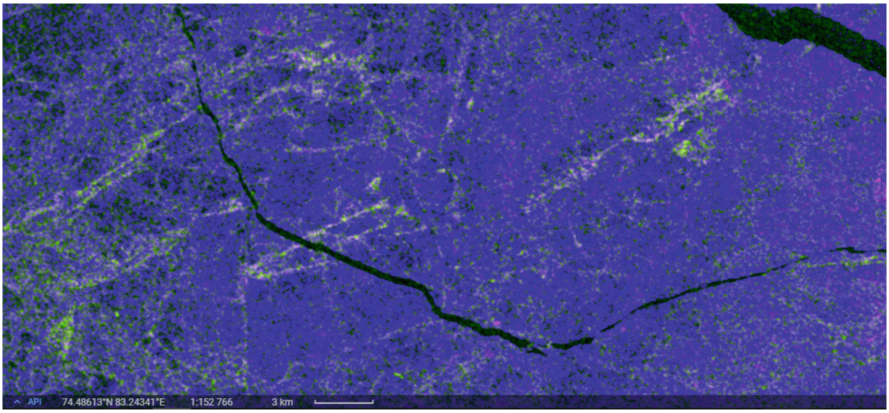

Fig. 4. Sentinel-1 radar space image of ice field with spot signatures of ships inside the ice channels in the central Russian Arctic on December 13, 2021, visualized with GIDOP EOS (LV product), Ratio Application, scale 3 km.

In Fig. 5, we present radar space image of ice field with long main icebreaker channel in the central Russian Arctic on December 13, 2021, visualized with GIDOP EOS (LV product), Band Combination Application, scale 3 km. There are spot signatures from ships in the channel.

In Fig. 6, we present radar space image of ice channel generated by moving ice class ship at the moment of rendezvous with standing icebreaker in Russian Arctic. Distance between ships is about 400 m.

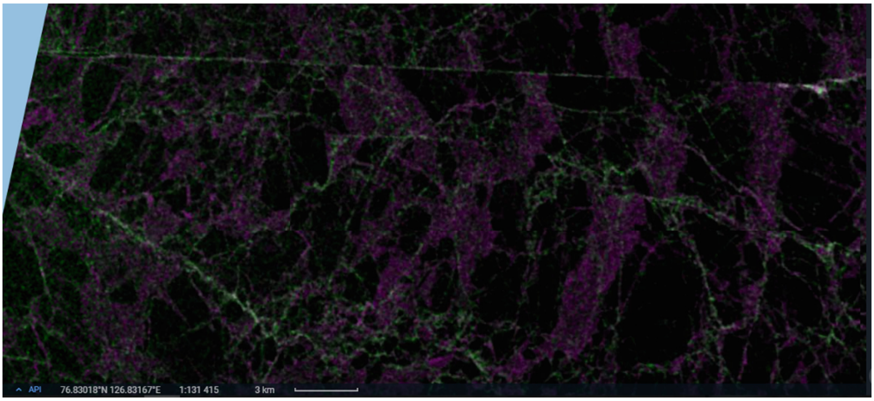

Fig. 5. Radar space image of ice field with long main icebreaker channel in the central Russian Arctic on December 13, 2021, visualized with GIDOP EOS (LV product), Band Combination Application, scale 3 km.

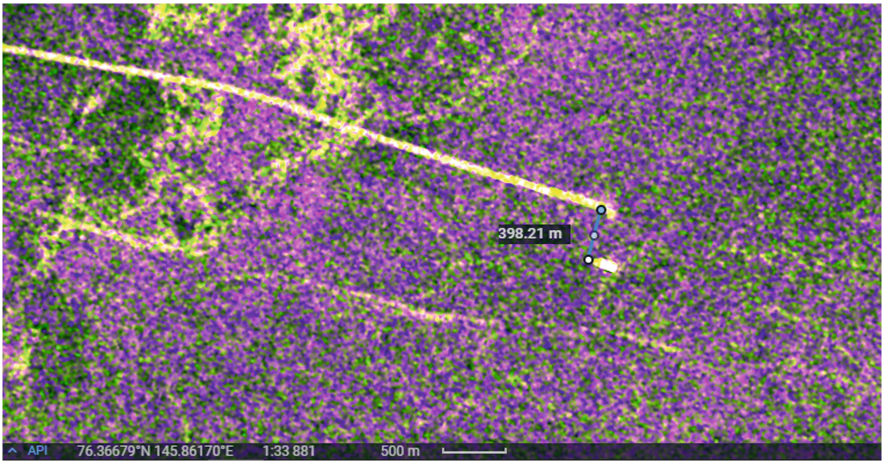

Fig. 6. Radar space image of moving ice class ship at moment of rendezvous with standing icebreaker in Russian Arctic on December 13, 2021, visualized with GIDOP EOS (LV product), Band Combination Application, scale 500 m.

Thus, we developed DADI within global environmental economics under COVID-19 pandemic and climate change in the form of MDAS for AML during PN with free access GIDOPs as modules. The developed DADI allows to track ships during PN in icy arctic waters and to map dangerous weather risk factors, as well as to support the different business investigation functions in the event of major incidents and disasters related to natural risk factors, including ice risks. Within developed DADI in the form of MDAS for AML during PN, we use widely as supercomputer modelling data and the active remote sensing geodata from Sentinel-1 satellite with synthesized aperture radar (SAR). One more time note, that full decoding of Figs. 1, 2, 3, 4, 5 and 6 and its discussion was not task of this article.

4 Discussion

Developed above-mentioned DADI in the form of MDAS for AML during PN can be used in educational and training purposes. With the help of proposed DADI, students get access to a very large volume of geo-data and learn to work with its for solving practical problems in various areas of AML during PN. Especially useful MDAS for AML during PN will be for Master's programs in global environmental economics.

5 Conclusion

In article, we considered development results of DADI in the form of MDAS for AML during PN within global environmental economics in Industry 4.0 period under conditions of climate change and COVID-19 pandemic. Within study, we used risk management, situational analysis, big data technologies, web-technologies and building database methods. We used as active remote sensing and supercomputer modelling geodata. We demonstrated some using examples of MDAS for AML during PN to the navigation in Russian central and eastern Arctic. Presented in article research results have significant scientific novelty and can be used by different players, including energy export sector, insurance business and institutional investors.

Acknowledgements. In research, we use platform https://www.researchgate.net/profile/Valery_Abramov2/ for preliminary discussion and data exchange.

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Using Digital Solutions in Railway Logistics: The Experience of Medium-Sized Businesses

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Abstract. At present, the state policy in the field of digital technologies confirms the concern about the digitalization of all sectors of production and industry, including the transport and logistics complex. At the same time, the creation of an ecosystem of the digital economy in Russia implies that digital data is a key factor of production in all spheres of socio-economic activity. In the article, in order to achieve the goal of increasing the efficiency of organizing the business process of transportation activities, the need to expand the possibilities of introducing automated systems that support the adoption of effective management decisions is substantiated. As an example the article demonstrates of the use of digital solutions, that have proved their effectiveness based on THE experience of medium-sized businesses, their advantages and disadvantages are indicated, the article provides analytical data from the logistics company Liter-Trans (including the results of cooperation with the German company German Transport Engineering, which is engaged in multimodal transport design throughout the world), and also substantiates the need to create and use not only IT systems that are adequate to the realities, but also the implementation of "end-to-end" IT technologies, based on the principle of complementarity and unity of infrastructure, ensuring the network interaction of business processes and the creation of value chains for all participants in the transportation process, which will improve the quality of logistics services and the efficiency of the environment for doing a business.

Keywords: Digital economy · Digital logistics · Business processes · IT technologies · IT tools · Rail logistics · Freight · Medium-sized businesses

1 Introduction

The Russian state policy in the field of digitalization is defined in the National Program "Digital Economy of the Russian Federation", the implementation management system of which was approved by Decree of the Government of the Russian Federation on 2019/03/02 №234 (as amended on 2020/08/21). One of the goals of this program is to create an ecosystem of digital economy of the state, involving the consideration of digital data as a key factor of production in all spheres of socio-economic activity [1]

I. Ilin et al. (Eds.): ICDT 2021, LNDECT 157, pp. 171–182, 2023.
https://doi.org/10.1007/978-3-031-24434-6_17

and, at the same time, effective interaction (including cross-border) between business, the scientific and educational community is ensured, state and citizens [2–4].

All branches of production and industry, including the transport and logistics complex, are puzzled by the issues of digitalization. For effective work in the freight market and building up the transit potential of Russia, the transport complex needs to constantly develop, to increase the speed, quality, and convenience of cargo transportation.

The previous reform of 2011–2012, which took place during the implementation of the "Structural Reform", caused significant changes in the transport services market: then the usual logistics chains that suited the shippers were cut off as a result of the transfer of the fleet to private operators. It was during this period that the transition of logistics to new conditions for the implementation of business processes began. Now the transport market participants experience instability approximately every 3 years, being in a pendulum regime between the "surplus" and "deficit" of the fleet, with a very short period of the equilibrium price. The state of market volatility for the period from January 2008 to October 2021 can be assessed by the dynamics of the indexation of tariffs for Russian Railways [5] (a subject of natural monopoly in the field of freight rail transportation in Russia) and rates of operators (rent of gondola cars [6]) (Fig. 1).

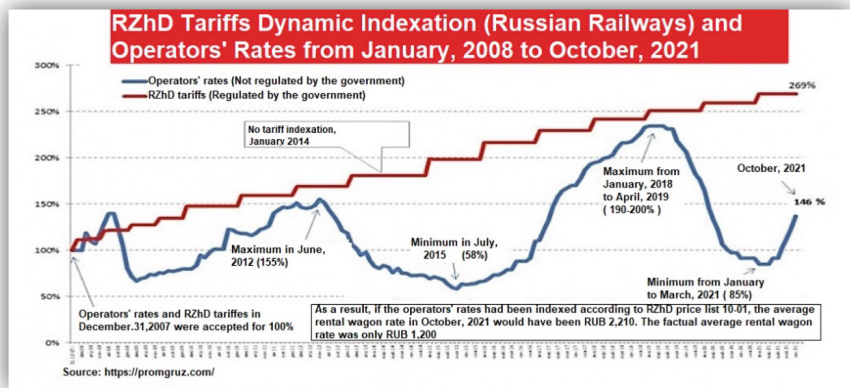

Fig. 1. Dynamics of indexation of Russian Railways tariffs and rates of operators (gondola car rental) from January 2008 to October 2021

It should be noted that the rates of operators in 2021 grew in the II quarter, in the III quarter the growth also continued (and even in those market segments where the high season was over [7]). The overall increase was about 30% compared to Q2 2021, while rates on the spot market exceed the rates for long-term contracts. During 2020 and 2021 Covid-19 has made its own changes in the management of a logistics business [8].

The main initiative for the development of transport and logistics services is the creation of an automated resource for maintaining a single catalog of services in the field of freight transportation, which provides consumers with access to the entire range of services, conditions, and parameters of cargo transportation.

The most popular technologies are the Internet of goods, big data, intelligent systems, blockchain, wireless communication technologies, virtual and augmented reality technologies.

The purpose of the article is to summarize the experience of medium-sized companies in terms of IT solutions that have proven their effectiveness in the practice of railway transportation during 2021, identify problems of their use and distribution, formulate proposals to improve their user capabilities, and justify the need to create and use adequate realities, not only IT systems, but also implementation of "end-to-end" IT technologies based on the principle of complementarity and unity of transport, logistics, production, and trade infrastructure, which ensures the network interaction of business processes and the creation of value chains for all participants in the cargo transportation process that can improve the quality of logistics services, the efficiency of the business environment.

2 Materials and Methods

The research methodology is based on the use of methods of system analysis, the substantiation of theoretical provisions was carried out on the basis of reasoned conclusions collected and generalized by the authors during the study using general scientific, general economic, economic-statistical and empirical methods. Theoretical and methodological basis consisted of modern achievements of domestic and foreign scientists and logistics practitioners in the use of digital solutions in railway logistics. The information and empirical base were made up of data from special scientific and periodical literature, information from the regulatory framework of Russian Railways, analytical reports of the logistics company Liter-Trans, a German company engaged in multimodal transport design around the world, German Transport Engineering, as well as open sources the Internet [9, 10].

3 Results

In the current technological revolution, all industries, including railway logistics, are moving to Industry 4.0, where data and analytics in digital form are central components and factors of production in all spheres of socio-economic activity, which increases the competitiveness of countries. Intelligent transportation [11], considered as an innovative product of digital logistics, contributing to the creation of innovative integrated transportation services.

The consumers of digital logistics products in the field of railway freight transportation are, first and foremost, small and medium-sized companies, which currently experience an acute need for information and analytical systems and technologies when managing business processes in conditions of incomplete and inconsistent information available to entrepreneurs.

The work within the target program of the Ministry of Transport of the Russian Federation "Development of small and medium enterprises in the sphere of transport" only partially solves the problems that need to be solved by business and which can be eliminated in the implementation of industry projects of this program, namely: "digital transport" and "digital logistics" [12–16]. To achieve the goals of effective management of business processes in Russia and the formation of an appropriate business environment, it is necessary to develop and use IT systems that will not only be adequate to current conditions, but at the same time combine end-to-end IT technologies based on a unified transport, logistics and trade infrastructure, which will be able to ensure the integration of business processes and create consumer value.

One of the elements of the digital transformation strategy in railway transport is digital platforms for managing the transportation process. In the process of developing and implementing digital platforms, the rules of interaction are being revised and business processes are being optimized between departments. In order to implement the state program in 2019, the board of directors of Russian Railways approved the Strategy for the digital transformation of the company until 2025, which influenced the level of digitalization of all railway supply chains when interacting with other participants in the transport market.

Interaction in forecasting and planning cargo transportation is divided into several stages in the formation of cargo transportation volumes - for a year, a quarter and a month. Formation of the forecast parameters of loading the railway administrations of the CIS countries for transportation to Russia and in transit through Russia is carried out on the basis of the analysis of statistical data on the transportation of goods.

Various structural divisions are involved in the planning of freight traffic. For operational end-to-end production planning of freight traffic on railway transport and for other purposes, it is advisable to launch an electronic document management system (EDM). However, when implementing, for example, in the Russian logistics company Liter-Trans, it was difficult to convince counterparties to use EDI instead of the usual paper media, but the pandemic accelerated the transition to the digital era.

In 2021, the number of clients and partners who switched to EDM increased by 82% (Fig. 2), which made it possible to reduce printing costs, reduce the time for processing documents, increase the speed of refunds, and free employees from routine.

In addition to the digital corporate culture, there are a number of areas in the transport industry that are subject to priority digital transformation:

- development of transport and logistics systems in a single transport space based on customer orientation;
- development and implementation of dynamic transportation process control systems based on artificial intelligence;
- formation of clear requirements for the creation and operation of innovative railway rolling stock;
- introduction of innovations ensuring the automation and mechanization of station processes;
- development, approbation, debugging and use of innovation for railway logistics infrastructure, including for the development of high-speed and high-speed traffic and organization of heavy freight traffic;
- development of the railway transportation safety management system and risk management methods in logistics;
- introduction of advanced technologies to improve the energy efficiency of production operations, as well as technologies in the field of environmental protection;
- development of an appropriate quality management system.

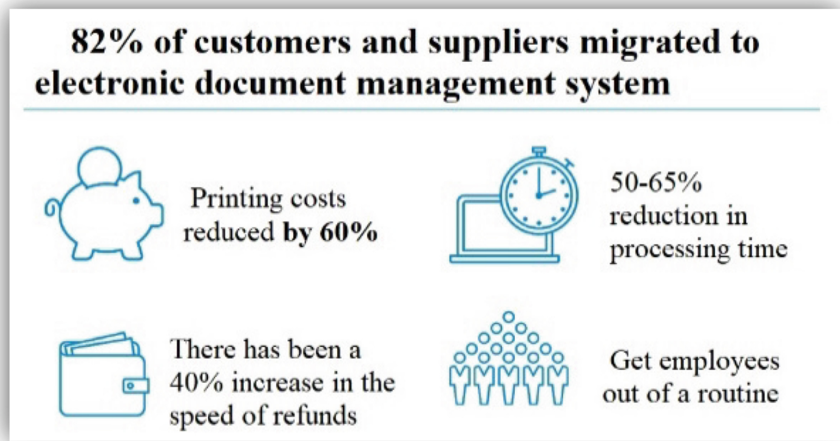

Fig. 2. Results of implementation (where or where to?) EDF in 2021

To achieve the goal of increasing the efficiency of organizing the business process of transportation activities, this article substantiates the need for a transition to automated systems that are capable of supporting the adoption of effective management decisions for the possibility of competent management of production processes in real-time, modeling and forecasting the development of specific situations in the transport and logistics market services.

The process of digitalization of Russian transport is impossible without optimizing business processes, revising the regulatory framework, and taking into account the intermediate results of the implementation of the national program “Digital Economy of the Russian Federation”. Despite the presence of the target program of the Ministry of Transport of the Russian Federation “Development of small and medium-sized businesses in the field of transport”, there are a number of issues that need to be solved by business and which can be resolved, among other things, by means of the implementation of relevant industry projects on digital transport and digital logistics.

In this regard, the transformation entails the introduction of changes in the existing production processes and mechanisms of cross-functional interaction between departments, the creation of a project office for the implementation of the digital transformation strategy, the organization of interaction with the scientific industry complex to participate in the creation of digital platforms and the implementation of scientific expertise at all stages of product development.

This article summarizes the experience of medium-sized companies in terms of IT solutions that have proven their effectiveness in the practice of railway transportation during 2021, identify problems of their use and distribution, formulate proposals to improve their user capabilities, and justify the need to create and use adequate realities, not only IT systems, but also implementation of “end-to-end” IT technologies based on the principle of complementarity and unity of transport, logistics, production, and trade infrastructure, which ensures the network interaction of business processes and the creation of value chains for all participants in the cargo transportation process that can improve the quality of logistics services, the efficiency of the business environment. It is worth noting that logistics companies have to use and analyze large volumes of Excel files, manually summarizing information from different sources in order to assess the fulfillment of the set shipping plan. So, there are tasks of reducing the time for generating reports, simplifying the process of transferring information between participants in the business process, and visualizing data for clarity when making management decisions. For this, reliable and scalable solutions were developed in the form of reports in MS Power BI depicting business processes, creating graphs, and customizing dashboards, which allow you to speed up iteration and implementation of solutions (Fig. 3).

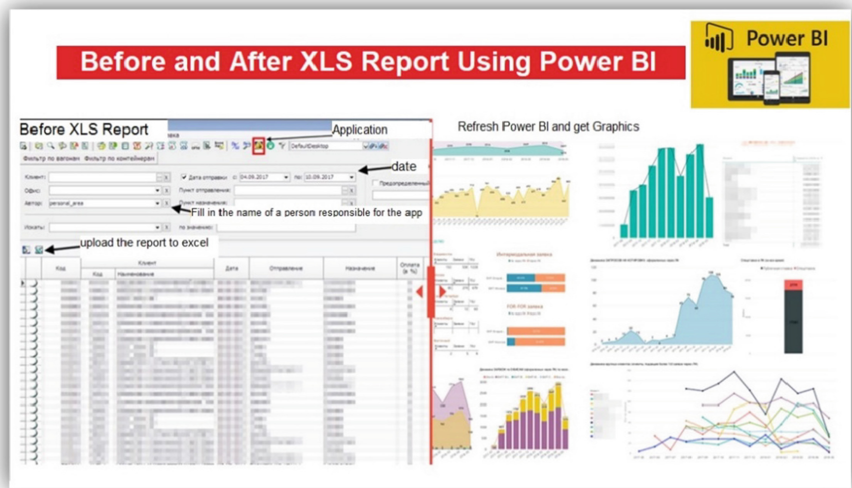

Fig. 3. Visual display of the result of using Power BI

So, data automation provides visualization of a number of parameters of shipment and the entire transportation of goods when making management decisions. Auxiliary filters display data on the required specific parameters (Fig. 4).

It is important to note that Power BI is a self-service BI and resident computing BI class. This Microsoft business intelligence software is comprehensive and integrates several software products that share a common technological and visual design, connectors, and web services.

Evaluating a number of digital solutions used in railway logistics based on the experience of Russian and German medium-sized businesses, it can be concluded that the programs and the tasks performed in them are fragmented, which complicates not only the process itself but also complicates the adaptation of new employees, reduces work efficiency by several times. To achieve the goal of increasing the efficiency of organizing the business process of transportation activities, it is necessary to switch to automated

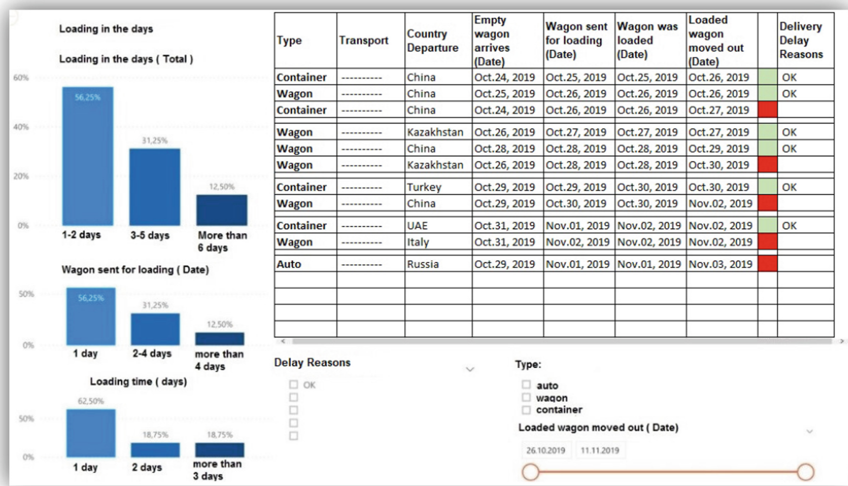

Fig. 4. Visualization of loading waiting parameters based on Power BI

systems that are capable of comprehensively supporting the adoption of effective management decisions for the possibility of competent management of production processes in real-time, modeling and forecasting the development of situations.

Since 2011, Liter-Trans has been a user of AS ETRAN (electronic bill of lading [17]) - an automated system for preparing and processing shipping documents for railroad transportation of Russian Railways across the territory of the Russian Federation. In 90% of the traffic volume, Liter-Trans LLC acts as a cargo owner, while not being a participant in the transportation process for Russian Railways JSC (the scheme of interaction between the participants in the transportation process is shown in Fig. 5).

Because of this, a company representing a medium-sized business cannot promptly receive information about the delay of a carriage at "loading/unloading" stations, although operators impose fines for the idle time of a carriage at stations for just such a company.

In 100% of cases, after the completion of the shipment (information about fines may come in the range from 1 to 6 months). For the client, this is a direct loss, since the transportation cycle has already been completed by that time. The most difficult thing is to collect the evidence base and supporting documents if the downtime was not the fault of the client himself. This process is very difficult and has a negative impact on customer relationships.

In this regard, it is expedient to implement, through AS ETRAN, the possibility for the cargo owner to receive operational information about the reasons for the downtime with supporting documents.

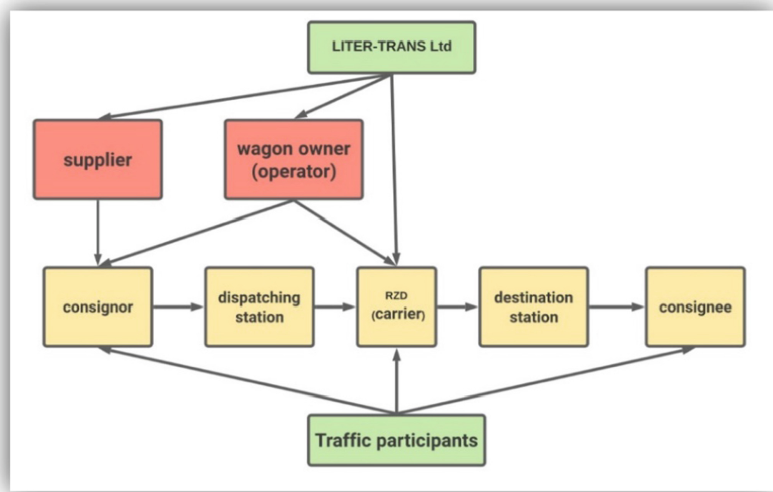

Fig. 5. Scheme of the interaction of participants in the transportation process (for example, LLC "Liter-Trans").

The lack of developed software for solving at least half of business processes in one space remains a significant gap for medium-sized businesses. This, of course, requires integrated industry standards and a willingness to exchange information (on balances in warehouses, applications for planned transportation, start getting access to supporting documents, etc.).

It is also worth noting the difficulty in the availability of a number of information solutions for medium-sized companies, such as an ERP system, VR, and Big data. However, the digital transformation of the transport industry is a dramatic increase in operational efficiency thanks to the use, in addition to traditional tools, of digital technologies and the integration of data from various lines of business. To maintain competitiveness, increase customer focus, and economic growth, the transport industry must be evenly transformed in all areas of activity.

Another project for the digitalization of railway transport is the creation of a digital freight transport platform. From our point of view, digital logistics should be based on comprehensive IT support of coordinated systems of production, trade and economic processes for the movement of goods, material flows in "value chains". Applied objectives in business processes of digital logistics: reducing time, labor and financial losses associated with data retrieval; using advanced information technology to form optimal interaction schemes (based on effective modeling of horizontal production, economic and trade relations) between the participants of the cargo transportation process, as well as production and economic relations between partner companies.

In order to prevent and minimize potential losses, as well as improve service for customers, the STZh-Complex AS was introduced, the software of which allows:

– increase customer awareness of the location of the car, (online);
– automatically notify customers about the emerging excess idle time of the car;
– take into account and calculate the final cost of the goods with delivery.

Calculation of the preliminary cost of delivery of cargo for the client can be made in such systems as: “ERAN”, “Rail-Tariff” and “Success”. Today the Rail-tariff program is the most convenient, but it should be noted that working with a large number of different software is very laborious.

Open-source data indicate that 2021 is breaking the record for a local fleet deficit. The company “Liter-Trans” operates both its own fleet of gondola cars and additionally rented. Starting from February to October 2021, through tenders, it was possible to successfully use the capabilities of the Digital Platform of the ETP GP. Federal Freight Company JSC has allocated more than 70,000 gondola cars to support small and medium-sized businesses, of which the company has shipped 2,200 gondola cars in deficient directions.

In the present conditions, it seems necessary to create and use not only adequate realities of IT-systems, but also implementation of “end-to-end” IT-technologies based on the principle of complementarity (additionality) of a single infrastructure that provides networking of related business processes and the creation of value chains for all participants in the transportation process, which will improve the quality of logistics services and the efficiency of the environment for doing such a business.

The creation of a mechanism based on the digital transformation of railway logistics will contribute to improving the efficiency of transport and logistics systems and complexes. This will simultaneously provide a platform for cooperation and coordinated development of Euro-Asian transport links (corridors).

Thus, the formation of chains (SCM - digital SCM using the Internet of Things technology) will ensure the optimization of information flows between all participants in railway supply chains, which will allow:

– reduce delays, downtime and, as a consequence, related costs;
– increase customer loyalty;
– increase profitability (due to improved quality of service, shorter transportation times, etc.).

The name of the process is also changing, Supply Chain 2.0 is replacing the Supply Chain, as well as the optimization criterion [18]. The benchmark for a minimum of costs and expenses is replaced by a maximum of economic effect and benefit. The basis for operational and strategic decisions is a model of complementary knowledge (competencies). Given these requirements, we can say that the total cost of an integrated management system built on the principles of digital logistics along the entire value chain will be minimal. At the same time, the total return on investment in its development will increase more than the sum of the effects of similar investments in the development of each of the individual subsystems. From our point of view, the use of advanced digital innovations in railway logistics can be considered a vector for the development of transport and logistics systems and complexes. This determines the relevance of defining the competence of personnel in the field of digital logistics.

4 Discussion

Following a digital transformation strategy [19], assets, services, and a management model for the transport industry are subject to digitalization. Thus, digital transformation implies not only a technological [20] but also, mainly, a managerial task. The key processes for such a transition involve:

- updating the regulatory framework, developing industry standards, and integrating with the National program for the digital economy in Russia;
- attraction and implementation of innovative technologies in logistics;
- automation of processes and their transformation in the creation of digital services (development of new technological processes and expanding the possibilities for the implementation of automated systems that support the adoption of effective management decisions);
- creation of a new corporate culture and development of human resources.

5 Conclusion

To implement the proposed mechanism, from our point of view, you need:

- development of a methodology for identifying points of "value" for the formation of harmonized value chains and transparency of logistics business processes aimed at achieving a common result;
- creation of a new architecture of business systems with seamless integration, the introduction of "end-to-end" IT technologies that ensure the network interaction of business processes and the creation of cross-industry cooperation;
- unification and standardization of advanced digital technologies, architectures and business models to solve problems of the transport and logistics complex and supply chain management in general;
- improvement of IT solutions used by transport and logistics SMEs, and cross-sector dissemination of international business best practices used in this area;
- revision of the rules of interaction and optimization of business processes between divisions within transport and logistics companies;
- determination of the operator of the unified digital logistics platform in cooperation with the scientific industry complex;
- training of professional personnel to work in the field of digital logistics, who will have a set of key competencies for creating effective information flows in the digital economy and developing analytical applications to optimize business processes at various levels of economic management.

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Implementing Multi-agent System for Dispatch and Control of Emergency Medical Care Ambulances to Enhance Emergency Response Effectiveness and Quality in Saint-Petersburg

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Abstract. In this paper, the authors propose an implementation of Multi-Agent System to support and enhance service quality and effectiveness of dispatch and control of Emergency Medical Care ambulances and reception. This work explains how such multi-agent system can function by monitoring, operating and cooperating with traffic control solutions in case of Saint-Petersburg, Russia. The description of MAS is given, as well as the main factors enabling its development in healthcare. Despite the fact that the state of the healthcare system in Russia does not allow talking about the imminent introduction of an autonomous system of this kind, it is necessary to consider increasing the efficiency of the ambulance team in the case of using innovative technologies, and provide a theoretical basis for future enhancements. The article also discusses aspects of ensuring the safety of personal and medical data of patients in the process of providing them with medical care and in the processes of information exchange between various agents of the proposed system.

Keywords: Medical care · Traffic · Transport · Autonomous vehicles · Healthcare

1 Introduction

Currently, the impact of digitalization and end-to-end technologies on all spheres of human activity is indisputable. Developments in such areas as artificial intelligence, machine learning, blockchain and the Internet of Things are used to automate processes in production, in logistics processes, learning processes and even the process of treatment [1]. With the use of end-to-end technologies, companies gain significant advantages and the ability to provide more personalized services quickly, efficiently and with reduced costs.

In this study, the authors consider the use of a multi-agent traffic control system in the provision of emergency medical care to a patient. The healthcare sector is one of the

I. Ilin et al. (Eds.): ICDT 2021, LNDECT 157, pp. 183–197, 2023.
https://doi.org/10.1007/978-3-031-24434-6_18

most socially important for both states and citizens, therefore, special attention is paid to improving the quality of services in medical organizations [2]. In the process of providing medical care, time indicators play an important role: the time of arrival to the patient, the time of making a decision to assign the patient to a certain medical organization, the waiting time for admission and surgical intervention and/or the provision of medical care.

A feature of the work of an ambulance emergency medical care is the fact that about 30% of calls to the dispatcher are false for various reasons from malicious deception to the caller's ignorance about the process of receiving medical services. Another feature is the need for a quick decision on assigning a call to a particular ambulance crew, rejecting a call and assigning an emergency code [3]. Depending on the decision taken, a basic life support (BLS) unit or an advanced life support (ALS) unit can be assigned to the call.

Taking this into account, the authors propose the following research questions to be studied in this paper:

1. How the multi-agent traffic control system will work in the provision of emergency medical care?
2. How to approach the design of Multi-Agent System (MAS) related to the implementation in emergency medical care (EMC) dispatch and control?
3. How to prevent possibility of having our system negatively affect healthcare quality?

In broad terms, we address the possibility of implementation of MAS in EMC, assess the degree of autonomy and cooperativeness of the agents in the system, and study the safety and security issues.

2 Materials and Methods

For our research, of particular interest is the degree of study of the problem of using traffic regulation to increase the efficiency of emergency medical care. We selected literature sources written not earlier than 2015 and devoted to the problems of using multi-agent systems in the healthcare sector, and studied their main ideas. All the sources studied during the study describe the possibilities of using a multi-agent approach to the provision of emergency medical services in different situations and countries.

The possibilities of using the MAS in cases of emergency events to help the victims were studied in detail by the authors in [4]. The article examines the use of various algorithms in a smart city for the fastest possible finding of victims in Iran: in the event of an incident, the agent of the coordination center receives information about the geo-position, the approximate number of victims and the severity of their injuries. Information is transmitted from the coordination center to the agents of the ambulance station and the fire station, who accept the call and respond to it as soon as possible. The ambulance crew, in the process of transporting the wounded, exchanges information with hospitals located in the area of the incident to resolve the issue of the placement and provision of surgical care.

The authors of the study [5] consider a multi-agent approach to prehospital emergency management and offer a more comprehensive set of agents: Emergency Medical

Services Center agent, ambulance agent, traffic light agents, Consulting Center agent, Service Quality Monitoring agent, healthcare agent provider and agent of National Medical Record System (EMR). The main conclusion of the work is that the use of MAS in managing the placement of ambulance patients is an effective solution due to such characteristics of MAS as autonomy, flexibility and collaboration in the decision-making process.

In the source [6], the authors consider the use of mobile agents to operate a smart ambulance. The activities of ambulance personnel undergo changes both in the process of going to the receiving medical institution and upon arrival, for example:

– according to the patient's personal data, the crew understands to which medical institution he is attached on a territorial basis, and gets access to the patient's medical record;
– assesses the condition during transportation based on the data of the anamnesis;
– the receiving organization prepares the necessary equipment and personnel to meet the patient.

Such changes are possible in the case of using data management services in a multi-agent system, where the medical institution in which the patient is examined provides information about the ambulance patient and the receiving medical organization. This interaction manifests itself following the concept of cooperativity/autonomy.

The study of the above literary sources led us to the idea that the interaction of agents in the process of providing emergency medical care can be adapted to the Self-Organizing Logistics framework [7]. The main idea of SOL framework is the introduction of the degree of autonomy and the degree of cooperativeness, which effect on the systems' development.

3 Results

3.1 Description of the Multi-agent Systems

The concept of Multi-Agent System has been around for a while, however, in recent times the research and utilization of complex Multi-Agent Systems has been revitalized and reapproached – now it can be properly and effectively realized with help of modern computing, data enrichment and machine learning. In essence, MAS is a system of autonomous agents that can function and cooperate within one dynamic environment and can have their own objectives [8]. Agents are flexible, have the ability to affect and help each other, and must continuously pursue their goals in ever changing, chaotic circumstances. To reach their objectives, they have the ability to perceive the environment, deliberate the input signals from the environment (perceive, process, make decision) and then perform actions that may affect the environment [9].

To ensure the effectiveness of the service, we propose that MAS is designed with following traits in mind:

– Decentralization: There is no designated controlling agent, instead, the agents coordinate with each other through observing each other, communicating and following system policies.

– Autonomy: Agents must be in some way functionally independent and autonomous. They don't necessarily have the same objective and they don't necessary can make the same decisions, however, they are able to reach heterogeneous goals together by coordination, reaching consensus and redistributing resources.
– Locality: Agent has a local view of the environment and is able to make decisions based on local factors and knowledge/data available to it. System can allow agents request to access information to improve decision making.
– Multi-Agent learning: Agents must improve themselves through interacting with environment and other agents, and by cooperation. They should be able to learn by observing and seeing patterns in environment and actions of the other agents.
– Multi-Agent problem solving: Complex MAS must try to optimize and learn to distribute tasks in a way to find effective solutions, even if it needs to decompose goals and redistribute them.

Developing a system with these traits will allow for high degree of autonomy and cooperation, and will result in high agent's ability to learn and improve by making use of machine learning.

3.2 Factors that Enable Development of MAS Supported EMC Services

In modern world our technology interfaces and sensors are intelligent and intertwined, and are rapidly developing every day, enveloping more aspects or our daily life. Miniature computers are able to handle complex calculations within milliseconds providing us with information and enriching our perception of the world. Interconnected devices support complex systems of decision making [10]. Healthcare and logistics are two spheres that can benefit greatly from recent technologic developments – advanced solutions may involve the implementation of advanced sensors, wireless technology, modern computing and use of machine learning and artificial intelligence. These developments enable the creation of intelligent multi-agent system that supports work of EMC personnel and allows to enhance decision making and automate a bulk of specific workflows of emergency dispatchers.

This system may be enhanced by additional integration of a wide selection of existing city-level systems, for example - traffic control, weather control, vehicle identification and CCTV monitoring systems. Information provided by these systems, and information shared by other cooperating agents will enhance decision making ability and routing capabilities of EMC MAS [11]. Additionally, integration of city-level traffic control system may be an opportunity to further improve response times by monitoring and redirecting city traffic in order to clear up lanes, intersections and busy routes with intention to give EMC vehicle a clear, unobstructed way towards the caller or hospital. The use of this kind of traffic control system integration will depend on urgency of the call, patient's status and history, and the type of response vehicle, with low priority calls leaving traffic unaffected, and urgent, life-or-death situations having the ability to drastically change how system handles the oncoming traffic.

In the proposed city case, Saint-Petersburg already has some of the modern traffic control technologies and systems implemented to support traffic routing and monitoring, in order to ease traffic load on the busy roads. The system in place has the ability to take control of most modern traffic lights and digital signs on highways, however, modern traffic lights are only placed on busy intersections of the main roads, and a big bulk of city's traffic lights are in state of modernization and have not been replaced yet, which can lead to problems in cases where EMC vehicle has to follow the route where it can't utilize the ability to cooperate with traffic control system and clear the way. Currently, the system in place has wide capabilities to monitor the traffic load on roads. It utilizes vehicle identification, CCTV integration and the use of geo-positional data via smartphones, GPS tools and locational tools integrated in modern vehicles. Fortunately, the city's road infrastructure is constantly getting updated and modernized, fitting to suit advanced traffic control system.

Another important system that should be considered to be integrated is any informational system used in healthcare and medical services. EMC agents should be able to access patient's records in order to achieve more precise decision making [12]. Access to medical history may allow agent to see any underlying conditions which may affect the objective's priority and urgency, which may lead agent to take another action, like re-routing to nearest hospital that has required equipment, or involving another agent that is occupied with actions of lower priority. Additionally, creation of efficient interfaces will allow EMC agents to provide data to hospital's receptions, giving healthcare workers ability to monitor the patient's status and location, therefore allowing them prepare and create conditions for safe and efficient reception.

Unfortunately, Russia's system of unified medical records is still in development and, for now, hospitals use their own local systems or workflows to handle medical records. Creation of system of unified medical records for state hospitals is an important task, and by establishing interfaces for such a system with EMC agents will drastically improve decision making abilities [13]. Another worthwhile notion would be integration of private, commercial healthcare providers, allowing agents to consider them as destination for hospitalization or allowing them to access any medical history of their clients. This will be a hard task, will require existing system of unified medical records and efficient cooperation of the state and private healthcare providers, but such integration should be considered.

To further illustrate the possibilities of interactions and integration with medical and transport systems we have provided a diagram that highlights the interactions between agents, their interfaces and foreign systems (see Fig. 1). Developing interactions via interfaces ensures that agents will be able to connect to various stand-alone medical systems, only access information available to them and will have no effect on the work of connected systems, unless they are allowed.

3.3 Description of the Multi-agent System Implementation in Emergency Medical Care Dispatch and Control

The main aim of the proposed multi-agent system is to enhance citywide ability to respond to medical calls and enhance dispatching and routing of Emergency Medical Care vehicles to hospitals and treatment centers. It implements the use of self-driving autonomous vehicle-agents, staffed with medical personnel and equipped with various sets of medical tools, depending on the type and specialization of the vehicle, which can vary from simple dispatch car mostly used for routine checkups, to ambulances

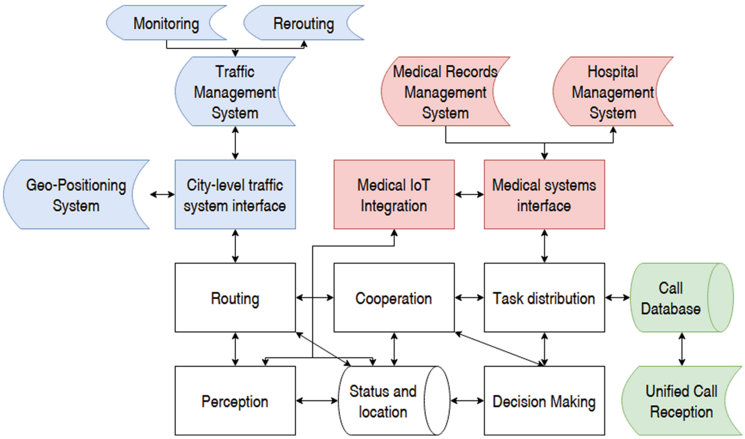

Fig. 1. Example of system interaction and interfacing in the work of autonomous agents.

equipped with oxygen providing equipment, to vehicles equipped with life support units used in urgent and dire situations. Vehicles will make use of modern computer vision-supporting sensors, which have the ability to notice, discern and identify various objects at high speeds and heavy traffic movement. If the city's traffic light system is equipped with special sensors that allow the reception of signals, sent by government vehicles to manipulate the traffic light or routing, agents should also be equipped with that type of signaler [14]. Additionally, it will benefit from integration of various kinds of medical IoT equipment, interfaces and sensors, which will be able to monitor the condition of the patient and inform destination hospital, vehicle staff on duty and reassess the condition and urgency of the patient, with the possibility of changing destination or route.

Agents should be connected to each other, and to external systems via wireless connection, using protocols and optimizations to ensure prevention of data loss [15]. Agent's connections to external systems, like citywide traffic-control systems, medical and hospital systems and databases, and dispatch call databases, should be provided by specialized interfaces that give agents abilities to interact and make requests related to their objectives: providing information about the patient, providing full description of the call, sequencing traffic route manipulation, and sending work orders to hospital to prepare patient receptions.

Our proposed workflow of Multi-Agent System of automated vehicles can be described this way:

- Call registration – The call is being received, registered, processed and added into call database, accessible by EMC agents.
- Call distribution – After the call has been registered and added into database, it is distributed to the most suitable agent based on location data and various other factors, e.g., condition and priority.
- Dispatch – EMC agent begins traveling to location of the call.
- Patient checkup – After arriving to location, medical staff examines the patient, writes initial diagnosis and decides the further course of action.

– Patient transfer – If medical staff decides that hospitalization is advised, or necessary, the agent begins moving towards destination hospital.
– Hospital reception – Agent brings the patient to suitable reception of the hospital that is informed about incoming patient beforehand, and is prepared to receive him.

Naturally, the first step of EMC workflow is call reception. The call reception can happen via many interfaces: emergency telephone call, online request, call to a hospital or a doctor, health-monitoring device notification and etc. When that happens – the call and all available information is processed and added into unified and standardized citywide database, accessible by agents and monitored by them in real time. When the call is registered and added to the database, it is distributed to one of the available agents nearby (see Fig. 2). After the task has been successfully assigned to one of the agents, he begins work by following fastest route to the call location, utilizing cooperation with other city-level systems, and, in certain urgent cases, taking advantage of traffic routing and traffic light signalers to clear the way to the call location.

After arriving at the call's location, medical staff will examine the patient and write initial diagnosis. Based on the condition of the patient, medical staff can decide to hospitalize them, or even decide that an urgent transfer to emergency ward is needed. When that happens, agent will drive the patient to the hospital that is most suited to accept the patient with given diagnosis and circumstances. Condition of the patient and the nature of the call can determine the route and actions taken by the agents. During the transfer, hospital is notified about agent's current location, estimated time of arrival, patient's condition and information about diagnosis, allowing the hospital's reception to prepare accordingly. After successful send-off, agent will enter stand-by mode and, depending on locational call frequency, work load and position of other agents, may decide to stay in standby near the hospital, move to another district with higher work load or travel to a location where call response times are higher – hospitals are far away, and there are no available agents standing there on stand-by. This will allow to decrease overall response times and cover more area of the city. The following figure provides visual presentation of areas with less than 20 min response times for medical vehicles. Similarly, agents will seek out areas with high response times and enter standby mode, awaiting new calls.

The description of possible MAS implementation in EMC lead us to the consideration of its positioning in the SOL framework. The SOL framework considers four levels of the degree of autonomy and four levels of the degree of cooperativeness. Using the perceptual mapping of the framework we consider the MAS system to be positioned at The Intelligent Collective quadrant, meaning the degree of autonomy of the system is medium-high, and the degree of cooperativeness is also medium-high. It needs to be stated that extreme forms of SOL are less likely, however, the medium degree of the autonomy of the system is introduced via the use of self-driving vehicles with the human being in it. This means that the vehicle is operating on its own, or autonomously, however in case of emergency it can be controlled and manipulated by the personnel in it. The degree of the cooperativeness of the system is medium-high, which is ensured by the possible cooperation of the ambulance vehicle and the traffic light system, and the use of sensors in the city environment and in the ambulance itself.

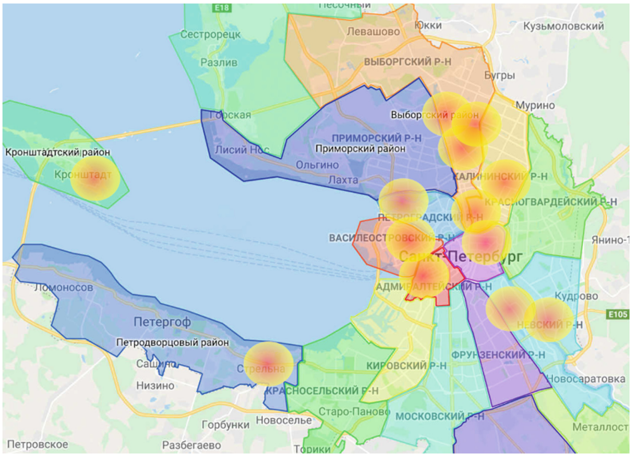

Fig. 2. Visual presentation of locations of areas with 20 min or less response times of EMC teams.

3.4 Patient and Call Prioritization

To distribute emergency calls to the dispatcher, we adapt the use an algorithmic approach using a decision tree. This approach has proven itself back in 1985 - using a decision-making algorithm for distributing ambulances to calls depending on the severity of the patient's condition, the dispatch center is seeking to accelerate the provision of medical care, increase the flow of patients and service more calls.

In addition, such criteria as [16–18]:

- the time until the end of the working hours of a specific crew;
- location relative to the patient's medical attachment area;
- the crew being busy with another call: depending on the severity of the call at work, the crew may be redirected to a more urgent call.

To use the call distribution and prioritization system, four emergency codes are proposed to be used:

- Not an emergency - in this case, the dispatcher recommends either staying at home and taking the necessary measures, or suggests getting to the hospital on patients' own.
- Code 1 - the lowest priority of the call, the dispatcher warns the caller that the waiting time can be long. These calls can be delayed up to 30 min. An ambulance crew is assigned only if there are no unserved calls with Code 2 or 3. An ambulance assigned to call code 1 can be reassigned to more urgent calls if necessary.
- Code 2 - the average priority of the call, a situation that does not pose a threat to the patient's life. The nearest ambulance crew is sent to the call, either ALS or BLS, the delay is allowed up to 5 min.

– Code 3 - an incident that threatens the patient's life. These calls must be responded to as quickly as possible. The closest available ALS crew is assigned to the call, the crew can be reassigned to these calls if they had an assignment for a call with code 1. If there is no ALS in free access, the closest BLS crew is assigned.

Given the development of end-to-end innovative technologies at the present time, or rather the widespread use of artificial intelligence and machine learning in healthcare, the authors propose to consider the use of machine learning for managing ambulance call dispatching. However, in cases where the use of machine learning is not possible due to funding constraints, IT infrastructure, highly skilled workforce unavailability or other factors, hospitals can successfully continue to use software of their own design or purchased from vendors to make decisions about the distribution of ambulance crews.

Machine learning technology can be successfully used to increase the efficiency of receiving an application for an ambulance call. The operator, following the instructions of machine learning algorithms, asks questions to find out the emergency code of the situation and the appointment of the ambulance crew. An example of an algorithm decision tree is shown in Fig. 3.

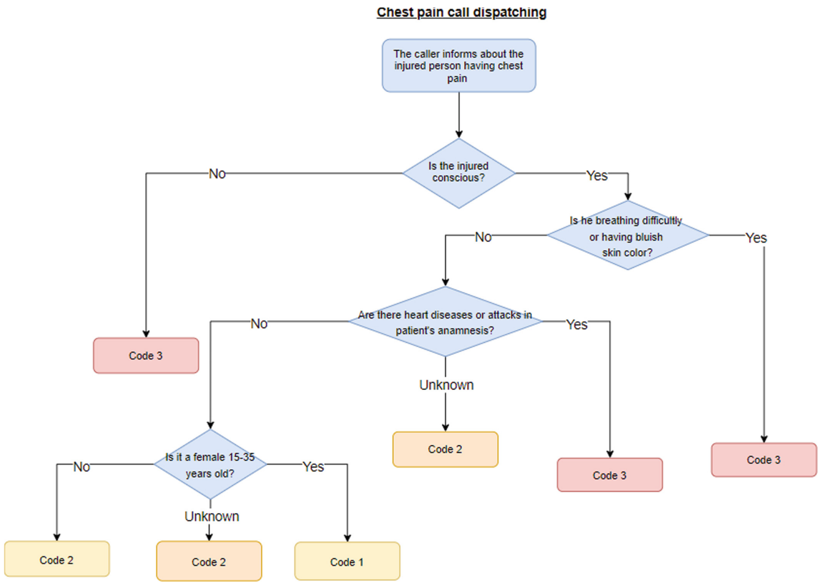

Fig. 3. An example of an algorithm for making decisions on the assignment of an emergency call code.

To obtain complete control over the condition and vital signs of a patient during transportation from the scene to a hospital in an ambulance, equipment with sensors can be used to implement the concept of the Internet of Things [19]. IoT sensors can perform the following functions:

– measurement of blood pressure and pulse;
– measuring the level of blood oxygen saturation;
– echocardiogram and ultrasound examinations;
– tracking other changes in the patient's vital signs.

Using the Internet of Medical Things in the process of transporting a patient to a medical institution would ensure the real-time observing of his vital signs, leading to the better cooperation of the systems' agents such as awaiting hospital, medical personnel in the ambulance and in the hospital, and agent of dispatching center.

3.5 Traffic-Control and Cooperation

The solution to organization of MAS's cooperation and control is best described as a decentralized, heterarchical system, consisting of standalone agents capable of deducing and making decisions on local, bottom level. The objective of organizing cooperation in MAS is ensuring that agents are able to autonomously determine their course of action, without negatively affecting performance as compared to centralized system, and not to forego the possibility of making the optimal decision, that can be achieved by group distribution of tasks and collaboration between agents [20]. Agents have the possibility to connect and communicate with each other, and, in addition, they have interfaces to connect to and access external systems and databases.

The process of cooperation and communication between agents is supported by implementation of a variation of asynchronous backtracking algorithm (ABT) [21] – an algorithm that supports autonomous and asynchronous, but cooperative work of the agents, allowing them to find the optimal solution to the situation at hand. The key feature of this approach is assignment of priorities to agents, directly affecting their decision making and temporary hierarchy. Each agent focuses on their local state, sharing their own information and decisions during ABT discussion [22].

To give an example of ABT discussion, we can review the basic task redistribution process. When a new call is added to a shared database, agents nearby are assigned priorities based on their distance to the call's location, with closes agents receiving highest priority. The number of agents, or distance for agent's search will depend on numerous factors, most relevant of which are overall work load and call type – increasing search distance may allow to involve available agents from far away if agents near location are not up to the task. To reach the conclusion, first, the agent with the highest priority shares his readiness or inability to undertake the task, sharing information about himself: vehicle type, medical staff on duty, estimated travel time, traffic load in the area, etc. Then, the agent with the highest priority asks the agents with lower priority if they agree with his decision. In case they don't agree with this decision, they share information about themselves and why are most fitting to this task (visualization of this process can be seen on Fig. 4). This repeats until agents reach an agreement – pool with agents and their priorities is ensured to have at least one who is ready to take on the task.

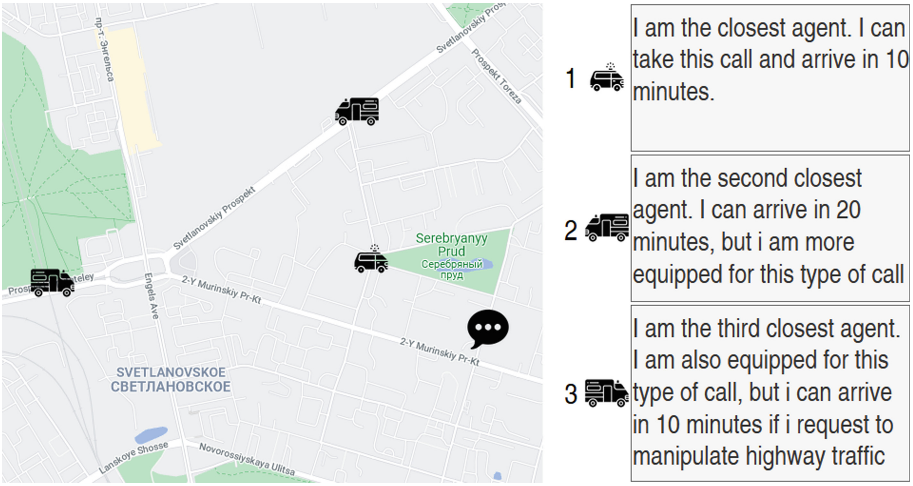

Fig. 4. Visualization of agent call distribution discussion process supported by asynchronous backtracking.

3.6 Ensuring Safety

Medical data is particularly sensitive, and its use brings with it many complexities associated with the need to protect data and resist data leakage. It is important to ensure the necessary level of protection of personal data at every stage of their processing, which turns out to be a difficult task in the process of collecting and recording information, organizing and storing it in a database, clarifying details and, finally, deleting information that has lost its relevance [23].

The healthcare sector in Russia leads the rating of data breaches: about two-thirds of medical institutions are faced with the loss of personal information of patients, but many try not to disclose this fact. The Ministry of Health of the Russian Federation recognizes and is fighting this problem at the legislative level, in particular by issuing Order No. 911н dated 24.12.2018 “On approval of the Requirements for state information systems in the health sector of the constituent entities of the Russian Federation, medical information systems of medical organizations and information systems of pharmaceutical organizations.” According to the order, the software and hardware of medical and pharmaceutical information systems must be located on the territory of the Russian Federation, be certified by the Federal Security Service of the Russian Federation, provide for regular data backup, log and store information about access to documents, ensure the placement of information in a unified state system in the field of healthcare etc. [24].

Medical institutions work with huge amounts of data every day, and, unfortunately, not all organizations have completed the transition to electronic document management and automated accounting. Partly electronic and paper-based recordkeeping carries a double administrative burden on doctors, nurses and receptionists.

Another important reason for data leakage is the negligence or carelessness of personnel when working with the system. In addition, medical institutions can often lose data due to insufficient interaction with developers [25]. Vendors can offer turnkey implementation of a medical information system without being responsible for data protection. As a result, the data can be minimally protected, or even be in the public domain, which is absolutely unacceptable in the case of personal and medical data.

After we have studied the above sources, we can conclude that the consequences of such leaks can be very serious for both the patient and the clinic and its employees - fines, reprimands, dismissals, a ban on continuing professional activities and imprisonment are possible punishments in the event of a medical data leakage.

To protect the personal data of patients, medical institutions need to build a security system. In general, we propose the project for building a personal data protection system consisting of several stages:

– Collection of data on existing information systems.
– Modeling security threats.
– Determination of security levels.
– Development of technical specifications.
– Designing a personal data protection system.
– Development of organizational and administrative documentation governing the processing and protection of personal data.
– Delivery of information security tools, their installation and configuration.
– Certification of personal data information systems for information security requirements (optional).

The first stage is the modeling of threats, which are considered in relation to the current medical information system. After that it is needed to determine the composition and content of organizational and technical measures that will ensure data security. They should work at all levels of the information system: MIS, workstations, data transmission channels, DBMS, virtual infrastructure. At the MIS level, built-in security mechanisms and various additional means of protection against unauthorized access can be used, for example, antivirus complexes, intrusion prevention systems, firewalls and data leakage prevention systems. A wide range of tools is also used at the level of workstations. For protection, certified operating systems are used, as well as antiviruses, intrusion prevention systems and firewalls. At the level of data transmission channels, in addition to the already mentioned tools, cryptographic gateways can be used. On the market, such products are presented both in the form of software and hardware complexes. Special security systems are used for the DBMS. As for the virtual infrastructure, trusted and secure hypervisors can provide security.

Errors can occur at any of these stages. For example, if an organization misidentifies threats, there is a risk of data leaks. And if the specialists of the medical institution consider that the information system requires a higher level of security than it actually needs, they will have to take excessive measures and install unnecessary means of protection. This can lead to a manifold increase in the cost of implementation and maintenance of the system.

Another aspect of security related to our system is currently not supported by regulations - autonomous ambulances must be able to completely reverse an automatic decision and go into manual mode. This mechanism should be thought out and tested as much as possible, but the basic ideas of the algorithm we consider to be as follows:

– only a senior member of the ambulance team can cancel the decisions of the car and transfer it to manual control;
– the system must implement protection against accidental cancellation, as well as login using the user's biometric data.

Security measures when using a stand-alone multi-agent system must be carefully designed and must be applied. Only a disciplined approach will allow you to avoid data leakage and effectively use the proposed system.

4 Discussion

The research was aimed at exploring the possibilities of using a multi-agent system to provide ambulance in emergency situations. For this, we propose a new model of interaction of end-to-end technologies: autonomous vehicles, sensors of the Internet of things, machine learning methods. In addition, an algorithm was proposed for the dispatch center to distribute calls between ambulances, as well as measures to ensure the safety of the proposed solution.

The authors conducted an analysis of past studies on the MAS in EMC, which showed the relevance of studying such a model due to the effectiveness of the autonomous system. In addition, the paper considers the position of the proposed model in the SOL framework, which allows us to assess the degree of autonomy and cooperativeness of our solution. The medium degree of autonomy and cooperativeness of the system means that most decisions are made by the system without the participation of an observer or a coordinator, but the system has a mechanism for cancellation and manual control if necessary.

Unfortunately, the current state of the development of information technologies in the healthcare sector in Russia does not favor the early implementation of autonomous solutions. Nevertheless, the preparation of a theoretical basis for studying the possibilities of using autonomous machines, computer vision and decision-making systems is important for the further development of technology.

5 Conclusion

The authors consider the concept of a multi-agent system, its characteristics and key principles of interaction; the factors influencing the possibility of using the multiagent approach in the provision of emergency medical services have been analyzed. Despite the fact that on the territory of the Russian Federation there are a large number of obstacles to the development of the studied approach, the development of digital technologies does not stand still: The Internet of Things, Machine Learning methods, Big Data analytics contribute to the digitalization of the medical industry.

The authors consider the process of operation of automatic vehicles - MAS agents, as well as the principles of dispatching and prioritizing incoming calls for the provision of ambulance services. In addition, the proposed model is analyzed with respect to the SOL framework, operating in terms of the degree of autonomy and cooperativity of the system participants. Medium-high degree of autonomy and cooperation means that the proposed system is located in the Intelligent Collective quadrant of the framework.

Finally, the authors consider the most important aspects of security when working with medical data, which is one of the most sensitive personal data of a patient.

A further area of research can be the construction of the IT and technological architecture of the proposed solution, as well as a more detailed consideration of the workflow processes of medical personnel and the dispatcher of the coordination center when distributing calls.

Acknowledgement. The research is partially funded by the Ministry of Science and Higher Education of the Russian Federation under the strategic academic leadership program 'Priority 2030' (Agreement 075-15-2021-1333 dated 30.09.2021).

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Modelling the Berths Throughput of Export Coal Terminal with Stochastic Methods

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Abstract. Transportation research is devoted to stochastic processes and throughput modeling for marine side of coal export terminals. The difference in calculated and operational throughput (in Russia is 2–3 times difference) is significant problem for investors and the price of port handling. Operating experience has been accumulated over the past decade, which can be the basis for more efficient simulation calculations. The operations structure, bulk vessels, port planning and design in the proposed stochastic model is detailed and based on the existing terminal in the Far East of Russia (Daltransugol) in the period up to 2018. The dataset is highly elaborate and includes operations of handling equipment, vessels, port services and downtime due to weather conditions. Assumptions about the initial data are based on probability distributions of the mathematical model. The average result (probability P50, median) is the throughput of 20.47 mln t/year, optimistic (P10) – 24.94 mln t/year, and pessimistic (P90) – 15.75 mln t/year. The range of the results is adequate, given that the actual cargo turnover of the existing terminal ranged from 17.0 mln t in 2015 to 20.1 mln t in 2018. The novelty of probabilistic operational statistics and efficiency issues, which in details are demonstrated in numerical experiment, could be the planning clarification for new upcoming projects and support for decision-making problems for existing coal terminals to maximize the throughput. Important finding, this could be done by searching of big non-operational losses (absence of coal in storage area, absence of fleet, change of conveyor routes, etc.).

Keywords: Throughput modelling · Export marine terminals and ports planning · Ports and terminals stochastic processes · Port performance · Marine terminals benchmarking

1 Introduction

The coal industry is an important element in the national economies of many countries. It is the basis of energy balance and industrialization of booming economies (China, India and Japan) and a source of cash-flow income for export-oriented countries (Indonesia, Australia, Russia and South Africa). Coal production, consumption and trade have remained stable even in the turbulent times of the COVID-19 pandemic and amid

I. Ilin et al. (Eds.): ICDT 2021, LNDECT 157, pp. 198–209, 2023.
https://doi.org/10.1007/978-3-031-24434-6_19

discussions about the future green energy world full of renewable sources for energy production.

Coal covers one-third of the global electricity generation (mainly the Chinese coal power) and plays a crucial role in industrial development. The transition to wind and solar generation will take a significant amount of time. In coal mining and power generation from coal, offsetting environmental measures are being introduced through carbon capture and storage (CCS) technologies [1]. This indicates that the global coal supply chain will remain an important part of international trade flows, supported mainly by maritime logistics.

China (309 Mt) and India (211 Mt) were the two largest coal importers in 2020, supported by export from Indonesia (405 Mt), Australia (390 Mt), Russia (212 Mt) and South Africa (63 Mt) [2]. The export of coal to Asia via Russia's existing export terminals in the Far East has been growing annually (2020 data: Vostochny 26.8 Mt, Daltransugol 26.5 Mt, Shakhtersk 10.7 Mt, etc.). Upcoming projects will double or even triple the regional cargo turnover in the near future (VaninoTransUgol, enlargement of Daltransugol, Zarubino, etc.) [3].

In today's Russia, after the breakup of the USSR, modern coal export terminals with conveyors were built only in the 2000s: the second stage of Vostochny Port (1996), Rosterminalugol in port Ust-Luga (2006), Daltransugol in port Vanino (2008), and Posyet (2014). These terminals were designed with an overestimated annual capacity reserve, which is associated with the limitations and remnants of Soviet norms in the Russian technological design standards for ports. Operating experience has been accumulated over the past decade, which can be the basis for more efficient simulation calculations. The actual operational throughput of each coal export terminal was twice-thrice as high as the values incorrectly calculated in the design documentation.

This study suggests a novel stochastic processes approach to determining the marine side throughput capacity of coal export terminals in Russia and potentially elsewhere. This approach includes operational research and data science of terminal equipment, vessels, weather conditions and port operations. Drawing on the example of a modern coal terminal in Russia's Far East this study introduces a stochastic method for calculating the throughput capacity of an export coal terminal to obtain a range of results: the most probable base case scenario (probability P50 – 50% probability, from the English "Probability"), optimistic (probability P10) and pessimistic (probability P90) values of cargo turnover.

According to the IEA [2] and the statistical review of world energy by BP [4], global coal production has been growing each year (see Fig. 1) with slight declines during the global financial crises in 2014 and the COVID-19 pandemic in 2020. Despite legitimate concerns about air pollution and greenhouse gas emissions, coal use is likely to continue to be significant in the next decades in absence of concerted environmental government policy of countries. This mostly applies to China, which will increase production capacity and emissions until 2030 and then reduce them to carbon neutrality by 2060.

Existing Russian regulatory framework for technological design of ports[1] employs an analytical modeling method that allows obtaining only discrete (one number) results of throughput. Such results often significantly underestimate the potential cargo turnover

[1] SP 350.1326000.2018 «Norms of technological design of marine ports».

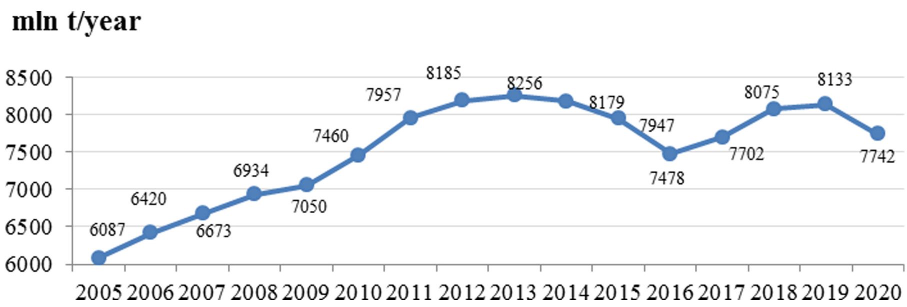

Fig. 1. World coal production [BP].

of export terminals, which contributes to mutual mistrust between the design and research community (contractor) and industrial companies (client). This is explained by mandatory use of coefficients that were determined by the USSR statistics authorities in the 1960–70s: berth occupancy, berth idle time due to weather factors, and transition from technical to operational productivity of handling equipment. As an example, Table 1 demonstrates 100–200% discrepancy between the designed and actual operation throughput of two Russian coal export terminals (Rosterminalugol and Daltransugol). Such discrepancies stimulate the development of new alternative modeling methods, including stochastic models. This should be based on the accumulated experience of terminals and modern mathematical methods and software tools.

Table 1. Characteristics of two Russian coal export terminals (Rosterminalugol, Daltransugol).

#	Characteristics	Rosterminalugol (port Ust-Luga)	Daltransugol (port Vanino)
1	Owner	Ural Mining Metallurgical Company (UMMC)	SUEK
2	Launch year	2006	2008
3	Equipment of marine side	3500 t/h conveyors, 2 shiploaders, 2 berths, 70 000 t maximum vessel deadweight	3500 t/h conveyors, 2 shiploaders, 2 berths, 163 000 t maximum vessel deadweight
4	Throughput in design documentation	8 mln t/year	12 mln t/year
5	Actual operational throughput	24.5 mln t/year (2019) 26.5 mln t/year (2020)	20.5 mln t/year (2019) 23.2 mln t/year (2020)

The main scientific contribution related to the activities of coal terminals was made by: V.H. Barros [5], T.A. Robenek [6] and N. Umang [8] about berth allocation problem; U.S. Bugaric [7] about bulk cargo unloading; T.A. Van Vianen [9–11] about stockyards and operations of stacker-reclaimers; A.J.A. Kleinheerenbrink [12] about heuristic calculations of dry bulk terminals; G.C. Menezes [13], N. Boland [14] and O. Unsal [15] about integrated scheduling and planning problem on export terminals of ore and coal. Several chapters of marine ports handbooks by H. Ligteringen [16] and C.A. Thorensen [17] are devoted to the matters of technological operations of bulk terminals and vessels. Contemporary guidelines for planning, site selection, design, vessel handling, operations, hazard management, storage facilities, transshipment, maintenance and environmental considerations of specialized bulk terminals were issued by PIANC in 2019 [18].

There are various schools in the international scientific community about coal terminals planning: in the Netherlands (Delft University of Technology), they study bulk terminals as an integrated technological system; in Australia (The University of Newcastle TUNRA Bulk Solids), more attention is paid to equipment for transshipment and transportation of cargo flow; in South Korea (Pohang University of Science and Technology), the focus is shifted to scheduling and planning of bulk carrier ship operations.

Among the works of Russian scientists, there is a limited number of studies about bulk terminals. The studies by Y. Spassky [19] and A. Kuznetsov [20] are focused on increasing the efficiency of handling equipment at marine side of coal export terminal using dynamic simulation of weather conditions and ship calls. Most of the Russian scientific research works are devoted to the modeling of maritime container terminals, these are the studies by S. Pavlenko [21], V. Pogodin [22] and A. Kuznetsov [23], whose findings can be partially used for bulk coal terminals.

Stochastic modeling is based on the use of statistical technologies, the most common of which is the Monte-Carlo modeling method. In the process of modeling, a value from a random range of probabilistic data distribution figures for each parameter is inserted in a given calculation equation. The cycle is repeated many times, which allows plotting the probability distribution of the results. In particular, according to company Palisade [24], probabilistic studies of transport and logistics are carried out by several universities: Technical University of Denmark (uncertain elements into decision-support models for transportation projects), Ohio State University + Pennsylvania State University (ocean carrier ships' transit time). Around the world, there is a growing interest in stochastic modeling, which is widely used in the oil and gas industry for probabilistic modeling of reserves, for managing the schedules and investment budgets of large-scale projects.

Stochastic modeling and optimization for marine coal terminals has been applied in some studies. The probabilistic assessment of cargo flows and throughput using stochastic processes modeling methods is in the early stages of elaboration by some authors. The stochastic approach is often tied to the modeling of a single or a very limited number of factors: N. Le Carrer accounts the stochastic nature of tides [25]; A. Azaron considers weather conditions as an environmental variable [26]; A. Agra proposes weather conditions and unpredictable berth waiting times as stochastic parameters and processes [27]; X. Feng developed simulation model for crude oil tanker operations mostly focused on navigation and tides in one-way approach channel to the terminal [28]. The main contribution in operation modelling of dry ports and coal terminals: T. Crainic made dry-port optimization for tactical planning based on integer programming [29], Z. Guo proposed to use stochastic modelling to solve deballasting scheduling problem for coal export terminal [30], B. Zhu created simulation model for overall export coal terminal from railway trains to marine side vessels [31]. Most of the studies are focused on improving of performance of marine terminals – the most common approach, which M. Hervás-Peralta [32] proposed to solve by splitting the terminals on most relevant functionalities and increasing the knowledge about them.

The difference in calculated and operational throughput is significant problem for investors and the price of port handling. Originally created stochastic model and open-book demonstration of most-probable statistics on marine side of coal terminal are the novelties, which haven't been published in previous papers yet.

2 Materials and Methods

To establish the model's calculation algorithm, a deterministic model was prepared as the first step, which incorporates the calculation logic and the sequence of operations and takes into account every possible factor. Next, the deterministic model is used as background for building the stochastic model that takes into account the distributions of parameters.

Simplified process flow diagram (see Fig. 2) of the marine side was set with following characteristics: technical productivity of conveyor equipment 3500 t/h (conveyors, ship-loading machines); 2 berths for mooring of vessels; 2 shiploaders; deadweight of vessels 25,000–185,000 t.

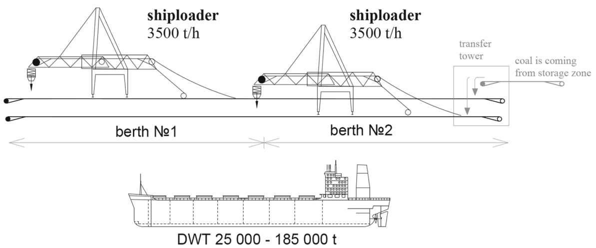

Fig. 2. Process flow diagram of the marine side of coal export terminal.

The algorithm and processes of stochastic modeling for bulk export terminal throughput on the marine side is shown in Fig. 3. The model is divided into 3 modules:

- worktime fund of the marine side,
- berth available time,
- fleet.

The integrated formula of marine stochastic throughput modelling is provided below:

$$T_{year} = \sum_{j=1}^{m} T_{groups} = T_{calendar} \cdot \sum_{j=1}^{m} \frac{A_j \cdot SLS_j}{TBAT_j} \tag{1}$$

where T_{year}—annual throughput of marine side, t/year;
$T_{calendar}$—total calendar time (available worktime fund), h/year;
A_j—share of type "j" vessels in total ship calls, %;
SLS_j—shipload size for type "j" vessels, t/vessel;
$TBAT_j$—total berth available time for type "j" vessels, h/vessel.

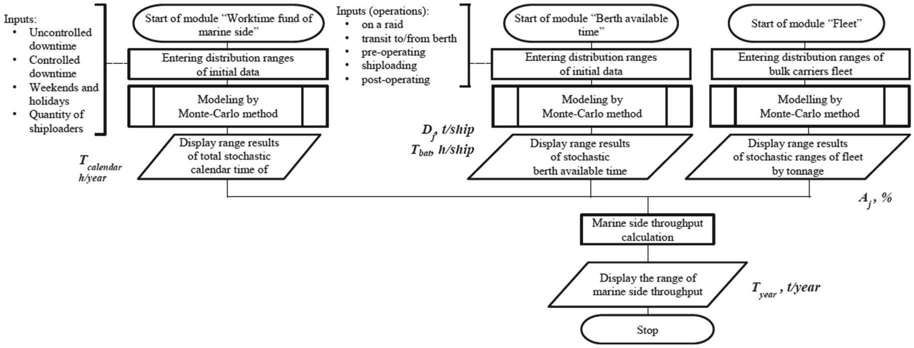

Fig. 3. Algorithm and processes of stochastic modeling for bulk export terminal throughput on marine side.

The "Worktime fund of marine side" module is used to determine the probabilistic range of available hours of operation of the sea cargo front during the year. It is influenced by the following initial data: uncontrolled downtime due to weather factors, controlled downtime, non-working days, and the number of shiploading machines. The value is determined as the maximum theoretically possible worktime fund minus total shiploaders' downtime due to various factors (detailed breakdown of data is provided in previous study of authors):

$$T_{calendar} = T_{max} - T_{downtime} \quad (2)$$

where $T_{calendar}$—total calendar time (available worktime fund), h/year;
T_{max}—maximum theoretically possible worktime fund, h/year;
$T_{downtime}$—total downtime (uncontrolled and controlled), h/year.

The "Berth available time" module is used to determine the probabilistic time ranges for the cycles of shiploading operations for each tonnage group of bulk carriers. The cycle is influenced by shunting operations in the port's water area, operations at the berth (mooring, loading of coal in normal and trimming modes, shiploader movements), and release of registration documents and permits. The most time is spent on shiploading onto the vessel performed in the normal and trimming modes, when shiploading capacity decreases during movements of shiploader between holds and operator-dependent downtime (lunch, shift changes). Shiploading operations duration is determined using the following formula (detailed breakdown of data is provided in previous studies of authors):

$$T_{bat} = T_{raid.in} + T_{entry} + T_{pre} + T_{loading} + T_{post} + T_{exit} + T_{raid.out} \quad (3)$$

where T_{bat}—berth available time, h;

$T_{raid.in}$—obtaining of permits and waiting on a raid, h;
T_{entry}—ship transit to berth, h;
T_{pre}—pre-operating time for mooring and draught measurement, h;
$T_{loading}$—operating time at berth for shiploading, h;
T_{post}—post-operating time for clearance of departure and unmooring, h;
T_{exit}—ship transit from berth, h;
$T_{raid.out}$—obtaining final permits to go out from terminal, h;

The "Fleet" module is used to determine the distribution of vessels by tonnage groups (figure Aj to Formula 1). Fleet distribution depends on the technical limitations of vessels and commercial factors. According to the statistical data analysis results, an increase in the share of bigger vessels (Panamax and larger) is observed each year. Detailed logic of calculations and breakdown of data is provided in previous study of authors.

During modeling, each stochastically described input is inserted into the given calculation equation described by the mathematical model. The cycle is repeated many times, and the result of each iteration is recorded. Monte-Carlo modeling gives a more realistic picture of possible results, enabling assessment of both a single figure and possible ranges. Probability distributions are described and mathematical links are identified for the parameters that affect the marine side throughput. This helped develop a stochastic model of the coal export terminal's marine side throughput. This model was then used to run experiments whose results are described in the next chapter.

3 Results

Modeling by Monte-Carlo method was performed with 5,000 iterations for each experiment, which helped obtain averaged results due to the generation of random new values in each of the runs. In a probabilistic calculation, the model is continuously recalculated and recorded at each iteration. The results may be presented as a graphical probabilistic distribution with optimistic (P10), average (P50) and pessimistic (P90) values, and a sensitivity analysis may be carried out.

An experiment was carried with a terminal whose initial parameters are close to the existing operating terminal Daltransugol in port Vanino at around 2018. In general, the modeled system can be characterized as follows. On the marine side, coal is loaded onto bulk carriers with deadweight of up to 185,000 t using two shiploaders, each with capacity of 3500 t/h (capacity corresponds to filling 75% of the buckets of reclaimer wheel at storage). The most common tonnage groups of vessels are 50,000–80,000 tons and 80,000–120,000 tons, each providing about 40% of the cargo turnover. For 25% of vessels, there are shipping limitations due to the design features of the vessel or restrictions on draft near the berth. Due to its geographical location and severe climate conditions, the terminal has a long winter period with occasionally unsuitable weather conditions for loading coal onto vessels. Some ships are loaded with different grades of coal in accordance with the customer's requirements and contractual obligations. Stochastic modeling was performed in @Risk software in accordance with the logic of the model and the initial parameters given in the section "Model and Dataset".

In the quantile assessment of the results, the median x_2 (50% quantile) corresponds to the throughput modelling of 20.47 mln t/year, and quantiles x_1 (25% quantile) = 22.81 mln t/year and x_3 (75% quantile) = 17.96 mln t/year. At the same time, in a sample of 100 iterations (years) with a 95% confidence interval, the lower limit of the throughput modelling will be 19.69 mln t/year and the upper limit – 21.10 mln t/year. The narrow interval indicates an accurate estimation.

With stochastic process modeling, the average result (probability P50, median) is the throughput of 20.47 mln t/year, optimistic (P10) – 24.94 mln t/year, and pessimistic (P90) – 15.75 mln t/year. The range of obtained results is adequate, taking into account the actual cargo turnover of Daltransugol terminal varying from 17.0 mln t in 2015 to 20.1 mln t in 2018. The probability density of the experiment is shown in Fig. 4.

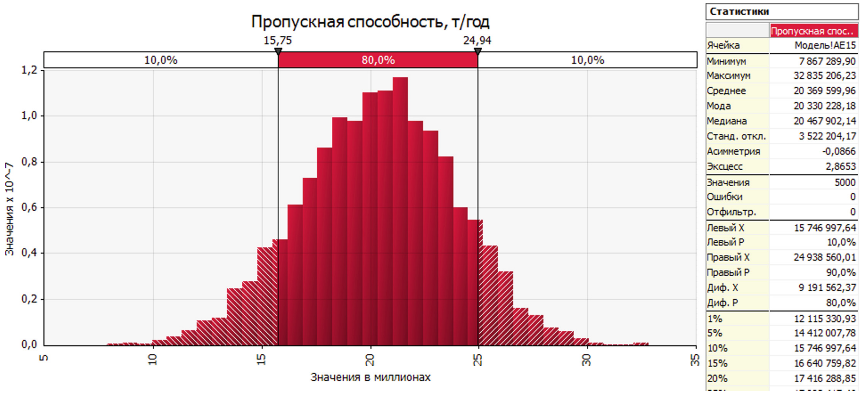

Fig. 4. Probability density of the experiment throughput modelling results (horizontal axis – probabilistic results of calculated throughput in mln t, vertical axis – density in 10^{-7}).

Total calendar time (availability of worktime fund) has an impact on shiploading performance. For two shiploaders, maximum theoretical operating time is 17520 h/year, which is unattainable in reality due to various downtime. In the stochastic experiment, the following values of the worktime fund were obtained (Fig. 5): median (P50) – 7,449 h, optimistic (P90) – 9,071 h, and pessimistic (P10) – 5,728 h.

A sensitivity analysis was carried out to evaluate the influence of the initial parameters of total calendar time on the probabilistic throughput results. The identified factors with the most impact are operations when the marine side is idle for a long time: absence of coal in storage zone (impact on the results of ±3.8 mln t/year), change of conveyor routes for the coal grade (±3.6 mln t/year), absence of fleet (±2.0 mln t/year), and weather-related downtime (±2.0 mln t/year). Downtime due to weather conditions refers to uncontrolled parameters. At the same time, the terminal can improve efficiency by changing its controlled downtime: accumulating the coal for availability in the storage, as well as pre-contracting and scheduling of vessels. In fact, Daltransugol terminal increased throughput of its railway zone, which helped increase its throughput in 2019 (24.5 mln t/year) and 2020 (26.5 mln t/year). Thus, the sensitivity analysis based on the 2018 data correctly indicates absence of coal in storage as one of main factors (Fig. 6).

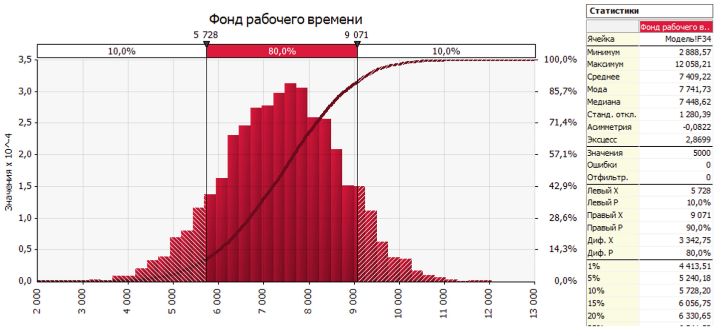

Fig. 5. Probability density of total calendar time (horizontal axis – probabilistic results of inputs for total calendar time in hours, vertical axis – density in 10^{-4}).

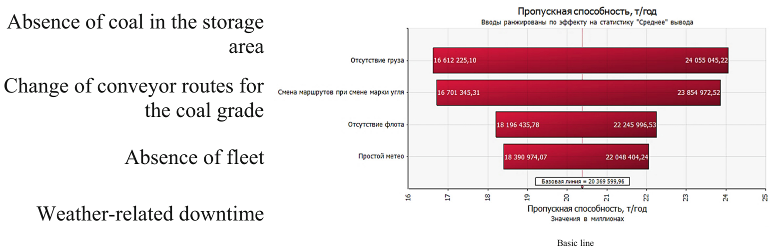

Fig. 6. Sensitivity of total calendar time (horizontal axis – throughput in mln t/year, vertical axis – title of parameter).

The experiment results demonstrate that the model has been verified. The adequacy of stochastic model has been established with the behavior of the mathematical model, which quite accurately coincides with the operations and performance of the marine side of coal export terminal. The model is valid: it can be used to select and determine the properties of each parameter and the influence on the result. When the parameters are recalculated, a change in the throughput modelling results occurs within a reasonable range, which indicates sufficient stability of the model.

4 Discussion

Process operations at marine export terminals are diverse in terms of characteristics, dynamics and intensity. On the one hand, a high level of detail is required to obtain calculated results that are close to reality of operational terminal performance. On the other hand, clients always required adequate results even though they provide insufficient initial data, especially at the early stages of projects. Stochastic processes modeling is a satisfactory tool and application at various stages of the project cycle. The range of probabilistic results obtained in the stochastic mode, is sufficient to understand and take into account various uncertainties. The range will grow narrower as more specific results of port planning and design are imported into the model.

An example of stochastic modeling experiment of a coal export terminal is close to the final stages of the project cycle, since the data were obtained from an operating terminal. There is a potential for using stochastic modeling in a stage-gate process in the management of big-scale projects (see Fig. 7).

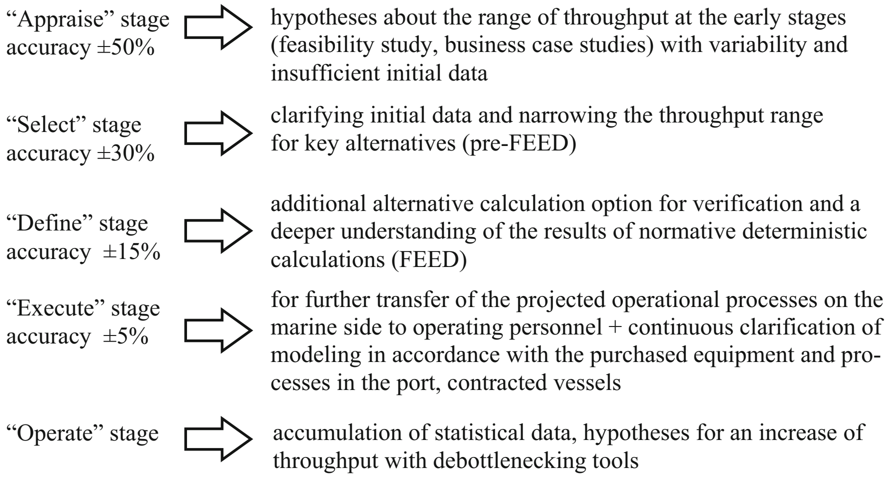

Fig. 7. Proposal for the implementation of stochastic modeling in project stage-gate process.

Stochastic modeling researches in maritime industry has a high scientific potential and opens up possibilities in terms of solving operational problems. Further development of the stochastic modeling of marine terminals depends on the interest and actions in the gathering of statistical databases among companies, industries and countries. On the international level, this can be managed and applied through professional communities (like PIANC with a wide network of commissions and working groups). Stochastic modeling coupled with benchmarking tools could definitely improve the operations of existing terminals and create an additional value in the port planning and design of new marine facilities. Adoption of stochastic calculations of processes appears promising not only in the context of process operations and cargo throughput, but also for expanding indicators of the economic efficiency of projects.

5 Conclusion

Key highlights and ideas of the article: a novel stochastic approach to calculating the marine side throughput of coal export terminals is proposed; probabilistic throughput values are defined, including the optimistic (P10), average/median (P50) and pessimistic (P90) figures; the factors with the highest impact on the marine side throughput are determined by sensitive analysis; the implementation of stochastic modeling in project stage-gate process is proposed.

Methodological contribution of this study in marine ports stochastic modelling is based on creation of detailed model and open-book demonstration of probabilistic statistics, uncertainties and performance results of existing Russian export coal terminal. Such approach has potential of use for marine coal terminals in any country or for other cargoes. The novelty of probabilistic operational statistics and efficiency issues, which in details are demonstrated in numerical experiment, could be the planning clarification for new upcoming projects and support for decision-making problems for existing coal terminals to maximize the throughput. Important findings of paper that this could be done by searching of big non-operational losses (like absence of coal in storage area, absence of fleet, etc.).

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Evolution of Supply Chains in the New Digital Reality

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Abstract. The article is devoted to complex research in the process of digital transformation of global supply chains. The author focuses main attention on the specifics of the creation and functioning of such structures. The ultimate goal of the logistics industry transformation is to change the role of the digital information flow, its transformation into a tool for organizing and managing logistics systems of a new type, which scale will allow to effectively solve not only economic but also urgent environmental and social problems. As a research problem, the author defined an attempt to analyze the nature of structural changes taking place in the logistics industry and highlight the key factors of influence. The basic content of the research is analysis of the role of global supply chains in the new digital reality and the problems that arise in the process of their creation. Special attention is given to determining the place of information systems in the structure of digital supply chains.

Keywords: Global logistics chains · Supply chain management · Digital transformation · Focus company · Holding structures · Information systems

1 Introduction

In recent years, the digital transformation of the logistics industry has encompassed the flows of work performed, goods and services produced, information, and even capital.

The relevance of the research topic is due to the fact that the development of modern technologies contributes to the transformation of local supply chains into global supranational structures that play a decisive role both in the operating activities of companies and in the process of creating final consumer value. The purpose of this article is analysis of the process of creating and functioning of such structures, highlighting the key principles of digitalization of supply chains. Special attention is given to determining the place of information systems in the structure of digital supply chains. In addition, an attempt is made to analyze the nature of structural changes taking place in the logistics sector, to identify the key factors of influence and formalize the conditions necessary for the development of global digital supply chains.

Digitalization of any field of activity implies the mass introduction of technologies for creating, transmitting, and processing information. In logistics, this has led to changes

I. Ilin et al. (Eds.): ICDT 2021, LNDECT 157, pp. 210–221, 2023.
https://doi.org/10.1007/978-3-031-24434-6_20

in the global supply chain and types of competition. Greater transparency of business processes, the emergence of new forms of doing business, and increased supply to end consumers due to increased competition is a natural consequence of digitalization.

Considering the situation at the macro level, it can be noted that the mass transition to digital platforms has led to a qualitative leap in all aspects of economic relations – in production cooperation, scientific and technical cooperation, labor migration, investment, and trade.

Starting with the incomplete use of ready-made digital products and the adaptation of existing technologies to the operational needs of business, the digitalization of logistics systems has led to the formation of comprehensive technological platforms and qualitatively new links between the participants of the supply chain based on the Internet of Things, digital alter egos of real economic objects and blockchain technology [1–3].

2 Materials and Methods

The digitalization of logistics requires a comprehensive restructuring of the interaction of business processes both within the company and between the company itself and the environment.

Empirical methods (description, classification, analogy, abstraction and generalization), theoretical methods (analysis, synthesis, induction and deduction), as well as elements of economic analysis were used as research tools.

The leaders in supply chain business process automation are large holding structures that control most of the world's logistics flows. When digitalizing supply chains, the object of analysis can be both processes implemented directly within the holding (internal supply chains) and the processes of interaction of the entire structure with external counterparties (external supply chains).

The economic nature of holding structures implies the division of the cycle of creating the final consumer value between independent economic entities. Separate parts of a single technological process have to establish the exchange of intermediate goods and services that are components of a single final product. Such a division of the production process most often has a supranational format and involves cross-border logistics flows.

The need to implement the described scheme formed the basis for developing international cooperation when economic and even technological production chains, which work is based on a common strategic plan and is subject to a single production cycle, contain links under the jurisdiction of several countries. The task of achieving continuity of the technological process of creating the final product determines the need for rapid movement of many parts and components within the system.

The intermediate outcome of this process was the transfer of labor- and capital-intensive industries to developing countries, while knowledge-intensive industries remain concentrated in economically developed regions. In an unstable geopolitical situation, certain stability of global logistics flows is achievable only when cooperative processes are intra-corporate.

International cooperation implemented through internal channels of large corporations has generated an active exchange of not so much finished products as their assemblies and components. Such a phenomenon can be defined as intra-industry trade, which has significantly increased the volume of commodity flows both within national markets and internationally [4, 5].

The change in the global logistics system is a consequence of the ongoing digital transformation of most sectors of the global economy. New forms, methods, and mechanisms of organization of production and distribution of products are emerging, sources of obtaining competitive advantages are changing. In addition to economic parameters, product quality, and service conditions, environmental, social, and resource-saving factors begin to play a significant role. Different consumer values form new rules for the development of logistics systems.

Modern economic theory distinguishes the object and process decomposition of the structural components of the supply chain. According to the first approach, the supply chain can be defined as a set of companies whose interaction involves information, material, and financial flows, and the flow of services, starting at the source of raw materials and going all the way to the end consumer. In turn, in terms of the process approach, the supply chain is a set of flows and corresponding processes responsible for the coordination and cooperation of all participants in the chain to create an added product and, ultimately, the formation of customer value.

The combination of the two approaches in the analysis of economic systems allows to describe the structure and determine the process links between the elements of the logistics chain. Process structure analysis complements the list of their functions, providing the researcher with comprehensive information [6].

In many cases, the system functioning is determined not so much by the properties of its constituent elements but by the qualities resulting from their interaction with each other. To maintain the integrity of the overall structure, it is necessary to ensure the integrity of its elements. Applying this approach to the supply chain, one can conclude that in addition to harmonizing business processes and optimizing interaction procedures of companies that form a logistics chain, the principles of process management should be applied to each link of such a chain separately. In practice, the latter means the need to optimize all business processes, not only in companies directly involved in the functioning of the supply chain but also in the links responsible for supporting and managerial components of the logistics process. And if the process approach at the level of a particular company has traditionally been the responsibility of its management, then reaching the level of supply chain management requires a radical revision of the approach to the holding management processes.

The solution of this issue forced companies, first, to abandon some business processes, outsourcing them, and second, to make efforts to strengthen the remaining activities through related diversification. The latter has led to the creation of many vertically integrated holding structures through the inclusion of suppliers and buyers responsible for the core business process and a wave of mergers and acquisitions of companies that had the necessary competencies in the supporting processes.

As a result of the described transformations, traditional intra-corporate value chains have undergone a radical transformation, forming new supply chains according to one of two possible scenarios: either internal supply chains for vertically integrated holding structures with a large number of subsidiaries or external supply chains for independent companies providing services to a central company on outsourcing terms.

Thus, the source of the formation of global supply chains can be both the increasing market interaction of independent counterparties and the creation through mergers, acquisitions, and organizational transformations of holding structures that control the entire logistics chain from the producer of basic raw materials to the consumer of final products [7, 8].

The modern scale of supply chains suggests that their management is interdisciplinary and can be considered in the context of analyzing business processes and modeling their architecture, and managing the flows and stocks of various resources – information, financial, material ones, etc.

The process of modeling and supply chain management should take into account the key features of the latter:

1. Complexity of knowledge. Supply chain management involves the joint use of methods and tools of a range of economic disciplines – from logistics and financial analysis to strategic management and marketing.
2. Structure nesting. Each of the global logistics chain links can be a simple supply chain. In this case, an analogy could be drawn with the upper-level business process, each element of which can be decomposed to the lower-level business processes.
3. Informatization/digitalization of processes. A key element of supply chain management, aimed at combining all the elements of the subject area into a whole. It can be argued that global digitalization has made possible the practical implementation of the ideas underlying this concept.
4. Dynamism of changes. Unlike internal business processes, limited by accepted regulations, job descriptions, and formal organizational structure, supply chains have much greater flexibility in time and space since they include all participants in the logistics process.
5. Variability in structure. The final form of the supply chain structure is determined by the company that initiates its creation, taking into account the specifics of each participant, which leads to a significant variety of end results both in terms of approaches to optimizing logistics activities and at the level of external attributes.
6. The long-term nature of the expected results. Despite the maximum flexibility and variability inherent in the nature of digital supply chains, business needs long-term planning that considers the demands of end consumers.
7. The role of intermediaries. As the length and complexity of the supply chain structure increases, the importance of the role of logistics intermediaries and other ancillary process participants increases, and they can exert significant influence on the main participants in the supply chain network structure.
8. Customer-focusedness. Regardless of the structure and number of links included in a particular logistics chain, the pulling principle of organizing logistics activities and working with the end consumer on the one-stop-shop principle remains dominant.

In addition to the basic characteristics, it is possible to identify a number of concepts that provide insight into supply chain structure development directions.

1. Vendor-Managed Inventory (VMI). The supply chain inventory management system assumes that the supplier fully manages the buyer's inventory based on information about sales and product residuals.
2. Quick Response (QR). A multilevel system for information exchange between supply chain participants. Its purpose is to ensure that production can be quickly readjusted in response to changes in market demand. The top two levels exchange information about the state of inventory between the supplier and the retailer with automatic generation of orders for stock picking. The VMI system and the technology of transit movement of goods (Cross Docking) are located on the two lower levels.
3. Efficient Consumer Response (ECR). An approach based on lean production tools, which aims to combat inefficiencies within the supply chain and increase the latter's response to consumer demands. The main focus is to establish information exchange between the logistics and marketing components of the global supply chain.
4. Sustainable Supply Chains (SSC). The concept is designed to combine the process of building supply chains, including procurement, transportation, production issues, and the current environmental and social agenda.
5. Risks in global supply chains. A full extent of the logistics chains under consideration generates risks that were absent at the national level. These include geopolitical and macroeconomic factors, the threat of social and weather disasters. This significantly complicates the modeling and debugging of business processes in global supply chains [9, 10].

3 Results

In general, the supply chain consists of suppliers, consumers, and a focus company. A detailed analysis involves object decomposition, identifying key supply chain objects and their functions. As a result, an organizational chart of the participants in the supply chain and a functional scheme of their interaction is formed. Creating both schemes is significantly complicated by a large number of analyzed objects closely related to each other.

The supply chain formation always takes place in the context of an analysis of the activities of a particular company, while the same transaction, viewed from the perspective of different counterparties, can act as an element of several independent supply chains. The company which supply chain is analyzed is taken as the focus one. A distinctive feature is its ability to exert a controlling influence on the supply chain. There are two options for supply chain formation: power-based (or natural) and cooperative (institutional). In the first case, the place of the focus company is occupied by the strongest participant in the value chain, in the second – by a coordinating company created to work with equal partners, or a company that has a monopoly right to carry out a key type of activity, for example, JSC Russian Railways. Regardless of the alternative under consideration, the question of the location of the control center for the entire supply chain and the scale of powers that the participating companies are ready to give to this body is quite sharp. The choice of the model of relations within the logistics chain depends on the specific way of solving this issue [11].

Object decomposition involves a sequential transition from the upper-level elements of the system to its elementary components – from groups of participants and functions to consideration of the roles of specific chain links and their operations.

In modeling the supply chain, the question of its reasonable length, i.e., the permissible limits of the model, inevitably arises. Formally, the length of the supply chain is determined by the number of its links – independent participants in the chain. The following options are distinguished based on this criterion:

- minimum supply chains are formed by first-tier suppliers and consumers grouped around the focus company;
- extended supply chains imply that suppliers and consumers form a multilevel hierarchy;
- maximum supply chains involve the unification of all participants in the logistics chain – from suppliers of basic raw materials to buyers of final products.

At that, it is incorrect to correlate the length of the supply chain with its scale. The maximum supply chain can be formed within the borders of a single state, while each of the three links of the minimum chain can be located in a separate country. As a key parameter, it is more appropriate to consider the coordinating capabilities of a particular focus company, which directly affects the number of participants integrated into a given supply chain.

Another basic characteristic of the supply chain is its height (vertical structure) – the number of elements in each link, i.e., counterparties of a certain type. Moreover, this applies to the main members of the association and service companies – suppliers of auxiliary goods and services (transport companies, banks, insurance companies, consulting companies, software suppliers, etc.). Assessing the importance of such elements for the supply chain is a key parameter that distinguishes Russian and Western practices of analyzing logistics structures. In domestic practice, auxiliary participants are taken out of the supply chain and analyzed as third-party entities. In foreign practice, a diametrically opposite approach is implemented – logistics intermediaries are considered as key players, along with suppliers and consumers. The described difference in approaches leads to differences in the process of optimizing supply chains since it has a significant impact on the level of their integration. Heterogeneous in nature, logistics chains become much more monolithic if only direct links between key suppliers of goods and services are considered.

To return to the role of the focus company, it is worth noting a radical change in the approach to assigning such status after the emergence of the 4PL concept. By definition, a focus company is a company that manages the supply chain, monitors and controls all the relations between its participants. This concept implies that all logistics operations in the entire supply chain are managed by a single logistics provider, which immediately changes its status from an auxiliary link for suppliers and consumers (one of whom plays the role of a focus company) to a structure that occupies a dominant role in relation to the rest of the participants in the commodity distribution chain. The 4PL provider not only provides services that play a key role in the functioning of the logistics chain but also turns into a focus company responsible for most management solutions for the entire supply chain. Consolidation of control functions in one chain link makes the latter more flexible and resilient to external influences. The process of transforming a 4PL provider into a direct participant in the supply chain with its subsequent transformation into a focus company corresponds to the institutional way of forming logistics chains discussed above.

The supply chain decomposition procedure begins with an analysis of end-to-end business processes and descends to the level of business processes of its constituent companies. Strategic management of the global logistics chain involves the division of end-to-end business processes into three groups:

1. CRM – Customer Relationship Management.
2. SRM – Supplier Relationship Management.
3. SCM – Supply Chain Management.

The first and second systems are responsible for interaction with contractors external to the holding and their functional integration; the third is responsible for the integration of processes within the holding structure. Practical difficulties with the integration of logistics flows determine the sequence of actions: usually, companies start with the automation of material resource management processes and their physical distribution [12, 13].

Regardless of the sequence of steps in the automation of logistics activities, it is important to maintain the key principle of supply chain formation – customer-focusedness. In this case, "customer" means not only the consumer of the final product or service but also all intermediate participants in the commodity distribution process. Such an approach increases the flexibility and competitiveness of the entire supply chain, and at the same time, due to synergies, the efficiency of each participant in the chain also increases.

The accelerating pace of changes in customer demand is forcing companies to be proactive – to be able to respond to new market conditions, the necessary adjustments in automated supply chains must be made in advance. The ability to anticipate the future and quickly reconfigure the logistics process becomes a key factor for obtaining competitive advantages.

The above principle of customer-oriented logistics chains implies a comprehensive response to the market demand – a prompt change in the overall strategy must be supported by the ability to implement such changes at the micro-level. Such flexibility can only be achieved through continuous improvement of the supply chain's organizational, process, and information components, combined with training and increased motivation of personnel at all levels of the logistics process. Effective supply chain automation is only achievable if all links in the chain are considered as a whole.

The company's second-generation ERP system implies digitalization of all elements of the business process – production, warehouse accounting, accounting, financial services, and internal logistics. During the operation of such systems, a structured array of information about the material and financial assets of the company, multilevel transactions, the permissible load on logistics and sales channels, and other information required for making both strategic and current decisions is formed. Nevertheless, this information is not enough to build a complete logistics chain when it comes to a holding structure. This problem is solved by creating a set of CRM-class systems, which must be linked both between themselves and with ERP systems of the respective companies. Such architecture supposes the harmonization of independent internal information flows of individual companies with information flows accompanying the movement of material and financial assets throughout the supply chain within the holding structure [14].

4 Discussion

In global supply chains, intermediate products can change ownership and cross customs borders multiple times before being transformed into final products or services. The formation of global logistics chains is transforming the landscape of the global economy by adding new links to the system. As a result, not only the format of individual companies is changing, but the entire institutional environment is evolving. These processes run in parallel with each other, accelerating the overall pace of development of global supply chains. Growth drivers are as follows:

– increase in the coverage and number of users of the global Internet;
– significant growth rates in the e-commerce segment;
– a high degree of state participation in the digitalization process.

And if the first two points can be attributed to "traditional" factors, the third, which appeared relatively recently, has become the key to the speed of formation of global supply chains. The problems that can be solved exclusively at the state level include issues related to the form of regulation of new types of organizational, economic, and legal relations in the global digital environment. It is necessary to develop digital tools, rules of global digital logistics chains, and uniform principles of regulation by states.

The result should be as follows:

– forming procedures for collecting, transmitting, processing, and storing data that minimize the likelihood of their leakage to third parties;
– setting up procedures for interaction between business and government in a digital format, without the use of paper documents;
– improving the legal aspects of the use of digital signatures and virtual alter egos;
– expanding the scope of blockchain technology;
– determining the legal status of cryptocurrencies;
– development of legal interaction regimes with digital economy objects.

The specific difficulties associated with the formation of digital supply chains include the need to maintain a high degree of information openness in multilateral interactions within the network, which significantly complicates ensuring commercial information safety.

A fairly striking example is cloud information systems, which are expected to be widely distributed in the coming years. Their use in the implementation of digital technology platforms implies a clear definition of the status of the customer, user, and provider of this service and respect for personal data privacy. The cross-border nature of cloud technologies aggravates the situation.

Issues related to the legal status of cryptocurrencies are characterized by even greater tension and uncertainty. On the one hand, there is a steady increase in investors' interest in this instrument. On the other hand, some states have begun to legally restrict such technologies' use. A legal vacuum and the lack of national regulators' intelligible actions can be stated in most cases.

The use of the Internet of Things, neural networks, and artificial intelligence in building global logistics chains raises the question of the need to redefine the legal status of subjects in a situation where the functioning of individual parts of the system and information exchange between them takes place without human participation.

The level of digitalization of business processes of leading companies already today allows to state that there is a direct dependence of the effectiveness of their activities on the operation quality of supporting information systems. The scale of the latter determines the critical importance of preventing unauthorized access to data and other information security offenses. The digitalization of global supply chains adds to these threats the risk of data loss in the cross-border exchange of information between elements of the system controlled solely by artificial intelligence – rules for the processing and use of different types of information need to be determined in advance. Another negative consequence of the scale of logistics systems is the loss of transparency for individual links in the chain, which lose an idea of what data are used to make certain decisions.

Successful development of global digital supply chains requires the following:

- high-quality access with minimal restrictions for both companies and individuals to the global network to form a single information space;
- formation of a favorable legal environment for the development of digital supply chains and related services;
- interest of states in the growth of the digital segment of the global economy;
- creation of a digital cross-border intersectoral information environment.

The last item should be clarified. When building global logistics chains in digital format, the task of synchronization, optimization, and, as a result, maximum integration of the activities of all participants in the chain arises. With the active assistance of national private and state structures, only international organizations can overcome the inter-country gap [15–17].

The digital transformation of the logistics industry, which includes radical changes in information, financial and material flows, is inevitable since it is part of forming a new digital reality. At that, the effectiveness of this process depends not so much on the speed of implementation of digital technologies as on the quality of basic logistics systems. Companies seeking to become pioneers in building digital supply chains should focus on improving the productivity, flexibility, and transparency of the management of their logistics complexes.

All of the above allows us to formulate the key principles of digitalization of supply chains.

1. Providing access to a common information system to each participant in the supply chain with the ability to obtain and exchange data on all relevant issues.

2. Automation of supply chain business processes using information systems built based on mathematical models.
3. Information transparency of the main business processes regarding their current state and expected results for all participants in the logistics chain.
4. Creation of a single information support center for the supply chain.
5. Formation of a balanced scorecard and its integration into the decision support system.
6. Coordination of operational logistics tasks with the strategic objectives of the system development.
7. An interface that allows dialogue with the system on the one-stop-shop principle.
8. Formation of a structure of roles that provides the necessary level of access to information for all participants in the chain.
9. Ability to access the analytical reporting system from mobile devices.

Implementing these principles in the course of optimization and subsequent digitalization of the global supply chain will increase the flexibility, transparency, and predictability of the logistics chain functioning, which will ensure an increase in the level of competitiveness and economic efficiency of each of its participants. The speed of transformation of local logistics chains into a single global logistics chain is most determined by the level of digitalization of logistics business processes.

The ultimate goal of the logistics industry transformation is to change the role of the digital information flow, its transformation into a tool for organizing and managing logistics systems of a new type. Digital tools allow creating logistics structures, scale, and complexity of which would have been unattainable for practical implementation recently, and the digital flow should become the entity that will connect the links of global logistics systems. The latter circumstance makes the quality of the information flow a key success factor in building global supply chains, which entails the need to revise the processes of information support for logistics activities, the rules for the use of information, the criteria for assessing its usefulness, the principles of interaction with state regulatory authorities.

It is assumed that the information flow linking each element of the digital logistics chain will provide the formation of a common target function and, as a consequence, a significant synergistic effect. The creation of such megastructures will allow to effectively solve not only economic but also urgent environmental and social problems.

It can be concluded that the main purpose of creating global digital logistics systems is not so much to increase the economic efficiency of their participants through the introduction of new technologies (which is certainly important) but to solve with their help the global problems that humanity has faced in recent years [18–20].

5 Conclusion

As a result of the research of the process of formation of global supply chains, the following results were obtained. First, the prerequisites for the transformation of local logistics chains into global supranational structures were considered. Formalized the leading role of holding structures in the formation of global supply chains, which based on the specifics of their economic activities.

Secondly, based on the decomposition of the structure of supply chain and identified process links between its elements, an attempt was made to assess the reasons for the formation of global supply chains, taking into account their key features and concepts that give an idea of the possible directions of their further development.

Thirdly, the options for the formation of a global supply chain and its basic characteristics were considered, the content of the concept of "focus company" and the role of such structures in ensuring the process of functioning of the logistics chain were analyzed.

In addition, the types of information systems that serve as the basis of digital supply chains were identified. In conclusion, the main drivers and specific difficulties of the formation of global logistics systems were considered, and the key principles of digitalization of supply chains were formulated.

The significance of the study lies in the systematization of factors contributing to the formation of global supply chains, identification of the role that global logistics systems play in the process of forming a new digital reality and opportunities that give rise to the emergence of such structures.

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The Significance of the Economic and Human Potential of the Yamalo-Nenets Autonomous Okrug for the Scenario Development of the Russian Arctic

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Abstract. One of the toughest challenges that Russia faces today is the need to adopt policies that would help the country to solidify its positions in the Arctic region. Progressive development of this region will allow the Russian Federation to protect its national interests. The present study is aimed at predicting the scenario development of the Yamalo-Nenets Autonomous Okrug (YNAO), the Arctic through the prism of its economic and human potential. The YNAO performance is analyzed according to the target indicators of "The 2035 Development Strategy of the RF Arctic and National Security Provision". The following ones are the indicators that reflect the economic performance of the region: the proportion of households that use broadband Internet against the total quantity of households in the Russian Arctic; the proportion of gross regional product (GRP) produced in the Arctic against the total amount of GRP produced by the country; the share of investments made into fixed capital in the Arctic zone against the total investments made in the RF, etc. Human potential is evaluated using indicators such as: life expectancy of those born in the Arctic; the average salary of employees working for organizations that operate in the Arctic. The findings of the research study cover the possible scenarios of further development of the YNAO drawing on the current situation, reveal the dynamics of the target indicators and describe some new fuel and energy, infrastructure and tourist projects the region implements.

Keywords: Arctic region · Socio-Economic Development · Arctic economy infrastructure

1 Introduction

The Arctic zone is a gem, a priceless asset of the Russian Federation, whose significance is only going to grow both in terms of the social life of the country and its economy. The theoretical grounds of this study embraces the existing laws and regulations, scientific literature on the Arctic zone, official statistics of the Rosstat and rankings of agencies.

I. Ilin et al. (Eds.): ICDT 2021, LNDECT 157, pp. 222–232, 2023.
https://doi.org/10.1007/978-3-031-24434-6_21

The authors of the paper believe that the economic and human potential of the Arctic zone is a major factor that has to be taken into consideration when we predict possible options and construct scenarios according to which the YNAO can develop. The Yamalo-Nenets Autonomous Okrug is a vast region of the RF in the Arctic and it functions as the fuel and energy base of the country. Economically, the region is focused on industrial production, primarily hydrocarbon production and processing of natural gas, oil, and gas condensate. The hypothesis of the research is that the trends currently noticed in the economic and human potential of the Arctic zone can be the foundations for constructing possible scenarios of how the region can develop in future. The research uses the base values of the target performance indicators of "The 2035 Development Strategy of the RF Arctic and National Security Provision". The purpose of the article is to analyze possible scenarios for the further development of the Yamalo-Nenets Autonomous Okrug (Russian Federation), taking into account the dynamics of target indicators of socio-economic potential.

2 Materials and Methods

In March 2021, the RF Government approved "The 2024 Government Program of Socio-Economic Development of the Arctic". The objectives include more intensive economic development of the RF Arctic territories, their larger input in the country's economic growth, and creation of better conditions for the macro-region to achieve sustainability in the development of society and economy. Thus, a growing number of scientists and experts are taking an interest in constructing scenarios to project the Arctic's future [1–4].

O.R. Young did research to design the future of the Arctic. He proposes two paradigms for the development of the Arctic: neo-realist/geopolitical and socio-ecological systems. The neo-realist paradigm is based on the right to use the Arctic resources depending on the countries' jurisdictions without considering the uniqueness of its eco-system. On the contrary, the idea of socio-ecological systems relies on the principles of systems and eco-focused governance of the Arctic zone [5]. Young elaborates on the second paradigm in his further works and speculates upon the ideas of the Arctic's sustainable development [6].

It is worth paying attention to the work by L. Heininen, K. Everett et al. called "Arctic Policies and Strategies – Analysis, Synthesis, and Trends". The authors carried out an integral analysis of the policies implemented by Arctic and non-Arctic countries and researched the strategies which may be used to manage human capital, protect environment, control pollution and climate change, improve health and safety, boost economy, promote tourism, build infrastructure, support science and education in the Arctic. According to the study, the region is strategically significant for both Arctic and non-Arctic states [7].

Investigating probable strategies that can contribute to the evolution of the Russian Arctic, M. Laruelle points out that, theoretically, the region opens up opportunities that are unique for the Russian economy and it can provide the country with substantial profits for as long as several decades. Thus, in case of an optimistic scenario, the region can be turned into a leading strategic resource base of Russia. From the scientist's standpoint, the development strategies of Russia in the Arctic do not simply concern the relationships between the country and other large international states [8]. In addition to providing economic resources, the Arctic can potentially become a new platform for the regional development of Siberia and the place where human capital can be accumulated by means of migration [9–12].

The papers [13–15] define the specific role of Russia's Arctic territories. These regions have a great investment potential and can see the processes that will lead to the modernization of the economy. Some of the most acute problems of the Arctic are that the demand for innovation among companies is insignificant while the government does not take any strong action to promote cooperation between the agents of the innovative process.

The socio-economic adaptation of Russian Arctic to today's requirements has been studied by G.F. Romashkina, N.I. Didenko, D.F. Skripnuk in works [16–18]. The authors emphasize that the international Arctic has high growth rates. In contrast, the Russian territories in the Arctic show progress mostly in the socio-economic and sociocultural contexts, but have failed to reach any notable achievements in terms of technology or institutions. They say that although the schemes and strategies applied for the development of Russian Arctic have had a positive impact, no qualitative transformation has taken place so far. The researchers point out that the socio-economic policy of the Arctic zone has to be urgently adapted to the new trends and global development processes. However, the situation is not likely to alter unless high-quality human capital is created in the Arctic. It is human capital that should turn into the main source of the region's competitive advantage in the changing environment [19, 20].

Another study that is worth mentioning was conducted by A. Emelyanova. The researcher makes forecasts about how the Arctic population will change from the perspective of its age and gender composition as well as its level of education. Three scenarios are introduced to project the feasible development that may unfold in the Russian Arctic: Moderate Development, Arctic Take-off (Forcing) and Arctic Depression (Decline) from 2015 to 2050. It is highlighted that the two favorable scenarios can unfold only provided that suitable socio-economic conditions are initiated in the region to favor positive migration of well-educated and highly-qualified people who choose to put time into lifelong learning and self-development. The author comes up with an idea that the Arctic will most probably maintain a status-quo respecting the size of population, which may range from 9.6 (Arctic Depression) to 11.6 (Arctic Take-off) million people in 2050, amounting to just a tiny share of the total population of the Arctic countries [21].

According to T. Vlasova, A. Petrov and S. Volkov, the Arctic is undergoing continuous social and environmental transformations. The outcomes of these transformations are uncertain and hard to predict. Sustainability of the Arctic is absolutely vital and the region's development has to be closely monitored. The authors focus on working out the principles and approaches that need to be applied in order to maintain the sustainability of the socio-ecological system of the region. They also justify the projection process and the choice of the indicators. In addition, the paper discusses coherent strategies that should be followed to make sure that the monitoring follows the principles of socially-oriented observations [22].

Some researchers think that sustainable development can be achieved in the Arctic if the region's reliance on non-renewable resources and the public sector in the economy can be reduced. This should be done in a way so that a simultaneous shift of focus is possible towards knowledge and innovation economy. This is where the development of local human potential comes to the foreground. If the right strategy is employed to develop and unlock human potential, economic growth can be stimulated in the region. Anyway, the Arctic has to tackle some really grave problems if it wants to transform itself into such a region. We should not forget that the internal growth of the region is discouraged due to the local constraints (institutional, financial and infrastructural ones) and, most importantly, because of the lack of human potential [23, 24].

We should point out a novel approach used by the International Expert Group on Thematic Scenarios of the Future development of Russia's Costal Arctic Zone until 2050. The experts accentuate the combination of "hard" and "soft" factors saying that these are the most important driving forces of the economic growth in the Arctic. The market of raw materials (a totality of natural resources and their prices on the world markets) was defined as a "hard" factor in the projections of development, while internal policies (federal and regional policies carried out on the Arctic territories) act as a "soft" factor. Four likely scenarios are the outcome of the two driving forces' overlapping each other: "Owner Region", "Arctic Dragons", "Ghost Towns", "Corporate Islands" [25].

The experts define technology and internal policies as major priorities of the social development in the Arctic. The technologies responsible for access to the internet, operation of satellite phones, small transportation means, small aviation, etc. are believed to be of paramount importance. Talking of internal policies, it seems essential to provide the population with access to education, health care, and make effective self-governance of indigenous peoples possible. The above boosters of social development give way to the following development scenarios: "A Cyber-Tent or a Reindeer Herder's Paradise", "Tourism", "Survival", "Stratification".

"The 2020 Development Strategy of the RF Arctic and National Security Provision" specified two scenarios that considered the socio-economic development trends of the Arctic: innovative and inert.

The innovative scenario is grounded on the competitive advantages of the Russian Arctic, i.e. the region's natural resources. Thus, economic growth can become qualitatively new on condition that state-of-the-art technologies are exploited on this territory. The innovative scenario is optimistic about the development of the high priority sectors of the Arctic's economy, for instance: megaprojects, monotowns, infrastructure improvement or projects, promoting cooperation between various regions of the Russian Arctic.

The inert scenario means that the current trends in the sectors of the Arctic economy will remain consistent. The scenario takes into consideration the conservative estimates of some key indicators. The growth rates of real incomes of the public, gross regional product and labor productivity are expected to be lower than the average Russian figures, while structural changes and growth in private investment will take time and effort. The RF regions in the Arctic will keep on specializing in raw materials while the prices of natural resources on the world market are expected to be unstable and volatile, even if the trends are positive. Insofar as social life, the population will continue to outflow from the region and the living standards are expected to fall down.

A group of researchers headed by K.S. Zaikov found their own path in constructed the 2035 Arctic scenarios. The experts grouped the development prospects of the region into optimistic, pessimistic, and intermediate scenarios and specified the characteristics of each variant [26].

All the above can offer a proof of the relevance of the research objective.

The source data of the study are legal acts (both federal and regional ones), works produced by national and foreign scientists who looked into various aspects of the Arctic, official statistic data of the Rosstat and some rankings of specialized agencies. The progress of the Arctic was evaluated using the target indicators of "The 2035 Development Strategy of the RF Arctic and National Security Provision" (the RF Presidential Decree No 645 dated October 26, 2020). The Strategy represents a comprehensive program aimed at increasing economic growth on the territory and improving its living standards. The data were collected and interpreted on regions, such as: Nenets Autonomous Okrug (hereinafter NAD), Chukotka Autonomous Okrug (Chukotka AD), Murmansk Oblast, Yamalo-Nenets Autonomous Okrug (YNAO), Arkhangelsk Oblast (excluding NAD), Krasnoyarsk Krai, Sakha (Yakutia), Karelia and Komi. The last five territories refer to the Arctic zone only partially. However, the indicators were estimated for the entire RF constituent entity. The target indicators were broken down into two specific groups: economic development and human potential development. Empirical methods, such as observation, comparison and description were followed in various phases of the research study. The research adopts the analog approach. The latter employs certain parameters and properties of analog as well as extrapolation, which is based on projecting the detected trends and patterns on the future development of the region. The dynamics of the indicators and trends was interpreted to find out about the current and future position of the YNAO in the development of the Arctic zone as well as in the provision of the country's national security.

3 Results

In order to acknowledge the conditions of scenario development for the Yamalo-Nenets Autonomous Okrug, some features characterizing this development were contrasted against those of other constituent territories of the RF Arctic zone. The specifications below show the major features that are distinctive for the current development stage of the RF regions in the Arctic (Table 1).

Considering the statistics, the YNAO has the highest level of access to the internet. Thus in 2019, it was 93.9%, which is 12.6% above the base value. This indicator even exceeds the figure projected for year 2024. Nevertheless, in 2019 we observe a 2.4% declining trend in the share of access in comparison to year 2018. The share of households having access to broadband internet in Murmansk Oblast was quite significant in 2019 (83.6%), but all the other Arctic regions failed to reach the criterion value.

The estimated shares of gross regional product against the total GRP created by the entire country demonstrate that the figure is the highest for the YNAO (above 3% in 2017–2019). The share of the YNAO in the base value is 0.545, i.e. the area is responsible for more than a half of the value of this indicator for the Russian Arctic.

Table 1. Target indicators of the YNAO economic development compared to the Russian Arctic [27–29]

Indicators	Base values for the Russian Arctic	The values of the YNAO indicators				
		2015	2016	2017	2018	2019
1. The proportion of households using broadband internet against the total quantity of households in the Arctic (%)	81.3 (2019)	82.9	…	93.3	96.3	93.9
2. The proportion of GRP generated in the Arctic zone against the total gross regional product created by Russia's regions (%)	6.2 (2018)	2.73	2.93	3.28	3.38	3.27
3. The share of added value created by high-tech and science-intensive enterprises in the GRP (gross regional product) of the Arctic (%)	6.1 (2018)	…	0.5	0.4	1.4	0.8
4. The proportion of investments into fixed capital realized in the Arctic against the total investments made into fixed capital in the entire country (%)	9.3 (2019)	5.61	7.41	6.67	5.74	4.48
5. The share of internal R&D costs and the costs of technological innovations covered by organizations in the Arctic in the total internal R&D costs and costs of technological innovations covered by organizations in the RF (%)	1 (2018)	0.02	0.01	0,02	0.03	0.03
6. The proportion of investments into fixed capital aimed at protecting and using natural resources rationally in the total amounts of investments made into fixed capital in the Arctic (%)	2.6 (2019)	…	…	2.19	0.95	1.33

The share of added value created by high-tech and science-intensive enterprises in the GRP (gross regional product) in all regions of the Arctic is much smaller than the planned figure. Thus, it can be inferred that more active growth of high technology sector and science-intensive industries is needed.

Despite the fact that the indicator "Proportion of investments into fixed capital in the Arctic against the total investments made into fixed capital in the entire country" indicates a declining trend, the YNAO shows the highest value among other territories of Russia's Arctic zone. It was 4.48% in 2019, followed by Krasnoyarsk Krai for which this indicator was 2.21% in the same year.

The share of internal R&D costs and the costs of technological innovations is low in virtually all the regions except for Krasnoyarsk Krai, where this indicator was more than two times as big as the base value established for 2019. The lowest value of the indicator is in the NAD. It is slightly higher (from 0.01 to 0.03) in the YNAO. Presumably, this situation can be explained with the fact that the area suffers a shortage of advanced technologies.

For the YNAO the share of investments into fixed capital made in order to protect and rationally use natural resources in the total investments into fixed capital in the Arctic went down from 2.17 in 2017 to 1.33% in 2019. Murmansk Oblast is the leader in terms of this indicator, where it amounts to 3.05%.

Over the past 5 years the characteristics of human capital in the Arctic have demonstrated a positive trend (Table 2).

Table 2. Target indicators of the human potential development in the YNAO comparing to the Russian Arctic [27–29]

Indicators	Base values for the Russian Arctic	The values of the YNAO indicators				
		2015	2016	2017	2018	2019
1. Life expectancy at birth in the Arctic zone (years)	72.39 (year 2018)	71.7	72.13	73.53	74.07	74.18
2. The coefficient of migration gain of the Arctic zone (per 1000 people of average annual population)	−5.1 (year 2018)	−22.3	−6.5	−4.5	−3.2	−2.4
3. The unemployment rate in the Arctic zone calculated in accordance with the methodology of the International Labor Organization (%)	4.6 (year 2019)	3.6	2.6	3.2	2.1	1.9
4. The average salary of employees in the organizations operating in the Arctic (thousand rubles)	83.5 (year 2019)	80.32	86.92	94.22	102.18	105.79

By and large, life expectancy in all Arctic regions had risen, matching the all-Russian trend, but was lower than the average Russian figure. Only three out of nine regions achieved the base value of the development strategy by this indicator: Arkhangelsk Oblast, Sakha (Yakutia) and the YNAO. The lowest level over the last 5 years is observed in the Chuckotka AD.

As for the coefficient of migration gain, divergent trends are common for the regions in the Arctic zone. Thus, the transfer from negative values (outflow) in 2015–2018 to migration gain in 2019 was observed in the Nenets and Chukotka Autonomous Okrugs. The migration outflow registered in four Arctic regions (Arkhangelsk Oblast excluding the AO, Krasnoyarsk Krai, and Sakha (Yakutia), the YNAO) was lower than the projection, which is positive news. However, the situation in Murmansk Oblast and especially in Karelia and Komi is far from being reassuring.

Migration outflow prevailed in most of the Arctic regions from 2015 to 2019, so the unemployment rates had fallen. The regions with the lowest unemployment rates in 2019 were the YNAO (1.9%) and the Chukotka AD (3.8%). They had values that were even below the claimed base indicators. Other regions were not able to catch up with the base value of unemployment rate in 2019.

The average salary of people employed by the organizations of the YNAO exceeds the pay grade established by the Presidential Decree, but the region is not the leader by this indicator. Two other Arctic regions have the actual value of this indicator above the base figure: it is 31% higher in the Chukotka AD, and 1.7% higher in the NAD. In 2015–2019 the average growth rate of this indicator in the YNAO (7.44%) makes it possible to project its value in 2024 as 113.66 thousand rubles, which is above the established criterion value too.

4 Discussion

Substantial risks accompany the present and future of the Arctic regions. We are witnessing a long-term crisis, international sanctions that have been imposed against some Russian citizens and companies, growing restrictions on the international capital markets, falling oil and gas prices, and the worsening economic situation that can bring about further recession of the Russian economy.

Considering the classification proposed by the International Expert Group on International Expert Group on Thematic Scenarios of the Future development of Russia's Costal Arctic Zone until 2050, it looks like the best development option of the Yamalo-Nenets Autonomous Okrug is the scenario called "Arctic Dragons". It can integrate the unfavorable environment of the international resource markets with the positive national policies implemented deliberately with regard to the Arctic territories. If this scenario unfolds, the unfavorable international business environment will spur the "non-oil and gas" diversification of the Arctic economy, which will lead to the advancement of the processing industry and promotion of Arctic tourism.

Some arguments can be put forward to support this statement. Over the last 10 years, oil and natural gas prices have fluctuated quite a lot, demonstrating ambiguous and unstable dynamics. They have been highly dependent on the decisions made by the OPEC countries and international policies, including the sanctions the Western world imposed on Russia.

According to the reports on the programs and schemes implemented in the YNAO over recent years, new processing production facilities were set up in the area to develop the gas-chemical cluster on Yamal: as part of the Yamal LNG project, the Yamal LNG plant has been commissioned to full capacity, the Arctic port of Sabetta has been constructed to operate round the year, a decision has been made to build the Arctic LNG-2 plant.

As for the 2035 Development Strategy of the YNAO, it is worth mentioning the plans of the region to implement fuel and energy megaprojects: the "Ob LNG" and development of gas transport infrastructure. Large-scale transport infrastructure projects are conceived, such as: The Northern Latitudinal Railway, the Northern Latitudinal Railway-2, a bridge crossing over the river Ob, modernization of airports ("Salekhard", "Novy Urengoy"), reconstruction of the network of major automobile roads. The Autonomous Okrug is going to continue developing the energy system. An industrial and logistics center and a tourist and recreational complex will be set up in Labytnangi and on the Polar Urals, respectively.

5 Conclusion

In terms of economic development, the Yamalo-Nenets Autonomous Okrug has some premises for the unfolding of the optimistic scenario. The performance of the region can be evaluated positively as it has high rates of access to broadband Internet, gross regional product, investments into fixed capital, natural resources protection and rational use. There are some threats to the optimistic scenario, which are the low levels of added value generated by high technology industries and science-intensive sectors of economy, and insufficient investments in internal R&D and technological innovations.

The conditions in the region are favorable for the development of human capital. This is evident from the figures that are lower than the base one for the Russian Arctic as well as from the stable trends towards reduction in the migration outflow from the region, as well as rising life expectancy. It can be claimed that human potential in the YNAO is in high demand and in deficit on the labor market. As a result, the region has low unemployment rates, the average salary is high and exceeds the average base values for the whole Russian Arctic.

Upon the approval of the 2035 Development Strategy of the YNAO, the target indicators should be analyzed in more detail and the scenarios for development of this region should be defined with more precision. Further research may reveal the expected outcomes of the Russian Federation government program – "The Socio-Economic Development of the Russian Arctic". The quantitative indicators measuring its execution include indicators, such as: accumulated non-budget investments into projects carried out by residents and regions whose social and economic development can be assessed as advanced; the number of newly created jobs.

Acknowledgements. This research study was conducted with the financial support of the Russian Foundation for Basic Research (project No. 19-29-07131 "Modelling and measuring human capital and forms of its manifestation in the context of economy digitalization: resources, flows, institutions").

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Artificial Intelligence in Aviation Industry

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Abstract. Artificial Intelligence is rapidly developing and being introduced into an increasing number of industries, such as medicine, agriculture and construction. This trend has not ignored the aviation industry, but it is only in its infancy. This article focuses on the technological perspectives of the aviation industry and their potential impact on the development of the industry. This research will allow the reader to gain a better understanding of the application of artificial intelligence-based technologies in the aviation industry. The article provides a proper analysis of both technologies already developed and those in the project stage, allowing the reader to gain a complete understanding of the aviation technology sector, especially within the aircraft operating stage. It discusses how the introduction of advanced technology can solve the major problems currently facing the industry, such as: high maintenance and refueling costs and environmental pollution. One of the most promising technologies for autonomous aircraft piloting is analyzed and potential areas of its application are investigated. Both the already existing spheres, within which it can be used to improve the efficiency of tasks, and the areas that may form in parallel with the final approval and launch of this technology, such as autonomous air taxis, air transportation of small and large-sized cargo, are considered, and the main problems and barriers of their implementation at the current time are presented.

Keywords: Artificial intelligence · Machine learning · Aviation · Air vehicle · Air logistics · Autonomous flight

1 Introduction

Aviation in today's world is an important component of both the economy, science and national defense. Air transport confidently holds leading positions in terms of mobility, speed and reliability, thanks to which this type of transport remains one of the most popular not only in passenger and cargo transportation, but also in performing tasks of emergency medical assistance, reconnaissance, construction of pipelines, power lines and other structures.

The fundamental issue in aviation is flight safety, which is approached rather strictly and comprehensively, starting from the stage of aircraft development, when a large number of activities on certification and testing of onboard systems and equipment is

I. Ilin et al. (Eds.): ICDT 2021, LNDECT 157, pp. 233–245, 2023.
https://doi.org/10.1007/978-3-031-24434-6_22

carried out, to the stages of operation [1]. This approach makes air transport the safest mode of transport. The risk of a commercial jetliner crash with multiple fatalities is about one in three million. Over the past 60 years, fewer people have been died in commercial airplane crashes in America than in automobile accidents in the United States in a typical three-month period [2].

However, due to strict safety regulations and industry specifics, the aviation industry is quite conservative in terms of integrating new technologies [3]. Often various technical solutions successfully used in other areas find their application in aviation only after many years. A striking example of such technology is the use of artificial intelligence, the process of implementation of which is now at an early stage, but some progress has already been made. One of the main reasons for the slow introduction of Artificial Intelligence in the field of aviation is the need for a large number of tests and certification [4].

Artificial Intelligence technology is a broad field and its definition is constantly evolving as it develops. In this article, the author will follow the definition of the European Aviation Safety Agency (EASA): "Artificial Intelligence - any technology that appears to emulate the performance of a human" [5].

Recently, the development of artificial intelligence has accelerated, aided by the evolution of machine learning, as well as improvements in computing power, storage, and communication networks. AI is not one type of machine or robot, but a series of approaches, techniques and technologies that exhibit intelligent behavior (e.g., logical reasoning, problem solving and learning), environmental analysis and taking action with a certain degree of autonomy to achieve specific goals [6]. It is anticipated that there will be various developments in the future where AI can display an even broader range of human abilities (such as creativity and intuition), or where AI outperforms humans [7].

It has been recognized that AI more effectively controls flight, within software/hardware performs prediction and decision making tasks for various tasks, such as intelligent maintenance, flight route optimization, calculation of the amount of fuel to refuel [8].

However, despite all the benefits of artificial intelligence, real problems arise. AI applications raise many ethical, social, economic and legal issues, such as who is responsible for an accident, how to protect AI from cyber-attacks or how to ensure data protection and transparency [7].

The purpose of this article is to analyze the current state of application of technologies based on artificial intelligence in aviation, as its active introduction into the industry occurred relatively recently. Also, the purpose of this article is to analyze the barriers and complexities of the application of such technical solutions. To solve this, research was conducted in the field of already implemented technical solutions, as well as promising trends in technology development and their impact on the industry as a whole. The article also analyzed the reasons for the immaturity and slow pace of implementation of such technologies in the industry.

2 Materials and Methods

2.1 Aircraft Operation Support Technologies

For the analysis of technologies based on Artificial Intelligence in support of aircraft operation, a literature search on the selected topic was conducted. The articles were searched in the databases Sciencedirect, Cyberleninka, as well as various electronic resources were used. During the analysis, including the study of thematic manuals and presentations of companies-manufacturers of air transport and software, such as Airbus and AIM Group.

Based on the information obtained, conclusions were made about the most promising technologies used in the aviation industry, analyzed the advantage of their implementation, as well as their coverage of the main tasks of aviation.

As a result, conclusions were made about the effectiveness of applying such technologies, due to the solution of a wide range of problems faced by airlines during the operation of the aircraft.

2.2 Application of Autonomous Piloting Technology

The analysis of the technology of autonomous piloting with the application of Artificial Intelligence was conducted on the basis of the thematic literature, found during the study of electronic resources and the website of the aircraft manufacturer Airbus. Based on the information obtained, conclusions were made about the area's interest in developments in this direction.

Proceeding from potential of application of technology of autonomous piloting articles with opinions of researchers of the given area in databases Sciencedirect, Cyberleninka and Scopus have been studied, and various electronic resources and sites of profile companies and developers have been involved. Based on the data obtained, the main types of autonomous flying vehicles were classified and the areas and trends of their application were highlighted.

As a result, conclusions were made about the relevance of this technology, as it has many advantages over controlled air vehicles and provides a wide range of applications, from logistics to saving human lives.

2.3 Barriers to the Introduction of Autonomous Aircraft

In reviewing the literature on autonomous piloting, it was observed that the authors point to an unprepared industry in terms of the application of this technology at this time. Based on the statements of the authors of the articles, as well as after studying the literature from Sciencedirect sources, electronic resources, as well as studying the publications of the European Union Aviation Safety Agency (EASA), the main reasons for the immaturity of the industry to such advanced technologies have been highlighted.

The main problem is the lack of prepared requirements and a regulatory framework for such aircraft, which prevents development companies from putting them into operation. However, based on the statements of EASA, it was concluded that work on solving this issue is actively underway and soon all the necessary requirements will be formed, after the introduction of which companies will be able to fully operate autonomous aircraft.

3 Results

3.1 Aircraft Operation Support Technologies

One of the main tasks facing aviation companies is to maintain the airworthiness of aircraft and ensure flight safety. For this purpose, scheduled inspections and checks of the technical condition of airplanes are constantly carried out after a certain calendar time or a certain number of hours of flight time specified in the maintenance program.

Aircraft maintenance is also one of the most important aspects of airlines' operating costs. In 2017, it was reported that airlines spent $70 billion on maintenance, repair, and overhaul, and this figure was expected to rise to $88 billion in 2018 and increase even more to $115 billion in 2028 due to the increase in aircraft deliveries [9].

A clear logistics organization is needed to support the maintenance process. The aviation engineering service of airlines makes calculations based on statistics of failures and malfunctions, as well as established resources and service life of aviation equipment and submits requests to supply authorities for the required aviation technical equipment, maintains contact with supply authorities for timely implementation of requests and uninterrupted replenishment of stocks in warehouses [10].

Nevertheless, at present, most airlines, due to the lack of components and spare parts in their warehouses for some types of aircraft, have to wait for deliveries from abroad, incurring time losses for customs clearance and logistical support (up to 14 days). [11] This leads to additional downtime of aircraft and a decrease in operational efficiency. Such situations in aviation are called Aircraft On Ground (AOG) - a condition when an aircraft cannot operate due to technical reasons. The consequence of this condition is flight delays and delays, and as a consequence, losses for airlines, and the downtime of aircraft, as a rule, is associated with high costs.

To solve this problem, various platforms are being developed to enable predictive aircraft maintenance. One such platform is RunAvia service from the Russian group of developers AIM Group. This service works using the principles of machine learning and analysis of large data streams (flight hours, takeoffs, landings, cycles, maintenance schedules, passport data on failure rates/replacement times, etc.), which allow predicting the pre-failure condition of a part in advance. Application of this approach provides a number of advantages for airlines:

1. Increased flight safety and service quality by implementing predictive maintenance measures;
2. Generation of the lists of recommended spare parts based on the number of aircraft in the fleet and operational data;
3. Optimization of the cost of the spare parts stock for the aircraft fleet;
4. Timeliness of parts delivery;
5. Reducing the number of downtime of aircraft in the fleet [12].

Based on the presented information, it is not surprising that predictive maintenance systems and services are gaining more and more attention in the aviation industry, because their integration can significantly reduce the already high operating costs of airlines.

For example, one of the largest aircraft manufacturers in the world, Airbus, has also introduced its own service "Skywise" and announced its launch in 2022. The service is capable of analyzing operational data using machine learning and generating results on the need for maintenance based on predictions. A key feature of this service is dynamic aircraft health monitoring, which allows to monitor the condition and health level of all its systems in real time. Based on the company's statements, Airbus is taking a course on the digital transformation of the entire aviation ecosystem [13].

In the course of aircraft operation, airlines incur high operating costs not only for aircraft maintenance, but also for refueling, especially given the current upward trend in aviation fuel prices. For example, the cost of the most popular type of jet fuel for civilian carriers Jet A-1 increased by 40% in 2021 (Fig. 1). [14] Over the last decade, fuel costs have averaged 28.2% of total operating costs. This is why an accurate estimation of fuel consumption is of paramount importance for airlines in terms of profit, since each extra ton of kerosene adds weight to the airplane and, consequently, increases fuel consumption during the flight. Filling more fuel on board not only increases the weight of the aircraft, but it also affects the performance of its engines in the long run. This ultimately shortens the life of the engines, which need more frequent maintenance than planned [15].

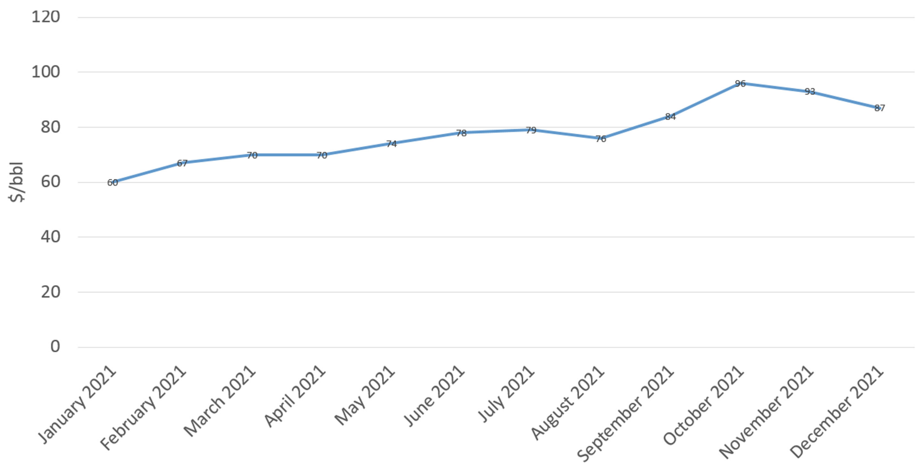

Fig. 1. Average Jet A-1 fuel price for 2021

In addition, the increased fuel consumption of airplanes provokes an increase in the amount of pollutants emitted into the environment. Atmospheric pollution near large airports and at cruising altitudes is currently considered not only a local problem, but also a global one due to climate change and destruction of the Earth's ozone layer [16].

At the moment, estimation of fuel consumption for a flight is usually performed using engineering approaches and calculations, taking into account the number and power of engines, flight distance, mass of the aircraft, planned weather and nature of the flight. However, the actual flight characteristics usually deviate from the predicted ones. The reason for this is that it is difficult to accurately determine all the required factors for the calculations, especially for the takeoff and landing phases, where the actual values deviate from the predicted ones by 22.3% on average, against 3% for the cruise flight phase. In order to solve this problem, a Cascade principal component least squares (CPCLS) neural network model was developed. To train the neural network we used the data from one of the airlines that operated international flights in different regions for two years. Based on the training sample CPCLS was trained to predict the value of fuel consumption as close to the actual value. As a result, the neural network learned to predict fuel consumption for the entire flight with an average error of 1%, which proved its own effectiveness [15].

3.2 Autonomous Piloting Technology

The high level of air transport safety is also ensured by the skill and qualification of pilots who have thousands of hours of flight time and profound knowledge of the theory and practice of flight operations. Nevertheless, according to the data of the Inter-State Aviation Committee (IAC) in 2011, the main causes of air accidents in Russia in 80% of cases are deviations in the actions of flight personnel during the execution and organization of flights, and only in 20% of cases - failure of aircraft equipment [6].

To reduce the influence of human factor in aviation, auxiliary systems are constantly being developed, for example, “Automatic Flight Control System” (ABSU) - a long-established system that automates a range of different tasks, in order to reduce crew fatigue, improve safety and increase flight efficiency. It allows to maintain optimum speed and course, to land the aircraft according to the course-glide system. However, ABSU is not independent, is constantly monitored by the pilot, and usually gives him recommendations during the flight [17].

Airbus, the aircraft manufacturer, decided to develop a new autonomous taxi, take-off and landing (ATTOL) system. This system implies full automation of taxiing on the airfield, taking off and landing of the aircraft. The ATTOL is based on the machine vision technology based on the video data from the video cameras located on the airplane hull. More than 500 test flights were conducted during system testing, of which 450 were dedicated to collecting raw video data and fine-tuning algorithms, and a series of six test flights, each of which included five takeoffs and landings, were used to test autonomous piloting capabilities. In 2020, Airbus SE reported the successful completion of the ATTOL project and stated that, based on the experience gained, it would gradually integrate artificial intelligence technologies into aircraft technology [18].

It is worth noting that the principle of visual piloting can not only improve flight safety, solve the problem of the distribution of echelons in the airspace of airfields and reduce the intervals between takeoffs and landings of aircrafts, but also open the way to completely new directions in the aviation industry.

Autonomous Drones

One such area is the use of autonomous drones. The drone market is already showing a big jump in development. Drones came from the military-industrial complex and are being actively introduced into business and private life. They are used for aerial surveys, agricultural surveillance, and engineering and surveying (Fig. 2). Interact Analysis analysts say the commercial drone market will grow tenfold to $15 billion by 2022.

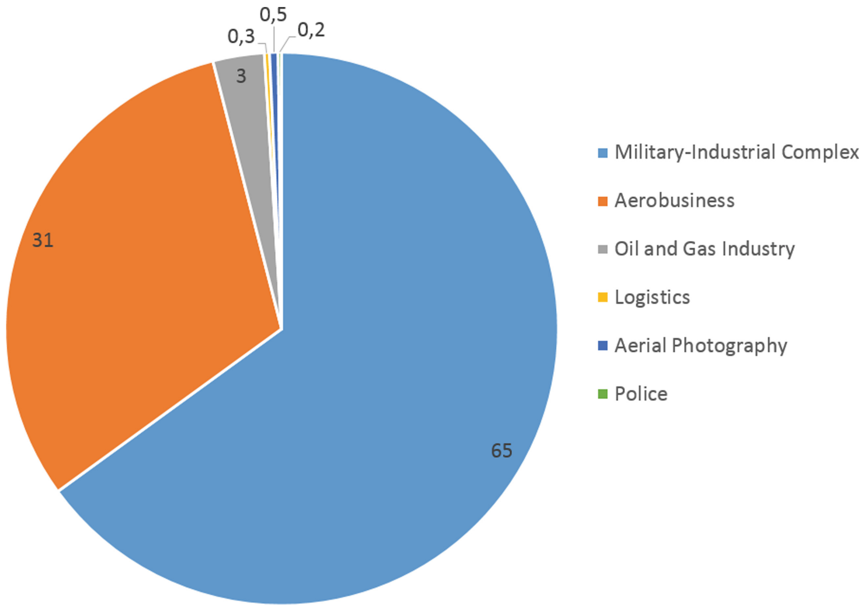

Fig. 2. Areas of application of drones

One of the potential applications of autonomous drones is air logistics. For example, in 2020, Amazon, the most popular online store in the U.S. in terms of electronic sales, received permission from the U.S. Federal Aviation Administration for commercial delivery of goods by drone. For this purpose, the company uses a drone of its own design: the MK27 hexacopter, capable of lifting loads weighing 2.5 kg and transporting them to a distance of up to 12 km. Such parcels account for 75% to 90% of all Internet orders. When delivering goods over such short distances, drones can have a 37% cost and 60% time advantage over ground transportation.

However, for the full implementation of air couriers, some issues need to be resolved, such as finalizing the rules for flying drones over populated areas, the responsibility of drone owners, and privacy when using cameras on drones.

Amazon, as one of the innovators of smart logistics, has already made a patent for warehouses, “hives” with multi-level parking lots for drones. Deutsche Bank analysts predict that in ten years, drones will be able to reduce the unit cost of each Amazon product by 1.5 times [19].

Nevertheless, the capabilities of autonomous drones will allow them to be used not only to deliver goods, but also to respond to natural disasters and provide humanitarian assistance. Two categories of autonomous drones can be distinguished within this direction, performing different functions:

1. Post-disaster damage assessment;
2. Logistics of light humanitarian cargo.

Drones performing the first function involve the use of high-resolution cameras in real time to quickly assess infrastructure damage after any natural disaster. According to calculations, five such drones are enough to fly a seven-kilometer perimeter at an average speed of 60 km/h for 25–30 min. Similar drones in manned mode are already used in countries suffering from major earthquakes and tsunamis, such as China and Japan. In China, quadcopters have already proved their value in assessing damage from earthquakes such as the Sichuan earthquake in 2008 (69,000 dead and 18,000 missing).

Drones in the second category involve the delivery of basic essential supplies to provide survivors in any disaster, such as water and food, basic medicines and equipment, LED lights, and receivers for emergency communications in remote areas [20].

In addition, in times such as today, when the world is hit by the COVID-19 pandemic, research is underway into the use of drones to deliver emergency medical kits and collect samples for tests. The results show that the use of drones in emergency medical care can greatly facilitate specimen collection, optimize the speed of response and delivery of patient care, all of which will help save more lives [21].

Autonomous Cargo Aircraft

However, the drone market is not limited to compact drones. In today's world, more and more attention is being paid to the concept of cargo drones capable of carrying heavier loads over long distances. China is particularly interested in such drones because it has a very diverse landscape with hills, mountains and plateaus occupying more than two-thirds of the total land area. This makes it very difficult to build highways, railroads, and commercial airports, making it difficult to develop land, rail, and air freight transportation in these regions. On the other hand, these constraints are stimulating the development of a potentially promising market for autonomous drones for cargo delivery. Some logistics companies, such as SF-Express, are developing both light and heavy aircraft, with payloads ranging from 10 kg to 1500 kg and a maximum flight range of 20 km to 1200 km [22]. Also of particular interest is the Beijing startup Sichuan Tengben Technology, which is developing an unmanned aerial vehicle capable of carrying 20 tons of cargo and flying up to 7,500 km [6]. Such drones are expected to be used for the following tasks:

1. Transportation of cargo from airport to airport;
2. Parachuting cargo to the destination [21].

It is worth noting that the concept of drones is considered not only for cargo delivery in the difficult landscape of China, but also in the Arctic zones of the Russian Federation. On October 26, 2020 the President of the Russian Federation signed the Decree "On the strategy for the development of the Arctic zone of the Russian Federation and ensuring national security for the period up to 2035". This document defines the measures to achieve the main objectives of the development of the Arctic, their stages and the expected results of the implementation of these measures, including the development of digitalization. One of the promising areas within this trend is the development and operation of unmanned aviation systems and unmanned aircraft equipped with artificial intelligence systems. The use of drones in the Arctic zone has economic feasibility and corresponds to the directions of digitalization of the economy and the introduction of workable technologies, and drones of permanent Arctic basing will be the key to the competitiveness of the Russian Federation in the Arctic [23].

For 2021, the operation of drones in all regions of the Arctic zone of the Russian Federation is episodic. Each flight is carefully planned, carried out exclusively in normal weather conditions during daylight hours and in conditions of known terrain and terrain. However, unmanned aerial systems perform a huge number of functions of a regular nature:

1. Mapmaking, high-resolution photography and video;
2. Delivery of cargo, including medical supplies;
3. Wildlife research;
4. Assistance in case of a dangerous situation;
5. Designing routes and determining infrastructure installation points [24].

In order for drones to perform their tasks systematically, they must become all-weather and capable of performing their functions regardless of conditions. Only in this case can they become really useful and economically profitable, because any downtime only brings losses.

Separately, the need for autonomous piloting without manual control by an external operator should be noted. Only in case of implementation of such technology, it is possible to achieve regular flights, similar to manned aviation, on the same route and flight plan, which helps to reduce costs for external pilots at points of departure and destination [25].

Autonomous Air Taxis

In addition, one of the promising areas of application of artificial intelligence for piloting is autonomous air taxis. This is a completely new class of aircraft, which, compared to classic helicopters, will be safer, quieter and cheaper to operate and maintain. Given the current limitations of flight duration, due to limited battery capacity, most of the research into the use of air taxis to date has focused on inner-city or urban routes. However, there are plans to expand to regional and intercity missions in the coming decades. The concept of autonomous air taxis is revolutionary, especially when coupled with the use of real-time transportation reservation information platforms such as Lyft or Uber.

Expectedly, the potential for large-scale aerial operations within cities has caused a major furor in the field of aeronautics, as evidenced by the fact that more than 1,000 test flights of full-size autonomous air taxis were conducted in 2019 [25].

Such major companies as Airbus, Boeing, Uber and Rolls-Royce are doing the development of air taxis, and startups are constantly being founded, presenting equally interesting working prototypes. However, despite the large number of developments and successful tests, test launches of air taxis are constantly postponed due to the lengthy preparation of requirements for autonomous aircraft [26].

3.3 Barriers to the Introduction of Autonomous Aircraft

At the moment, the proliferation of capabilities provided by drone-related technologies and techniques is limited by existing restrictions on the use of drones at certain sites. These restrictions are caused by safety hazards arising from the flight of autonomous drones, such as collisions with vehicles, dangerous technical elements of road infrastructure or people. The risk of drones colliding with other objects can be considered low, but the consequences of such an accident, according to studies, can be quite serious, especially considering that the weight of professional UAVs already reaches tens of kilograms, and some models of drones run on liquid fuel [27]. This trend underscores the importance of the safety aspects of drone operation, which requires comprehensive research in this area to develop appropriate safety measures and procedures [28].

According to EASA, the aviation industry may obtain approvals for the use of Artificial Intelligence in air transport by 2025, with the prospect of expanding the use of this technology for commercial and transport aircraft in 2035. The agency published an AI Roadmap based on AI trustworthiness to tackle the ethical and societal issues around AI, which declares the importance of an ethical approach to artificial intelligence to build citizen trust in the technology. In addition, ethical principles should be based on existing regulatory frameworks. As a result, the following seven key requirements for reliable Artificial Intelligence were identified: Accountability, Technical robustness and safety, Oversight, Privacy and data governance Non discrimination and fairness, Transparency, Societal and environmental well-being. At the moment the guidelines are not mandatory and do not impose any legal obligations, but over time the agency will test and improve these criteria for full approval of the full list for certification of drones [5].

Another problem with the introduction of drones is the infrastructure of cities. At the moment they are not adapted for autonomous flights. For the successful integration of this type of transport in cities, it is necessary to equip places for takeoff and landing and to think about the regulation of traffic [26].

4 Discussion

Artificial Intelligence-based technologies are among the most promising for implementation in the aviation industry, as evidenced by the large number of research papers devoted to this topic. Despite the conservatism of the aviation industry, major airlines are already interested in Artificial Intelligence and are conducting their own developments in this area, and promising startups are appearing in the market. The analysis revealed that such interest is due to the large number of advantages offered by advanced technologies. They can help airline operators to reduce the operating costs of aircraft maintenance and service, as well as reduce environmental damage from flights. All this can not only solve the major problems facing the aviation industry, but also affect the improvement of flight safety, as well as reduce the cost of services provided by airlines.

Autonomous piloting technology was considered separately. During the analysis, it was concluded about potential areas of its application. First of all, this approach is actively considered for application in the transportation of small and large-sized cargo, which can contribute to solving a number of problems, such as delivery to hard-to-reach areas, humanitarian aid in emergencies and even medical assistance in a global pandemic situation. Secondly, autonomous drones can be used to solve a wide range of tasks related to terrain exploration, aerial photography, as well as the construction of routes. The third promising area for the application of autonomous piloting is a completely new type of transport - air taxis. As part of the current trend of increasing road traffic, this type of transport can be an excellent solution within large cities.

However, to fully implement and introduce autonomous piloting technology into our lives, it is necessary to solve a number of issues related to the regulation of autonomous air vehicles, the development of requirements for their certification procedures, as well as the equipment of special places for convenient operation.

5 Conclusion

Artificial intelligence could revolutionize the aviation industry, and it will not happen in some distant future, it is happening now. Artificial intelligence is already helping to make transportation safer, more reliable, more efficient, and cleaner by introducing systems to predict how much fuel is needed for refueling, as well as predictive maintenance systems. Autonomous piloting technologies could revolutionize aviation. Autonomous drones can deliver goods, respond to natural disasters and provide humanitarian assistance. Autonomous drones can be used to deliver bulky goods as well as perform a wide range of tasks in hard-to-reach areas. Also, based on autonomous piloting technologies in aviation, completely new types of aircraft may emerge, such as autonomous air taxis, which in the future may take the lead in air passenger transportation.

However, in order to fully utilize the full potential of smart technology, it is necessary to resolve a number of issues on the regulation of Artificial Intelligence in the industry.

Research in this direction could continue. This could be a study not only of civil aviation, but also of military aviation, which also pays great attention to new technologies and has its own unique range of tasks, in the solution of which technologies based on Artificial Intelligence can help. There could also be separate studies on a particular range of aviation technologies or aircraft for a broader analysis of their application in different fields, such as the oil and gas industry, the agricultural industry or the field of scientific research.

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Data Management in the Offshore Wind Farm System

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Abstract. The paper analyzes the problems of construction and operation of offshore wind farms focusing on their design, remoteness to the location, transportation and installation. The main problem considered in the work is the timely maintenance and repair of offshore wind turbines in the Arctic region and minimization of accidents and environmental damage. The aim of the study is to develop a data management model of wind turbines to minimize emergency situations. Simulation of design, transportation and installation of offshore wind farms is performed by an alternative graph in conditions of multi-variant structure components. The approach proposed for determining the value of particular indicators is based on simulation modeling. An agent-based approach is used assigning agents to the system objects and building relationships between these agents. Modeling was carried out in the Anylogic program.

Keywords: Arctic strategies · Energy · Offshore wind farms · Ecology and climate · Energy supply of the arctic territories · Data management methods

1 Introduction

Power supply is a pressing issue for the Arctic. The strategic guidelines of the Arctic countries are aimed at sustainable energy development. These goals are also outlined in the strategies of the circumpolar countries. For the countries with territories in the Arctic region, the measures to ensure energy supply and security are dictated by specific living conditions due to the nature and climate of these regions. On the one hand, the active development of the Arctic region facilitates the spread of technologies towards the territories of northern latitudes. However, difficult climatic conditions, remoteness from the cities, melting of permafrost soils and glaciers raise serious concerns and are sources of serious restrictions for ongoing or planned projects. On the other hand, renewable energy sources are gaining increasing popularity. This paper focuses on wind energy, the system of offshore wind turbines, in particular. Long distances, unpredictability of weather conditions, technical complexity of organizing system control make adjustments in the implementation of the project. Data management in the offshore wind turbine system in the Arctic region of the Russian Federation is considered in terms of the design

I. Ilin et al. (Eds.): ICDT 2021, LNDECT 157, pp. 246–263, 2023.
https://doi.org/10.1007/978-3-031-24434-6_23

of complex systems and their further functioning in conditions of climate instability. Special attention is paid to the emergencies that have already occurred in this region.

The analysis of works on the problem revealed scientific interest in studying various issues of supplying energy to the Arctic territories.

The article [1] analyzes the problems of installation of offshore wind farms and the division of the general design problem into several subtasks, i.e. the methods of installing wind turbines at their place of operation are considered separately. In the course of the study, the authors come to the conclusion that in the future, different mechanisms that determine different approaches will be designed. In other words, it is necessary to develop the models that can be transformed into each other, be flexible to achieve high accuracy and design speed.

The work [2] discusses the limitations for floating wind farms, such as design, remoteness to the location, assembly and installation method. The weather conditions are taken into account when installing wind stations in the sea. The authors provide an overview of some weather forecasting methods: the Markov model, collection of information from buoys. It is concluded that the complexity of the forecast is still a decisive factor when choosing a transportation route.

In [3], a new way of comparing factor pairs in determining the constraints for wind farms in the sea is considered. This approach is based on the Representative Cost Ratio (RCR), which compares pairs of factors to interpret the relationship between the importance index (importance intensity scale) and its descriptions. In this method, all constraints are considered at the beginning of the analysis and then combined into one bit mask. The data undergoes a standardization process to facilitate the final accumulation by introducing a new scale for assessing the factor. Further, two matrices are constructed for pairwise comparison. The first matrix is a pairwise comparison matrix with the same number of rows and columns, and the second is a normalized matrix that is created by dividing each element of the matrix by the sum of its columns. The authors propose this relatively simple but reliable method to determine the most suitable regions for offshore wind energy.

The study [4] proposes using wind turbines in conjunction with an array of tidal flows. This interaction reduces the cost of generating electricity by increasing the amount of energy and reducing the capital cost of installed capacity.

The authors used the energy trace superposition model to estimate the amount of energy. To assess the costs, the impact of peak loads was considered, which showed positive dynamics compared to classical wind turbines. The paper shows that the estimate savings amount to 10–12% in capital costs in the joint operation of tidal centers and wind turbines.

Scientific work [5] discusses the effect of wind farms on animals in the southern part of the North Sea. The work examines the impact on animal populations in terms of seasonality. Animals are exposed to the greatest anthropogenic influence during the breeding season and in spring, and the damage is estimated at about 50%, depending on the species. The authors cite the European Commission's estimate that 240–450 GW of offshore wind energy will be needed by 2050 to keep temperatures below 1.5° during climate change.

Paper [6] analyzes the production of electricity over the past 20 years. The authors note that electricity generation contributes 40% to global CO2 emissions, as the production cycle uses natural gas, oil and coal. The demand for renewable energy sources has increased in the last 10 years, and the demand for wind energy, in particular, has grown by about 85%. However, modern technologies, the size of wind turbines produce a large amount of greenhouse gases, analogues of CO2, which can vary depending on the geographic location. A multivariate analysis of the intensity of greenhouse gas emissions was performed and a scatter plot matrix was built. Three configurations were considered separately to make the study consistent: single turbine, onshore wind farms, and offshore wind farms. It is concluded that offshore wind farms provide high power generation at extreme wind speeds at sea when using a large hub height and larger rotor diameter.

In the study [7], the dynamics of the market value of wind and solar energy in Germany is considered using time series by regions, which reflect the technological composition and distribution of capacities. Offshore wind power is ranked as the most stable in terms of green energy market value. Stronger decreasing pair correlation of wind generation over distances leads to more pronounced differences in regional value factors. The analysis indicates the existence of a significant negative relationship between the regional power density of wind energy and regional value factors.

In paper [8], the analysis of past incidents is divided into two parts. First, the authors propose a statistical analysis of incidents caused by weather conditions in the Arctic such as strong wind, stormy sea, temperature drops. The authors also analyzed regions where environmental hazards are similar to those in the Arctic. The incidents were classified according to their severity into five damage scales. Most incidents were recorded in the North Sea region, accounting for 86% of the total. Second, attention was paid to deficiencies in safety measures, design requirements, operational planning and component reliability. Importantly, the most frequently damaged offshore structures were semi-submersible platforms, followed by vests, jacks and concrete support structures. A large number of incidents involved helicopters and loading buoys, while other structures were less affected by natural disasters. In addition, emergency management plays a critical role in preventing major casualties and protecting crew members in the event of an accident. Emergency planning requires considering possible extreme natural events at the site of an operation so that it would be effective under all circumstances. There is a need for improved safety management methodologies that can cope with both natural and technological risks and ensure that risk-informed decisions are made. In addition, stakeholders should be aware that with the expansion of offshore operations, the risk of multiple and simultaneous incidents during storms will also increase, as well as risks to the Arctic environment.

The study [9] examines technologies in the wind energy sector that may be implemented in the future. Among them there are mobile systems with the help of attaching to the ground with cables, which is also possible to do with the drones. These systems have a simple design, which greatly reduce the cost of the initial investment, since less material is required for their construction. However, there is little research concerning the susceptibility to corrosion, difficult climatic conditions, uniformity of power supply. The concept of synergy of wind and wave energy in the framework of hybrid platforms at sea is developing now, an example of which is the Blackbird system in Amsterdam. A similar project was implemented in the North Sea. Various structures of propellers and aeroelastic systems were considered. In this case, the vibration of mechanical systems is used to produce energy.

In paper [10], it is noted that offshore oil and gas activities must comply with the rules on zero adverse impact on marine biological and ecological resources. Compliance with this rule is verified by the industry and independent research institutions. The focus of exposure-based marine research has shifted towards the potential impacts that could result from chronic exposure to low concentrations, especially in benthic fish populations, due to increasing emissions and remaining uncertainty about impacts on marine water resources.

In paper [11], the study is carried out for the Longyearbyen region in Norway, which is located at a distance of one thousand km from the North Pole. The authors determine the renewable energy potential in the region through modeling. It is worth noting that the joint use of sun and wind as energy sources in the Arctic can be quite effective. The authors propose a model for assessing the potential of renewable energy sources with limiting the needs of the population and replacing existing thermal farms. This model can be extended to other regions.

The study [12] examines the impact of new technological factors on the legal system in the Arctic and the scientific developments in the field of studying the seabed, such as ice observatories, seabed structures and satellite remote sensing. These progressive methods are difficult to implement in the existing legal framework of UNCLOS due to the complexity of the legal organization of research on the territories of foreign countries relative to the research state.

Changes in the existing international treaty are rather difficult to announce, therefore the authors propose to develop additional legal documents stipulating the procedure for scientific research.

For climate modeling, four scenarios of future weather data were created in paper [13] to estimate variability and spectrum of changes. The division is based on parameters of global temperature and atmospheric circulation. As a result, yield variability in the region is indicated by 20–30% with an overall cooling due to melting ice and permafrost in the Arctic. This factor also affects the weakening of wind energy generation, as wind systems are not yet ready for temperature extremes.

The study [14] is based on modeling wind speed, estimating wind speed and limiting land use on the Arabian Peninsula. As a result, the options have been developed that can be implemented in the region. Sources of uncertainty for further investigation include turbine degradation, the role of dust and the impact of the footprint on actual wind turbine operation and power generation. Sandstorms are particularly frequent in Saudi Arabia and more experimental and model studies are needed to quantify the potential impact of sandstorms on turbine performance. The modeling framework presented in this paper may prove useful to other countries seeking to strengthen their wind energy infrastructure.

The review of scientific research revealed the main trends in the technological development of wind energy. For example, there are projects of wind farms that do not have a stable attachment to the ground, but are attached to cables, and there also developments in the field of manned quadcopters with the function of generating electricity. This approach saves on the initial investment, increases the system's resilience to climate change and increases the efficiency of power transmission to the distribution point. However, a number of questions are open regarding the strength of anchorage to the ground, as well as the ability to control objects in the air. In terms of environmental impact, noise is emitted from wind plants as well as from blades, due to which the surrounding animal world suffers greatly. Birds are known to be accidentally hit by the blades. WPPs have a particularly strong effect on birds during the breeding season, since the animals are weakened and have small offspring that cannot fly high enough.

From the point of view of the economic field, wind farms have not yet revealed their potential, as they are considered a rather expensive way of generating electricity due to the high cost of investment. Also, there is a problem of transmission of electricity over long distances, which undoubtedly requires additional costs. In addition, there is the issue of designing offshore wind farms. The difficulty lies both in the transportation of the necessary materials and equipment, and in the construction and installation.

However, the Arctic region can be called promising for the development of renewable energy sources due to strong winds in this region.

That is why the main problem considered in this work is modeling the processes of timely maintenance of offshore wind farms in the Arctic region to minimize emergency situations and environmental damage. Solving data management problems in the system of offshore wind turbines makes it possible to provide reliable energy supply to the Arctic territories.

The object of this study is the system of offshore wind farms.

The subject of the research is data management in energy structures and complexes.

The purpose of the study is to develop a data management model in the system of wind turbines to minimize emergency situations.

When analyzing the problem, the following particular tasks were identified that need to be solved to achieve the goal: the design of offshore wind farms; the location of the energy complex; the impact of the system on the environment; the approaches to data management in energy supply; data management in the system of wind turbines; data management models and methods.

2 Materials and Methods

2.1 Research Methodology

The methodological basis of the research is the theory of systems modeling. The theory of systems modeling is the theory of replacing the original object with its model and the study of the properties of the object. Within the framework of the study, the wind energy system is replaced by an alternative graph and the study of the wind energy system is performed on an alternative graph. The partial numerical solutions of the formulated problem are obtained on the basis of simulation modeling in the Anylogic program.

2.2 Modeling in Anylogic

As a modeling method, an agent-based approach was chosen, which consists in assigning agents to various objects and building relationships between the agents. This approach helps to model middle-level processes that affect both the entire system and the external environment. In agent-based modeling, the parameters of active objects - agents are first established, and their behavior is determined. Any object that is important for the system can be represented as an agent: people, households, cars, equipment, even products and companies. Then the connections between the agents are established, the environment is set, and the simulation is started. The individual actions of all agents make up the behavior of the whole system being modeled.

3 Results

For a broader consideration of the problem, the design stage of offshore wind farms has been analyzed. An alternative graph of the wind farm has been built and the factors influencing both the design of the system and the further operation of the system have been highlighted.

During the design process, it is necessary to process and store a large amount of data. It should be noted that the quality of the data is also of great importance, since the further management decisions will strongly influence the operation of the facility.

Taking into account the peculiarities of the Arctic region, such as difficult climatic conditions, temperature instability, melting of permafrost and transport inaccessibility, the design of complex objects requires special attention.

The alternative graph has been built, with the factors that have the strongest impact on the cost and environmental assessment of the project (Fig. 1).

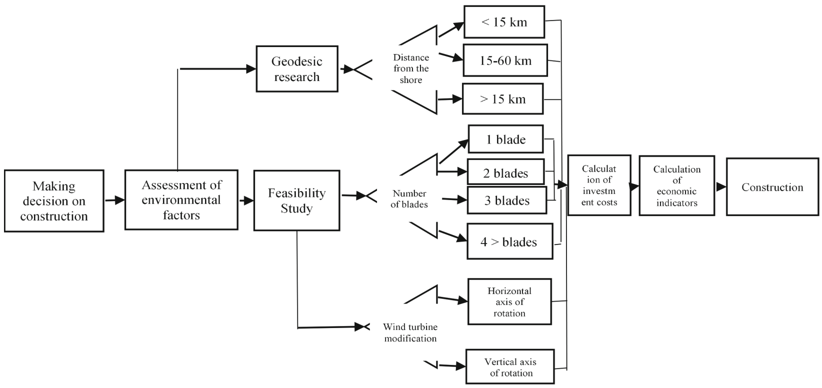

Fig. 1. Wind farm (WPP) design graph.

Figure 1 shows the options that can be implemented when designing a wind farm. Depending on the chosen option, the cost of the project implementation and its profitability during operation will change. For example, the distance from the coast will determine the additional equipment besides wind turbines, as well as the length of cables through which electricity will be transmitted. In this regard, both investments and current expenses for the supply of electricity will increase.

To assess the variability of alternative options and the subsequent decision-making, it is necessary to consider the factors that affect the WPP system. During the analysis, large groups of factors were identified such as economic, environmental, political, socio-cultural ones and information.

For each of the groups, indicators are identified that can be taken into account over several periods to calculate the average values.

These indicators should be considered within the framework of the state where the project is planned, which is due to significant differences in the groups of factors. In this study, it is the Arctic region of the Russian Federation (Fig. 2).

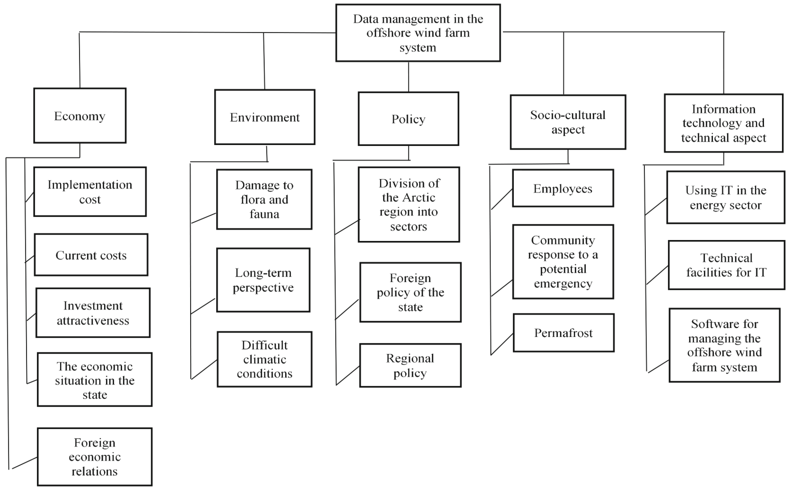

Fig. 2. Factors affecting the system.

For a more detailed consideration of the maintenance of offshore wind farms, modeling in the Anylogic program is used. Within the framework of the study, two types of maintenance work are considered: regular maintenance and emergency (urgent) maintenance.

For the first type of work, the following restrictions are set:

– maintenance is carried out every two weeks;
– the maintenance team travels to the turbine by sea transport;
– the time of work is 10 h.

For the second type of work, the following restrictions are set:

– the average time between breakdowns is 50 days;
– the troubleshooting team arrives by helicon ter;
– troubleshooting time is from 10 to 20 h.

The process of modeling is based on an agent-based approach, which consists in assigning all participants an agent role, indicating the limitations, distinctive features and description of actions for a specific task.

Modeling starts with identifying the agents that are involved in the process. In this study, these are:

- wind turbines (10 units);
- helicopters (2 pieces);
- sea transport (5 units);
- service center (singular);
- an additional agent - transport.

This gives us the first view of the model, showing the vehicle types, wind turbines and service center. The result is shown in Figs. 3 and 4.

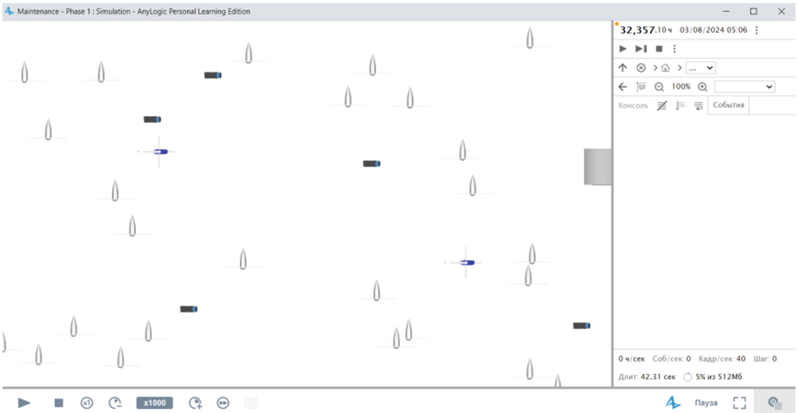

Fig. 3. First stage of modeling.

Further, it is necessary to indicate the logic of actions for each type of transport, with the help of the state chart.

By defining states and transitions, it is possible to specify the conditions under which a helicopter or sea transport will move from the service center to the turbine.

A diagram is created inside the Transport object. The initial state AtCeneter reflects the location of the vehicle in the service center. Further, when the error message is received, the state changes to MovingToTurbine, which means the movement of vehicles to the turbine. The next transition reflects the completeness of the previous state, that is, when the transport arrives at the turbine, and the maintenance work Servicing begins. Further transition is carried out according to the timeout, which is set for each type of transport, causing the MovingToMC state - returning to the service center. The branching of the transition occurs to work out the cycle, which indicates the need for further repair, that is, the transition to the next turbine, or return to the service center, if there is no need for maintenance. The result is shown in Fig. 5.

Fig. 4. Second stage of modeling.

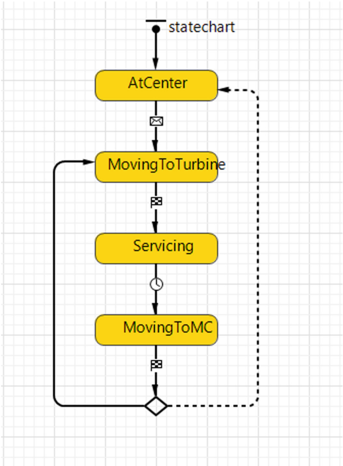

Fig. 5. Transport state chart.

The fourth step in modeling is to identify the actions of the service center. Management of the same type of data elements is carried out using collections, for which it is possible to set common parameters. This simplifies the interaction between agents, as well as further modeling.

That is why two classes are defined for vehicle types that affect the entire project. Graphic representation is shown in Fig. 6.

Further, it is necessary to indicate the functioning of the transport using an algorithm with a cycle. In this case, the type of request for repair work is analyzed, and it is checked

Fig. 6. Classes of vehicle types.

whether the required agent is free at the moment. So, when modeling, vehicle movements to turbines for carrying out repair work are displayed.

The next step in the simulation begins with setting the parameters for determining the time intervals of the turbines. The first parameter is the average time before the accident, which is 50 days by default. The second indicator is the timing of scheduled maintenance - 2 weeks by default. Next, a function is added to manage transport requests (Fig. 7), which links the state of the turbine and the need for a specific transport.

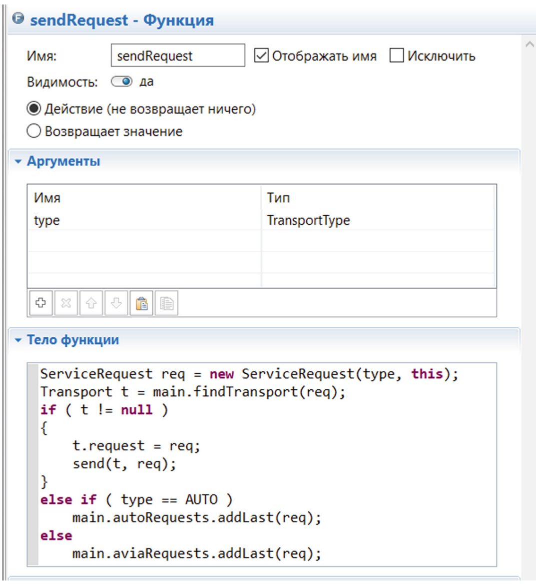

Fig. 7. Transport request management function.

Now it is necessary to indicate the behavior of wind turbines, which is also done using a state chart. The description of the turbine states includes three values: normal, scheduled maintenance, and malfunction. As shown in Fig. 8, the states Normal and ScheduledService can change when a message is received about the need for scheduled maintenance or about the performed scheduled maintenance, respectively. The Failure state occurs at a predetermined rate, as previously indicated, every 50 days. The result of the leveling of the breakdown is transmitted by a message to the state of the operating unit.

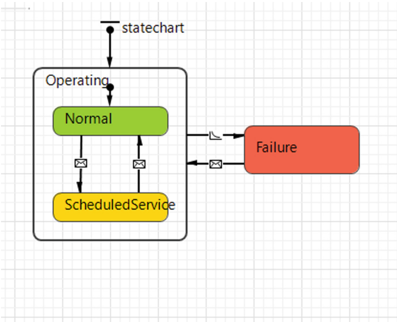

Fig. 8. Turbine state chart.

To display the breakdown of the wind turbine, it is possible to adjust the mechanism of the movement of the turbine blades. On the properties tab of the location and size of the agent, we establish a connection between the state and movement of the blades. The changes are shown in Fig. 9.

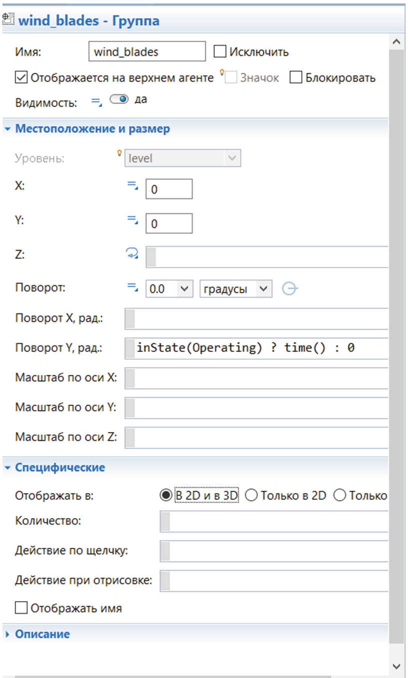

Fig. 9. Modifying the properties of turbine blades.

At this stage, the display of the model has changed, an indication of the operation of the turbines, which occurs in the case of a breakdown, has been added. Turbines that require regular maintenance are highlighted in yellow, unexpected breakdowns with the need for emergency repair, are highlighted in red. Figure 10 shows modeling at this stage.

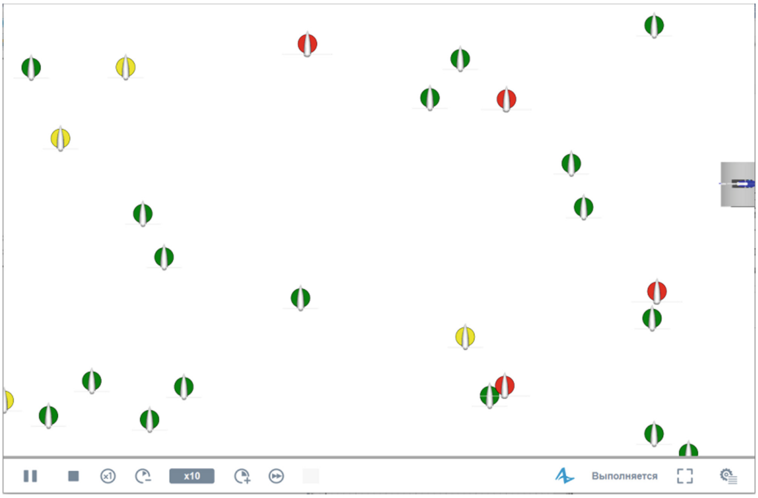

Fig. 10. Fifth stage of modeling.

The next step is to add actions to the transport state chart. For example, when moving from AtCenter to MovingToTurbine, the action is moveTo (msg.turbine). The transition to Servicing is carried out upon the arrival of the agent. The vehicle, upon reaching the wind turbine, begins to carry out repair work, and therefore, it does not require additional actions. Further, when the timeout goes to MovingToMC, the action is launched, which indicates that the repair was completed and it was returned to the service center. The process is shown in Fig. 11.

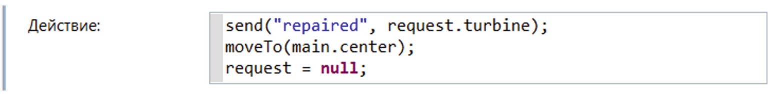

Fig. 11. Transition from Servicing to MovingToMC.

When branching transitions, one of them leads to the MovingToTurbine, and the condition and action are specified for it. The first serves as a check for the available requests from the turbines, the second determines which specific request was received and what kind of transport is required. The encoding is shown in Fig. 12.

Now all the necessary agents and interactions between them are modeled and it is possible to run the model. The results are shown in Figs. 13, 14, 15, 16, 17, 18 and 19.

Условие:

```
type == AUTO
        ? !main.autoRequests.isEmpty()
        : !main.aviaRequests.isEmpty()
```

Действие:

```
request = type == AUTO
        ? main.autoRequests.removeFirst()
        : main.aviaRequests.removeFirst();
send(request, this);
```

Fig. 12. Transition from MovingToMC to MovingToTurbine.

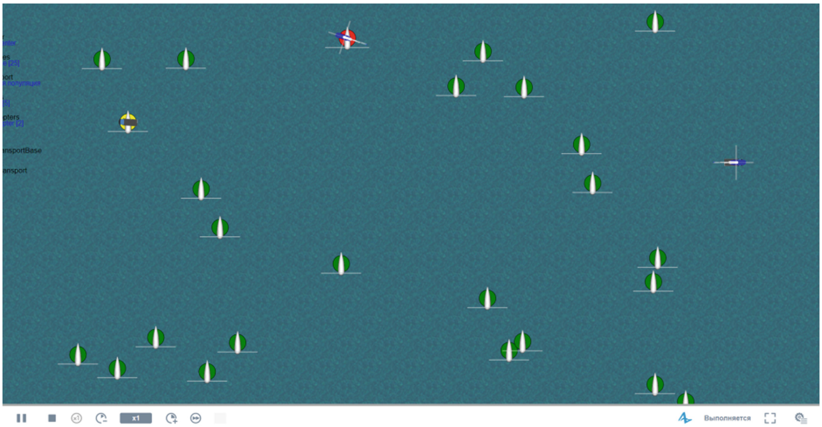

Fig. 13. Start modeling.

Fig. 14. The example of vehicle movement.

Fig. 15. The example of troubleshooting.

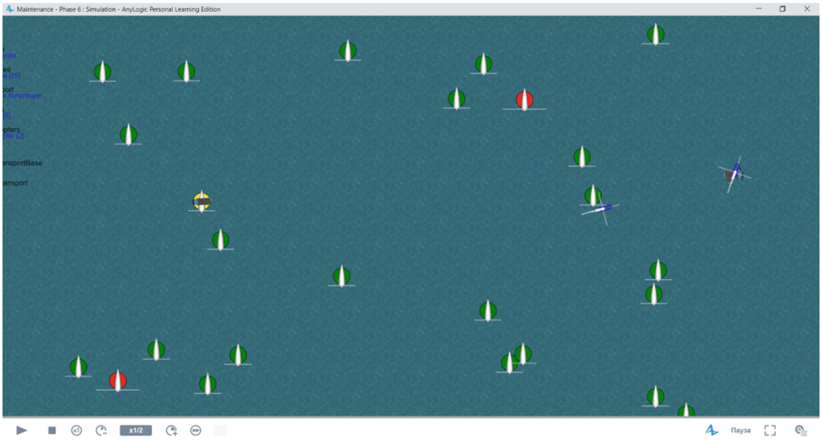

Fig. 16. The example of vehicle movement after troubleshooting.

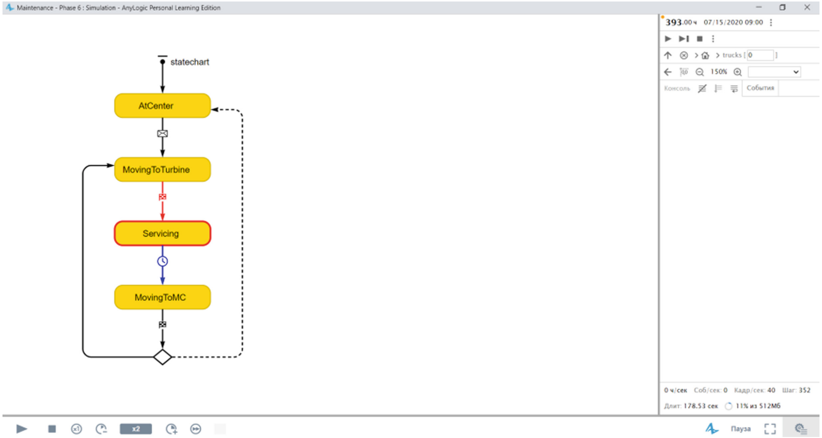

Fig. 17. Enlarged functioning of transport during simulation.

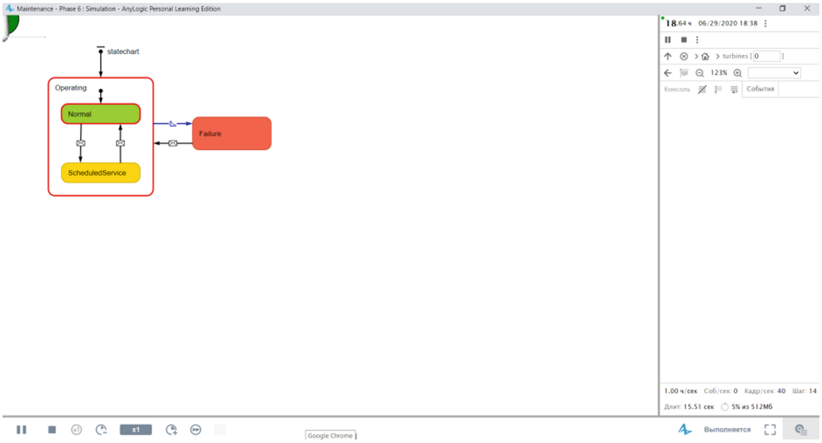

Fig. 18. Enlarged operation of the turbine during simulation (operating state).

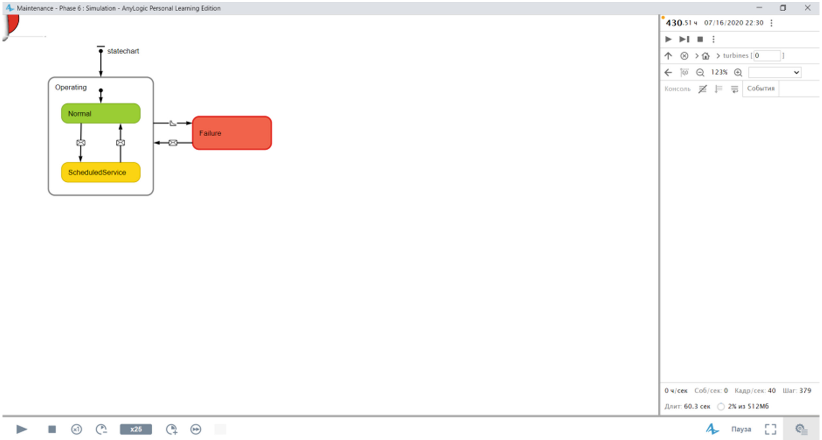

Fig. 19. Enlarged operation of the turbine during simulation (emergency state).

4 Discussion

The construction of the model began with the definition of the agents that participate in the process. Our model consists of the following agents:

– wind turbines (10 units);
– helicopters (2 pieces);
– sea transport (5 units);
– service center (singular);
– an additional agent - transport (to determine the actions of modes of transport).

Thus, the first view of the model is obtained, which displays the types of vehicles, wind turbines and a service center.

The operation model shows how maintenance work can be optimized during the operation of offshore wind farms. In this model, you can adjust the duration and frequency of service work, and consider their impact on the system as a whole, mainly in terms of the life of the system [15].

This approach allows you to take into account the main operating elements of the system, build relationships between them, and adjust them if necessary.

The agent model consists of objects with personalized properties and behavior.

Information for the agent-based model is taken directly from the company's database: maintenance is carried out every two weeks; the maintenance crew travels to the turbine by sea transport; the time of work is ten hours; the average time between breakdowns is 50 days; the troubleshooting team travels by helicopter; the troubleshooting time is from 10 to 20 h. Using real data allows you to make correct predictions and test hypothetical scenarios more accurately.

In AnyLogic, agent-based modeling can be combined with a discrete-event approach or system dynamics. The model can consist of power generation points, which are modeled as agents in the supply chain, and a discrete event method can be used to reflect the internal generation points in the model. The individual behavior of each agent in the model can be specified using system dynamics.

5 Conclusion

The purpose of the study is to show data management in a power supply system [16–18]. Data management in an offshore wind turbine system designed to generate electricity in arctic conditions is considered in the paper. Sustainable energy supply is a pressing issue for the Arctic territories. The authors propose modeling an offshore wind farm in the form of an alternative graph [19, 20]. The value of particular indicators of the formulated task can be obtained on the basis of simulation using the agent-based approach, which consists in assigning agents to certain objects and building relationships between the agents. Simulation modeling was carried out in the Anylogic program.

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Effective Management of Multimodal Logistics in Russia

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Abstract. Digital technology has firmly entered our daily lives, and it is almost impossible to imagine life without it. Considering autonomous transportation vehicles and the degree of heterogeneity of traffic flows, it is reasonable to say that their share will only increase in the coming future, which will naturally initiate further growth in the intellectualization of vehicles and transportation infrastructure to ensure their efficient management and improve the quality of services provided. As a process, logistics continues to become more complex due to the growing demand for sophisticated information and communication systems. The challenges of developing transportation systems are more relevant than ever in Russia's market environment. And the problem of digitalization of multimodal transportation systems in Russia is becoming more and more acute. The demand for multimodal transportation is growing every year, and the potential for the development of multimodal cargo transportation schemes in Russia is very high. Considering successful cases in various industries, we can assert the feasibility of implementing multimodal transportation systems in Russia.

Keywords: Multimodal transportation systems · Logistics · Transport

1 Introduction

The challenges of transport systems development are more relevant than ever in the market conditions of Russia. Logistics services ensure the accessibility of territories, create safe and comfortable living conditions for the population, and form the conditions for economic development.

Multimodal transportation, in turn, helps organizations to minimize the cost of cargo transportation, reduce transportation time, etc. As part of the increasing number of goods to be transported, the need for multimodal transportation systems is becoming more and more acute. Those bright examples of organizations that have implemented multimodal transportation systems to digitize individual processes (in fewer cases) and process chains (in more cases) show excellent results in the market in Russia.

I. Ilin et al. (Eds.): ICDT 2021, LNDECT 157, pp. 264–272, 2023.
https://doi.org/10.1007/978-3-031-24434-6_24

The combination of different modes of transport, the restrictions imposed on the transportation, all this must be taken into account when organizing multimodal transportation.

The purpose of this article is to analyze the trend of digitalization of multimodal transportation in Russia on the example of cases of implementation of multimodal transportation systems in various companies.

2 Materials and Methods

The modern trend of transport development is the formation of multimodal transport systems. Multimodal transportation is one of the most complex operations in transport and logistics management. The participation of different modes of transport in the transportation of goods makes it possible to increase the efficiency of the transport process, improve logistics schemes for the delivery of goods in time, reduce the economic impact on the environment, improve transport service territories and the use of rolling stock [1, 2]. Such freight flows are usually subject to careful control. The need for a more efficient logistics process drives the demand for transportation and logistics applications; this demand is consistent with other advanced technologies [3].

Given a set of transportation requests in which the point of origin and destination are far apart, logistics service providers must find appropriate vehicle routes to fulfill these requests at the lowest possible cost.

In view of performing an analysis of multimodal transportation in Russia, an analysis of the existing literature was conducted. Studies that contribute to an in-depth understanding of the topic of open access work were selected.

The following search engines Scopus and ScienceDirect were used to search and select information.

The following search string was used in Scopus:

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TITLE-ABS-KEY (multimodal AND transport AND Russia) AND (
LIMIT-TO ( PUBSTAGE , "final" ) ) AND ( LIMIT -TO ( OA
, "all" ) ) AND ( LIMIT -TO ( PUBYEAR , 2021 ) OR
LIMIT-TO ( PUBYEAR , 2020 ) OR LIMIT -TO ( PUBYEAR ,
2019 ) ) AND ( LIMIT -TO ( LANGUAGE , "English" )
```

As a result of the search, 6 articles from open access journals were found.

The keywords “Multimodal transportation Russia” with the following refinements were searched in ScienceDirect:

– Years: 2021, 2020, 2019;
– Article type: Review articles, Research articles;
– Access type: Open access & Open archive.

The search found 92 articles from open access journals.

A manual check of the results was performed to analyze the articles. Based on the analysis of abstracts, the most relevant articles for this paper were selected. The number of articles analyzed was reduced. The articles were divided into large categories showing the industry of the study. These categories are presented in Table 1.

Table 1. Article categories by search results

Category	Literary source
The concept of multimodal transportation	[4, 5, 7]
Designing multimodal transportation systems	[6, 13, 14, 21]
Optimization of multimodal transport systems	[12, 15]
Multimodal transport systems in the regions of Russia	[17–20]
Trends in the development of multimodal transport systems	[8–11]

In addition, it can be noted that of all the articles that made it into the final review, some were thematic and concerned a specific region or example, while others covered concepts. Thus, we can conclude that these articles reflect both the practical and historical state of the art.

Given a set of transportation requests in which the origin and destination are far apart, logistics service providers must find expedient vehicle routes to fulfill these requests at minimal cost.

Wolfinger D. et al. in their paper argue that, given a set of transportation requests in which the origin and destination of each request are located far apart, logistics service providers must find appropriate routes of vehicles to fulfill these requests at minimum cost [4].

Unit of cargo can be transported in one of two ways [4]:

– unimodal;
– multimodal.

The main advantages of combining multiple modes of transport for multimodal transportation are both lower costs and less environmental impact compared to traditional unimodal transportation.

The existing multimodal transport system emerged during the 2nd and 3rd industrial transport revolutions as a result of the digitization of transport systems of various modalities (road, air, rail, water) and their introduction into the telecommunications and then into the information space [5]. Multimodal transportation implies the use of at least two modes of transport to transport goods from the starting point to the end point [6].

Multimodal transportation network design includes three components:

– selection of transit stations;
– determination of transport routes;
– determination of transport modes.

Archetti C. et al. in their work divided multimodal transportation into three stages [7]:

- Advance transportation is transportation from the point of origin to a transfer terminal where the cargo changes modes of transport; it is usually by road;
- Long-distance transportation is a section that covers a greater distance. Long-distance transportation is by rail, sea, inland water, or air.
- Final transportation is the so-called last mile, i.e. the last way to the place of delivery, and, as in the case of pre-carriage, in most cases is carried out by road transport.

The organization of multimodal transportation in the areas of rail, road, sea transport in international communication will increase the competitiveness of Russian transport and logistics companies, will allow the country to realize its transit and export potential, as well as increase income from export transportation services.

Researchers consider trends in the development of multimodal transport systems and scientific and methodological problems of territorial and transport forecasting and planning [8–11].

The need for digitalization of multimodal transport is described in Kobzeva E. et al. [12].

Martin F. et al. write that determining the optimal pricing for parcel delivery that involves frequent transshipment in the context of multimodal transport and the use of multiple common resources is a difficult task [13].

Guo Y. et al. in the study propose a new model of multimodal distribution of automated vehicles, which takes into account the characteristics of automated vehicles and three types of distribution [6].

In this paper [14] considers the method, applying more complex models based on queuing networks, which allow to describe in detail the route of applications movement inside the object with a nonlinear hierarchical structure. The proposed method is suitable for describing a wide range of freight and passenger transportation systems, including river ports, seaports, airports and multimodal transport hubs.

In the article [15] presents multicriteria approach with time indicators for optimization of cargo flow distribution in multimodal transport-technological system.

This article [16] reviews the approaches to network modeling and stability assessment of multimodal transport networks.

The authors also consider the development of multimodal transport systems in different regions of Russia [17–20].

There is an urgent need to develop more effective ways of organizing multimodal logistics systems for remote fields and facilities for their maintenance, infrastructure development [21].

The correlation of price and quality, delivery, payment, transportation and storage schemes constitute the commercial success of the transportation service. The correctness of their choice leads the organization either to an increase in profits or to monetary losses [1]. It follows from the above that an effective logistics process in an organization must apply tools to analyze and visualize the complexities associated with transportation. These tools should integrate information, warehousing, personnel, materials, and the safe delivery of the final product. As part of the logistics process, the company must always consider the location of the product and analyze the various factors associated with this location [22].

Table 2 shows data from the Federal State Statistics Service for 2005–2019 on the transportation of cargo in containers by individual modes of transport.

The data reflect an upward trend in the number of shipments of various cargoes in Russia. With a further increase in the indicators, organizations will not be able to effectively manage logistics processes without the use of various sophisticated information technologies in the organization of various types of transportation.

Table 2. Transportation of cargo in containers by individual modes of transport.

	2005	2010	2015	2017	2018	2019
	Cargo transported, million tons					
By railroad transport	17,4	23,0	28,6	37,8	42,4	48,0
By sea transport	3,1	1,4	1,2	1,4	1,5	1,2
By inland water transport	0,3	0,7	0,3	0,4	0,3	0,3
Total	20,8	25,1	30,1	39,6	44,2	49,5

3 Results

The creation of a multimodal transport system is one of the directions of digitalization of transport systems and networks. It is important to note that the successful and promising research and implementation of the idea of building multimodal transportation systems is a powerful impetus for the development of the economy as a whole.

A lot of companies are implementing multimodal transportation in order to reduce the delivery time, transportation cost, cost reduction, etc. In its majority, each individual case of implementation of such systems is individual and is aimed at digitalization of not a single process. Let's look at three striking examples of the implementation of multimodal transportation systems and their results.

Thus, one of the most famous cases of implementation of multimodal container logistics management system is TMS (Transportation management system) project, based on SAP Transportation Management (SAP TM) solution implemented at SIBUR. SIBUR is one of the largest exporters on the Russian container transportation market, automating the through logistic chain. The system made it possible to automate an end-to-end process, rather than a separate link in the logistics chain, thereby maximizing the productivity of the ZapSibNeftekhim logistics complex.

It is planned that this solution will lead to a 30–50% reduction in equipment downtime, a 30% reduction in labor costs of multimodal logistics, as well as compliance with delivery lead times on 95% of shipments [23].

Vostok-Service is a developer, manufacturer and supplier of protective clothing, footwear and personal protective equipment (PPE) with more than 120 branches in 56 regions of Russia and CIS countries, international assets in Europe, Asia and Africa, as well as its own retail network of 280 stores located in 170 cities of Russia and CIS countries. Based on the results of the tender, the industry solution from ITOB - 1C: TMS Logistics. Transportation Management. The software product is implemented on the basis of 1C: Enterprise 8 and is integrated into 1C: ERP.

Several times increased the speed of processing tasks for multimodal transportations, with a number of convenient tools for correcting and supplementing tasks, received by the logistician from managers. The use of special handy tools has allowed limited the formation of flights within the framework of only one carrier, which greatly accelerated the process: if before the introduction of a single request for cargo spent about a minute, now for a minute gets to handle 20–50 jobs for multimodal transportations [24].

The task set by KERAMA MARAZZI in 2018 was to establish a rhythmic shipment of feldspar, the raw material necessary for the production of ceramic tiles, from Turkey to Russia to its production sites in Orel and Malino in the Moscow region. Specialists of separate subdivision of Russian Railways Logistics in Moscow developed and successfully implemented a multimodal delivery scheme using water and rail transport along the route: port of Gulluk (Turkey) - Rostov port - stations Mikhnevo, Luzhki Orlovski, Stalniy Kon of Moscow Railways. Russian Railways Logistics is the largest multimodal logistics operator in the CIS and Baltic countries.

Full range of services included vessel freight and transportation to Russian port, cargo transshipment to railroad and delivery to destination stations. Total transportation time of one consignment was 30 days [25].

These cases confirm the effectiveness of implementing holistic information systems in the business process of logistics organizations. However, it is important to understand the need to digitalize not individual blocks, but the entire logistics chain to achieve the sustainability of the organization and increase its competitiveness.

The organization of multimodal transport in the new socio-economic conditions requires a clear basis for the interaction of transport, production, commercial and other organizations in the field of legal regulation, planning and finance, technology, technology and transport management [26–28]. All elements included in the system of multimodal transportation (material flow, rolling stock, network of roads and terminals, transport-forwarding complexes) must meet certain requirements.

When planning the route and choosing the necessary transport it is necessary to start from the features of the cargo, the end point, the terms of delivery, pros and cons of each type of vehicle. Competent careful preparation allows you to choose the optimal and most profitable scheme of multimodal transportation.

The most popular combinations of transport modes:

– car - plane;
– train - plane - car;
– car - ship;
– train - ship - car;
– car - train.

Depending on the chosen scheme, the rates for the services provided and the delivery time will differ. Often the customer chooses the most preferable option - urgent delivery or low cost, because air transportation will be the fastest, but will cost the most, and the cheapest transportation by sea will take the maximum time.

4 Discussion

The study revealed an upward trend in the need for the introduction of multimodal logistics in Russia. A further increase in the figures may make it impossible to effectively manage transportation. This problem is very acute for many organizations right now. However, for more accurate results, it is necessary to consider in more detail the situation with multimodal transportation in different regions of Russia due to different climatic, transport, social and other conditions.

The creation of a multimodal transport system is one of the directions of digitalization of transport systems and networks. Identification of best practices has highlighted only a few areas where multimodal logistics can be applied. Unfortunately, not many organizations make it possible to monitor the application of new technologies in their business processes, which leads to an incomplete collection of information in the study. The considered combinations of transport are quite universal, but it is necessary to take into account the focus of the organization, the type of cargo and similar various factors for the organization of multimodal transportation system.

Further research is planned to determine the main trends in the development of multimodal transport in Russia, as well as to determine the impact of multimodal transport on the sustainable development of regions.

5 Conclusion

The number and geography of freight transportation increases every year. The quality of rendered services in this sphere also increases. Nowadays multimodal transportations are used increasingly more often for cargo transportation. This type of transportation implies a comprehensive approach to the organization and coordination of cargo delivery, because it involves using several modes of transport.

The demand for multimodal transportation is growing every year, and the potential for the development of multimodal cargo transportation schemes in Russia is very high. The main advantage of the multimodal method of delivery is the use of the maximum quality of each mode of transport, with their competent combination. Digital technology allows a new level of control over the transportation process, using different types of communication. Implementing a multimodal logistics management system is a way for organizations to adapt faster to changing conditions. This can include legislation, consumer demand and behavior, and foreign economic factors. Minimizing costs, increase profits by improving the efficiency of logistics processes.

Thus, today, the implementation of a multimodal container logistics management system can automate the end-to-end logistics process, which allows for maximum productivity in the organization.

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Arctic Port Activity Management Digitalization in Ice Season

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Abstract. In the paper, there are presented digitalization development results for Arctic port activity management in ice season within Industry 4.0 period under climate change and COVID-19 pandemic. In study, there are used situational analysis, web technologies and building database methods in distributed networks. As the research result, to increase the efficiency and reliability of port activity management in ice season within environmental economics, it is proposed the using of geodata from remote sensing and modelling. As the digital managerial support instrument, it is proposed to use aggregate modular managerial decision support system, which integrate the heterogeneous hardware and the software resources in distributed networks. As the research results, there are demonstrated examples for arctic ports in the area of the Ob and Yenisei rivers. The research results presented in this article has significant scientific novelty and can be useful to different players within Arctic port activity management in ice season, including insurance business.

Keywords: Digitalization · Geo-information management · Web technologies · Arctic ports · Environmental economics · Climate change

1 Introduction

Arctic port activity management (APAM) in ice season (IS) is complex multi-leveled activity within environmental economics. Currently, there is a need to digitalize APAM in IS during climate change and COVID-19 pandemic in accordance with the concept of Industry 4.0. Recently, a lot of logistics businesses are planning and implementing a wide range of information technologies [1–5]. Industry 4.0 leads to serious information technological changes in port activity [6–10], including natural risks management (NRM) [11–14], and training area [15].

I. Ilin et al. (Eds.): ICDT 2021, LNDECT 157, pp. 273–280, 2023.
https://doi.org/10.1007/978-3-031-24434-6_25

The goal of this research is to develop digitalization instruments (DIs) for APAM in IS. In paper, we present the DIs development results for APAM in IS within geoinformation management (GIM) paradigm [16–21], in large environmental projects [22–25] within environmental economics [26, 27]. We give attention to aspects of climate change [11] and COVID-19 pandemic [4, 5], including the issues of information collection and processing with big data [28–30].

2 Materials and Methods

Within study, we used geodata from different geoinformation digital online platforms (GIDOPs), including EOS and its Land Viewer (LV) product, https://eos.com/lv/, which allows limited open access to space images from different satellite missions. In research, we used situational analysis, web-technologies and building database methods. Also, we used Internet of things, machine learning and big data technologies [28–30] for geodata from remote sensing and modelling.

3 Results

As a result of performed situational analysis, we put forward the claim that in present conditions of climate change and COVID-19 pandemic, it would be advisable to develop arctic ports infrastructure. Preference should be given to those Arctic ports where climate change and the global pandemic situation lead to an improvement in their general operating conditions, for example, an increase in cargo turnover, including export cargo turnover. For these reasons, within the framework of the conducted research, we prefer Arctic ports in the area of the Ob and Yenisei rivers, through which export supplies are carried out and their significant increase is planned.

As a significant research result, we have developed an aggregated modular management support system (A2M2S) for APAM in IS with free access to geoinformation digital online platforms (GIDOPs) as modules. As examples we present results of using A2M2S for APAM in IS to arctic ports management in the area of the Ob and Yenisei rivers, because they have very important role in the Russian Arctic development and to modern arctic cargo transportation.

In Fig. 1, we present a general view of arctic ports in area of Ob and Yenisei rivers, visualized with GIDOP Marine Traffic as module of A2M2S for APAM in IS. It can be seen that those ports are located deep inside the Arctic territories and implement a mode of transportation, which is commonly called river-sea. Under this regime, it is necessary to control natural risks and the processes generating them on significant river and sea spaces. Well known, arctic ports in the area of the Ob and Yenisei rivers are covered with ice for several months from autumn to late spring, sometimes even until early summer. All above-mentioned factors have to be taken into account within the framework of the APAM in IS for the arctic ports in the area of the Ob and Yenisei rivers.

Fig. 1. Arctic ports and ship traffic in area of Ob and Yenisei rivers visualized with GIDOP Marine Traffic on 12th November 2021.

In Fig. 2, we present general view of the port Arctic LNG 2, which is developing on right bank of Ob river, visualized with GIDOP Marine Traffic.

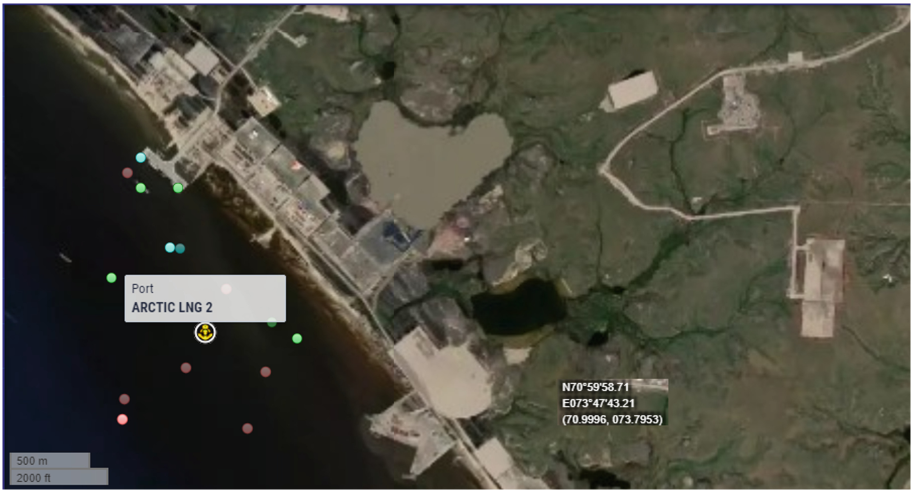

Fig. 2. Port Arctic LNG 2 on right bank of Ob river visualized with GIDOP Marine Traffic on 12th November 2021.

In Fig. 3, we present a space image of port Arctic LNG 2 visualized with GIDOP EOS (LV product). It is seen, LNG production infrastructure coupling with the port. Icebreaker channels are seen very clearly.

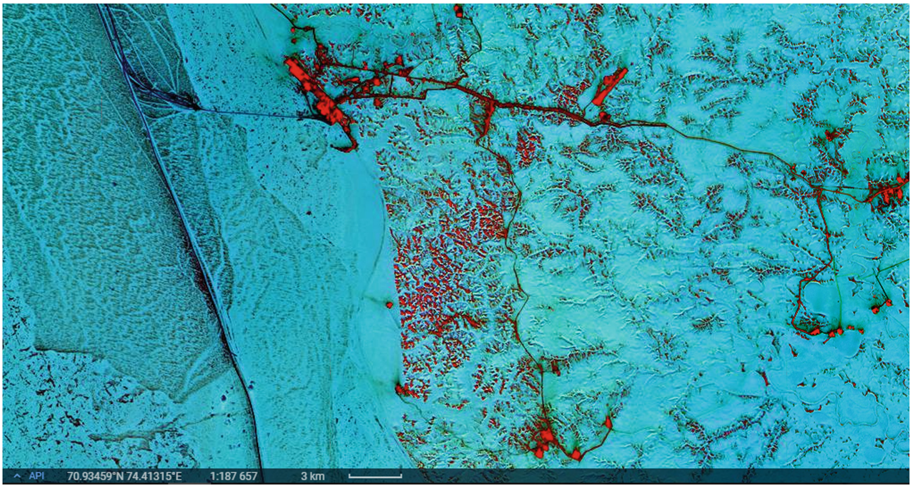

Fig. 3. Sentinel-2 space image of port Arctic LNG 2 visualized with GIDOP EOS (LV product) Agriculture Application on 29th April 2021, scale 3 km.

In Fig. 4, we present screen of wind and air temperature fields from GIDOP Earth on 29th April 2021. Weather conditions was very mild on this date.

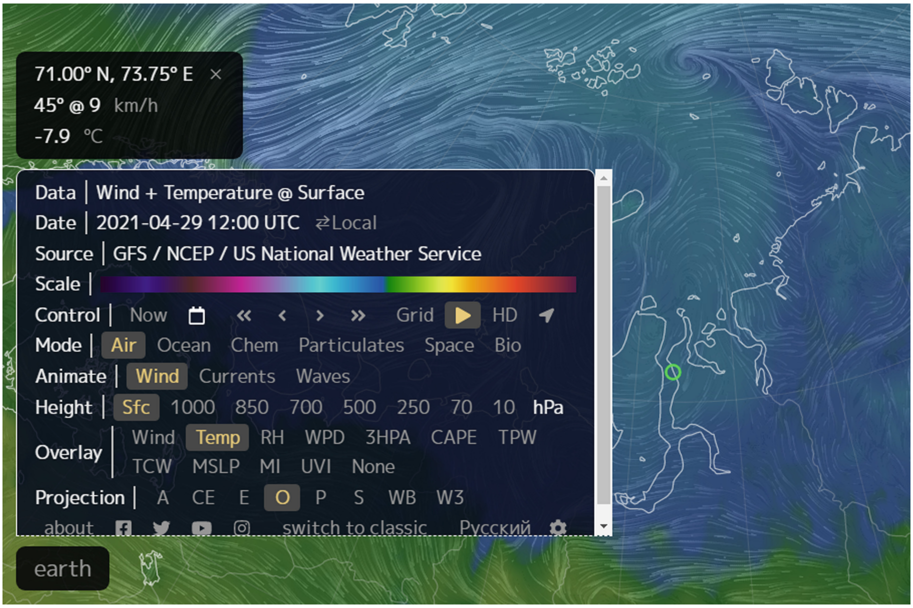

Fig. 4. Screen of wind and air temperature fields from GIDOP Earth on 29th April 2021 12:00 UTC.

In Fig. 5, we present general view of the port Dudinka on right bank of Yenisei river, visualized with GIDOP Marine Traffic. This port is very far from open sea.

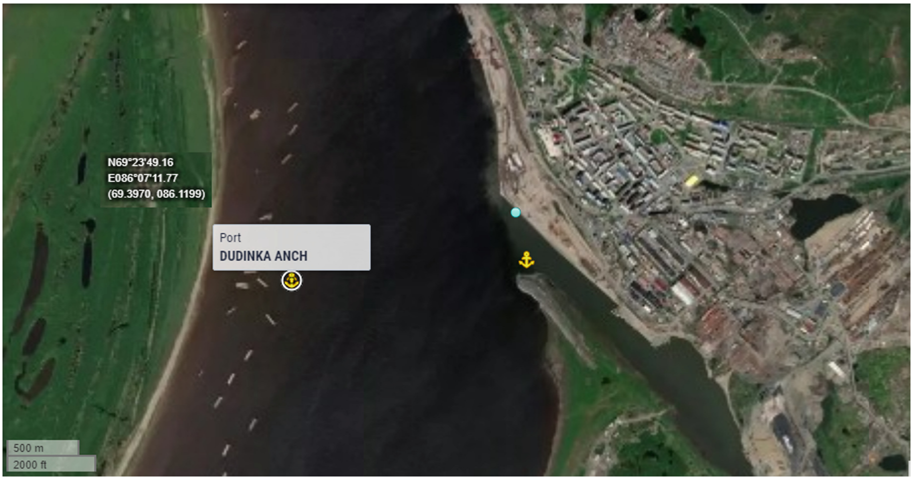

Fig. 5. Arctic river port of Dudinka visualized with GIDOP Marine Traffic on November 12, 2021, 14:57 UTC.

In Fig. 6, we present a space image of ice field with the icebreaker channels near the artic river port of Dudinka visualized with GIDOP EOS (LV product).

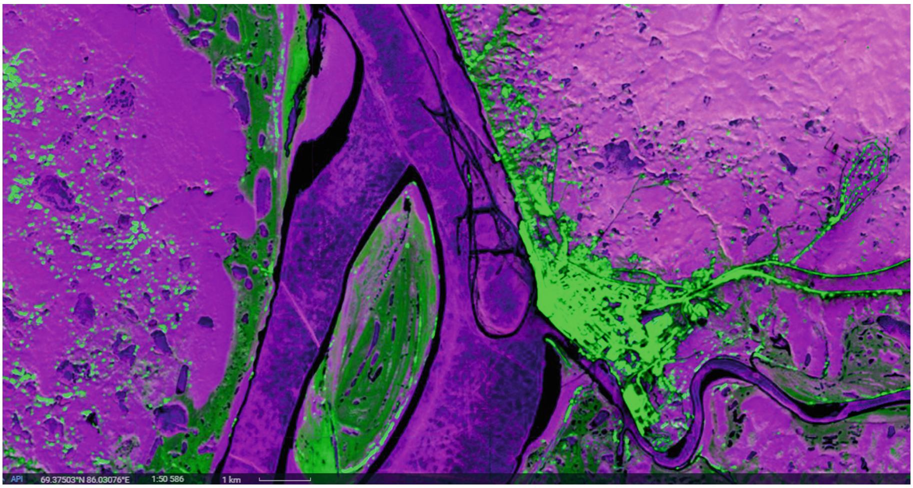

Fig. 6. Sentinel-2 space image of ice field with the icebreaker channels near the artic river port of Dudinka visualized with GIDOP EOS (LV product) Land/Water Application on May 21, 2021, scale 1 km.

Thus, we have developed A2M2S for APAM in IS with free access GIDOPs as modules within environmental economics under COVID-19 pandemic and climate change. One more time note, that full decoding of Figs. 1, 2, 3, 4, 5 and 6 and its discussion was not task of this article.

4 Discussion

Developed above-mentioned A2M2S for APAM in IS can be used in educational and training purposes. With the help of proposed DI, students get access to a very large volume of geo-data and learn to work with its for solving practical problems in various areas of APAM in IS. Especially useful A2M2S for APAM in IS will be for Master's programs in environmental economics.

5 Conclusion

In paper, we present development results of A2M2S for APAM in IS within environmental economics during Industry 4.0 period under conditions of climate change and COVID-19 pandemic. While study, we used situational analysis, big data technologies, web-technologies and building database methods. We used remote sensing and modelling geo-data. Demonstrated some examples of A2M2S for APAM in IS using to the arctic ports in the area of the Ob and Yenisei rivers. The presented in article research results have significant scientific novelty and can be used for APAM in IS by different players, including insurance.

Acknowledgements. In study, we use platform https://www.researchgate.net/profile/Valery_Abramov2/ for preliminary discussion and data exchange.

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Usage of IT Solutions by the Members of the Supply Chains on the Example of Pharmaceutical Market

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Abstract. This article discusses the influence of digitalization on procurement and logistics on the example of automation systems. This trend has caused several changes in the SCM and CRM systems which now offer more features than they did years ago. Nowadays they go above and beyond traditional customer relationship management and are of great help to all the people involved in a supply chain management during all of the stages from procurement to operations management and delivery to consumers. The latter one will be emphasized on in the paper. The use of CRM has broadened. Nowadays it is widely used in all of the spheres including logistics. The use of CRM and Power BI for logistic companies is explained and illustrated in the article on the example of a pharmaceutical company. Moreover, the trends appeared under the pandemic circumstances will be considered.

Keywords: Logistics · CRM system · Digitalization · Pharmaceutical company · Customer-centered approach · Digital transformation

1 Introduction

The 21st century is considered to be a century of digitalization for a good reason. This trend has also influenced procurement and logistics. Digitalization has been affecting all the processes related to the supply chain management which led to the severe changes of the traditional features of SCM and CRM systems [1]. E-commerce automatization is concentrating on three systems: Supply Chain Management, Enterprise Resource Management and Customer Relationship Management. In order to effectively automatise all the processes involved in the product manufacturing and realization all of them are to be optimized. Traditionally, logistics focuses on the Supply Chain Management (SCM) systems yet CRM system is of key importance since the process of the product delivery to the customer is controlled and defined by it. An important role is also played by the way of approaching the customers [2, 3].

Besides, the research has indicated two key issues related to the supply chains. The first one being the difficulty in interaction between all of the members of the supply

I. Ilin et al. (Eds.): ICDT 2021, LNDECT 157, pp. 281–288, 2023.
https://doi.org/10.1007/978-3-031-24434-6_26

chains is believed to find the solution in the introduction of a CRM system. The second problem connected to the big data analysis can be answered by the BI systems. Besides the big data processing and analysis, it also allows to present the required information in the perception-friendly way.

CRM systems are becoming more and more functional and now are a good fit for logistics companies. They cover all the needs of the entrepreneurs both in B2B and B2C sections and simplify the process of work. The key sections of a CRM system for logistics company are … One more important role played by the CRM system in the company is getting closer to the customers and reaching a better understanding of the target audience needs [4].

Before talking about the digital trends, it is of key importance to highlight the relevant events of the logistics related to the pandemic. The first thing to notice is that the shipments were reduced due to the lockdown as the transportation capacity was severely reduced. The Asian market was first to start the process of the recovery and has almost gone through the crisis. The time of the shipments has increased forcing the less competitive companies to leave the market. The damping strategies were also noticed in the logistics since the demand has decreased. Logistics companies were forced to come up with the novel solution to the problem. The remedy was to introduce IT-technology and offer an opportunity to order delivery vis mobile devices. The first one was felicitous since most of the employees have started working remotely which was possible mainly due to the IT-technologies, especially, CRM systems. The second one is an answer to the upswing of demand on the delivery of the essential goods.

Both will be considered on the example of a pharmaceutical company.

2 Materials and Methods

The purpose of the study was to highlight the trends in the logistics on the example of the pharmaceutical industry and single out IT solutions.

The methodological basis of the study was the works [5–7], research on the management of project activities of organizations [8, 9], as well as case studies of the impact of the integration of IT solutions, such as cloud computing and CRM systems, on logistics processes [10, 11].

In addition, various reports were reviewed [12, 13], articles [14, 15] were examined and news reports [16] were also taken into account.

It was a study following a mixed-method approach for data collection.

The object of the explanatory research was pharmaceutical companies that operate all over the world and are recognized leaders of the field.

The main tasks of digitalization in terms of pharmaceutical companies were improving Overall Equipment Effectiveness, providing the ability to explore the customer requirements, achieving transparency, and an opportunity to promote its brands to the right audience. The key task was turning to hybrid selling. It is a strategy that combines two approaches: on-line sales and the sales activities defined through personal presence. The first one has become of high demand under the COVID-19 circumstances.

Besides, the methodology of IT projects management were also researched. The basic principles of the project management are:

1. Statement of the roles and responsibilities;
2. Constant business feasibility;
3. Learning through experience;
4. Focusing on the product;
5. Management by differences;
6. Management step-by-step.

It is also important to remember that whenever a new member or a system is integrated into a part of the environment, the whole environment changes. Thus, implementation of an IT-solution changes the responsibilities of the employees and the business processed involved.

The study considers possible solutions to the problems faced by the members of the supply chains.

3 Results

The paper describes the IT solutions integrated into the pharmaceutical companies over the last years and the impact of such integrations. Moreover, the key stages of implementation are mentioned as well as the causes of the process. The business processes optimized by the IT solutions were also considered in the paper.

The authors considered the issues of pharmaceutical companies related to the customer service and the decline of the income due to pandemic-related troubles, the principles of the IT solutions implementation, the process and the stages of the implementation as well as the result of this process.

The implementation of digital technologies includes but isn't limited by the following stages:

1. Planning;
2. Designing;
3. Implementing;
4. Supporting.

The main causes of the implementation of IT solutions were the lockdown circumstances forcing people to order medicine online and the decrease of the transport capacity due to several regulations as well as the limitations in international mobility.

According to the NOVARTIS report, COVID-19 has been a boost and 73% of the companies were noticed to improve a lot. One of the main changes is introduction of information technology systems.

Technology professionals believe that the healthcare and pharmaceutical industry's digital moment has arrived.

CRM systems were quite helpful as they allowed not only to easily track the drug development but also analize the drug commercialization process. Besides, novel CRM systems offer an opportunity to set the features just the way the pharmaceutical company needs them.

Novel CRM systems are a very flexible since its workflow and parameters that can be fully tailored to the client's needs. For instance, one of the CRM system manufacturers' clients has implemented a highly configurable suit (mobile, web and app) providing real-time access for key clinical trial needs. It has boosted the process of procurement [17].

The system is capable of providing insights into every phase of clinical trial management, empowering clients and key stakeholders to connect and use data within their studies in an entirely new way.

On the one hand, recent reports on COVID-19 have stressed the rise in the use of Internet and social media (Donthu and Gustafsson, 2020) [12]. The key reason is the rise of use of the social media and Internet which has become the main channel of purchasing activities.

Several cases of implementing CRM are presented below [18].

One of the challenges during the pandemic was the need to limit in-person patient contacts to the emergency only cases. Implementation of the CRM system was chosen as a way to overcome it. As a result, in spite of the increased call volume employees in the pharmaceutical industry were able to interact with patients from their own homes. Thus, both patients' expectations were met and the health of the staff was not endangered.

The second case of CRM system being of hand to the healthcare industry was the cloud containing all the redundant data for incoming patients. It has created a more efficient screening process and made it safer for both patients and the employees.

In a general way, the result of the implementation of the CRM system has enhanced the online sales of pharma by 60%, according to statista.com. Besides, during the pandemic the activity on the pharma websites has been noticed to increase by 35%.

One more important example that has become a center of the research conducted as a part of this study is a case of a Germany-based pharmaceutical company. The company specializes in fertility, diabetes, and MS treatment options. As a part of this implementation of a CRM-based marketing and sales strategy they have also adapted the customer-centric strategy. Thus, the company has accessed a new way of data collection which then transformed into the sales.

Customer-centric strategy

According to TechValidate research, such implementation has improved customer service by 40%, simplified project management across departments by 38%, and has improved the performance of marketing teams by 34% by making it easier for them to connect. Besides, ability to interact between departments has also been improved by implementation of a CRM system.

However, the whole process of implementation cannot be considered to be easy. On the contrary, it implies reorganizing existing principles of management and the whole system itself. Though the methodology of implementation of an IT solution used by the company considered is not mentioned in the report, this paper discusses the process as in the Signature methodology.

It is believed that introduction of an IT solution is mostly a technical task. However, though it is definitely related to that, the most significant changes are usually noticed in the organizational structure. The key tasks during that process are:

- Changes in the positions according to the requirements of the newly implemented system;
- Personnel training;

– Planning new organizational structure and roles reorganization;
– Preparation for the organizational structure change.

Besides, it is crucial to prepare all the partners to the upcoming changes, especially when they include several changes in the informational system. Otherwise, partners may not be ready for the new way of interaction.

The process of transition to the new system sometimes implies temporary usage of both systems: familiar and newly-introduced one. This period can be characterized by double effort expenditure.

According to the above-mentioned Signature methodology, the process of a CRM system integration implies going through 6 major steps (Fig. 1):

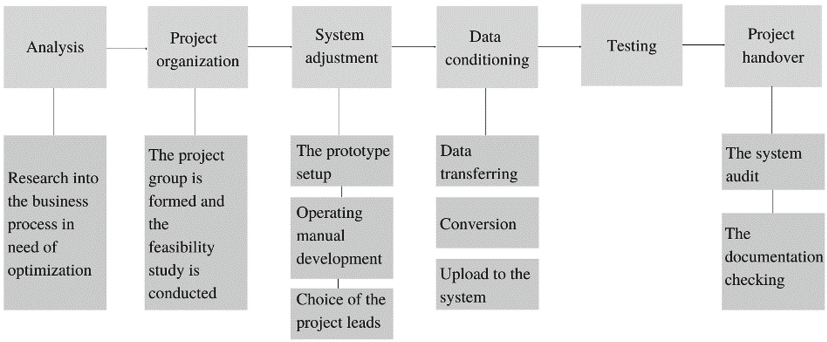

Fig. 1. 6 steps of a CRM system integration

Any IT solution implementation is focused on the achieving the intended objective and is limited by the timing and the funding.

While considering the pharmaceutical company in question, it is of high importance to notice the significance of the customer role played in the realization process. The company's target was to enhance the quality of interaction with the clients. This goal defined tre transition from the product-based strategy to the customer-centred one. After having the consumers involved into the marketing strategy, the figures rose dramatically. According to a data published by Accenture, "70% of pharma sales and marketing executives identified mastering multichannel marketing as a top strategic priority." Before implementation of CRM system, the major part of data was lost due to the logistical difficulties. Thus, CRM system was the solution to the problem faced by a pharmaceutical company in question. Even though the process of transition was challenging, the end justified the means which can be proven by the figures presented above.

One more crucial case to discuss is the experience of a pharmaceutical company that implemented BI system called Power BI in order to simplify the process of the data analysis, support the business processes development and the structural changes in the company, and ensure sustainable process of the data analysis even under the circumstances of increased flow of data. Power BI is quite easy to implement. Usually, there are to requirements from the clients:

1. Data actuality which is important since the financial director is eager to see the financial results of the previous day by 12 pm of the current one.
2. Data quality which may be lost during due to rounding. Approximate numbers may lead to the differences which must be remembered during the development.

In addition to that, usually the following requirements are also proposed:

1. Simplicity and visual clarity;
2. Design;
3. Compilation of various reports;
4. Solution completeness (meaning that the system is to make decisions, not just output factors and exponents);
5. Several visual requirements, for example, taking into consideration that the human being is more likely to pay attention to the information placed on the top-left corner.

After collecting all the requirements, the team has moved on to the development which included the following steps:

1. Data import and conversion;
2. Data prototype development;
3. The application development;
4. The solution presentation.

Power BI offers various graphs, tables and other types of visualization yet is still relatively easy to implement.

Thus, implementation of Power BI has been of great help to the above-mentioned company.

4 Discussion

Undoubtedly, the companies have been through a lot during the COVID-19 pandemic and are still experiencing the effects of a rapidly changing environment.

Having implemented the CRM system, it is crucial to make sure that all the employees are on the same wavelength with the changes. Training the staff is one of the significant steps of the CRM or any other IT system introduction. However, it is nearly impossible to install a system that would be changing at the same pace with the world. It only means that the company is to update the software while noticing the need in new features. It may be assumed that such trend will raise the demand in the business analytics able to conduct analysis in narrow-focused companies, such as pharmaceutical.

Besides connection to the prospects and the real-time analysis of the crucial processes, CRM systems also help meet the deadlines and track the products development stages. Thus, this IT solution is of great help while controlling the business processes from the drug production and to the delivery to the customer.

The implementation of the CRM architecture is the basis for exploiting further technological potentials [19].

As for other IT services, their for example, such ones as Power BI, their usage is of great help for those companies that are able to state the problem in need of answering clearly.

In addition to everything said before, it is paramount to mention that the future of digitalization combines such tools as Artificial Intelligence, neural networks, NLP, bioengineering, machine learning, evolutionary algorithms, etc. Only by integrating them with the traditional tools will it be possible to achieve success on the market of the future.

5 Conclusion

The COVID-19 pandemic and lockdown experienced by almost all of the countries has influenced the world of logistics that will never come back to normal. However, the flexible companies that are able to change considering the trends have great changes of becoming the leaders on the market.

One of the trends included the customers engagement in the sales process. Introduction of the CRM system was essential since it has helped not to lose the essential data. It also implied implementation of project management strategies along the way.

Thus, pharmaceutical companies can benefit from the CRM system implementation in the following ways:

– Product development and marketing processes control and optimization;
– Improving brand quality in a competitive market;
– Improving revenues by the means of engaging the customers in the marketing strategy
– Development of customer-centred services.

Reports and analytics updated and available at real time are the tools that allow pharmaceutical companies stay competitive on the rapidly changing market. It is of high importance to possess enough flexibility to be able to adjust to the new reality. The companies that managed to do it under the extraordinary conditions now have a chance at becoming the leaders on the market or at least at keeping the spot on it.

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In-Store Personal Navigation and Dynamic Pricing

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Abstract. This paper contributes to the existing field of research about self-organized logistics (SOL). Self-organized logistics is a system that consists of agents that rely on strong horizontal connections rather than on vertical ones while executing tasks. The agents do this without strong intervention of humans or a controlling software. SOL can be utilized in retail as an enhancement to customer experience in store. Self-driven smart carts equipped with sensors can provide guidance and assist shoppers.

Keywords: Logistics · Self-organization · Retail · Smart cart · In-store navigation · Shopping assistance

1 Introduction

Automation and digitalization of retail businesses have recently become a prerequisite for survival among competitors. Growing customer requests for fast and personalized service, rising labor and supply costs, huge investments in e-commerce expose the need of reshaping business models in retail. According to the recent Ernst & Young survey, nearly 82% of retailers are currently undertaking significant business and technology transformation programs in order to successfully respond to the new demands of the industry. And most of them are investing in artificial intelligence and robotization programs.

To address the challenges of a growing economy, retail companies are turning to the digital transformation (DX) of the value chain. Aligning technology processes towards business strategy using DX frameworks and best practices is a way to create organizations with fewer layers, support margins and win the fight for survival in the market.

Logistics robotization began to gain worldwide application as well, especially in retail where enterprises, both local and international, began to pay more attention to logistics as a necessary activity that ensures a high level of competitiveness of the enterprise. New trends and ideas are being introduced to the logistics domain, one of which is self-organized logistics.

Self-organized logistics is a system that functions based on between entity interaction rather than controlled by guidance of an entity higher in the hierarchy. It helps to optimize

I. Ilin et al. (Eds.): ICDT 2021, LNDECT 157, pp. 289–297, 2023.
https://doi.org/10.1007/978-3-031-24434-6_27

storing and transferring goods, as well as digital technologies that provide identification and forecasting of needs, optimization of routes, directions of material and information flows, including reducing the time of existence in supply chains. In other words, the issue of optimizing the delivery of goods in distribution networks from manufacturer to consumer or around manufacturer's facility is gaining more and more popularity these days.

This paper is intended to discuss ways the SOL and DX can be incorporated in retail chains as a tool for enhancing the in-store personal navigation experience and driving profitable growth through dynamic pricing.

Self-organized logistics in retail is an area that has relatively small coverage in the research field. Several articles explore self-organization systems application for improving network logistics in city infrastructure connectivity [1, 2]. Some papers focus on SOL application for external, off-premise logistics [3–5]. However, another popular focus for SOL is businesses that rely on internal logistics in warehouses and production facilities [6, 7]. These findings highlight ideas that can be applied in the field of retail.

Shopping carts that navigate autonomously and are aimed to assist customers in their buying journey have been proposed in multiple studies [8–10]. Chen et al. [11, 12], reported a shopping mall service robot, named KeJia, which is designed for customer guidance, providing information and entertainment in a real shopping mall environment. A wGO was developed [13] - an autonomous and self-driven shopping cart, designed to follow people with reduced mobility. The experiments have shown that the participants' satisfaction with the robot's behavior was high.

From a social point of view, the TOOMAS robot has been tested in home improvement stores Germany [14] and is even popular in domestic environments. A comprehensive overview of this robot usage in shopping malls has been given by Niemela et al. [15].

The majority of approaches mainly focus on navigation in case of customer guidance [16–18], while carrying out the customer's goods using gestures. Following the idea to support customers in the shopping process, Heikkilä et al. [19] demonstrated guidance situations with a social service robot for serving the visitors in a shopping mall.

In general, it is noted that the volume of sales using the robot is increasing [20–22].

2 Materials and Methods

2.1 Topic Description

While robots are usually considered to be physical autonomous systems executing some kind of physical activity, autonomous systems cover a broader spectrum which is not only defined by physical structures. Self-organized systems are defined as self controlled adaptive intellectual systems, which can control their own actions and internal state and can act independently from human intervention. This can include robotics or autonomous transport systems where data that is received with monitoring systems is used as a part of the autonomous process of decision making. The artificial intelligence role in robotics is growing steadily. Robots can be used for replacing humans or for helping them in any kind of activity which falls under the 4D (dirty, difficult, dangerous, and damaging) characteristics.

Creating SOL in retail businesses goes along with the digital transformation. To create a real value of implementing new technologies, the innovation processes have to be aligned with the main processes of a company and its corporate and finance strategies. Achieving a high level of digital transformation will add value to the most important factor of retail business - customer experience.

2.2 Retail Issues

Modern retailers need to be able to react quickly to changing market conditions. One of the ways to quickly adapt to the ongoing changes is the timely robotization of processes and operations. By robotization, we mean technical equipment and provision of individual business processes and organizational structures with automated devices and systems in order to increase overall work efficiency and reduce time and costs associated with the use of human resources in similar areas.

Even before the onset of the COVID-19 pandemic, which changed the business, retail underwent major upgrades to keep pace with both growing customer expectations and expanding supply chains. The changes affected the functionality associated with inventory activities, with logistics business processes, and operations. According to a study by Deloitte, retail is an area of activity in which companies plan to actively implement and are already introducing robotization into existing business processes.

The retail sector is highly competitive due to the saturation of all its segments with a large number of companies and individual entrepreneurs leading their active market. Both online stores and retail outlets strive to increase operational efficiency, increase customer satisfaction, increase staff and customer loyalty, and retain employees in the company.

During the pandemic, the share of online orders compared to the total volume increased from 11 to 16%. Given the fact that physical labor is present in 95% of warehouses around the world, the volume of workload and the growth in the number of orders for picking are growing, the pandemic is reducing the number of labor in the labor market, and the pace of transition to robotic systems is accelerating, similar to the world's leading companies. The pandemic has also created a new trend in retail digital development - touchless interactions. Due to government social distancing policies and hygiene requirements, stores are creating safe, touchless customer opportunities, such as contactless payments, online ordering through mobile applications, IoT-enabled devices in stores, etc.

The competition between online and offline sales increases due to the growing customers' requirements to service: they expect to receive individualized offers. Obviously, customization is a lot easier to create in e-commerce, so many customers are turning to online stores. Omnichannel distribution to clients and dynamic pricing gives a company a competitive advantage, providing them with an opportunity to perceive a customized experience in the usual format of an offline store. A great example of such a business model is the store by Amazon - Amazon Go. There are no cashiers or registers: as a client, you just walk in, pick out anything you want and walk out. The stores are integrated with mobile apps, customer experience is controlled by computer vision, sensor fusion, deep learning, and digital shelves. The emergence of new business models in retail like Amazon Go, created by tech giants, does not allow traditional formats of stores to survive without digital transformation.

2.3 SOL/DX - In-Store Navigation as a Solution

Logistics centers are one of the key elements of any large retailer. The world retail leaders, such as Amazon and Walmart, already use mobile robots both in their warehouses and in stores. They perform functions such as scanning inventory, handling incoming materials, harvesting, and more. For example, Amazon - the largest Internet retailer in the world with an annual turnover of more than 380 billion dollars. The company has created its own category of warehouse robots, Amazon Robotics, which today serve about 100,000 m^2 of racks in the company's distribution centers. Autonomous mobile robots are involved in the transportation of goods stored in a warehouse.

As orders come in, robots move goods that are on the racks inside the containers and then from the containers into special boxes, the size of which is prompted by the artificial intelligence system. After that, the inventory is delivered with workers at various stages of sorting. The workers are busy packing the received goods and handing the finished boxes for sending to the next robots. They, in turn, transfer the goods to vehicles awaiting departure. This is an almost perfectly structured process of autonomous operation of a warehouse complex using RPA.

2.4 Dynamic Pricing as a Solution

To apply the best e-commerce practices in offline store customer experience, companies now are investing in dynamic pricing solutions, as long as most of them acknowledge falling short on dimensions of pricing. Big data and analytics tools make it possible to understand consumers' price perceptions according to their location, preferences, and past experience.

While dynamic pricing is a way to fast profit growth and loyalty improvement, it doesn't always require sophisticated software and technologies. Companies can simply start with pricing analytics based on locations of stores, using box solutions. The next step is creating mobile apps, where a client will be able to see customized offers and prices, find or scan product barcodes and buy anything online or offline at these prices.

Among the risks of dynamic pricing solutions are bad input data that spoils analytics, the "black box" problem - end-users may not understand the logic behind the algorithms, trust issues from staff. To overcome these risks, end-users should be involved in implementing dynamic pricing solutions to tailor them to the company strategy and processes.

2.5 SOL/DX at Darkstores

The direction at the intersection of the in-store personal navigation and dark store warehouse logistics has great prospects, which can apply existing approaches of customer service robotics to assist staff that collects orders.

During the pandemic, many retail outlets switched to a mode of operation in the dark-store system. A distinctive feature of the dark store is that it is essentially a store without customers, for which the speed of order picking and delivery is important, as well as the conditions for storing the goods. Basically, this is a warehouse, without buyers and cash registers, where orders from buyers are collected, and which does not bear the costs associated with servicing the flow of buyers.

The employees move between the rows and select the goods ordered by buyers of the B2B and B2C segments. Quality control of order picking is carried out using a video surveillance system. Access to dark stores is available only to employees who complete orders and couriers of delivery services.

Buyers order online, the orders are formed in a darkstore, and then it's transferred for delivery either straight to the client or to a transport company for delivery to the consumer.

Practically this means that the smart carts and robotic assistant technology can be adjusted to help the staff collect orders by calculating the shortest routes, providing navigation to the right aisle with goods, bearing the weight of the packages.

2.6 In-Store Personal Navigation and Dynamic Pricing in "O'KEY" Retail Chain

"O'Key" is a leading Russian retail chain, specializing in the food trade with more than 70 stores in major cities of Russia. The company's strategy includes leveraging the latest trends and best international practices. With average stores' areas equaling 5,500 m^2, it becomes a suitable space to implement a new approach to customer navigation using automated assistance, such as smart carts. Goods zoning and display standards are one of the tools that help "O'Key" reach its goal to help customers get everything they need quickly while increasing the average check. The chain already utilizes digital scans for this aim, allowing customers to scan products and checkout themselves, therefore, skipping lines at the checkout. The suggested smart cart navigation serves as an improvement to an existing system.

The following sections aim to evaluate how robotic shopping assistants or smart carts can navigate customers around the store and use dynamic pricing in customer interaction (e.g. a robot/cart that follows a customer, detects (by video-tracking or by knowing the history of purchases) their interest in a certain product, and suggests to check out a product with a dynamically reduced price).

3 Results

3.1 How to Apply SOL/DX in a Supermarket

Smart cart. The idea embodied in the smart store solution is not fundamentally new. However, the following implementation in the "Okey" food retail company is proposed as a complex solution consisting of three main aspects: a robotic smart cart with self-checkout, smart cart navigation system and dynamic pricing.

We propose to equip the device with video cameras that ensure the recognition of goods and customers, sensors that record goods placement into the basket, as well as scales for automatic weighing of goods without a barcode, for example, vegetables and fruits. The electronic trolley system determines the purchase amount, and accepts payment via Android Pay and Apple Pay applications. The cart will also be equipped with a touch screen that displays a list of selected goods, and a terminal with which customers can pay for purchases at the exit from the outlet. The developers will be able to expand the existing cart grocery recommendation system. It will be a way of giving advice on what additional products to take to those already selected. Also, the cart will be provided with an interactive map of the supermarket, which will contain the location of the goods recommended by the cart and relevant goods. The proposed cart also offers a built-in additional module with a motor, with the help of which it can follow the customer.

Thus, information about the number of goods sold and the balance will be instantly sent to the information base of the store, and the buyer, by scanning the purchases using the reader on the "smart cart", saves time when paying for them at the self-service checkout.

Dynamic pricing. A smart cart will also serve as a marketing tool to execute the dynamic pricing approach by suggesting an adjusted price of a product which can be recommended based on the customer's history of purchases or current list of goods in the cart.

AI. Since the total area of the "Okey" chain's sales area is on average about 5000 m^2, the problem of quickly finding the right product remains relevant for customers. An internal store navigation system can help solve this problem.

A neural network is a structure of united neurons, its direct analog is the human brain. Artificial intelligence (AI) is an already trained neural network or a complex of them. AI training for navigation tasks does not differ from the standard one - any parameters that need to be processed are loaded into the neural network (to detect defects, for example, photos of crumpled boxes). As a supporting solution to the neural network-based solution for optimizing operations for trolley navigation around the shopping area floor, it is proposed to train a neural network that will find the shortest route for the buyer in the hall according to a preselected list of goods. This makes the most reasonable use of the customer's time and increases the overall speed of movement through the hall.

AR navigation. Thus, we can imagine the following implementation of an AR application using AR in the form of a shopping area navigator. First of all, it is necessary to build virtual maps of the premises in which navigation is to be performed. An alternative solution would be to add beacons instead, but the issue of accuracy and flexibility remains open with this method. This navigator can make it much easier to find the products that the user wants to come to.

3.2 Barriers and Limitations

New technology can be a crucial part of the development of a retail organization. But there are also negative aspects and limitations in the implementation of such devices.

These include:

1. High costs for the purchase and implementation of the necessary equipment. The use of such technologies can only be afforded by trade organizations that have a high customer flow and fairly large financial capabilities.

2. Usage of foil in packaging of some goods makes it difficult to transfer data using special sensors, therefore, it complicates the application of technology.
3. Most often, these technologies can be noted in the stores of retail chains, therefore, small stores with an area of up to 100 m^2 and not included in retail chains cannot physically accommodate such innovations.
4. Legal issues can arise if the dynamic pricing aspect is suggested to be implemented in some countries.
5. Management trust issues and weak change management, that can slow down the digital transformation processes.

3.3 Position Within Framework

The suggested solution can be classified as "The quiet one" within the existing framework. This is due to a rather individual degree of cooperativeness - each cart would mostly interact with a customer rather than other carts. However, the cooperativeness might be shifted towards "brother" considering the idea to suggest the customer buy products that are already in the carts of other consumers while navigating past them in a shopping area. This would affect the marketing aspect of carts, rather than logistic ones. The position on the autonomy degree would be in the "rudimentary" segment as the solution mostly focuses on the routing tasks controlled by a customer.

4 Discussion

4.1 Prospects: Moving to Other Quadrants

Considering that the currently suggested system lies within "The quiet one" quadrant it's worth analyzing what moving to other quadrants could contribute to the solution.

Increasing the degree of autonomy will bring the smart carts/robotic assistants to a system that could potentially be used in a dark store as a collaborative robot or as a warehouse robot. This could reduce the effort of pickers who walk around the warehouse a lot while assembling orders by working collaboratively with robots. Pickers spend most of their time walking and these bots reduce (or eliminate) some of the wasted time on walking that reduces productivity by taking up the task to push the heavy containers.

It seems that maxing out the degree of autonomy in the context of a retail store would not have a beneficial impact as the main goal of improving the in-store navigation revolves around customers and their experience. Such robots as shopping carts are just a tool to help the current shopping process and robots that max out this characteristic would be more useful in a warehouse.

Moving up on the degree of collaboration axis, when containers are filled up with goods/parcels travels to a packing station, another bot can be deployed to the picking worker's location. The further increase in autonomy could fully eliminate the pickers tasks because such net of interconnected robots could function as one system.

5 Conclusion

This paper aims to contribute to specify advantages and application of self-organized logistics in retail. The findings concluded that self-organized logistic systems can be a tool to increase the speed of customer in-store navigation, help customers carry groceries and other goods and engage them in the buying process. The potential also extends to the self-organization systems in a warehouse of a darkstore environment.

The potential for further research lies within the mentioned framework, each of the quadrants has gaps for analysis.

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Digitalization of Corporate Logistics Processes in the Architecture of Large Industrial Enterprises

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Abstract. Corporate logistics is one of the most difficult areas of economic activity of any large industrial enterprise. It forms complex material flows in industrial production, which affect almost all production management functions and are accompanied by financial and information flows. Thus, the processes of digitalization of logistics cannot be considered separately from the processes of digitalization of the enterprise as a whole. The paper discusses the organizational and economic features of building a business model of logistics processes at an industrial enterprise, its place in the business architecture of an enterprise, analyzes the possibilities of using an architectural management model in logistics. An architectural approach to building a business model for internal and external logistics of a company is proposed, within the framework of which internal and external information and organizational communications of logistics with the most important functions of production management are analyzed. The characteristic of modern methods and models of management of corporate logistical processes is given. Some features of building a system architecture for an enterprise that support a logistics business model are also noted. An information and service model for supporting corporate logistics is proposed and a description is given of the main information technologies and digital platforms that allow integrating the business processes of all participants in the corporate logistics network into a single architecture that ensures efficient management of corporate logistics.

Keywords: Digitalization · Logistics · Logistics system · Corporate logistics · Information system · Enterprise architecture · Digital platforms · Digital technologies

1 Introduction

In the information economy, projects for the digital transformation of business are increasingly being implemented. Logistics is becoming a priority area of digitalization as one of the most complex and costly areas of economic activity in the global world, including corporate logistics. The organization of supply has always occupied an

I. Ilin et al. (Eds.): ICDT 2021, LNDECT 157, pp. 298–308, 2023.
https://doi.org/10.1007/978-3-031-24434-6_28

important place in the management of large enterprises, especially where the range of inventory items used in the production process reaches tens and hundreds of thousands of items. In addition, large industrial enterprises often have a distributed structure and complex technological processes, the implementation of which requires the management of the movement of goods and materials, the storage and rationing of their stocks and the control of the level of work in progress, and this seriously complicates the management of material flows. Developing, logistics is gradually becoming one of the main strategic directions for managing any business related to the movement of material resources, and the management of logistics processes ensures the effective management of material, financial and information flows, synchronizing them in any distributed organizational structures, including large manufacturing corporations.

The digitalization of logistics in the modern global economy is becoming the main trend in business development. Corporate logistics is an essential part of the overall logistics system, and its digitalization requires a special approach and a thorough analysis of the organizational and economic model and IT support.

2 Materials and Methods

2.1 Some Organizational, Economic, and Informational Aspects of Building an Intracorporate Logistics System

In the modern economy, logistics is considered as the most important type of economic activity, the organization of which is based on serious scientific foundations and its digitalization is a priority in the concept of digital transformation of an enterprise. However, the digitalization of corporate logistics has certain features that should be taken into account when creating corporate logistics systems and require the use of methods, models and tools that support inventory management processes in a corporation, i.e. material flow [1]. The material flow includes all types of material resources used in production and providing it, as well as their storage and transportation, as well as internal production reserves, work in progress and finished products. Each movement of goods and materials has an informational reflection, linking all types of logistics operations into a single information space both within the enterprise and on the external circuit.

As separate areas, corporate logistics systems began to form, providing management of material flows within the technological cycle of production, and external logistics systems that support procurement activities and supply chain management. Corporate logistics systems allow you to control the level of stocks of materials, production reserves and work in progress, the supply of materials to production, the operation of technological transport, etc. External logistics systems control the fulfillment of purchase orders, transportation, warehousing, loading and unloading operations, harmonization of the goals of suppliers, intermediaries and consumers. Both types of systems have many common goals: reducing inventories of materials and work in progress, accelerating the turnover of working capital, reducing the duration of the production cycle, reducing production costs and product costs, etc.

The integration of external and internal logistics systems ensures the efficient functioning of the entire logistics system. The formation of a single information space makes it possible to build logistics business models according to uniform rules, which will ensure transparency, efficiency and efficiency in managing the movement of material assets at all stages from planning the need for materials for production to shipping finished products to the consumer.

Logistics systems management requires the use of modern digital platforms, transport and warehouse information systems, as well as supply chain management systems that ensure the interaction of all participants in the supply and marketing processes [2]. At the same time, their business processes are implemented within the limits that are limited by the needs of the enterprise for materials, the peculiarities of the production technology, production plans, the peculiarities of the shipment of finished products, as well as the system of storage, rationing and movement of goods and materials existing at the enterprise, etc. The business models of external logistics are much more typified compared to the business models of internal logistics, which are entirely dependent on the type and method of organizing production, the characteristics of the technological process, and the methods and models of rationing production and warehouse stocks. Building a business model for corporate logistics during the implementation of digitalization projects requires the use of the most modern and effective methods and modeling tools and cannot be considered locally and independently of the business model of enterprise management as a whole. At the same time, it should cover all parts of the material flow and be an integral system that takes into account the economic interests and technical and technological problems of all participants in the logistics process.

2.2 Architectural Approach to the Organization of Information Processes in the Intracorporate Logistics System

The digitalization of corporate logistics requires the integration of the logistics processes of all participants into the enterprise management system, and ensuring their interaction should be supported by powerful methodological, organizational and IT support. The modern economy is extremely mobile, which requires almost instantaneous reactions of its participants to a rapidly changing economic situation, which is especially typical for logistics processes. Any disruption, such as in the supply chain or a change in production technology, may require rapid organizational changes, business model adjustments and IT solutions. Such an opportunity in the corporate management system is provided by the architectural management model within the framework of the Enterprise Architecture. It provides support for the joint activities of all participants in the logistics process and relies on modern digital platforms, IT solutions and the information infrastructure of the organization [3, 4]. In turn, the implementation of the SCM concept allows you to build integrated supply chain systems, in which supply chain management is a process of planning, controlling and regulating the flow of raw materials, materials, work in progress, finished products, services and related information, from design, generation of applications and procurement through production and distribution to final consumption in terms of cost reduction. This stream includes all internal and external movements of goods and materials and the information corresponding to this movement.

In the information economy, supply chain management becomes a business strategy that ensures effective management of material, financial and information flows for their synchronization in any distributed organizational structures [5]. In addition, this business strategy allows you to predict product sales; optimize inventory planning, taking into account the selected inventory management model for each product category; optimize supply planning within the logistics network, taking into account planned sales, deliveries, stock availability, transport capacities, various restrictions and business rules. The supply chain integrates the activities of all participants in the logistics process, overlaps the boundaries of individual firms, i.e. all key business functions are integrated. A certain network structure of supply chains is being formed, in which each member of the network supplies each other with material and commercial products or services, adding a certain value to the product.

The enterprise architecture allows you to build organizational, economic and IT components on which the management processes of all participants in the chain are based, creating an integrated information environment for management and decision making. The enterprise architecture is the most important tool for making organizational changes in the business, improving the business model and reflecting these changes in the information infrastructure of the enterprise. Its construction allows to form a common vision of the business among all participants, not only of the logistics process, but also of the business as a whole. This is all the more important because logistics business processes permeate the entire business architecture, covering almost all areas of economic management (Fig. 1).

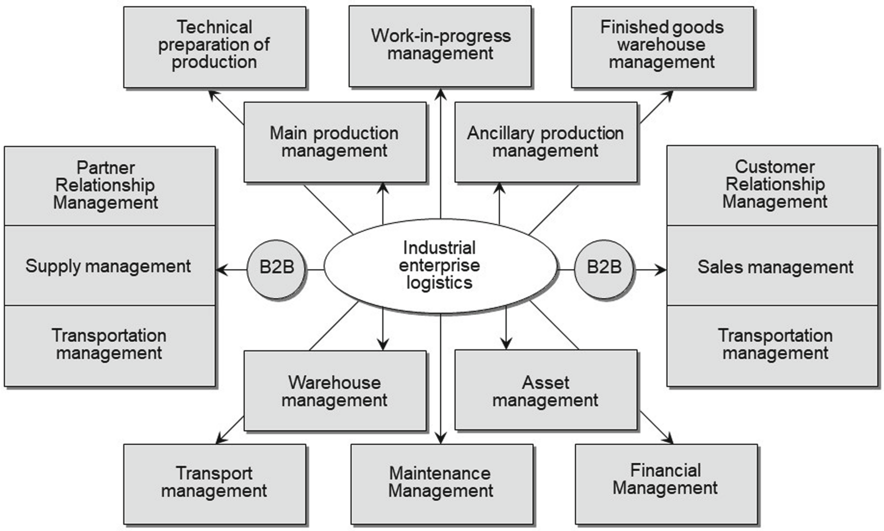

Fig. 1. Functional decomposition of the logistics of a manufacturing enterprise.

The implementation of the SCM concept in the Enterprise Architecture ensures the management of key business processes of the entire supply chain, which allows us to talk about the formation of architectural synergy through the use of a single business model for all participants in the management and integration of the logistics business processes of the corporation. As a result, an architectural model for managing the logistics system can be built, based on SCM applications in EA. It should be noted that the functional areas of logistics include supply, production, distribution and reverse logistics. These are the key business processes that form the basis of the logistics system.

EA offers a number of tools and methods for describing the structure of the logistics processes of an enterprise and a model for managing these processes, which allows us to formulate requirements for the IS Architecture and IT infrastructure [6]. The business model of the logistics processes of an enterprise should cover the entire set of internal and external logistics processes and is an integrated business architecture of the logistics system. EA must provide information interaction with the production preparation system, which specifies not only the production technology, but also its composition, consumption rates and the range of material assets; financial management system; management systems for the supply and marketing of products; quality control, etc. The activities of all the listed services and management systems are supported by certain applied IT solutions. The IT architecture ensures the execution of the business processes of the logistics system, and the IT service models allow the use of specific technologies and solutions. The architecture of information allows you to cope with the objective complexity of sharing information resources and information systems by all participants in logistics processes [7].

IT infrastructure plays the most important role in logistics digitalization projects. It is a platform without which a business cannot function effectively in the digital world. It is on the creation, management and formation of an IT infrastructure development strategy that is consistent with the business strategy that the main focus is on the digital transformation of the enterprise. IT infrastructure integrates many modern IT solutions, information technologies, digital platforms, network solutions, etc. It should provide reliable support for business processes and the ability to quickly change business architecture. Thus, EA allows you to build organizational, economic and IT components, which are based on the management processes of all participants in the logistics network, creating an integrated information environment for management and decision-making. The digitization of corporate logistics at EA relies on a range of applied IT solutions, modern communication tools and digital information platforms. This ensures dynamic cooperation both within the enterprise and with its business partners, and also gives the opportunity to control the costs, income and profits of all participants in the logistics network.

3 Results

An integrated approach to the problem of supplying enterprises was implemented in the methodology of planning the need for materials MRP (Material Requirements Planning). From this moment, the beginning of a real digital transformation of the business can be counted. The concepts of business management have gradually developed towards a process approach to management, in parallel with their development, more and more advanced information systems have been created that support these concepts. From MRP to MRPII (Manufactory Resource Planning), then to ERP (Enterprise Resource Planning), which already offered a set of integrated applications that allow you to create an integrated information environment for automating the planning, accounting, control and analysis of all the main business operations of an enterprise and, finally, to the concept of ERP II (Enterprise Resource & Relationship Processing), as a result of the development of the ERP methodology and technology in the direction of closer interaction between the enterprise and its counterparties [8]. All of the above concepts are supported by relevant information systems.

ERPII class systems are currently the basis for the formation of the information infrastructure of a modern enterprise in the course of its digitalization. In addition to the MRPII-compliant core, they contain a number of components. Including: a supply chain management system (SCM), the most important function of which is SCP (Supply Chain Planning), as well as an advanced planning and scheduling system (APS), which provides operational analysis of changes in order to make the necessary adjustments to the supply and production schedule [9]. The operation of these systems is based on the Collaboration Planning, Forecasting and Replenishment, CPFR standard developed by the VICS (Voluntary Industry Commerce Standard) association. In addition, SCM (SCP) solutions make it possible to carry out strategic planning of the supply chain structure, create supply chain plans, simulate various situations, evaluate the level of operations, compare planned and current indicators. SRM (Supplier Relationship Management) solutions are used to manage suppliers and implement the entire procurement cycle, including an electronic trading platform [10]. The manufacturing execution system (MES) ensures the efficient execution of the production process, coordination of internal and external orders, placement of orders for materials, control and regulation of stocks, state of work in progress, etc. The MES system can also be integrated with ERP and together with the customer relationship management system (CRM) provides control over the movement of finished products to consumers [11]. Product information (such as composition, technology, materials used, time limits, etc.) plays an important role in organizing corporate logistics processes. Technologies that support production management at all its stages are supported by Product Lifecycle Management (PLM). The basis of the PLM solution is the PDM product data management system, which is used mainly at the stages of design and technological preparation of production and is supported by a large set of IT solutions and CAD/CAM/CAE applications. The capabilities of modern PLM solutions provide quality management, support the joint activities of partners in the design and development of new products, project management, asset life cycle management, including planning and execution of equipment maintenance and repair (PMP) activities [12]. ERP, APS, PML, MES systems allow better control of the company's internal logistics business processes, while CRM, SRM and SCM systems support the management of external corporate logistics. The integrated business architecture and information infrastructure in EA provides access to the application solutions of all the listed systems to all participants in the corporate logistics process, in accordance with their priorities.

However, a number of logistics business functions require additional system support. These functions include the processes of warehousing materials in all parts of the logistics network; material handling processes; a number of processes associated with the preparation of production and some other processes of economic activity in the enterprise (Fig. 2).

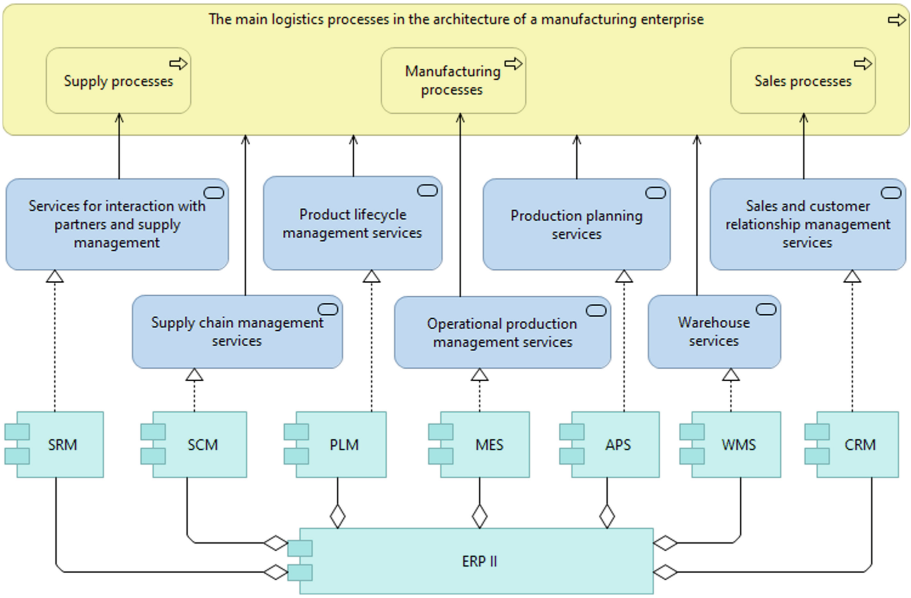

Fig. 2. Model of information and service support for corporate logistics.

Transport logistics solves the problem of coordinating the actions of participants in the transport process by ensuring their technical and technological contingency, coordinating their economic interests, and using unified planning systems. Thanks to transport, the logistics process of moving goods and materials is transformed into one technological chain, turning transport into a part of a single transport and production logistics process. Transport and logistics business processes should be integrated into the business architecture, and TMS (Transportation Management System) transport management systems should be integrated into the information systems architecture, providing a single information space for decision-making.

In the system of moving goods and materials, there is a need for their storage. The warehouse is an important link in the supply chain and operates on a strict schedule of receipts and shipments. Any large enterprise has a complex and often multi-level warehouse economy, the business processes of which are integrated into the business architecture and are usually supported by the WMS (Warehouse Management System).

4 Discussion

The basis for the digital transformation of business and digitalization of logistics is the rapid development of information and communication technologies (ICT) and their wide distribution and use in the business management system [13]. The development of digital platforms, the emergence of modern tools and technologies, applied IT solutions, models and methods of logistics management, as well as the use of best practices for managing material flows and stocks have ensured the digitalization of corporate logistics in the enterprise architecture.

Synthesizing the best achievements and best practices for implementing the SCM concept, The Supply-Chain Council (SCC) developed the so-called SCOR-model (Supply-Chain Operations Reference Model) – "Recommended Model of Operations in Supply Chains" [14]. The SCOR-model (Supply-Chain Operations Reference-model) considers five key business processes: Make – operations related to the production of the product; Source – operations for obtaining items by production; Deliver - operations for the delivery of goods to consumers; Return - operations related to return and disposal; Plan – unites and coordinates the activities of all participants in the supply chain and is an integrating element of the SCOR model.

The model integrates business processes, metrics, best practices, and technologies into a single framework to support communications between partners in the supply chain to improve performance. The SCOR model is a reference model that assumes its own language for describing the relationship between supply chain participants and a library of typical business processes. In addition, the SCOR model is an effective tool for diagnosing the supply chain and offers alternative options for its construction. Using the best practices and standard metrics proposed by the model ensures the high efficiency of the logistics system. It has become the most important tool for describing and evaluating the process of material flow through the supply chain. As an extension of this model, SCC developed the Design Chain Operations Reference (DCOR) model, which covers the business processes of product creation, and the CCOR (Customer Chain Operations Reference model), which together with the previous two, it makes up the IBRF model (Integrated Business Reference Framework – the recommended integrated business structure).

IBRF is a business planning tool that can link all value chains together, i.e., will make it possible to link customer requirements, product data management, product life cycle management, chain time and costs [15].

In the development of the process of digitalization of corporate logistics, modern information technologies and information digital platforms play an important role. First of all, it is the Internet, which provides many services, which has greatly expanded the information base, simplified the search for information and the exchange of information between cooperating economic entities. In addition, the following technologies are widely used:

– Mobile devices are technologies and solutions, the use of which opens up new business opportunities, especially in the field of control and organization of material flows;
– Cloud technologies that implement new approaches to accessing enterprise information resources, which is extremely important for the functioning of the supply chain;
– Big Data is a technology that provides work with huge amounts of information of various composition, located in different storages, which provides the ability to consolidate data coming from several sources;
– Blockchain is a set of blocks sequentially interconnected by an encryption hash code, which guarantees the safety, immutability and reliability of all transaction records. Blockchain increases trust in the collected and stored data, ensures reliable and secure payments and contracts [16];

– The Internet of Things is the most significant logistics management technology that allows you to connect any physical objects to the network. Cisco believes that the Internet of Things will revolutionize the logistics industry in the near future [17].

Robotics (RPA – Robotic Process Automation), unmanned vehicles, artificial intelligence and machine learning, virtual/augmented/mixed reality, 3D printing, etc. are of great importance in supporting logistics processes. It should also be noted a very important technology that provides a quick response of the architectural model management on the dynamics of the logistics network, which leads to an adjustment of the business model and requires an almost instant response to this information infrastructure. We are talking about intent-based networks [18], as a technology that significantly accelerates the provision of reliable services in a dynamically developing model of logistics processes, due to the rapid deployment and operation of an information infrastructure with specified parameters.

A special role in supporting logistics processes is played by digital information platforms [19, 20]. The concept of platforms is a modern business model, a place where producers and consumers can collaborate. The digital information platform is an ICT-based platform that provides interfaces and services according to certain standards that ensure the interaction of partners. The purpose of such structures is the integration of all participants in the value chain, as well as communication channels, distribution routes, and a community of potential customers. There are enough examples of such digital platforms, especially in e-commerce. The formation of digital platforms covers the entire spectrum of relationships between various subjects of the transport and logistics sector, namely the interaction of organizations and consumers (B2C), organizations among themselves (B2B), direct interaction between consumers and consumers (C2C), as well as interaction between organizations and the state (B2G).

5 Conclusion

The formation of a corporate logistics management system means doing business on the principles of integrating the main business processes, as well as planning and management models in the companies participating in the logistics system throughout the supply chain. In the architectural model of enterprise management, building a corporate logistics system makes it possible to create a single information space for supply chain management, reflecting the current state of the logistics process for all network participants, which ensures a quick response to any changes and a serious synergistic effect. The paper presents an analysis of digital platforms, modern tools and information and communication technologies, as well as methods, models, and best practices for managing material flows and stocks, which have become the basis for the digitalization of internal and external corporate logistics processes. An architectural approach to building a corporate logistics business model in the enterprise architecture is proposed, which allows analyzing informational and organizational-economic relations of logistics processes with the most important functions of economic activity and based on this analysis, building an information and service model for supporting corporate logistics.

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The Architecture of IT Services of an Oil Refinery Information Systems

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Abstract. An oil refinery is a compound process manufacturing complex that requires effective activity support by the information systems and technologies at all the levels. This article describes the functional requirements and the top-level architecture of IT services of an oil refinery enterprise information systems. The methodological basis of the article is a service-oriented approach to the design of management systems and their IT support.

Keywords: Oil refinery information systems · Architectural approach to the enterprise management · IT services

1 Introduction

An oil refinery is a compound process manufacturing complex that processes crude oil into a wide range of marketable products [1] (gasoline, kerosene, diesel fuel, liquefied hydrocarbon gases, etc.) and ships them to consumers. Refineries have the form of a complex production environment with compound technological equipment, tanks where oil is stored before transportation and immediately before refining already on the territory of the oil refineries [2], and an extensive network of pipelines – which are the cheapest and safest way to transport oil, allowing to transport oil and petroleum products on an ongoing basis.

Complexes like oil refineries require the usage of information systems and technologies. Manufacturing management involves the interaction of heterogeneous resources, the implementation of clearly planned and synchronized actions to implement both production processes and accounting procedures. Oil refinery enterprise automatization requires the design and implementation of IT support systems for production, technological and business processes that would ensure effective management based on the implemented IT solutions.

One of the key attributes of the intellectual technological procurement is operational flexibility. It implies instant reaction to the new situations caused by the changes of the raw materials quality, market demand, and the products and energy supplies costs. It is obvious that such uncertainty would impact the operation of the enterprise significantly.

I. Ilin et al. (Eds.): ICDT 2021, LNDECT 157, pp. 309–318, 2023.
https://doi.org/10.1007/978-3-031-24434-6_29

The ability to make changes in the operational strategies (e.g. changing the parameters of the technological mode, replacement of the catalysts, reconstruction of the technological scheme, etc.) is the basis of the optimization of the production processes aimed at the improvement of the quality of manufactured goods, increase in the yield of high-margin products with a reduction in production costs [3]. The complexity of process parameter control systems places demands on the corresponding control systems, which lead to the development and implementation of service-oriented IT architectures.

The article considers the requirements to the IT services of the oil refinery information systems formed in accordance with the architectural approach to the enterprise management. The services architecture designed by these rules allows to form an adequate IT support system considering the process needs, to minimize human intervention in the production and technological processes, reduce the likelihood of errors in production and accounting processes, to plan the movement of material values of the enterprise more efficiently, to ensure effective decision-making and implementation of managerial actions.

2 Materials and Methods

This paper applies a service-oriented approach to the analysis of the IT support requirements of the enterprise management system. This approach is based on a service-oriented representation of the enterprise architecture [4].

The enterprise architecture is a comprehensive model that combines heterogeneous elements providing effective operational management. The enterprise architecture model represents such elements as material and production infrastructure, business processes, organizational structure, document management, information systems and applications, data architecture, etc. within a single complex. It is important to coordinate the elements' capabilities to implement certain functionality in accordance with the requirements of information exchange to ensure effective collaboration [5]. This coordination is achieved by designing a system of services provided by some elements in response to the requirements of other elements. Due to the application of such approach the architecture of the enterprise is created in accordance with its purpose and flexibly responding to changing conditions.

Thus, the business process system defines the requirements to the appropriate IT support from information systems and applications. The latter provides IT services implementing the necessary functionality to automate processes. The architecture of IT services reflects the structure of the of the business processes requirements for the provision and processing of information by enterprise information systems. IT services are subject to decomposition in the same way as the processes they serve (Fig. 1).

In this article the oil refinery IT services architecture is formed in accordance with the adopted classification of information systems of the manufacturing enterprise, with such information system level as:

- BI, ERP – enterprise management level;
- MES – manufacturing execution level;
- SCADA (or APCS) – process control level.

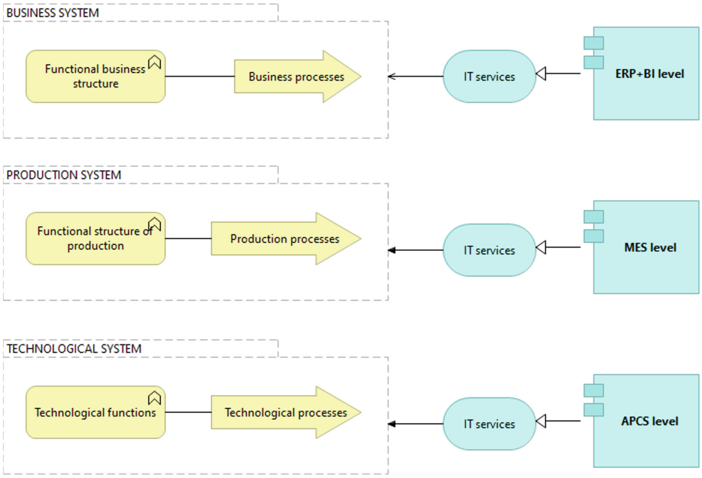

Fig. 1. Levels of information systems in a production enterprise.

The highlighted enterprise information system classes perform the following tasks:

- SCADA – automated process control systems: collection and aggregation of instrumentation and local control systems data with which the process flowchart and equipment are completed; transmission of the control signals to the process equipment;
- MES (Manufacturing Execution System) – automated enterprise management system: the tasks of synchronization, coordination, analysis and optimization of the product output within a particular production (shop floor) in real time;
- ERP (Enterprise Resource Planning) – resource planning system of the enterprise: solving the problems of managing the economic and financial activities of the enterprise;
- BI (Business Intelligence) – business intelligence systems: analysis of the business information, provision of the historical, current and forecasting aspects of the data analysis.

While considering production enterprises, oil refineries included, special attention is paid to the production automation, i.e. the production units activities automation. Refinery products are produced on a continuous basis, so the production system must be constantly monitored for a number of parameters - pressure, temperature, vibration, etc.

The main purpose of the information system implementation on the oil refinery enterprise is to ensure safety, reliability, and efficiency. Technological processes management is realized with the use of devices and sensors, which the production equipment is equipped with. All the data of the shops is accumulated and dispatched at the operator stations.

The process automation devices include programmable logic controllers (PLCs), intelligent electronic devices (IEDs), human-machine interfaces (HMIs), operator or engineer workstations, servers, printers, and wireless devices [2, 6].

They can be divided into operational (directly related to supporting the refinery operations, such as process control systems or security systems) and multiservice applications (supporting such operations as video surveillance, or applications related to such business applications as voice and corporate data) [7].

The development of information system architecture is primarily related to the ERP concept evolution to ERP II and ERP III. The classical ERP concept implies that an enterprise as a supply chain participant is to have a well-functioning internal material flows logistics (including management of finances, assets, inventories, and production planning).

The inventories are one of the most expensive assets for the refining enterprises. It can be explained by the geographical distance between the supply bases and the production units: companies are to have a stock reserve greater than the minimum required level in traditional conditions, since under the conditions of geographical remoteness of facilities the accurate supply planning is quite difficult. Since the industry specifics make it impossible for the refiners to minimize the amount of inventory, companies strive to achieve maximum savings on those costs that arise in the creation of inventory. Therefore, the appropriate organization of the supply chain and logistics is of crucial importance in the efficiency management [8, 9].

The logistics chain in the refining process [10] begins with the transportation of the extracted in the fields raw materials to the oil storage facilities, with its subsequent delivery to the refinery (Fig. 2). After that, the feedstock is processed into petroleum products, which go into tanks and reservoirs for temporary storage until they are transported to the consumer warehouses and storage facilities [11].

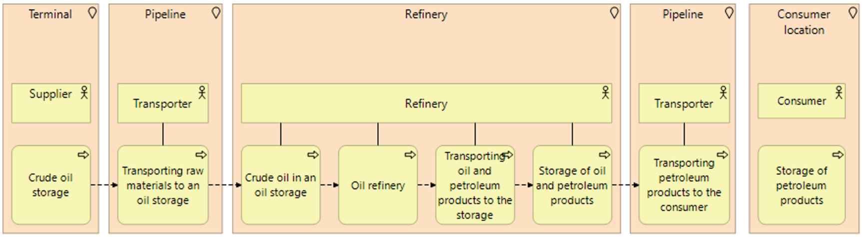

Fig. 2. The refinery supply chain.

Summarizing the wording of foreign authors, the supply chain can be defined as following: "The supply chain is three or more economic units directly involved in the external and internal flows of products, services and information from the source to the consumer" [12–14]. Supply chain management is a set of management approaches, information and tools that ensure the effective integration of suppliers, producers, intermediaries, and sellers. This is exactly the logistics organization that ensures availability of the product when and where it is needed at the right cost [15].

The supply chain efficiency improvement is an important source of the cost savings. Since the costs of the oil and petroleum products transporting, storing, and distributing to final consumers are quite high, it is important to develop and implement new logistics technologies and improve the product delivery processes.

ERP class systems are designed to integrate business processes of the company. The approach to the supply chain management automation has changed with the development of its ideology: the ERP II loop includes modules related to the interaction with other supply chain participants - CRM (Customer Relationship Management), SRM (Supplier Relationship Management), SCM (Supply Chain Management), HR (Human Resources Management), etc. ERP III concept implies corporative information system features development aimed at the integration with the Internet, data from the various sources integration, closer integration with the clients, and integration with the physical objects such as production equipment and robotic systems through the services system [16]. The development of corporate information systems for a refinery in accordance with the concept of ERP III involves the design and implementation of services related to the interaction between business systems (BI, ERP) and production systems (MES, APCS), as well as the digital services to transfer data from the production equipment into the production systems.

In terms of the services highlighted in the architecture of the modern oil refineries, Cisco emphasizes on the necessity of such services induced by the increased requirements of security, employee mobility, data access and collaboration with the specialists working remotely as [7]:

- integration of the corporate information system with the mobile applications and devices;
- control of the access to the objects;
- data access control;
- voice and video communications capability;
- location tracking (e.g. people, assets, vehicles).

3 Results

The architecture of a modern production enterprise implies a single information space that integrates data from all the subsystems of the corporate information system - APCS, MES, ERP, BI. The functional model and system of production, technological and business processes of a refinery analysis [17] allows to form a service-oriented model of interaction between the processes and IT systems of the refinery (Fig. 3).

The interaction of the different classes of the production enterprise information systems with the subsystems of technological, production and business processes are presented in Fig. 3. The detailed requirements for the IT services are described below.

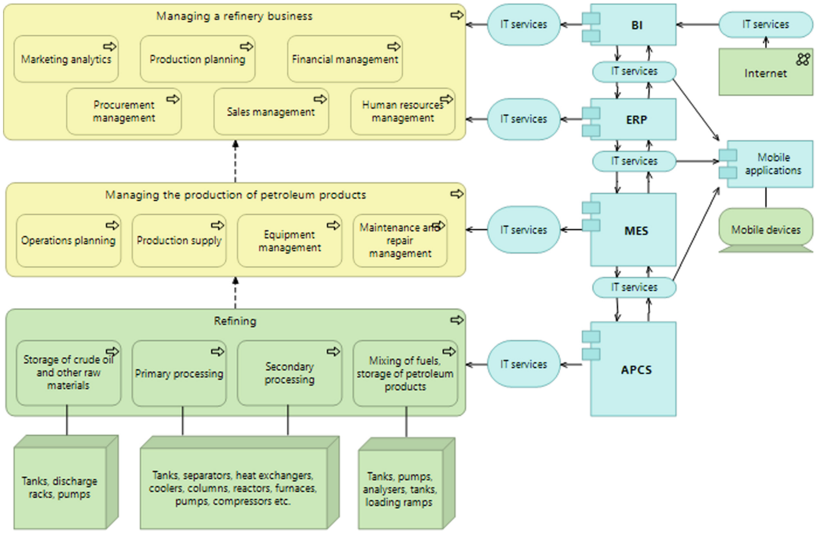

Fig. 3. Service-oriented architecture model for IT support for refinery processes.

ERP systems implement a wide range of such management functions of any enterprise as financial management, personnel management, procurement and sales management, etc. The functions presented in the ERP-systems are quite standard for the enterprises of various industries. Some of the specific requirements to the ERP services of the oil refining industry are listed below. BI-systems in close interaction with the primary data from the ERP allow to implement complex analytics to the support management decision-making.

Specific requirements to the BI and ERP systems of the oil refinery IT services:

- Operations planning subsystem:
  - Determination of an efficient petroleum products production plan based on the raw materials quality and in accordance with the requirements of the signed contracts for the purchase as well as the cost minimization criteria [18, 19];
  - Ability to dynamically adjust and recalculate the production plan;
  - Informing about the actual production;
  - Informing about the deviations from the planning output
  - Production plan indicating the need for raw materials by the type, quantity and timing.
- Marketing analytics subsystem:
  - Statistical analysis of the demand for petroleum products, including seasonal factors consideration;
  - Analysis of the petroleum products, crude oil, energy and other components of production prices;

  - Forecasting of the demand and prices for the petroleum products, crude oil, energy and other components of production;
  - Forecasting the quality of the incoming commercial oil using nonlinear regression methods;
  - Prediction of the results of oil refining on the basis of the forecast of the quality of commercial oil with the use of nonlinear regression methods;
  - Analysis of crude oil delivery prices depending on the method of transportation;
  - Identification of the most expensive and demanded products of the market in a certain period.

- Stockholding management subsystem:

  - Monitoring and control of the current stock of crude oil;
  - Monitoring the petroleum storage tanks filling;
  - Calculation of the reorder point (timing and quantity by the feedstock type);
  - Informing about the level of crude stocks;
  - Informing about the crude oil and petroleum products storage tanks filling;

- Sales management subsystem:

  - Control of the signed contracts for the sale of petroleum products (in terms, quantity, quality);
  - Sales plan for the period (in terms, quantity, quality);
  - Control of the petroleum products shipment in accordance with the signed contracts.

Managers of the production units are to balance the requirements, planned production output stock levels of raw materials, and production capacity capabilities. It means that they must have access to up-to-date and accurate information in order to make decisions about the ability to produce the next batch of products and consider the impact it will have on the rest of the production schedule. MES systems allow the production managers to access the necessary performance data in real time and make it possible for them to assess opportunities for efficient use of production resources quickly. MES systems focus on the shop floor operations management and provide transparency of information both in production and enterprise and throughout the supply chain.

MES level systems IT services requirements:

- Manufacturing management subsystem:

  - Formation of the production program for the planned period in accordance with the available production capacity, the planned volume of sales by type, quality and quantity of petroleum products, delivery dates, and the quality of the delivered oil;
  - Requirements of raw materials by type, quality and quantity in accordance with the production plan and taking into account the timing of delivery;
  - Ability to dynamically adjust and recalculate the production plan;
  - Reporting on the actual production results by type, quality, timing and volume;

- Informing about the actual production of products by type, quality, quantity and timing in the order-by-order section;
- Proactive informing about predicted risks of production plan non-fulfillment in the order-by-order section.

The oil refinery's APCS systems collect information via remote terminals, programmable logic controllers (PLCs) and intelligent electronic devices and transfer it back to the central station for the necessary analysis, control actions, as well as for the display of information on the operator's screens. Thus, the most important components of a control system are the master station, remote terminals and the communication between them.

In order to form the requirements to the systems of the class of the automated refinery process control system, it is important to understand its structure that consists of a set of different technological processes (units, sites, facilities). The production infrastructure of oil refining production can be divided into the following blocks:

- crude oil storage;
- primary refining;
- secondary refining;
- motor fuel compounding (blending);
- storage and shipment of the marketable products.

Intake, shipment and placement of the raw materials and petroleum products in the company are provided in areas equipped with loading and unloading racks, tanks and pumping equipment.

Technological installations for primary and secondary oil refining are a set of equipment (tanks, electric dehydrators, heat exchangers, furnaces, rectification columns, refrigerators, separators, reactors, absorbers, adsorbers, desorbers, pumps, compressors, etc.), interconnected by a system of pipelines which provides specialized production processes [20, 21]. Control over the technological parameters and safety of the processes performed at the units as well as their automatic control, including loading/unloading of the raw materials and petroleum products and accounting of the processed oil and the obtained products at all the production stages, is performed by the APCS systems with the use of the Electrical Control & Instrumentation and automation tools (EC&I). These include: pressure gauges; level gauges; temperature measuring devices; flow meters; control and shut-off valves; quality analyzers; sensors of pre-explosive concentrations, etc. Motor fuels are prepared at the mixing stations equipped with tanks, metering pumps, instrumentation, control valves and quality analyzers.

The IT services of the refinery control system level requirements are the following:

- Setting up the parameters of the technological processes in accordance with the developed production program;
- Monitoring of the process equipment operation parameters;
- Bringing separate types of equipment or the whole plant to a safe state according to the developed algorithms in case of exceeding the acceptable level of any of the parameters;

- Human-machine interface for the control of the technological equipment and installation operation parameters;
- Visualization of the process equipment operation parameters.

4 Conclusions

Effective management of a refinery implies the necessity of an accurate, reliable and up-to-date information at all levels of the enterprise: at the level of management of individual process units, at the level of management of production units, and at the level of business decision making. The corporate, multi-level IT architecture of a production enterprise provides such opportunity to present information both in the most detailed and appropriately aggregated form.

In this article the requirements to the oil refineries information systems IT services are formed based on the current trends in the development of information systems architecture as well as the needs of the oil refineries. Designing the IT architecture of an enterprise on the basis of services allows to develop an information management system that meets current business needs, including an automated system. Particular attention when designing the IT architecture of the refinery, is to be paid to the production management systems (MES) and process control systems (PCS). While implementing such systems in practice, IT solutions proposed by the developers specializing in specific industries enterprises automation are used.

Acknowledgement. The research was supported by the Ministry of Science and Higher Education of the Russian Federation (Agreement No. 075–15-2022–1136 dated 01.07.2022).

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