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IMPROVEMENT OF THE INFORMATION DECISION SUPPORT SYSTEM IN THE SPHERE OF TRANSPORT LOGISTICS OF ENTERPRISES

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The article is devoted to the problem of improving the information system for decision support in the sphere of transport logistics of enterprises. The relevance of the work is due to the importance of transport logistics as a source of increasing the level of economic efficiency of the enterprise and the imperfection of existing enterprise management information systems in terms of the quality of forecasting logistics indicators. The essence of improving the decision support information system in the field of transport logistics of enterprises is to improve the model database management subsystem by including a module for forecasting freight turnover by modes of transport. The volume of freight turnover is an important indicator that is used in short-term and long-term planning, which determines the task of improving the accuracy of forecasts. It is this task that was put into the idea of improving the decision support system in the field of transport logistics of enterprises. To implement the task, a procedure has been developed for choosing a predictive model from among the proposed ones, which provides the best estimate of the forecast accuracy for specific input data. This procedure is implemented in the software environment for statistical processing and data visualization R. The input data for forecasting are time series of freight turnover volumes by modes of transport, which can be obtained from any enterprise management system. Calculations were made to test the developed module. The list of models for selection contained such predictive models as: ARIMA-model, Holt-Winters model with additive seasonality model and Holt-Winters model with multiplicative seasonality model. The source of data is statistical information on freight turnover. The choice of the best model for forecasting is based on the calculation of the mean absolute percentage error (MAPE) for the test data. Approbation of the subsystem revealed its possibility of use. A comparative analysis of the constructed forecasts of freight turnover volumes for different types of transport and forecast models confirmed the feasibility of using an improved forecasting subsystem in the field of transport logistics. The use of an improved decision support information system creates conditions for improving the planning of transportation of the enterprise and increasing the economic efficiency of the enterprise.

УДОСКОНАЛЕННЯ ІНФОРМАЦІЙНОЇ СИСТЕМИ ПІДТРИМКИ ПРИЙНЯТТЯ РІШЕНЬ В СФЕРІ ТРАНСПОРТНОЇ ЛОГІСТИКИ ПІДПРИЄМСТВ

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Ключові слова:
транспортна логістика, вантажообіг, прогнозування, інформаційна система, система підтримки прийняття рішень

Стаття присвячена проблемі удосконалення інформаційної системи підтримки прийняття рішень в сфері транспортної логістики підприємств. Актуальність роботи зумовлена важливістю транспортної логістики як джерела підвищення рівня економічної ефективності діяльності підприємства та недосконалістю існуючих інформаційних систем управління підприємством у частині якості прогнозування логістичних показників. Сутність удосконалення інформаційної системи підтримки прийняття рішень в сфері транспортної логістики підприємств полягає в удосконаленні підсистеми управління

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базою моделей за рахунок включення модулю прогнозування вантажообігу за видами транспорту. Обсяг вантажообігу є важливим показником, який використовується при короткостроковому та довгостроковому плануванні, що зумовлює завдання щодо підвищення точності прогнозів. Саме це завдання і покладено в ідею удосконалення системи підтримки прийняття рішень в сфері транспортної логістики підприємств. Для реалізації завдання розроблена процедура вибору прогнозної моделі з переліку запропонованих, яка забезпечує найкращу оцінку точності прогнозу для конкретних вхідних даних. Ця процедура реалізована в програмному середовищі для статистичної обробки та візуалізації даних R. Вхідними даними для прогнозування є часові ряди обсягів вантажообігу за видами транспорту, які отримані з будь-якої системи управління діяльністю підприємства. Для апробації розробленого модуля здійснені розрахунки. Перелік для вибору містив такі прогнозні моделі: ARIMA-модель, модель Хольта-Уінтерса з адитивною моделлю сезонності та модель Хольта-Уінтерса з мультиплікативною моделлю сезонності. Джерелом даних є статистична інформація про вантажообіг. Вибір кращої моделі для прогнозування відбувається на основі розрахунку середньої абсолютної процентної похибки (MAPE) для тестової вибірки. Апробація підсистеми виявила її придатність для використання. Порівняльний аналіз побудованих прогнозів обсягів вантажообігу за різними видами транспорту та прогнозними моделями підтвердив доцільність використання вдосконаленої підсистеми прогнозування в сфері транспортної логістики. Використання удосконаленої інформаційної системи підтримки прийняття рішень створює умови покращення планування транспортних перевезень підприємства та підвищення економічної ефективності діяльності підприємства.

Statement of the problem

Transport logistics occupies a special place in the activity of any enterprise. This is due to the fact that, on the one hand, transport is an independent area for investing the capital of an enterprise, which later takes part in the processes of production, turnover, and so on. On the other hand, according to studies [1; 2], the costs of transport logistics account for 70% of all logistics costs of an enterprise and, therefore, are an effective source of increasing the efficiency of its activities.

Transport is an area that is located at the junction of the manufacturing sector and the service sector. Transport provides transportation of goods and passengers, helps to develop ties between enterprises, industries, regions, without creating any material values. At the enterprise level, the objects of management in the field of transport logistics are the choice of modes of transport, traffic volumes, directions and nomenclature of goods. Therefore, it cannot be considered outside the networks of the transport system of the entire state. If the state transport system functions effectively and is included in the global transport network, then this favors an increase in the volume of international traffic and an increase in the competitiveness of domestic transport, enterprises and the country's economy as a whole.

Railway transport in the transport system of Ukraine transports significant volumes of goods and passengers over long distances, and also ensures the implementation of export-import operations. Road transport ensures the transportation of passengers and goods mainly over short and medium distances (on average, up to 200 kilometers). Pipeline transport is essential for the movement of oil, petroleum products and natural gas. Ukraine has an integral network of pipelines. It consists of local oil pipelines, which pump oil from production sites to oil refineries, and main oil pipelines. The filling of oil and gas pipelines depends on international agreements on the purchase and transportation of these resources. River and sea transport are part of the water transport of Ukraine. River transport mainly carries out domestic transportation of goods along the Danube River. Air transport performs functions related to the connection of Ukraine with other countries of the world. This mode of transport mainly transports passengers, mail and goods, which quickly deteriorate.

According to [3], one of the problems that need to be addressed in the logistics sector of Ukraine is the unsatisfactory information support in the field of transport and transport logistics.

Analysis of recent studies and publications

Researches [4–6] and several other are devoted to the issues of transport logistics. It should be noted that in addition to the development of the transit potential of the state, the issues of transport systems, the interaction of various modes of transport at the international, national, regional levels, a significant number of studies are devoted to the development of individual modes of transport.

So, monographs [7; 8] are devoted to the problems and ways of development of road transport. Publications [9; 10] and others are devoted to ensuring effective innovative activity in the transportation of both passengers and goods by rail.

In their studies, the authors give different definitions of the concept of «transport logistics», do not always take into account the fact that transport logistics concerns not only the movement of goods, but also the transportation of passengers, give a different interpretation of the concept of «information support» in the field of goods transportation.

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According to [11], information support in transport logistics is an interconnected complex system of a large number of heterogeneous elements: software, global positioning satellites for vehicles, automated dispatcher workstations, means of computerized control of the state of the vehicle. The introduction of logistics information systems into the management processes of an enterprise allows solving such problems as:

a) increase in the speed of information processing and due to this, quick decision making;

b) increase in the volume of processed information and, due to this, analyze more options when making a decision;

c) minimizing errors in the collection and processing of information.

Logistic information is the knowledge that is necessary to ensure the process of managing the logistics system, and information support for logistics is the activity of processing, accounting, analyzing and forecasting information in order to integrate elements of the management system (planning, control and regulation). The data stream that comes through the communication channels is the basis for obtaining information. The higher the level of control, the more significant information is for decision making and the more harm a wrong decision will bring.

Automated information logistics processes are subject to such requirements as scalability, distribution, modularity, openness, etc [12].

The authors of [13] pay attention to the fact that during the development of a logistics information system, it is necessary special focus on methods for measuring and comparing logistics indicators, as well as methods for managing them.

To date, there is no clear approach regarding the number and composition of indicators that will fully characterize the work of the transport system of an enterprise, region, and not its individual components. Each type of transport has its own system of indicators, which reflects its specifics. There is also a group of indicators that is common to all modes of transport and for state planning and accounting bodies. This group of indicators includes indicators of the work of carriers. Indicators are conditionally divided into quantitative and qualitative.

The category of quantitative indicators includes: transportation of goods, freight turnover, transportation of passengers, passenger turnover [14]. Accounting for these indicators, as a rule, is carried out on an accrual basis for every day, decade, month, quarter and year. Individual transport ministries calculate the average daily work for the decade, month, quarter and year, respectively. Indicators of the activity of transport systems of regions and enterprises, such as cargo turnover, passenger turnover for various modes of transport and other indicators are provided to the state statistics bodies of Ukraine.

The most common modern integrated software systems in the world are such systems [15]:

a) ERP-systems, which provide management of all enterprise processes;

b) SCM systems, which provide logistic chain management.

ERP standard systems support the implementation of the main financial and management functions, so their use concerns manufacturing enterprises. The basic tenets of the SCM strategy are «deliver the right product – to the right place – just in time – at low cost – with the right service for the customer».

An integral part of most modern ERP systems is the presence of the «Logistics» contour [16]. For example, the «Logistics» program outline of the SAP R/3 information ERP system of SAP AG Corporation (Germany) consists of the following modules: sales and distribution (SD), production planning (PP), material flow management (MM), equipment maintenance and repair (PM), quality management (QM), service management (SM).

Support for logistics operations at enterprises is also implemented in the Oracle E-Business Suite integrated information system, developed by Oracle (USA) [16]. The main parts of the Oracle E-Business Suite system are: sales management, warehouse management, supply management. Using the enterprise logistics subsystem allows you to manage information and processes associated with all stages of material flow management, from input flows to shipment of products to customers. The papers [17–19] consider the issues of designing and developing a decision support system for managing the flow of goods and business transactions. Particular attention is paid to the dynamic interaction between various aspects of a sustainable transport system from the point of view of a transport company and the application of intelligent logistics based on the Internet of Things.

However, despite the fact that the use of modern information systems to support logistics operations at enterprises makes it possible to reduce the amount of manual labor, improve the quality and consistency of all types of accounting, the quality of predicting the logistics performance of an enterprise is still their «weak» point.

Objectives of the article

The purpose of the article is to improve the decision support system in the field of transport logistics of enterprises by improving the forecasting subsystem of freight turnover.

The main material of the research

Forecasting the volume of freight turnover is one of the important tasks in the organization of transport logistics at the enterprise, in corporations and at the state level. The activities and prospects of the enterprise's own transport support, as well as the organization of attracting external contractors, depend on the supply and demand for transport services. The volume of freight turnover of the enterprise for different modes of transport is an important indicator that should be the basis for short-term and long-term planning, which leads to high requirements for the quality of forecasts. It is this task that was put into the idea of improving the decision support system in the sphere of transport logistics of enterprises.

We will consider a decision support system as an interactive system that provides the user with access to models and data in order to support the decision-making process regarding semi-structured and unstructured tasks [20]. All types of decision support systems are characterized

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by a clear structure that contains three components: a user interface subsystem (block 1), a database management subsystem (block 2), a model database management subsystem (block 3). At the present stage of development of networks (global, corporate, inter-organizational), a message management system (communications or relations) is added to the decision support system. The general structure of the decision support system is shown in Figure 1.

The effective integration of all elements of the decision support system makes it possible to avoid difficulties in building a decision support system and increase the productivity of a computer system due to the special integration of the decision support system database with other internal and external databases, the effective use of complex mathematical models, and successful dialogue coordination with a database of models and a database, reducing the cost of creating and operating the system, etc.

To improve the accuracy of forecasting freight turnover by modes of transport, it is proposed to improve the forecasting subsystem in block 3 of the decision support system by developing a procedure for choosing a predictive model that provides the best estimate of the quality of the forecast.

To implement the proposed improvement, the software environment (programming language) R [21] (designed for statistical processing and data visualization), libraries *tseries*, *forecast*, *ggplot2*, *dygraphs* were used. The database of models for forecasting freight turnover (subsystem of block 3.1) consists of a test for checking the time series for stationarity and predictive models from the *forecast* library of the R language: ARIMA-model, Holt-Winters model with additive seasonality model and Holt-Winters model with multiplicative seasonality model. Modeling tools (block 3.2) include reports that are saved in text files. However, the base of predictive models can be expanded taking into account the wishes of specialists (users) and the level of development of science.

The decision support system is automated, since it provides for the active participation in decision-making (interaction) of the user. The proposal created by the system can be finalized, improved, and then returned back to the system for verification. After that, the offer is again presented to the user and so on until a decision is made by the user. The proposed decision support system is model-oriented, since it gives access to statistical models. The structure of the freight turnover forecasting subsystem of the decision support system in the sphere of transport logistics of enterprises is shown in Figure 2.

The input data for forecasting is statistical information on freight turnover by means of transport (monthly information), which is stored in a *.csv* file in the workspace of the R software environment (file «vantobig.csv»). The decision maker updates this file periodically with updated freight turnover data. The file stores information about the turnover of five types of transport (railway, road, pipeline, water and air). The unit of measure for turnover is billions of ton-kilometers.

The decision maker runs an R script that reads the freight turnover data from a file and writes it to an object in *ts* (time series) format. The special function *ts()* is used to create objects of this class. The *ts()* function has a *start* argument that can be used to specify the start date of the time series. The additional argument *frequency* allows you

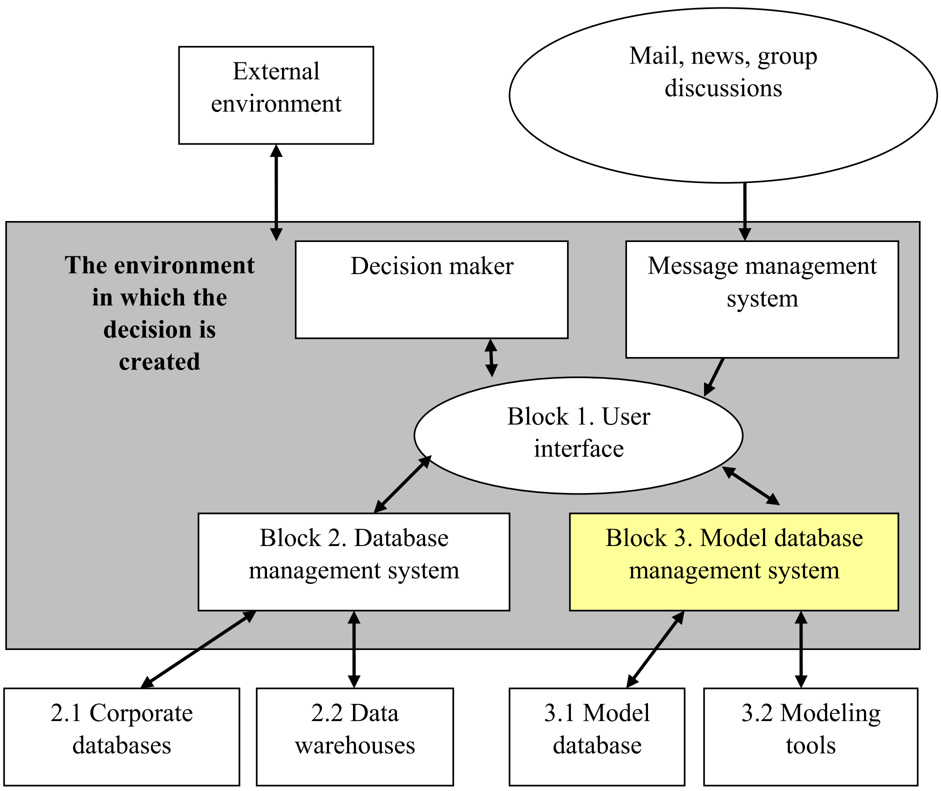


Fig. 1 – The general structure of the decision support system

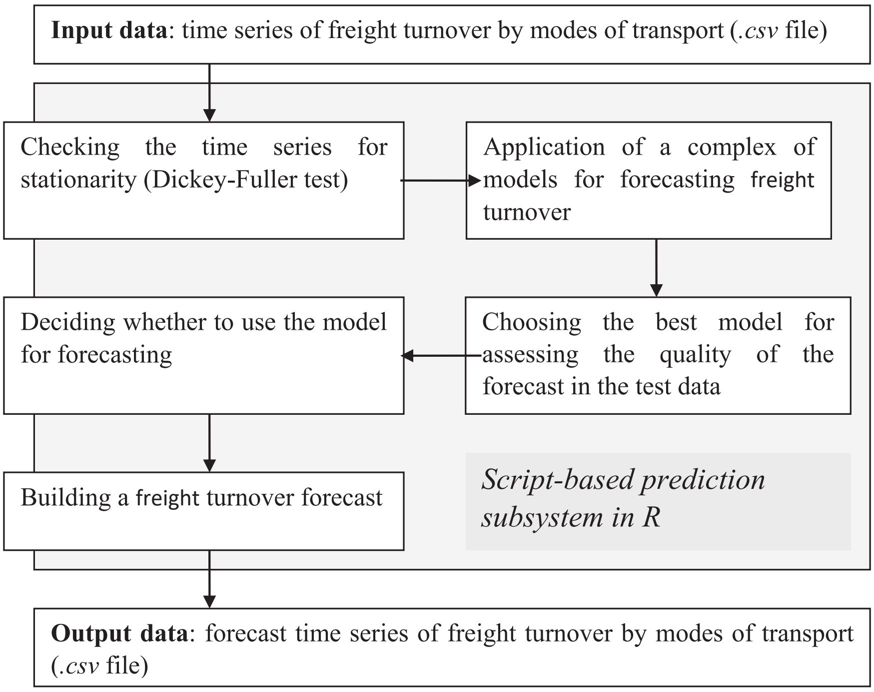


Fig. 2 – The structure of the freight turnover forecasting subsystem of the decision support system in the sphere of transport logistics of enterprises

to specify the increment of the following dates. Since the turnover in the system is monthly data, the value of the *frequency* argument is 12. The object created in this way looks like a matrix when viewed. The rows and columns of this matrix are automatically assigned names according to the values of the *start* and *frequency* arguments.

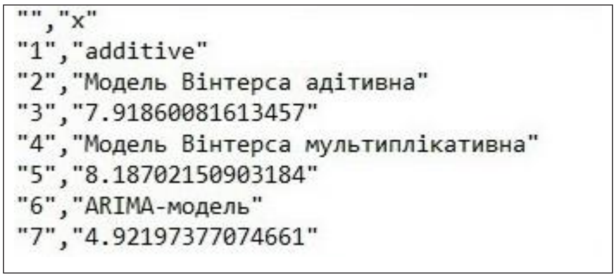
The next step in the analysis is to check the time series for stationarity using the Dickey-Fuller test (function *adf.test()* in the *aTSA* library of the R language). This check is necessary when applying the ARIMA model [22] for forecasting.

The choice of the predictive model is based on the training and test data, into which the freight turnover time series is divided. The measure used to select the best forecasting model is the mean absolute percentage error (MAPE). The decision maker is provided with a report in the form of a.*csv* file (for example, the file «auto_model.csv») with the values of this assessment. An example of a report is shown in Figure 3.

Based on the report, the decision maker selects a model to build a forecast of freight turnover for the medium term (next six months). To do this, a predictive function is called that matches the selected model. The built forecast is also saved in a.*csv* file in the R workspace (for example, the file «auto_forecast.csv»).

An example of a program code for forecasting freight turnover is shown below.

# Connecting the necessary libraries of the R language
library(dplyr)
library(readr)
library(ggplot2)
library(forecast)
library(dygraphs)
library(tseries)
# Loading information from a file into a variable
vantobig<-read.csv(file=»D:/documents/vantobig.csv», header=TRUE, sep=»;»)
# Writing to the variable *rail* of the time series of freight turnover of rail transport
rail<-ts(vantobig$rail, start = c(2006, 1), end =c(2020, 9), frequency =12)
# Plotting a time series



```
"","x"
"1","additive"
"2","Модель Вінтерса адітивна"
"3","7.91860081613457"
"4","Модель Вінтерса мультиплікативна"
"5","8.18702150903184"
"6","ARIMA-модель"
"7","4.92197377074661"
```

Fig. 3 – Report example about model accuracy evaluation (MAPE) in freight forecasting advanced decision support system

```
dygraph(rail, main = «Вантажообіг залізничний», xlab = «Рік», ylab = «млрд ткм»)%>% dyLegend(show = «follow»)%>% dyRangeSelector()
# Time series decomposition
rail_d<- decompose(rail)
plot(decompose(rail))
rail_d$type
# Checking the time series for stationarity
rail_adf<-adf.test(rail)
rail_adf
# Creation of training and test set
rail_train <- window(rail, start= c(2006, 1), end = c(2018, 12))
rail_test <- window(rail, start = c(2019, 01), end = c(2020, 09))
# Building a predictive model
rail_winters_a<- HoltWinters(rail_train, seasonal= c(«additive»))
rail_winters_m<- HoltWinters(rail_train, seasonal= c(«multiplicative»))
rail_arima<-auto.arima(rail_train)
# Building a forecast for a test data
rail_winters_a_pr<-forecast(rail_winters_a, h = 21, seasonal = 'additive')
rail_winters_m_pr<- forecast (rail_winters_m, h = 21, seasonal = ' multiplicative ')
rail_arima_pr <- forecast(rail_arima, h = 21)
# Estimation of forecast accuracy for a test data
accuracy_rail_winters_a<- accuracy(rail_winters_a_pr, rail_test)['Test set',]
accuracy_rail_winters_m<- accuracy(rail_winters_m_pr, rail_test)['Test set',]
accuracy_rail_arima<-accuracy(rail_arima_pr, rail_test)['Test set',]
accuracy_rail_winters_a
accuracy_rail_winters_m
accuracy_rail_arima
# Writing forecast accuracy estimates for a test data to a file
rail_mape=c(rail_d$type, ' модель Хольта-Уінтерса з адитивною моделлю сезонності ', accuracy_rail_winters_a [5], ' модель Хольта-Уінтерса з мультиплікативною моделлю сезонності ', accuracy_rail_winters_m [5], 'ARIMA-модель', accuracy_rail_arima [5])
write.csv(rail_mape, file=»rail_model.csv»)
# Building a forecast for the freight turnover of railway transport based on the selected model
rail_pr <- predict(rail_arima, start = c(2019, 1),27)
# Writing predictive values to a file
write.csv(rail_pr, file=»rail_forecast.csv»)
```

Approbation of the work of an improved decision support system for forecasting freight turnover was carried out on statistical data on monthly freight turnover by modes of transport in Ukraine for 2006–2020. The results revealed that for forecasting the freight turnover by modes of transport, the following models turned out to be the best:

a) for railway transport – model ARIMA (0, 1, 0)(2, 0, 0) with a lag of 12 periods, MAPE=4,9;

b) for road transport –model ARIMA (1, 1, 1)(2, 1, 0) with a lag of 12 periods, MAPE=11,1;

c) for pipelne transport – Holt-Winters model with multiplicative seasonality model, MAPE=17,7;

d) for water transport – Holt-Winters model with additive seasonality model, MAPE=22,4;

e) for air transport – Holt-Winters model with multiplicative seasonality model, MAPE=29,8.

Conclusion

Efficient transport logistics of an enterprise is an important component of its economic activity and a source of increasing its efficiency. Forecasting the volume of freight turnover is one of the important tasks in the organization of transport logistics, the results of which are used in the construction of short-term and long-term plans for the enterprise, etc. This determines the high requirements for the quality of forecasts.

The article presents an improved forecasting subsystem of a decision support system in the sphere of transport logistics by including a procedure for choosing a forecasting model that provides the best estimate of the quality of the forecast to the database of models.

To implement the proposed improvement, the R software environment was used, which is designed for statistical processing and data visualization. Approbation of the subsystem on the data of freight turnover by modes of transport in Ukraine revealed its suitability for use. A comparative analysis of the constructed forecasts of freight turnover volumes for different types of transport and forecast models confirmed the feasibility of using an improved forecasting subsystem in the sphere of transport logistics.

Prospects for further research in this area include expanding the database of predictive models and improving the user interface (block 1) when working with the subsystem.

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