# Improvement of the Quality of the Sea Passenger Terminal Based on Methods of Forecasting

## *Poboljšanje kvalitete terminala za ukrcaj putnika na temelju prognostičkih metoda*

N. N. Maiorov
Saint-Petersburg State University of Aerospace Instrumentation
Department of system analysis and logistics
Russia
e-mail: www.new.guap.ru

V. A. Fetisov
Saint-Petersburg State University of Aerospace Instrumentation
Department of system analysis and logistics
Russia
e-mail: www.salogistics.ru

DOI 10.17818/NM/2018/3.1
UDK 656.615:656.072
Original scientific paper / *Izvorni znanstveni rad*
Paper accepted / *Rukopis primljen:* 2. 5. 2018.

**Summary**

**Modern processes in the world economy directly affect the development and changes in sea passenger ports and their infrastructure. The principles of organization of the "city - sea passenger port" system are changing and becoming more complex. Recently there has been a significant increase in passenger traffic and cruise ship and ferry traffic in Baltic Sea. Since these objects are complex technical systems consisting of many elements, in their study it is necessary to use the system approach, to solve the problem of structure synthesis and the determination of objective functions. The objective of this publication was to study how the forecast for the development of demand for sea passenger ports (number cruise ships and passengers flow for next year) could be done by combining simulation and forecast functions. These tasks depend on the qualitative construction of specialized information simulation models. Such subsystems should be used by passenger port management for both operational everyday tasks and strategic tasks. One of the main goals of the forecast is the qualitative construction of an analytical function work of the terminal that determines the passenger flow based on real data. The article considers the solution of this problem by using the method of average growth rate and polynomial extrapolation. In the article, the characteristics and infrastructural features of the passenger ports of St. Petersburg are given, and the main directions of development based on the results of simulation are considered. The paper discusses advantages of using such forecast and their introduction in the early stages of operation of the terminal. The study represents an example of analytical information used for the forecast of the terminal load, the analysis of the workload and efficiency of the organization of the marine terminal in operational tasks using analytical function based on real data.**

**KEY WORDS**
transport hub
marine passenger terminal
passenger traffic
seaport
simulation model
analytical function
forecast function

***Sažetak***

***Suvremeni procesi u svjetskom gospodarstvu izravno utječu na razvoj i promjene u morskim lukama za ukrcaj putnika i njihovoj infrastrukturi. Načela organizacije sustava „gradske pomorske luke za ukrcaj putnika" mijenjaju se i postaju sve složenija. U posljednje vrijeme značajno se povećao promet putnika, brodova za krstarenje i trajekata na Baltiku. Budući da se radi o složenim tehničkim sustavima sastavljenim od više elemenata, prilikom proučavanja nužno je imati sustavni pristup kako bi se riješio problem sinteze strukture i određivanja objektivnih funkcija. Cilj je ovoga rada istražiti kako se može izraditi prognoza razvoja potražnje za pomorskim putničkim lukama (broj brodova za krstarenje i promet putnika u sljedećoj godini), kombinirajući simulacijske i prognostičke funkcije. Ti zadaci ovise o kvalitativnoj konstrukciji specijaliziranih modela simulacije podataka. Podsustavima trebalo bi se koristiti u lučkim upravama i prilikom obavljanja svakodnevnih, kao i strateških poslova. Jedan je od glavnih ciljeva prognoze kvalitativna konstrukcija analitičkoga funkcionalnog rada terminala koji utvrđuje protok putnika na temelju stvarnih podataka. U radu se razmatra rješenje ovoga problema metodom prosječne brzine rasta i polinomne ekstrapolacije. Opisana su obilježja infrastrukture putničkih luka u Sankt Peterburgu i razmatraju se glavni pravci razvoja na temelju rezultata simulacije. Raspravlja se o prednostima uporabe takvih prognoza i njihova uvođenja u početnoj fazi rada terminala. Ovo istraživanje predstavlja primjer uporabe analitičkih podataka u prognoziranju opterećenja terminala, odnosno analizu radnoga opterećenja i učinkovitosti organizacije pomorskoga terminala u provođenju radnih zadataka uporabom analitičke funkcije na temelju stvarnih podataka.***

***KLJUČNE RIJEČI***
*prijevozno središte, pomorski putnički terminal*
*putnički promet*
*morska luka*
*simulacijski model*
*analitička funkcija*
*prognostička funkcija*

## 1. INTRODUCTION / *Uvod*

Modern processes in the world economy directly affect the development and changes of seaports, terminals and transport systems. Particular attention should be paid to passenger terminals, their infrastructure, because recently there has been a significant increase in passenger traffic and the intensity of cruise ships and ferries. This aspect directly relates to the Baltic Sea. When considering the many large cities in the Baltic where passenger ports are present, it is necessary to distinguish both the availability of river passenger ports and a separate system of city berths. The system of the sea passenger terminal is a complex technical transport system, the success of which depends on a mass of factors. It is impossible to approach the study of such systems without taking into account the influence of the external environment. It is due to this impact that new functions, new properties of transport systems and new requirements to their infrastructure appear in such systems. The principles of interaction between the "city - sea passenger port" system are changing and becoming more complex. For example, the dynamic influence of the external environment forcing such systems to expand, build new quays and terminals, actively seek new destinations for cruise ships, attract new carrier companies and develop new logistics services. In a number of cases, it is possible to observe the situation of competition for passenger flows and accompanying freight traffic among various terminals within the borders of one megacity or region. The object of the study was selected passenger terminals in the St. Petersburg in order to establish the main development vectors.

The first major facility in St. Petersburg is considered the «Morskoy Vokzal". Initially, the building was built for the Baltic Shipping Company (founded in 1982) and at the same time served as a station for guests arriving by sea, and an inter-sea base for sailors of the shipping company. After the reorganization of the shipping company, the building became the property of the city. In 1997, the building received the name " Morskoy Vokzal ". The total length of the berths is 720 m, the depth at the berths is up to 9 m. As a result, the station is able to accept almost any cruise vessels, including large-tonnage vessels. Also on two berths out of five, there is a ramp for ferry ships. By its technical capabilities, the "Morskoy Vokzal" complex is capable of accommodating up to 1 million passengers arriving by sea. But due to the features of the constructed sea canal leading to the port, ships with a length of more than 200 m cannot approach the berths of the "Morskoy Vokzal". For this reason, the city required a specialized cargo and passenger port. This port became the "Morskoy Façade" [1]. This port was introduced in stages from 2008 to 2011. Now the complex includes four marine stations (three for cruise ships and one for ferry ships (ro-ro)) and seven berths. The stevedore of the port is the joint-stock company Passenger Port of St. Petersburg "Morskoy Façade". Cruise ships and ferries with a length of no more than 330 m and a draft of up to 8.8 m can berth in the port. The total length of the mooring wall is 2171 m, the depth of the approaching and the Petrovsky canals is 11 m, which allows taking the largest cruise ships of the Baltic. In addition, a special court serving infrastructure has been established. In the North-West Russia is the largest passenger terminal. According to the source [2], there is a tendency to unite the assets of the "Morskoy Vokzal" and the "Morskoy Façade" today. The intensity is given in Table 1 according to [1, 2].

In addition to these two objects, it is necessary to note the presence of passenger terminals on the Promenade des Anglais and Lieutenant Schmidt's embankment. These passenger terminals are located in the heart of St. Petersburg. Passenger stations for cruise ships on the coast of the same name were opened in the late 1980s and were supposed to be temporary construction. However, they are still working, actively adopting modern cruise ships. Because of the proximity to the city center, they are very popular, the proximity of the city infrastructure and if to draw a parallel with other countries in the Baltic, such terminals are in Helsinki (Finland) in Stockholm and in a number of others. The main condition of the sample was pedestrian proximity to the city center.

A modern trend in terminal management is the use of intelligent transport systems [3, 4]. Under the use of intelligent technologies, we will understand the technical solutions enabling to present the correct solution in the management based on real data [5]. Changes in passenger ports occur due to the introduction of new technologies and new solutions [6]. It is necessary to solve the problems of synthesis, construct the objective function of the work as a port in general and individual elements of the system for development an intelligent system. These tasks require the construction of the port in the analytical function. The accuracy of the construction of this function will determine the accuracy of subsequent calculations and future forecasts. It is also necessary to note the discrete nature [7] of the presentation of the initial data for simulation and forecasting. When the initial data is generated from a set of values, values that are lagging behind each other at equal intervals of time are selected.

## 2. METHODS FOR FORECASTING / *Prognostičke metode*

The task of forecasting is a very important task in the management of passenger sea terminals. Simulation and forecasting processes are closely related. On the one hand, it

Table 1 Intensity of cruise ship calls and passenger traffic in the port "Marine Façade" from 2012 to 2017

*Tablica 1. Intenzitet ticanja brodova za krstarenje i putničkog prometa u luci „Marine Façade" od 2012. do 2017.*

| Parameter | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2017 в % к 2016 |
|---|---|---|---|---|---|---|---|
| Number of ship calls (units), including: | 226 | 261 | 239 | 230 | 209 | 244 | ↑+16,7 |
| Cruise ships | 221 | 249 | 234 | 223 | 209 | 247 | ↑+18,2 |
| Ferry ships | 5 | 12 | 5 | 7 | - | 2 | increase |
| Passenger traffic (thousand people), including: | 422 | 504 | 483 | 493 | 456 | 563 | ↑+23,5 |
| Cruise ship passengers | 411 | 483 | 473 | 482 | 456 | 558 | ↑+22,4 |
| Ferry passengers | 11 | 21 | 10 | 10 | - | 5 | increase |

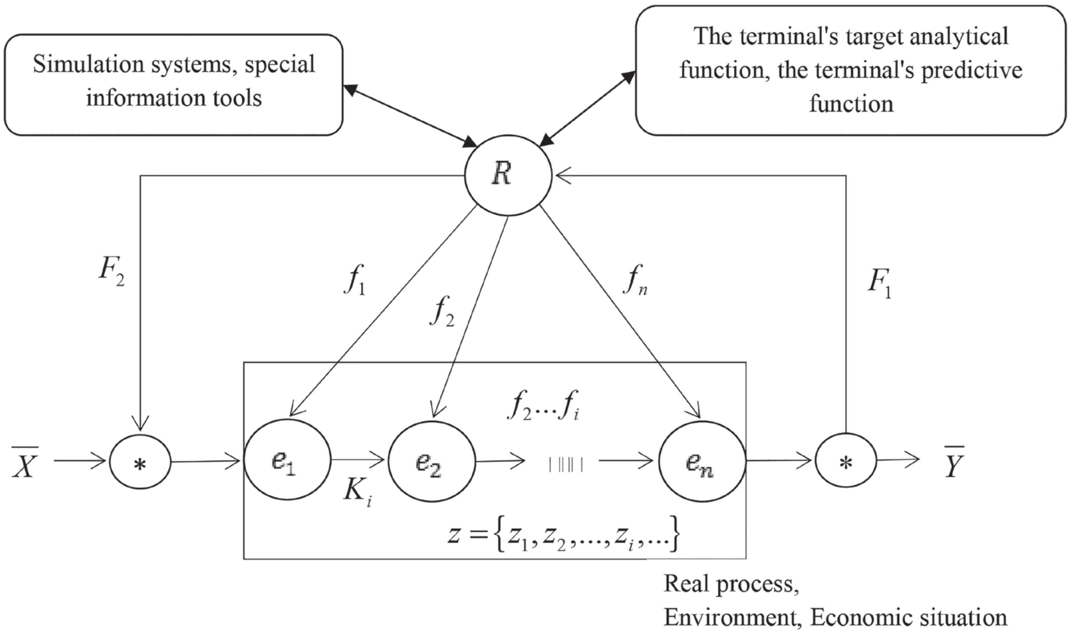


Figure 1 General scheme of terminal management using simulation methods for improving control accuracy
*Slika 1. Opća shema upravljanja terminalom uporabom simulacijskih metoda za bolje određivanje preciznosti kontrole*

allows always monitoring changes in processes in real time, on the other hand it allows to determine the analytical function of the system (for example, the forecasting function of passenger traffic taking into account the impact of the environment, or the forecast function of loading). The general scheme of terminal management using simulation methods is shown in Fig. 1

On figure 1: $e_i$ - elements (separate processes) of the passenger terminal, $e_i \in E$; R – the head of the terminal, the person making the decision, the controlling device; $K_i$ - communication on the transformation of the input to the output, a certain technological transformation with the passenger traffic and services, $k_i \in K$; $\overline{X}$ - system entrance, passenger traffic $x_i \in \overline{X}$; $\overline{Y}$ - the result of the system operation, the serviced passenger traffic and cruise ships $y_i \in \overline{Y}$); ⊙ - converters in control points of terminal processes); $f_i$ - communication on the impact on the system, the control effect on the processes of the passenger terminal, $f_i \in f$; $F_i$ - feedback for clarification of processes F; Z – internal resources (internal state) of the marine passenger terminal system.

The authors in [8, 9, 10, 11, 12] present specialized simulation models for forecasting passenger flows in terminals. These models have sufficient modeling accuracy. In addition, they allow you to visualize the processes in the terminal. But it is also necessary to determine the main target functions of the terminal. The objective function of the system should describe all items of the organization of sea passenger ports [13]. Consider the forecast of the terminal based on statistics of passenger traffic.

The forecast is understood as a scientifically grounded description of possible state of objects in the future, as well as alternative ways and timescales for achieving this state. An important characteristic is the lead time (period) forecast, i.e. the length of time from the moment for which there are recent statistical data about the object under study, up to the moment to which the forecast relates.

By the time of anticipation, forecasts are divided into:

- Operational (with a lead time of up to one month);
- Short-term (the lead-out - from one, several months to a year);
- Medium-term (the lead-out period is more than 1 year, but does not exceed 5 years);
- Long-term (with a lead time of more than 5 years).

Forecasting phenomena and processes includes the following stages:

1. Statement of the problem and collection of necessary information;
2. Initial processing of initial data;
3. Definition of the range of possible forecasting models;
4. Estimation of model parameters based on real process;
5. Study of the quality of selected models, adequacy their real process and the choice of the best of the models;
6. Construction of the forecast;
7. Substantial analysis of the received forecast.

For determine the forecast function, the following methods were chosen [14, 15]:

1. Prediction by extrapolation method;
2. Average growth rate forecast.

The boundary conditions and features of these models are given in Table 2.

Table 2 Features of this method

*Tablica 2 Značajke ove metode*

| Prediction by extrapolation method | Average growth rate forecast |
|---|---|
| The extrapolation method is applicable if the following assumptions are used:<br>1. The period of time for which the function is constructed should be sufficient to identify the development trend;<br>2. The analyzed process is dynamically stable and possesses inertia, i.e. for significant changes in the characteristics of the process takes time;<br>3. No strong external influences on the process under investigation are expected, which can seriously affect the development trend.<br>For the forecast of passenger traffic and ship calls, trend lines are used, which allow predicting any dependencies based on the derived mathematical functions. | The application of average growth rate [16] (and average growth rate) to describe the dynamics of a series corresponds to its representation in the form of an exponential or exponential curve drawn through two extreme points. Therefore, the use of this indicator as a generalization is appropriate for those processes whose dynamics change occurs approximately at a constant rate of growth. |

In the above forecast, functions were used: linear, logarithmic, exponential, polynomial (degrees from 2 to 6) and power-law functions. Next, calculate the coefficient of variation (for previous years) based on the mean square deviation and mean value. Further, absolute and relative errors of the obtained data are calculated when constructing the trend line [14] and the real value, as well as the average for the period under review. Absolute and relative error are calculated by formulas:

$$\Delta x = \frac{1}{N}\sum_{t=1}^{N}\frac{\left|X(t)-\bar{X}(t)\right|}{X(t)}, \quad \delta x = \frac{\Delta x}{|x|} \tag{1}$$

Where $\Delta x$ - absolute error, N - number of calculations and variables; $X(t)$, $\bar{X}(t)$ - average values for the period under review; $\delta x$ - relative error; $|x|$ - the true value of the variable.

The forecast value on *L* steps for marine passenger terminal can be obtained by the formula:

$$\hat{y}_{n+L} = y_n * \bar{T}^L, \quad \bar{T} = \sqrt[n-1]{\frac{y_n}{y_1}} \tag{2}$$

where $y_n$ - the actual value in the last n-th point of the series (the final level of the series); $\hat{y}_{n+L}$ - the predicted value (n + L) of the level of the series; $\bar{T}$ — the mean growth rate calculated for the time series $y_1, y_2, \ldots, y_t, \ldots, y_n$.

## 3. INITIAL DATA OF THE SEA PASSENGER TERMINAL FOR SOLVING THE FORECASTING PROBLEM / *Početni podaci terminala za prijevoz putnika za rješavanje prognostičkog problema*

According to the association of the Baltic ports of Cruise Baltic, the share of the region of Northern Europe and the Baltic Sea in the total structure of the world cruise market is 9.1%. Cruise tourism is developed on the Baltic Sea due to the cultural diversity of the region and the availability of modern ports, ready to provide quality services to passengers and ships. It should be noted that in terms of the number of passenger operations, (the number of times a passenger uses the port infrastructure during the stay of the ship), the Passenger Port of St. Petersburg is the leading port in the Baltic Sea, and in terms of infrastructure, and development is the first in Europe. St. Petersburg is one of the most remarkable tourist destinations in the region and it ranks second after Copenhagen in terms of the number of calls by sea passenger ships, and Passenger Port St. Petersburg ranks third in terms of passenger traffic volume among the ports of the Baltic Sea statistical data of the marine terminal "Marine Facade" (initial) are presented for the period 2009 - 2017 (fig. 2). During the period of 2017 year, 249 ship calls were made to the Passenger Port of St. Petersburg "Marine Facade" [1, 2].

| № | Year | Number of cruise ships | Passenger flow |
|---|---|---|---|
| 1 | 2009 | 115 | 247932 |
| 2 | 2010 | 254 | 372900 |
| 3 | 2011 | 327 | 527840 |
| 4 | 2012 | 226 | 422091 |
| 5 | 2013 | 261 | 503615 |
| 6 | 2014 | 239 | 483456 |
| 7 | 2015 | 230 | 492724 |
| 8 | 2016 | 209 | 456495 |
| 9 | 2017 | 249 | 557952 |

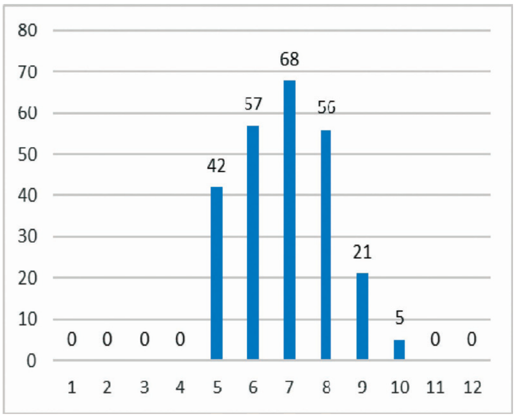


Figure 2 The number of cruise ship calls and the schedule of intensive ships in 2017

*Slika 2. Broj ticanja brodova za krstarenje i najava brodova za 2017.*

## 4. PRACTICAL RESULTS OF FORECASTING FOR PASSENGER PORT / *Praktični rezultati prognoziranja za putničku luku*

Based on the formulas (1) and the initial data (figure 2) was calculated number of cruise ships (table 3). To solve the forecast problem for 2018 year, mean values, relative and absolute errors, coefficients of variation were identified (Table 4, 5).

For example, the forecast function graph and the final analytical equation (polynomial function n = 4, n = 5) for forecasting number of cruise ships are presented in figure 3.

Table 3 Statistical and forecast value of the number of cruise ships on the basis of various polynomial models

*Tablica 3. Statistika i predviđanja broja brodova za kružna putovanja na temelju različitih polinomskih modela*

| № | Year | Cruise ships | Linear | Logarithmic | Exponential | polynomial n = 2 | polynomial n = 3 | polynomial n = 4 | polynomial n = 5 | polynomial n = 6 | Stepenny |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2009 | 115 | 220 | 192 | 201 | 178 | 131 | 118 | 111 | 113 | 170 |
| 2 | 2010 | 254 | 223 | 212 | 207 | 213 | 237 | 256 | 274 | 265 | 196 |
| 3 | 2011 | 327 | 227 | 225 | 214 | 239 | 283 | 293 | 287 | 299 | 213 |
| 4 | 2012 | 226 | 231 | 233 | 220 | 256 | 287 | 278 | 263 | 265 | 226 |
| 5 | 2013 | 261 | 234 | 240 | 227 | 264 | 264 | 248 | 248 | 238 | 236 |
| 6 | 2014 | 239 | 238 | 246 | 234 | 264 | 233 | 225 | 239 | 243 | 245 |
| 7 | 2015 | 230 | 242 | 250 | 242 | 254 | 210 | 220 | 227 | 244 | 253 |
| 8 | 2016 | 209 | 245 | 254 | 249 | 235 | 211 | 231 | 213 | 215 | 259 |
| 9 | 2017 | 249 | 249 | 258 | 257 | 207 | 254 | 241 | 248 | 271 | 266 |
| 10 | 2018 | | 253 | 261 | 265 | 170 | 356 | 222 | 455 | 883 | 271 |

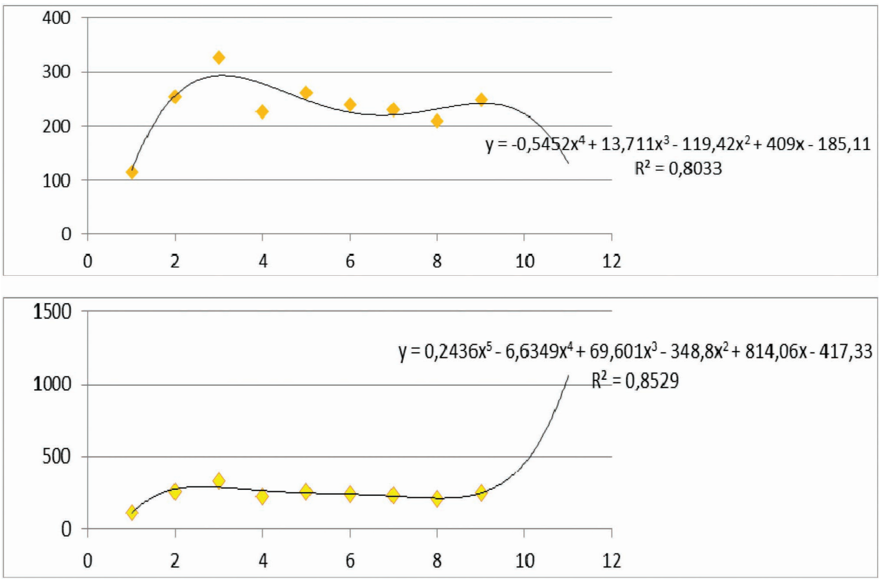


Figure 3 Forecast functions (polynomial function n = 4, n = 5)

*Slika 3. Prognostičke funkcije (polinomna funkcija n = 4, n = 5)*

Table 4 Absolute error

*Tablica 4. Apsolutna greška*

| № | Linear | Logarithmic | Exponential | polynomial n = 2 | polynomial n = 3 | polynomial n = 4 | polynomial n = 5 | polynomial n = 6 | Stepenny |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0,101233527 | 0,073942029 | 0,082828096 | 0,060752464 | 0,015189565 | 0,002546667 | 0,003729758 | 0,001609855 | 0,053536232 |
| 2 | 0,013366842 | 0,018179849 | 0,020539338 | 0,017948731 | 0,007630096 | 0,000951356 | 0,008764129 | 0,004715836 | 0,025350648 |
| 3 | 0,033941522 | 0,034769645 | 0,038543645 | 0,02987387 | 0,01499001 | 0,011503296 | 0,013712232 | 0,009555624 | 0,038804379 |
| 4 | 0,002348476 | 0,003614419 | 0,002807134 | 0,014854867 | 0,029766372 | 0,025615929 | 0,018429695 | 0,018948378 | 0,000224105 |
| 5 | 0,011305449 | 0,008904418 | 0,014377931 | 0,001434653 | 0,001439762 | 0,005740741 | 0,005733291 | 0,009879523 | 0,010662533 |
| 6 | 0,000413668 | 0,003060809 | 0,002147572 | 0,011411808 | 0,002678196 | 0,006617015 | 0,000208833 | 0,001707485 | 0,002703193 |
| 7 | 0,005689324 | 0,009774984 | 0,005681238 | 0,011471111 | 0,009681353 | 0,004754686 | 0,001534638 | 0,006971691 | 0,010901172 |
| 8 | 0,019374588 | 0,024063048 | 0,021463106 | 0,013803934 | 0,001268687 | 0,011644232 | 0,002337267 | 0,003198192 | 0,026835513 |
| 9 | 4,92191E-05 | 0,003933901 | 0,00366966 | 0,018649353 | 0,002393039 | 0,003511022 | 0,000313922 | 0,009746095 | 0,007466052 |
| Aver-age | 0,020858068 | 0,020027011 | 0,021339747 | 0,02002231 | 0,009448564 | 0,008098327 | 0,006084863 | 0,007370298 | 0,019609314 |

Table 5 Relative error

*Tablica 5. Relativna greška*

| № | Linear | Logarithmic | Exponential | polynomial n = 2 | polynomial n = 3 | polynomial n = 4 | polynomial n = 5 | polynomial n = 6 | Stepenny |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0,00046062 | 0,00038606 | 0,00041264 | 0,000341539 | 0,000116198 | 2,16487E-05 | 3,35592E-05 | 1,42045E-05 | 0,000314161 |
| 2 | 5,9822E-05 | 8,5576E-05 | 9,92013E-05 | 8,42785E-05 | 3,22547E-05 | 3,7137E-06 | 3,19818E-05 | 1,78104E-05 | 0,000129308 |
| 3 | 0,00014945 | 0,000154757 | 0,000180476 | 0,000124953 | 5,29899E-05 | 3,92409E-05 | 4,7837E-05 | 3,19717E-05 | 0,000182353 |
| 4 | 1,01764E-05 | 1,54891E-05 | 1,27429E-05 | 5,79782E-05 | 0,00010388 | 9,21096E-05 | 6,99456E-05 | 7,16274E-05 | 9,93619E-07 |
| 5 | 4,82225E-05 | 3,70888E-05 | 6,32758E-05 | 5,42669E-06 | 5,44576E-06 | 2,31935E-05 | 2,31618E-05 | 4,15467E-05 | 4,51891E-05 |
| 6 | 1,7373E-06 | 1,24634E-05 | 9,16276E-06 | 4,33009E-05 | 1,14826E-05 | 2,94395E-05 | 8,72139E-07 | 7,03616E-06 | 1,10418E-05 |
| 7 | 2,35313E-05 | 3,90633E-05 | 2,34995E-05 | 4,52072E-05 | 4,61106E-05 | 2,15967E-05 | 6,76579E-06 | 2,85221E-05 | 4,31618E-05 |
| 8 | 7,8937E-05 | 9,46386E-05 | 8,60686E-05 | 5,87488E-05 | 6,00174E-06 | 5,04291E-05 | 1,09527E-05 | 1,48742E-05 | 0,000103421 |
| 9 | 1,9758E-07 | 1,52586E-05 | 1,42664E-05 | 9,00036E-05 | 9,40797E-06 | 1,45606E-05 | 1,2643E-06 | 3,59846E-05 | 2,80962E-05 |
| Aver-age | 9,25215E-05 | 9,33772E-05 | 0,000100148 | 9,46039E-05 | 4,26413E-05 | 3,28814E-05 | 2,51489E-05 | 2,92864E-05 | 9,53029E-05 |

Using the method of average growth rate, the following dependences were obtained. The predicted value of ship calls for 2018 is 274 units. In Fig. 4 is a graph showing this forecast value.

$$\hat{y}_{9+1} = 249 * \sqrt[9-1]{\frac{249}{115}} = 274$$

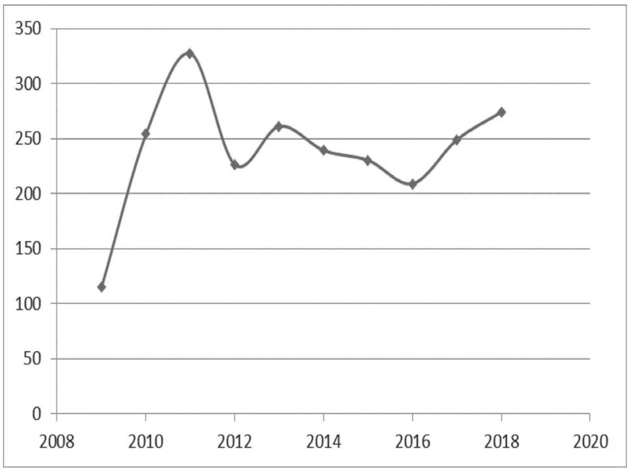


Figure 4 Number of cruise ships with a forecast value

*Slika 4. Broj brodova za krstarenje s prognostičkom vrijednošću*

## 4. CONCLUSION / *Zaključak*

The minimum average value of the relative and absolute errors corresponds to a polynomial trend line of the 5th order, but the minimum value of the coefficient of variation corresponds to a linear function [16]. Comparing the predicted values of the above functions - 253 and 455 cruise ships, we can conclude that in the absence of any measures to attract cruise and ferry vessels to the port, the forecast using a linear function can be true. However, otherwise the indicator with minimal errors is closer to reality, since no enterprise is interested in stopping development. Analyzing the obtained data, we get that the forecast for 2018 year will be correct in calculating the polynomial trend line of the 5th order.

The forecasting values for passenger traffic with the minimum value of the coefficient of variation and the absolute and relative errors are the values of the linear function, polynomial 3 and 5 order. The corresponding values are 575167 passengers, which is also true in the absence of any activities to attract cruise and ferry vessels to the port; 674144 passengers - what happens when carrying out activities to attract cruise and ferry vessels to the port; 887461 passenger-which is also possible with an increase in the number of calls to the port to 455 units from the previous forecast. Based on these values, decision-making person can define a strategy for managing the passenger port.

The values obtained are confirmed by analytical calculations. It becomes possible to simulation the operation of the passenger terminal based on this functions on new level of quality. These parameters must be entered into specialized simulation models, as [8, 9]. This improves the accuracy of forecasting and quality of terminal management. It is possible to build an intelligent control system for the sea passenger port based on this result. The present model can be used for research and forecast loading any key parameter of the sea passenger terminal.

## REFERENCES / *Literatura*


[1] Passenger Port of Saint Petersburg „Marine Façade". http://www.portspb.ru/en [accessed: 1. 4. 2018]

[2] Morskoj Vokzal, Sankt-Peterburg. http://www.fontanka.ru/2017/10/25/005/ [accessed: 1. 4. 2018]

[3] Cruise Europe. Port Handbook (2018). http://www.cruiseeurope.com/ [accessed: 15. 4. 2018]

[4] Baltic Sea Sewage Port Reception Facilities 2018. Baltic Marine Environment Protection Commission. www.helcom.fi [accessed: 15. 4. 2018]

[5] Ausubel, J. H., Marchetti, C. (2001). „The evolution of transport". *The Industrial Physicist*, Vol. 7, No. 2, pp. 20-24.

[6] Poniatovskii, V. V. (2006). *Morskie porty i transport (evoliutsiia)* [*Sea ports and transport (evolution)*]. Moscow: MSUMT, 429 pp. (In Russian)

[7] Ivanov, B. A., Nedviga, A. V. (2007). *Elementy teorii diskretnykh sistem avtomaticheskogo upravleniya*. Ukhta: UGTU, 112 pp. (In Russian)

[8] Krile, S., Maiorov, N., Fetisov, V. (2018). „Forecasting the operational activities of the sea passenger terminal using intelligent technologies". *Transport Problems*, Vol. 13, No. 1, pp. 27-36. https://doi.org/10.21307/tp.2018.13.1.3

[9] Maiorov, N., Fetisov, V. (2017). „Mathematical modeling and research of passenger flows in marine passenger port". *Naše more*, Vol. 64, No. 1, pp. 1-6. DOI 10.17818/NM/2017/1.1

[10] Maiorov, N., Fetisov, V. (2012). *Prakticheskie zadachi modelirovaniia transportnykh sistem* [*Practical Problems of Modeling of Transport Systems*]. Saint Petersburg: SUAI Publ., 185 pp. (In Russian)

[11] Jugović, A. (2006). „Organization of Maritime Passenger Ports". In: Jugović, A., Mezak, V., Lončar, S. (eds.), *Pomorski zbornik*, Vol. 44, No. 1, pp. 93-104.

[12] Dragović, B., Park, N. K.; Radmilović, Z.; Maraš, V. (2005). „Simulation modelling of ship-berth link with priority service". *Maritime Economics & Logistics*, Vol. 7, No. 4, pp. 316-335. https://doi.org/10.1057/palgrave.mel.9100141

[13] Wright, A. (2001). *Unctad monographs on port management. The economic impact of cruise ports: The case of Miami.* New York – Geneva, 33 pp.

[14] Makridakis, S. G., Wheelwright, S. C., Hyndman. R. J. (1998). *Forecasting: Methods and Applications*. New York: Wiley, 656 pp.

[15] Pindyck, R. S., Rubinfeld, D. L. (1998). *Econometric models. Economic forecasts*, 4th ed., Boston, MA: McGrawHill/Irwin, 634 pp.

[16] Holt, C. C. (1957). *Forecasting trends and seasonals by exponentially weighted averages*. O. N. R. Memorandum, Vol. 52. Pittsburgh: Carnegie Institute of Technology. Reprinted in: *International Journal of Forecasting* (2004), Vol. 20, No. 1, 5-10.