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Non-Poisson character of vessel traffic on the Szczecin–Świnoujście fairway

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Abstract
In this paper the hypothesis about Poissonian character of vessel traffic stream from Świnoujście to Szczecin has been verified. And the hypothesis about Non-Poissonian character of vessel traffic stream from Szczecin to Świnoujście has been verified. To reach this goal, VTS data from second half of 2009 has been used. To description of non- Poissonian vessel traffic stream, for the first time, mixed distributions have been used.

Introduction

Process of vessel reporting is a Poisson process, when the vessel traffic is completely random (isn't disturbed). But this is a theoretical situation. In fact, the vessel traffic is always more or less disturbed. Each vessel regulation disturbs the vessel traffic stream [1, 2]. There are many regulations on the Szczecin–Świnoujście fairway [1, 3] (a speed limit, an order to maintain minimum distance between successive vessels, a passing ban and other). But these disturbances not always disturb so strongly the randomness of the vessel traffic stream. As author has been shown in [4], in the first half of 2009 the vessel traffic stream from Świnoujście to Szczecin has Poissonian character and the vessel traffic stream from Szczecin to Świnoujście hasn't Poissonian character. In this paper the vessel traffic in second half of 2009 has been considered and a form of probability density function used to description of non-Poissonian vessel traffic stream has been determined.

To find that a given process is Poisson process, a hypothesis about exponential distribution of time between reporting successive fairway units must be verified.

Vessel traffic stream from Świnoujście to Szczecin

Szczecin–Świnoujście VTS system has 11 points where times of vessel reports are registered. In this paper reporting times at 4 points: 11_KILOMETR, CHELMINEK_N, KREPA_DOLNA, INOUJSCIE have been considered. Let X denotes the waiting time for the reporting of the successive vessel at the given reporting point. In the second half of year 2009, at 11_KILOMETR point, 1320 vessels have been registered. Using the chi-square goodness-of-fit test [2, 5, 6] and programme *Statistica* we find that the test statistic is equal to 7.9 and probability $p = 0.09$. So we are unable to reject the hypothesis that the time between reporting of fairway vessels has an exponential distribution. Parameter λ of this exponential distribution is equal to 0.0049. Figure 1 presents frequency histogram of random variable X at 11_KILOMETR point.

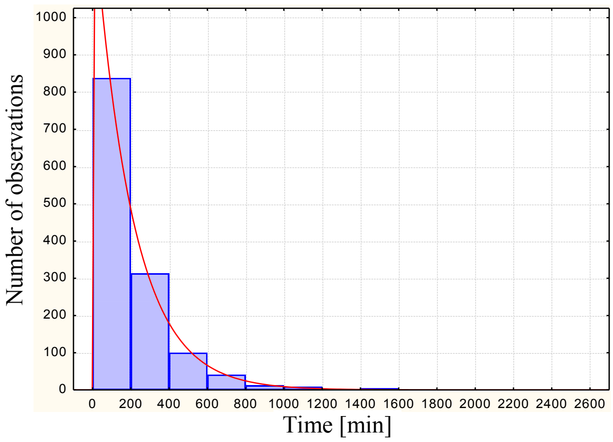

Fig. 1. Frequency histogram of the time between reporting at 11_KILOMETR point

The similar situation is at the rest considering points (Figs 2 and 3).

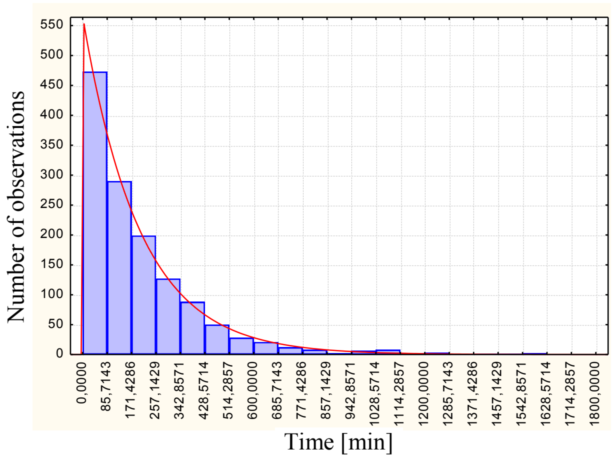

Fig. 2. Frequency histogram of the time between reporting at CHELMINEK_N point

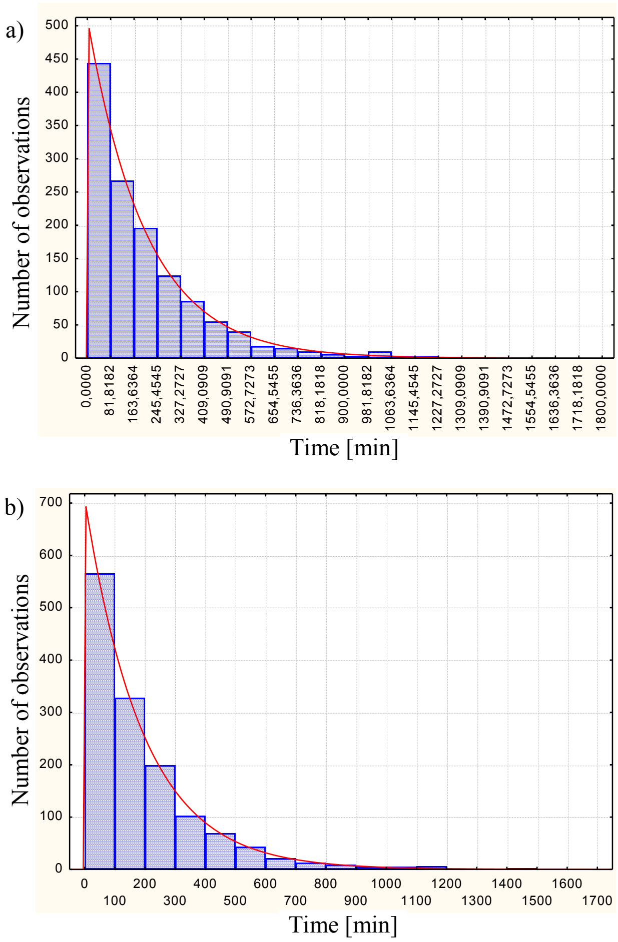

Fig. 3. Frequency histogram of the time between reporting at: a) KREPA_DOLNA point and b) INOUJSCIE point

Vessel traffic stream from Szczecin to Świnoujście

Using the chi-square goodness-of-fit test and programme *Statistica* for all four points we must reject the hypothesis that the time between reporting of fairway vessels has an exponential distribution. Any typical distribution used in *Statistica* haven't been correspond to variable X. To find the form of probability density function of variable X, mixed distributions have been used. Probability density function of a mixed distribution has the following form:

$$f(x) = a \cdot \mathrm{pdf}(D1) + b \cdot \mathrm{pdf}(D2) \qquad (1)$$

where:

- a, b – such real numbers, that $a + b = 1$;
- $\mathrm{pdf}(D\mathrm{i})$ – probability density function of variable with $D\mathrm{i}$ distribution.

Procedure of determination good fitted mixed distribution to variable X consists in two stages:

Stage 1: 3graphic fitting a pdf curve to graph of data of variable X (using function *Manipulate* in programme *Mathematica*) [7];

Stage 2: using the chi-square goodness-of-fit test for mixed distribution, determined in graphic fitting.

Vessel traffic at 11_KILOMETR point

In the second half of year 2009, 1309 vessels have been registered at this point. These data on 16 intervals have been divided (each contained over 10 elements) [6]. And the chi-square goodness-of-fit test has been used. Figure 4 presents the pdf curve fitted to data at 11_KILOMETR point.

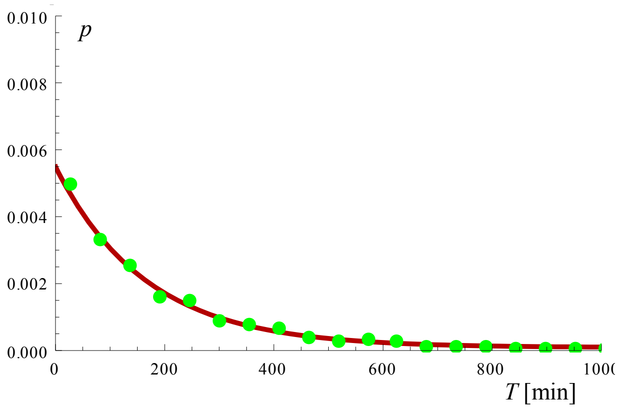

Fig. 4. Data and fitted pdf graph at 11_KILOMETR point

Using trial and error approach the probability density function of variable X has been determined. It is the mixed distribution: 0.9 (pdf of exponential distribution) +0.1 (pdf of uniform distribution). It has the following form:

$$f(x) = \begin{cases} 0.0054e^{-0.006x} + 0.000091 & \text{for } 0 \le x \le 1100 \\ 0.0054e^{-0.006x} & \text{for } x > 1100 \end{cases} \qquad (2)$$

The chi-square test statistic is equal to 17.27 and the critical value, at the 0.05 level of significance, is equal to 24.99. So there is no evidence to indicate that time between reporting successive fairway units is not distributed by probability density function (2).

Vessel traffic at CHELMINEK_N point

In the second half of year 2009, 1310 vessels have been registered at this point. Figure 5 presents the data at CHELMINEK_N point.

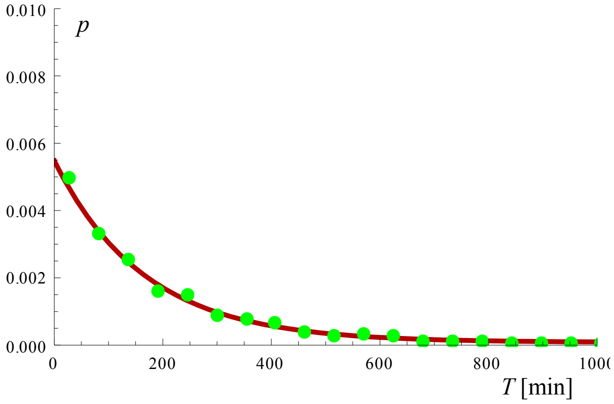

Fig. 5. Data and fitted pdf graph at CHELMINEK_N point

Using the chi-square goodness-of-fit test and trial and error approach, the probability density function of variable X has been determined. It is the mixed distribution: 0.9 (pdf of exponential distribution) +0.1 (pdf of uniform distribution). It has the following form:

$$f(x)=\begin{cases}0.0054e^{-0.006x}+0.000088 & \text{for } 0\le x\le 1130\\ 0.0054e^{-0.006x} & \text{for } x>1130\end{cases} \quad (3)$$

The chi-square test statistic is equal to 17.1 and the critical value, at the 0.05 level of significance, is equal to 24.99.

Vessel traffic at KREPA_DOLNA point

In the second half of year 2009, 1276 vessels have been registered at this point. Figure 6 presents the data at KREPA_DOLNA point.

Using the procedure of determination good fitted mixed distribution to variable *X*, its distribution has been determined. It is the mixed distribution: 0.92 (pdf of exponential distribution) +0.08 (pdf of uniform distribution). It has the following form:

$$f(x)=\begin{cases}0.005336e^{-0.0058x}+0.0000552 & \text{for } 0\le x\le 1450\\ 0.005336e^{-0.0058x} & \text{for } x>1450\end{cases} \quad (4)$$

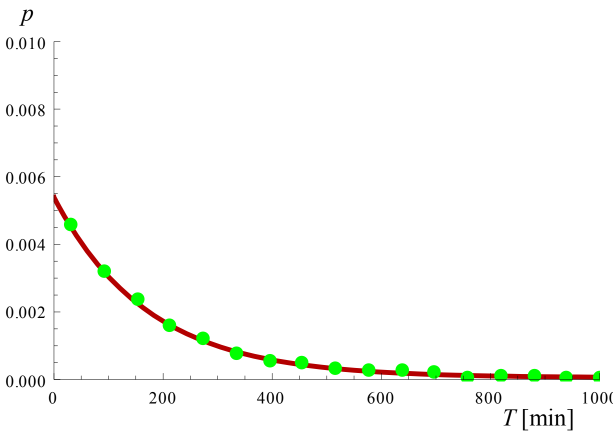

Fig. 6. Data and fitted pdf graph at KREPA_DOLNA point

The chi-square test statistic is equal to 20.17 and the critical value, at the 0.05 level of significance, is equal to 24.99.

Vessel traffic at INOUJSCIE point

In the second half of year 2009, 1210 vessels have been registered at this point. Figure 7 presents the pdf curve fitted to data at INOUJSCIE point.

Using the chi-square goodness-of-fit test and trial and error approach, we obtained the probability density function of variable *X*. It is the mixed distribution: 0.9 (pdf of exponential distribution) +0.1 (pdf of uniform distribution). It has the following form:

$$f(x)=\begin{cases}0.005157e^{-0.0057x}+0.000077 & \text{for } 0\le x\le 1300\\ 0.005157e^{-0.0057x} & \text{for } x>1300\end{cases} \quad (5)$$

The chi-square test statistic is equal to 17.58 and the critical value, at the 0.05 level of significance, is equal to 23.68.

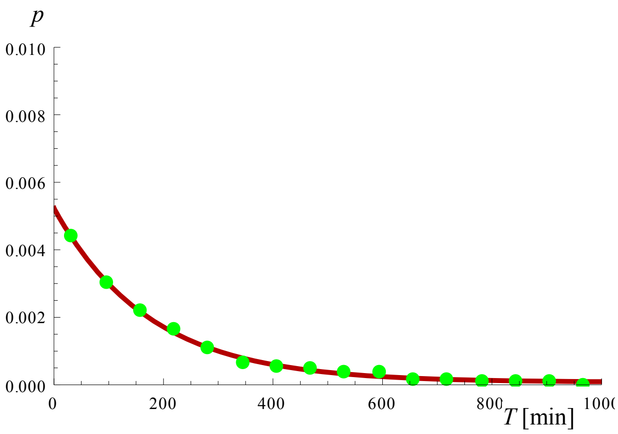

Fig. 7. Data and fitted pdf graph at INOUJSCIE point

Coclusions

Based on the results presented herein, the following conclusions can be drawn:

- At each VTS reporting point for vessel traffic stream from Świnoujście to Szczecin the reporting process is Poisson process.
- All vessel traffic regulations on the Świnoujście–Szczecin fairway aren't disturbing factors of the randomness of the vessel traffic stream from Świnoujście to Szczecin.
- At each VTS reporting point for vessel traffic stream from Szczecin to Świnoujście the report process isn't Poisson process.
- A departure from Szczecin seaport turned out to be the most disturbing factor on the fairway Szczecin–Świnoujście.
- For south vessel traffic stream, to description of reporting process, mixed exponential-uniform distribution has been used.
- Determination of probability density function form of time between reporting successive fairway units allows studying ships traffic more exactly.

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