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STATISTICAL ANALYSIS OF DATA SAMPLES COLLECTED IN AN EXPERIMENTAL INSTALLATION

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Abstract: *The paper presents the estimation of the statistical parameters for experimental data collected in an installation consisting of several water meters of the same type. The installation considered was used for measuring the individual consumption of the water volume during a year; in each month the individual consumption was considered. The appropriate data analysis was performed on the experimental data collected from the water meters in the experimental installation, data being grouped in a certain number of samples.*

Key words: *reliability, statistical parameters, water meters.*

1. Introduction

Estimation theory is a branch of statistics and signal processing that deals with estimating the values of parameters based on measured/empirical data. The parameters describe an underlying physical setting in such a way that the value of the parameters affects the distribution of the measured data. An estimator attempts to approximate the unknown parameters using the measurements [3], [5].

The paper presents the estimation of the statistical parameters for experimental data collected in an installation consisting of several water meters of the same type.

The experimental installation used in the research consists of water meters of the same type and the same precision class - class B, mounted in the apartments from a block of flats [1].

The installation considered was used for measuring the consumption of the water volume during a year; in each month the individual consumption was considered.

2. Estimating the Statistical Parameters for Data Samples

The statistical analysis is performed for data samples collected monthly, during a year. Data was collected from the water meters considered, in 40 apartments in a block of flats, by recording the individual consumption every month. The average individual consumption was calculated for each apartment, for each season - winter, spring, summer and autumn, by taking into account the consumption in the appropriate three months corresponding to each season [1].

Table 1 presents the four samples corresponding to each season/quarter of the year, their size being n = 40, which is the number of apartments considered in this research.

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Experimental data Table 1

No. of apartment	**Number of persons**	**Average/person**			
		Winter (3 months)	**Spring (3 months)**	**Summer (3 months)**	**Autumn (3 months)**
1	2	1.9	1.883333	2.266667	1.7
2	2	0.6	0.383333	0.516667	0.55
3	2	0.983333	0.95	0.666667	0.583333
4	2	3.183333	2.15	3.783333	3.016667
5	2	0.683333	0.983333	0.866667	1.3
6	3	1.888889	0.333333	0	0.777778
7	2	1.583333	1.533333	1.983333	2.383333
8	2	2.383333	2.5	2.75	4.583333
9	2	1.05	1.383333	2.016667	1.45
10	3	1.277778	1.2	1.144444	1.411111
11	2	0.933333	1.95	0.666667	1.45
12	2	0.216667	2.983333	0.033333	0.166667
13	2	3.3	3.45	4.516667	3.55
14	3	2.177778	2.233333	2.822222	2.188889
15	2	3.416667	2.95	3.133333	2.133333
16	2	0.8	0.816667	1.816667	1.016667
17	2	1.5	1.666667	2.5	2.166667
18	2	1.016667	2.366667	2.466667	2.866667
19	2	4.783333	4.366667	6.9	4.95
20	2	1.716667	0.4	2.183333	1.1
21	2	1.433333	3.266667	4.333333	0.416667
22	2	2.716667	6.066667	7.05	6.05
23	2	0.666667	1.166667	1.166667	1.333333
24	2	1.066667	1.016667	0.883333	0.716667
25	2	0.783333	1.116667	1.983333	1.483333
26	3	0.488889	0.566667	0.644444	0.633333
27	2	0.366667	0.65	0.533333	0.483333
28	2	2.833333	4.5	3.183333	2.966667
29	2	1.166667	1.5	1.833333	1.333333
30	3	3.022222	3.122222	3.277778	2.511111
31	2	1.3	1.3	1.883333	1.5
32	2	1.5	1.666667	2.333333	2.166667
33	2	1.2	0.9	1.25	1.333333
34	3	1.744444	2.366667	4.044444	3.088889
35	2	1.7	2.233333	2.933333	2.166667
36	2	1.716667	2.25	2.516667	2.1
37	2	1.766667	2.25	3.183333	2.466667
38	2	1.1	1.083333	1.5	1.45
39	2	0.883333	1.433333	1.466667	1.05
40	4	4.158333	6.5	6.666667	5.166667

2.1. Case study I

The experimental data represents the average individual consumption corresponding to the winter months; it is extracted from Table 1 and is grouped in a sample of size n, indicated in the following array:

$$x1 = \{1.9\ 0.6\ 0.98\ 3.18\ 0.68\ 1.88\ 1.58\ 2.38\ 1.05\ 1.27\ 0.93\ 0.21\ 3.3\ 2.17\ 3.41\ 0.8\ 1.5\ 1.01\ 4.78\ 1.71\ 1.43\ 2.71\ 0.66\ 1.06\ 0.78\ 0.48\ 0.36\ 2.83\ 1.16\ 3.02\ 1.3\ 1.5\ 1.2\ 1.74\ 1.7\ 1.71\ 1.76\ 1.1\ 0.88\ 4.15\}; \quad (1)$$

- size of the sample:

$$n = 40; \quad (2)$$

- determining the number of classes [4], [5]:

$$k = 1.87 \cdot [(40 - 1)^{0.4}] + 1 = 9; \quad (3)$$

- the appropriate histogram is presented in Figure 1 and indicates a Weibull distribution function [4], [5];

- Goodness-of-fit tests (Kolmogorov-Smirnov) and determination of the distribution; the critical value of the statistics of the Kolmogorov-Smirnov goodness-of-fit tests for the sample size is $d_{n,\alpha} = 0.2150$. The value of the statistic of the Kolmogorov-Smirnov goodness-of-fit tests for the sample is $d_1 = 0.1663 \le d_{n,\alpha} = 0.2150 \Rightarrow$ Weibull distribution [2];

- parameter estimation for the Weibull distribution; the values of the estimated parameters of the Weibull distribution for the considered sample are: $\eta = 1.8710$, $\beta = 1.8049$, where η is the scale parameter and β the shape parameter [6].

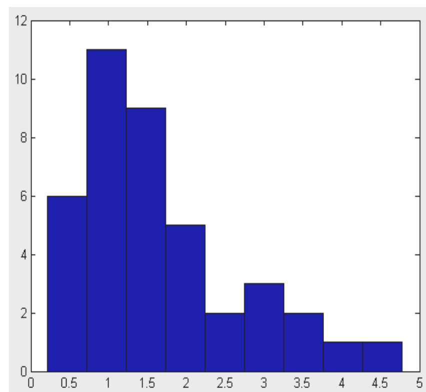

Fig. 1. *Histogram for sample 1 - average individual consumption in winter*

2.2. Case study II

The experimental data represents the average individual consumption corresponding to the spring months; it is extracted from Table 1 and is grouped in a sample of size n, indicated in the following array:

$$x2 = \{1.8/2\ 0.9/2\ 1.8/2\ 6.6/2\ 1.3/2\ 2.2/2\ 4.7/2\ 1.2/2\ 5/3\ 1.1/2\ 7.5/2\ 7.2/3\ 11.3/2\ 1.3/2\ 1\ 1.1\ 4.4\ 1.7\ 1.3/2\ 4.7/2\ 1\ 0.6\ 0.85\ 0.6\ 0.5\ 2.55\ 1.5\ 7.7/3\ 2.8/2\ 1.8/2\ 5.9/3\ 4.7/2\ 3.1/2\ 11.5/2\ 1\ 1\ 17/4\} \quad (4)$$

- size of the sample:

$$n = 40; \quad (5)$$

- determining the number of classes [4], [5]:

$$k = 1.87 \cdot [(40 - 1)^{0.4}] + 1 = 9; \quad (6)$$

- the appropriate histogram is presented in Figure 2 and indicates a Weibull distribution function [4], [5];

- Goodness-of-fit tests (Kolmogorov-Smirnov goodness-of-fit test) and determination of the distribution; the critical value of the statistics of the Kolmogorov-

Smirnov goodness-of-fit tests for the sample size is $d_{n,\alpha} = 0.2150$. The value of the statistic

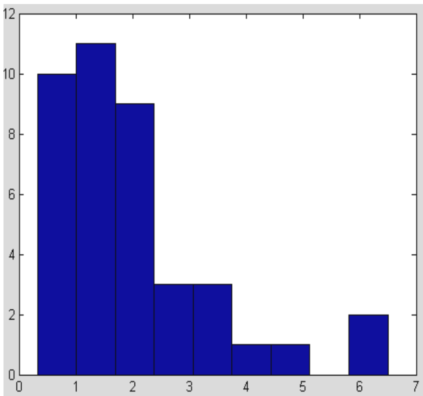

Fig. 2. *Histogram for sample I1 - average individual consumption in spring*

of the Kolmogorov-Smirnov goodness-of-fit tests for the sample is $d_1 = 0.1589 \le d_{n,\alpha} = 0.2150 \Rightarrow$ Weibull distribution [2];

- Parameter estimation for the Weibull distribution; the values of the estimated parameters of the Weibull distribution for the considered sample are: $\eta = 2.2539$, $\beta = 1.68$, where η is the scale parameter and β the shape parameter [6].

2.3. Case study III

The experimental data represents the average individual consumption corresponding to the summer months; it is extracted from Table 1 and is grouped in a sample of size n, indicated in the following array:

$$x3 = \{3.8/2\ 0.55\ 0.75\ 3.75\ 1\ 2.1\ 2.3\ 1.1\ 4.6/3\ 1.35\ 5.4/2\ 6.8/3\ 5.9/2\ 0.9\ 1.5\ 1.25\ 5.4\ 0.75\ 1.15\ 5.3/2\ 1\ 0.75\ 1.15\ 2.2/3\ 1\ 2.8\ 1\ 7.7/3\ 1.75\ 2.5\ 1.7/2\ 5.9/3\ 3.3\ 1.4\ 3\ 1.35\ 0.65\ 22/4\}; \quad (7)$$

- size of the sample:

$$n = 40; \quad (8)$$

- determining the number of classes [4], [5]:

$$k = 1.87 \cdot [(40-1)^{0.4}] + 1 = 9; \quad (9)$$

- the appropriate histogram is presented in Figure 3 and indicates a Weibull distribution function [4], [5];

- Goodness-of-fit tests (Kolmogorov-Smirnov goodness-of-fit test) and determination of the distribution; the critical value of the statistics of the Kolmogorov-Smirnov goodness-of-fit tests for the sample size is $d_{n,\alpha} = 0.2150$. The value of the statistic of the Kolmogorov-Smirnov goodness-of-fit tests for the sample is $d_1 = 0.1297 \le d_{n,\alpha} = 0.2150 \Rightarrow$ Weibull distribution [2];

- Parameter estimation for the Weibull distribution; the values of the estimated parameters of the Weibull distribution for the considered sample are: $\eta = 2.7903$, $\beta = 1.1091$, where η is the scale parameter and β the shape parameter [6].

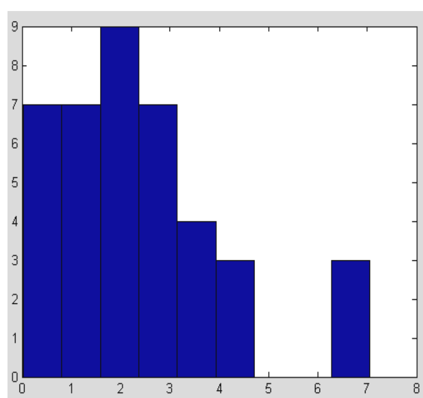

Fig. 3. *Histogram for sample I1I - average individual consumption in summer*

2.4. Case study IV

The experimental data represents the average individual consumption corresponding to the autumn months; it is extracted from Table 1 and is grouped in a sample of size n, indicated in the following array:

$$x4 = \{1.7\ 0.55\ 0.58\ 3.01\ 1.3\ 0.77\ 2.38\ 4.58\ 1.45\ 1.41\ 1.45\ 0.16\ 3.55\ 2.18\ 2.13\ 1.01\ 2.16\ 2.86\ 4.95\ 1.1\ 0.41\ 6.05\ 1.33\ 0.71\ 1.48\ 0.63\ 0.48\ 2.96\ 1.33\ 2.51\ 1.5\ 2.16\ 1.33\ 3.08\ 2.16\ 2.1\ 2.46\ 1.45\ 1.05\ 5.16\}; \quad (10)$$

- size of the sample:

$$n = 40; \quad (11)$$

- determining the number of classes [4], [5]:

$$k = 1.87 \cdot [(40 - 1)^{0.4}] + 1 = 9; \quad (12)$$

- the appropriate histogram is presented in Figure 4 and indicates a Weibull distribution function [4], [5].

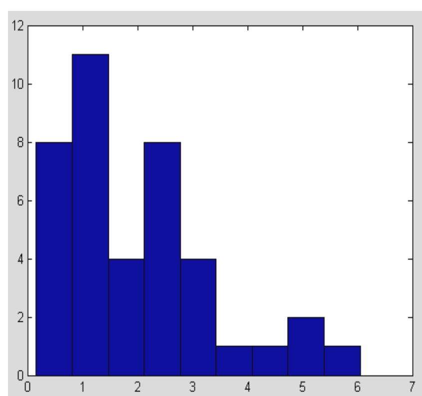

Fig. 4. *Histogram for sample IV - average individual consumption in autumn*

- Goodness-of-fit tests (Kolmogorov-Smirnov) and determination of the distribution; the critical value of the statistics of the Kolmogorov-Smirnov goodness-of-fit tests for the sample size is $d_{n,\alpha} = 0.2150$. The value of the statistic of the Kolmogorov-Smirnov goodness-of-fit tests for the sample is $d_1 = 0.1654 \le d_{n,\alpha} = 0.2150 \Rightarrow$ Weibull distribution [2];

- Parameter estimation for the Weibull distribution; the values of the estimated parameters of the Weibull distribution for the considered sample are: $\eta = 2.2215$, $\beta = 1.5863$, where η is the scale parameter and β the shape parameter [6].

3. Conclusions

Water meters, as measuring devices, may measure with errors that are greater than the admissible ones; this fact may lead to errors in the metering of the consumed water and to financial losses for the water company or the client; on the other side, conditions for the irrational utilization of the potable water resources are created. As a consequence, it is necessary to develop an algorithm which would provide information on how frequently the verification would be required for the water meters to remain within the appropriate performance specifications.

This paper presents an experimental study conducted on water meters, as part of an application of the parameter deviation, application aimed to enable the quality assurance in metrology.

As further work, it is intended to develop an algorithm for calculation of the calibration life of the water meters, as a function of metrological reliability; this requires the determining of the parameter deviation functions, and then, based on these functions, one can calculate the calibration life for the considered device.

The proposed algorithm will be used in the analysis of the metrological reliability of the water meters, for determining the calibration life of the water meters, since it is necessary for the water meters to remain within the appropriate performance specifications in order to prevent any financial losses and also, in order to reduce the irrational water losses.

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