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"MILLIY STATISTIKA TIZIMIDA YANGI BOSQICH: BARQAROR RIVOJLANISH MAQSADLARI, XALQARO STANDARTLAR VA ZAMONAVIY TENDENSIYALAR"

APPLICATION OF NON-PARAMETRIC METHODS TO ENHANCE STATISTICAL ACCURACY WITHIN UZBEKISTAN'S NATIONAL DATA SYSTEM

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ABSTRACT

This article investigates the role and practical significance of non-parametric tests in modern statistical analysis. The relevance of the research is determined by the necessity of enhancing the accuracy of data and the quality of hypothesis testing during the alignment of the national statistical system with international standards. The article analyzes the limitations of traditional parametric methods, specifically their shortcomings in cases where data does not follow a normal distribution. The advantages of non-parametric tests (Mann-Whitney-Wilcoxon test, Wilcoxon Signed-Rank test, Sign test, Kruskal-Wallis Test, Spearman rank-correlation coefficient) are scientifically substantiated, highlighting their flexibility regarding sample size and distribution shape. Furthermore, the effectiveness of these methods in identifying intergroup differences based on real-world statistical data is demonstrated. The findings serve to improve analytical processes within national statistical practices and ensure the reliability of forecasts.

Keywords: national statistical system, non-parametric tests, normal distribution, Mann-Whitney-Wilcoxon test, aviation demographics, statistical hypothesis, data analysis.

INTRODUCTION

Aligning the national statistical system with international methodological standards and enhancing the accuracy of data analysis are fundamental to evaluating the effectiveness of a country's economic policy. In recent years, the Republic of Uzbekistan has initiated comprehensive reforms to modernize its statistical infrastructure, primarily guided by the Resolution of the President of the Republic of Uzbekistan dated August 3, 2020, No. PP-4796, "On measures to further improve and develop the national statistical system of the Republic of Uzbekistan."[234] This decree approved the National Strategy for the Development of Statistics for 2020–2025, which emphasizes the transition to advanced analytical methods, the digitalization of data collection, and the integration of international

[234] President of the Republic of Uzbekistan. (2020). Resolution No. PP-4796: On measures to further improve and develop the national statistical system of the Republic of Uzbekistan. https://lex.uz/docs/-4926736

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best practices into domestic processes[1]. In implementing these strategic goals, selecting precise methods for testing statistical hypotheses remains a critical challenge for researchers and statisticians alike. While traditional parametric methods often rely on the strict assumption of a normal distribution, practical socio-economic data, market indicators, and transport flow statistics frequently exhibit non-normal distributions or contain significant outliers. In such contexts, the application of non-parametric tests which do not require specific distributional assumptions becomes essential for ensuring the reliability of statistical conclusions and the integrity of evidence-based policymaking. The purpose of this article is to examine the role and practical significance of non-parametric analysis, specifically the Mann-Whitney-Wilcoxon and Wilcoxon tests, within the national statistical framework, demonstrating their robustness through the analysis of an international transport dataset. The research utilizes the "Air Passengers" dataset, focusing on the demographic characteristics of passengers, such as gender and age, to evaluate the effectiveness of non-parametric methods in identifying significant intergroup differences where traditional models may yield biased results.

LITERATURE REVIEW

The application of non-parametric methods in socio-economic research has gained significant traction due to the inherent complexity and non-normality of real-world datasets.

The foundational work of Wilcoxon (1945) [2] and Mann and Whitney (1947) [3] established the rank-sum test as a robust alternative to the Student’s t-test, specifically for independent samples. According to Siegel and Castellan (1988) [4], non-parametric tests are indispensable when dealing with ordinal data or when the assumption of normality is violated. Further, studies by Conover (1999) [5] emphasize that rank-based methods effectively preserve statistical power even in the presence of extreme outliers, which are common in large-scale demographic datasets.

In the aviation industry, demographic analysis has traditionally relied on parametric models; however, modern research suggests a shift in methodology. Belobaba et al. (2015) in *The Global Airline Industry* [6] highlight that passenger behavior and age distributions often exhibit significant skewness due to varying economic factors and regional market dynamics. This shift necessitates the use of "distribution-free" tests to ensure the precision of market segmentation and business intelligence.

RESEARCH METHODOLOGY

The study aims to determine whether gender significantly influences the age distribution of passengers. The following hypotheses were established:

Null Hypothesis H_0: There is no significant difference in the age distribution between female and male segments ($M_1 = M_2$)

Alternative Hypothesis H_a: There is a statistically significant difference in the age distribution ($M_1 \neq M_2$)

Due to the inherent skewness and non-normality of aviation demographic data, the non-parametric Mann-Whitney-Wilcoxon (MWW) test was implemented. Unlike parametric alternatives, the MWW test is "distribution-free," meaning it does not require the data to follow a normal curve. By focusing on data ranks rather than raw values, this method effectively neutralizes the impact of outliers and provides a robust comparison of population medians.

The study utilized a balanced sample of 100 observations (50 female and 50 male) from the Kaggle "Air Passengers" dataset [7]. The methodological workflow involved pooling all observations and assigning ranks from 1 to 100 based on age.

For hypothesis testing, a normal approximation of the sampling distribution of W was employed. According to the established criteria for the MWW test, the normal distribution form is applicable provided that $n_1 \geq 7$ and $n_2 \geq 7$. Given that our sample size ($n = 50$) for each group) exceeds this threshold, the expected mean, standard deviation and Z-score were calculated using the standard formulas:

$$\mu_w = \frac{1}{2} n_1 (n_1 + n_2 + 1);$$

$$\sigma_w = \sqrt{\frac{1}{12} n_1 n_2 (n_1 + n_2 + 1)};$$

$$Z = \frac{W - \mu_w}{\sigma_w}.$$

The final Z-statistic and p-value were derived through Python and cross-validated using the ‘‘wilcox.test’’ function in R to ensure computational accuracy.

RESULTS

The empirical execution of the study began with an analysis of the data distribution. Before proceeding with the rank-sum methodology, it was essential to verify the normality of the dataset.

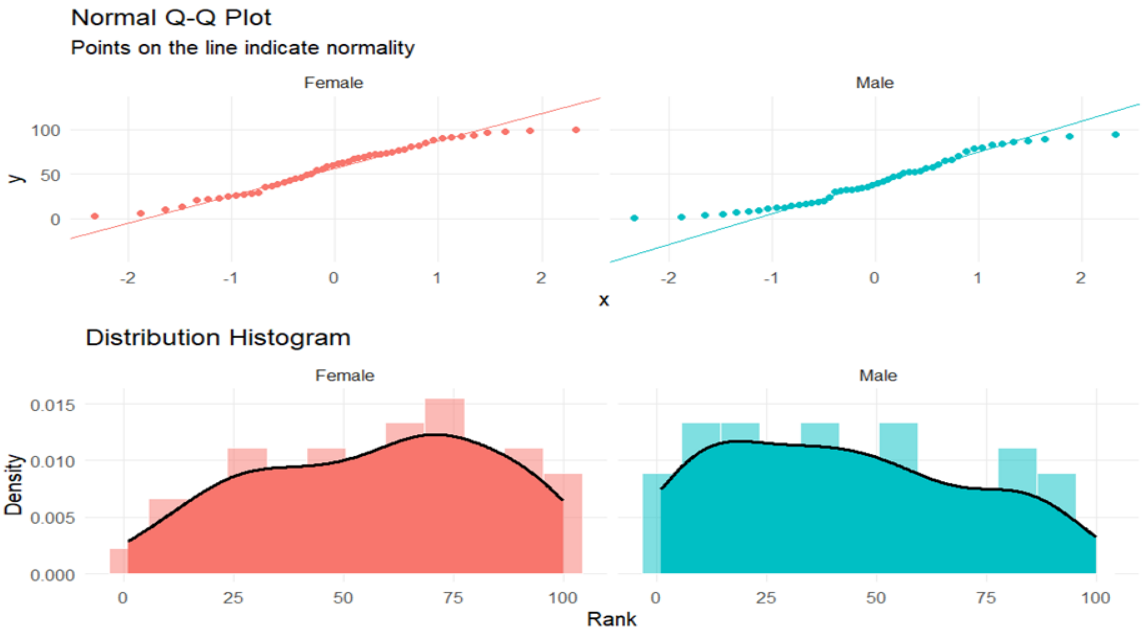


Figure 1: Normal Q-Q plot and distribution histogram[235]

The visualization in Figure 1 confirms that both the female and male segments exhibit non-normal distributions, as evidenced by the deviations in the Q-Q plots and the non-symmetrical density curves in the histograms. These diagnostics provide the empirical justification for the use of the non-parametric Mann-Whitney-Wilcoxon test.

Following the distributional analysis, the Mann-Whitney-Wilcoxon rank-sum methodology was applied. By transforming raw age data into a standardized rank format, the study effectively mitigated the influence of the non-normal distribution patterns.

The test was conducted on a balanced sample ($n_1 = 50, n_2 = 50$), where the observed rank totals demonstrated a clear divergence between the two groups. The female passenger segment (W_f) reached a sum of 2860, while the male segment (W_m) totaled 2190. Utilizing the normal approximation framework, the following statistical parameters were derived:

- Expected Mean (μ_w): 2525
- Standard Deviation (σ_w): 145.06
- Z-score: 2.31
- P-value: 0.0211

Comparing the resulting p-value of 0.0211 against the significance threshold ($\alpha = 0.05$) led to the rejection of the null hypothesis H_0. This statistical outcome confirms a significant "location shift," indicating that the age distribution of female passengers is positioned higher than that of the male group.

[235] Source: Compiled by the author based on Kaggle dataset using R

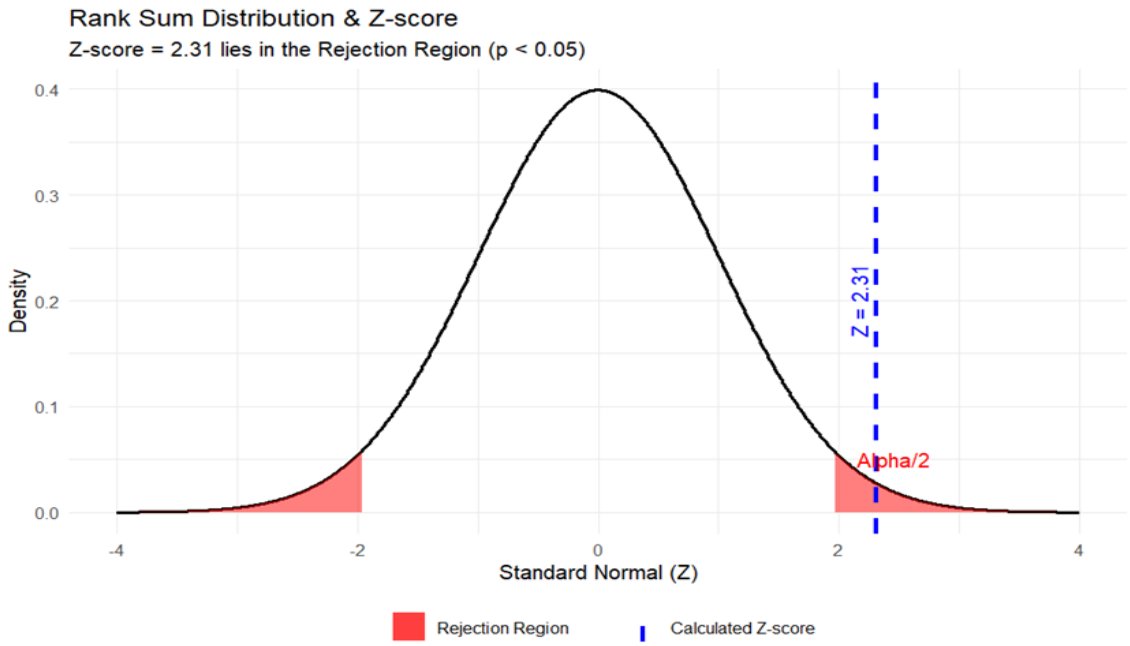


Figure 2. Normal approximation of the Mann-Whitney-Wilcoxon rank-sum distribution[236]

The visualization in Figure 2 confirms the statistical validity of these results. The empirical rank sums for both segments are situated in the extreme tails of the distribution. The calculated Z-score of 2.31 falls clearly within the critical rejection region, providing visual evidence that the observed age disparity is not a product of random chance. The probability of observing such a shift by pure coincidence is only 2.11%.

IQTISODIY STATISTIKA KAFEDRASI — Toshkent davlat iqtisodiyot universiteti —

[236] Source: Compiled by the author based on research findings using R



Figure 3. Boxplot of rank distribution by gender[237]

The comparative analysis reveals a distinct "location shift" between the groups. The median rank for female passengers is visibly higher, situated above the 50th percentile, while the male median remains in the lower quartile range. The "jitter" points indicate that while age ranges overlap, the density of higher ranks is concentrated within the female segment. With a calculated p-value of 0.0211, the visual gap between these two boxes represents a statistically significant difference, rather than a random sampling fluke.

DISCUSSION

The empirical results of this study provide critical insights into both the demographic trends of the aviation sector and the methodological necessity of non-parametric testing.

The rejection of the null hypothesis confirms that the age distribution is not uniform across genders in the sampled population. The observed "location shift" towards higher ranks for female passengers suggests that, within this specific dataset, the female demographic represents a more mature segment of the market. From a business intelligence perspective, such findings are vital for airlines to tailor their marketing strategies, cabin services, and loyalty programs to the specific needs of different age-gender clusters.

Beyond the specific data, this research underscores the necessity of moving away from traditional parametric assumptions in sectoral analysis. As demonstrated by the preliminary diagnostics, real-world aviation data is frequently

[237] Source: Compiled by the author based on Kaggle dataset using R.

characterized by skewness and outliers. By employing the Mann-Whitney-Wilcoxon test, this study ensured that the reported p-value and Z-score were not artifacts of distributional violations, but a true reflection of the underlying population dynamics.

In alignment with the strategic goals of Presidential Resolution No. PP-4796, these results advocate for a more rigorous, evidence-based approach to data processing in Uzbekistan. Adopting robust non-parametric frameworks in national reporting can significantly enhance the reliability of socio-economic indicators. This study serves as a practical model for how international statistical standards can be integrated into the analysis of domestic and sectoral datasets to support more informed policymaking.

CONCLUSION AND RECOMMENDATIONS

This study successfully applied the Mann-Whitney-Wilcoxon non-parametric framework to identify significant demographic shifts in aviation data. The analysis demonstrated that when normality assumptions are violated, rank-based testing provides a stable and accurate alternative. The findings confirm a statistically significant difference in the age distribution of passengers, proving that gender is a relevant factor in demographic modeling for this sector. For future research and practical application within Uzbekistan's national statistical system, it is recommended to prioritize non-parametric diagnostics as a standard procedure in socio-economic reporting to ensure the precision of national data.

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