

# ASSESSMENT OF THE INFLUENCE OF SEASONALITY ON SELECTED AIRCRAFT MAINTENANCE FACTORS

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**Abstract:** The work deals with the identification of seasonality and its possible influence on the consumption of chemical material and worked time in the aircraft maintenance organization. The aim of the work was to analyze data from the maintenance organization, identify seasonality and its influence and, if necessary, propose a new staffing strategy that would take seasonality into account. The Kruskal-Wallis test was used to identify seasonality in the data and the Ljung-box test to confirm the independence and randomness of the data. The results showed that seasonality occurs only in worked time, which was also assumed. Seasonality was not confirmed for the consumption of chemical material. The work confirms that seasonality occurs in aviation, but not in all areas.

Key words: *aircraft maintenance, seasonality, worked time, material consumption, Kruskal–Wallis test*

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## 1. Introduction

In the current economic environment, cost optimization is one of the key objectives of most companies across industries. To this end, company management systematically strive to increase the efficiency of their core production and supporting (e.g., administrative) processes ensure maximum utilization of available resources, all with the aim of maintaining long-term competitiveness and sustainability. In this context, any form of inefficiency—whether material, financial, time-related, or human—is considered an undesirable phenomenon that negatively affects organizational performance. The identification, analysis, and subsequent elimination

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of such losses therefore become an integral part of modern management and represent a fundamental prerequisite for achieving higher productivity and quality.

All the above also applies to air transport, both for air carriers and for maintenance organizations, suppliers, and other entities participating in the aviation industry. Aviation is an industry that is burdened by seasonality in many aspects. Seasonality affects not only demand for air transport but may also manifest itself in other activities related to aviation, such as maintenance and repair operations. The ability to predict future traffic trends is a key prerequisite for effective planning and resource allocation; this is confirmed by Sajanraj et al. [1], who state that forecasting transport usage is an integral part of transport system planning, as it enables the more efficient use of available resources. For this reason, it is appropriate to monitor and analyze the impact of seasonality in aviation.

This article addresses the issue of aircraft maintenance and repair, specifically the analysis of the impact of seasonality on two factors—the time demand of the maintenance process and the consumption of a selected type of material resource, namely a two-component polysulfide sealant with anticorrosion protection, used mainly in integral fuel tanks of aircraft and for fuselage sealing. This material is used on all types of aircraft. Consumption data comes from real operational conditions in a maintenance organization. Seasonality analysis is important mainly for planning material orders and setting the right supply strategy. Another reason is the planning of shifts of maintenance organization employees during the year.

## 2. Analysis of the Current State of Knowledge

The impact of seasonality on air transport has been assessed in the past in many areas of civil aviation. One such area is the evaluation of seasonality in airport operations and for example, their financial performance. In study [2], the relationship between seasonality and airport profitability was identified. A so-called "seasonality score" was defined, the occurrence and magnitude of which positively or negatively affect the profitability of a given airport. The impact of seasonality on airport operations was also examined in a general context in study [3], which showed that at least 36% of airports worldwide are affected by a significant degree of seasonality. However, the authors also point out that major airports are less affected by seasonality. Article [4] demonstrates the relationship between charter flights and seasonality. Article [5] examines the number of passengers, aircraft movements, the share of passengers and cargo, and other related data. Although it does not explicitly focus on seasonality, it captures temporal changes through time-related variables.

Another area of aviation in which research on the impact of seasonality has been conducted is bird strikes. This issue was examined in study [6], in which the authors evaluated data from 122 airports worldwide and showed that the occurrence of bird strikes is influenced by seasonality—the highest numbers occur in late summer and autumn, and this finding applies to both the Northern and Southern Hemispheres. However, in the Northern Hemisphere the number of bird strikes was significantly higher.

Existing publications in the field of aircraft maintenance that address the impact of seasonality on maintenance processes deal with the calculation of downtime costs

during maintenance [7] and with the prediction and management of spare-parts purchasing to reduce aircraft downtime [8].

Article [7] presents a general model for calculating opportunity costs caused by maintenance (downtime—the period when the aircraft is not available for operation due to maintenance, failure, or other restrictions), based on data from a specific airline. The aim of the article is not focused on the identification of seasonality; seasonality is perceived only as one of the external factors derived from historical data or defined by the market.

Article [8] presents a general model for predicting and managing spare-parts purchases to reduce aircraft downtime. The data are based on real operational conditions. The main goal is the analysis and comparison of predictive models for aircraft downtime. In this article, seasonality is not perceived as an independent input factor; seasonality is part of the time series, and if it exists, it can be considered in the models.

When predicting material consumption during aircraft maintenance in maintenance and repair organizations, it is often assumed that the lowest material consumption occurs during periods when demand for maintenance and repairs is lowest. In the Northern Hemisphere, this period typically occurs in the summer months, as the aircraft fleets of most airlines operating in the Northern Hemisphere are deployed to serve increased demand for air transport.

The identification of seasonality should be based on statistical analysis of data related to the given factor. On this basis, demand for a given factor in a specific period can be appropriately estimated. In this case, it involves a general assessment of the existence of seasonality in maintenance time requirements and an assessment of the existence of seasonality in the consumption of the given material. Demonstrating a significant impact of seasonality can, in subsequent years, prevent the accumulation of material in warehouses. This is particularly important for materials with a defined expiration date. Exceeding the expiration date due to non-use leads to higher inefficiency caused by the need to incur additional costs for the disposal of expired items.

Above mentioned approaches applied methods of mathematical statistics for solving. There are several ways how to incorporate uncertainty into mathematical approaches, for example using fuzzy sets as shown in article [9]. In this article the authors use fuzzy linear programming to optimize aircraft fleet utilization under irregular operational conditions while accounting for uncertainty in operational parameters.

## 3. Methodology

To demonstrate the impact of seasonality in the number of worked time and material consumption, data on worked time in the maintenance hangar and on material consumption—the two-component polysulfide sealant—were used. To test the impact of seasonality, the Kruskal–Wallis test [10, 16] was applied, which is one of the options for demonstrating seasonality. The use of the Kruskal–Wallis test as the main test for seasonal comparison of groups is recommended in studies [11–13]. Another reason for choosing the Kruskal–Wallis test is the relatively small amount

of data used for testing. Due to the limited amount of data and the failure to meet the normal distribution criteria, the ANOVA test was not used.

The test is based on the assessment of median equality for more than two samples. It is a non-parametric test, i.e., a test that does not require the assumption of normally distributed data. Within the test, the following hypotheses were formulated:

1. $H_0$: the medians of individual periods are equal; seasonality is rejected

2. $H_1$: the medians of individual periods are not equal; seasonality is not rejected

In the Kruskal–Wallis test, the test statistic Eq. (1) has the following form:

$$H = -3(n+1) + \frac{12}{n(n+1)} \sum_{i=1}^{k} \frac{T_i^2}{n_i}, \tag{1}$$

where
$n$ is the total number of observations,
$n_i$ is the number of observations in individual periods,
$T_i$ is the sum of ranks in individual periods.

If the sample size in each group is greater than 5, the test statistic $H$ (1) approximately follows a $\chi^2$distribution with $k-1$ degrees of freedom, where $k$ is the number of observed periods. If:

$$H_{crit} > H \ldots\ldots H_0 \text{ is not rejected}$$

$$H_{crit} \leq H \ldots\ldots H_0 \text{ is rejected}$$

Before using the Kruskal–Wallis test, it is important to test the randomness and independence of successive data. For this purpose, the Ljung–Box test [15] (also sometimes referred to as the Q-test) is used. In the Ljung–Box test, the hypotheses are as follows:

$H_0$ : the tested data are independent and random, with no autocorrelation

$H_1$ : the tested data are dependent and exhibit autocorrelation

The Ljung–Box test statistic $Q_{LB}$ Eq. (2) has the following form:

$$Q_{LB} = n(n+2) \sum_{k=1}^{m} \frac{\rho_k^2}{n-k}, \tag{2}$$

where
$n$ is the length of the time series,
$m$ is the number of lags,
$\rho_k^2$ is the estimate of the autocorrelation function at lag $k$.

The test statistic $Q_{LB}$ Eq. (2) approximately follows a $\chi^2$ distribution with $m$ degrees of freedom. The main indicator for assessing the validity of the null hypothesis is the $p$-value, which is compared with the chosen significance level. If the significance level is $\alpha = 0,05$, the following applies:

$$p - \text{value} > 0.05 \ldots \; H_0 \text{ is not rejected}$$

$$p - \text{value} \leq 0.05 \ldots \; H_0 \text{ is rejected}$$

# 4. Case Study

Testing the impact of seasonality on the number of worked time and on the consumption of the two-component polysulfide sealant was carried out using real data provided by an organization performing aircraft maintenance and repairs. The data covers the period from January 2023 to June 2025. Including data from before 2023 would have been distorted by the impact of the COVID-19 pandemic.

To determine the impact of seasonality on aircraft maintenance time requirements, total monthly worked time on all aircraft were used. To determine seasonality in material consumption, monthly consumption values of the given material were used.

The following procedure was adopted:

1. collection of data on the monitored variables,
2. initial analysis of the collected data—initial formulation of assumptions,
3. verification of data independence and randomness using the Ljung–Box test,
4. application of the Kruskal–Wallis test.

**Collection of data on the monitored variables**
The data were provided directly by the maintenance organization. These are real data on monthly numbers of worked time and on the consumption of the two-component polysulfide sealant in individual months over the observed period January 2023 – June 2025. Three datasets were available containing information on worked time, purchase order issue dates, warehouse receipt dates, consumption, etc.

**Initial analysis of the collected data—initial formulation of assumptions**
Before the initial analysis, it was necessary to perform a selection of the supplied data according to the chosen parameters. In this case, this involved filtering data on material consumption and worked time from the overall dataset.

The analyzed data were divided into periods as required. Since testing of seasonality assumed that the lowest maintenance demand occurs in summer months, the data were divided into three sub-periods: February–May (Q1), June–September (Q2), and October–January (Q3). After determining the ranking of observed values in the entire dataset, two datasets were formed, each consisting of 30 data points (Fig. 1).

| | Analyzed period | Consumption (pcs) | Rank | Sum rank |
|---|---|---|---|---|
| Q1 | II.23 | 1 | 5 | 199 |
| | III.23 | 3 | 8.5 | |
| | IV.23 | 15 | 25 | |
| | V.23 | 11 | 23.5 | |
| | II.24 | 2 | 7 | |
| | III.24 | 37 | 30 | |
| | IV.24 | 5 | 15 | |
| | V.24 | 7 | 18.5 | |
| | II.25 | 10 | 21 | |
| | III.25 | 4 | 11.5 | |
| | IV.25 | 1 | 5 | |
| | V.25 | 27 | 29 | |
| | | | | |
| Q2 | VI.23 | 19 | 27 | 123 |
| | VII.23 | 1 | 5 | |
| | VIII.23 | 10 | 21 | |
| | IX.23 | 5 | 15 | |
| | VI.24 | 4 | 11.5 | |
| | VII.24 | 0 | 2 | |
| | VIII.24 | 7 | 18.5 | |
| | IX.24 | 0 | 2 | |
| | VI.25 | 10 | 21 | |
| | | | | |
| Q3 | I.23 | 0 | 2 | 143 |
| | X.23 | 19 | 27 | |
| | XI.23 | 4 | 11.5 | |
| | XII.23 | 11 | 23.5 | |
| | I.24 | 3 | 8.5 | |
| | X.24 | 4 | 11.5 | |
| | XI.24 | 6 | 17 | |
| | XII.24 | 5 | 15 | |
| | I.25 | 19 | 27 | |

| | Analyzed period | Time worked (h) | Rank | Sum rank |
|---|---|---|---|---|
| Q1 | II.23 | 32 786 | 13 | 232 |
| | III.23 | 38 328 | 29 | |
| | IV.23 | 30 748 | 10 | |
| | V.23 | 36 261 | 25 | |
| | II.24 | 34 259 | 16 | |
| | III.24 | 32 605 | 12 | |
| | IV.24 | 36 103 | 23 | |
| | V.24 | 33 146 | 14 | |
| | II.25 | 35 602 | 20 | |
| | III.25 | 37 253 | 27 | |
| | IV.25 | 36 257 | 24 | |
| | V.25 | 34 938 | 19 | |
| | | | | |
| Q2 | VI.23 | 33 419 | 15 | 56 |
| | VII.23 | 21 727 | 1 | |
| | VIII.23 | 28 559 | 4 | |
| | IX.23 | 30 044 | 9 | |
| | VI.24 | 29 673 | 6 | |
| | VII.24 | 26 541 | 2 | |
| | VIII.24 | 28 898 | 5 | |
| | IX.24 | 27 120 | 3 | |
| | VI.25 | 31 429 | 11 | |
| | | | | |
| Q3 | I.23 | 34 478 | 17 | 177 |
| | X.23 | 37 672 | 28 | |
| | XI.23 | 35 879 | 22 | |
| | XII.23 | 29 866 | 7 | |
| | I.24 | 35 605 | 21 | |
| | X.24 | 37 065 | 26 | |
| | XI.24 | 34 698 | 18 | |
| | XII.24 | 29 988 | 8 | |
| | I.25 | 39 076 | 30 | |

**Fig. 1** *Input datasets (author's own processing).*

Fig. 1 contains two columns; the left column represents worked time in the hangar, and the right column represents material consumption in individual months. Both columns include the division into predefined examined periods and the ranking of individual values.

For data visualization, a column chart was used, allowing clearer interpretation of the data (see Fig. 2). These charts clearly show data for individual months in the period 2023 to June 2025.

Based on the provided values, three median values for individual periods were calculated for each dataset. The calculated values are shown in Tab. I and graphically illustrated in Fig. 3.

Based on the calculated and plotted median values, an initial comparison of differences between periods was made. At this step, this indicates a significant difference in medians in the time worked dataset, while no significant difference appears in the two-component polysulfide sealant consumption dataset.

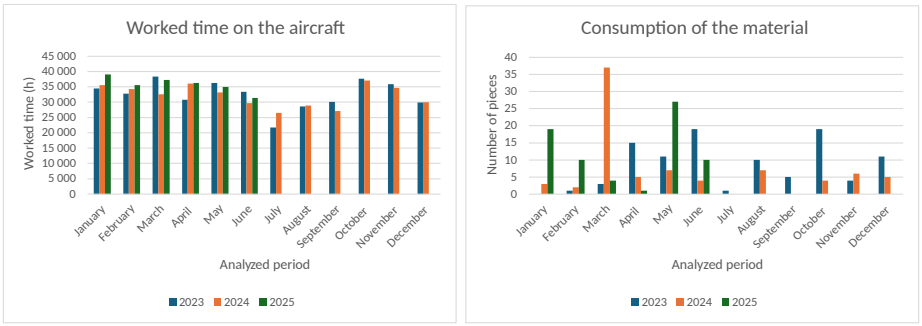


**Fig. 2** *Graphical representations of worked time on aircraft per month and total consumption of the given material per month (author's own processing).*

| | Median | |
|---|---|---|
| | Worked time | Consumption |
| Q1 | 19.5 | 16.75 |
| Q2 | 5.0 | 15.00 |
| Q3 | 21.0 | 15.00 |

**Tab. I** *Median values of ranks in individual periods in each dataset (author's own processing).*

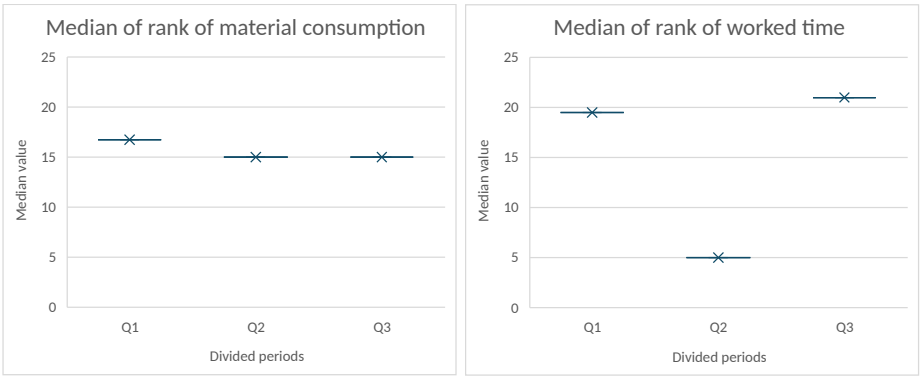


**Fig. 3** *Differences in medians values of rank in individual periods in each dataset (author's own processing).*

### Verification of data independence using the Ljung–Box test

In this part of the statistical analysis, the Ljung–Box test was applied. All statistical calculations were performed using the R programming language.

For the worked time dataset, the $p$-value was 0.3547, and for the material consumption dataset, the $p$-value was 0.8169. Since in both cases the $p$-value is greater than the standard significance level of 0.05, the null hypothesis is not rejected. The data are independent and random and show no signs of autocorrelation. In the next

step, the Kruskal–Wallis test can be applied, as the requirement for data independence is met.

**Application of the Kruskal–Wallis test**

The Kruskal–Wallis test was employed to investigate the presence of seasonal effects across both datasets. Since the sample size in each of the three groups is greater than 5, the test statistic $H$ approximately follows a $\chi^2$ distribution with two degrees of freedom. For the test itself, the significance level was set to the value $\alpha = 0.05$.

The total number of observations was $n = 30$ in both analyzed datasets. For the values of $n_i$, both datasets have $n_1 = 12$, $n_2 = 9$, and $n_3 = 9$. The values $T_i$ represent the sums of all ranks for a given period.

For the worked time dataset, the calculated test statistic was $H = 14.29$. For the dataset concerning consumption of the two-component polysulfide sealant with anticorrosion protection, the value was $H = 0.59$.

In statistical tables [11], for significance level $\alpha = 0.05$ and two degrees of freedom, the critical value is $H_{crit} = 5.99$. The correctness of rejecting or not rejecting $H_0$ was additionally verified by calculating the $p$-value. For the worked time dataset, the $p$-value was $< 0.001$. For the material consumption dataset, the $p$-value was 0.74.

For the worked time dataset, the test revealed statistically significant differences among the seasonal periods, $H = 14.29$, $p < 0.001$, confirming the rejection of the null hypothesis and indicating a clear seasonal pattern in worked time. Conversely, for the material consumption dataset (specifically the two-component polysulfide sealant with anticorrosion protection), no significant seasonal variations were detected, $H = 0.59$, $p = 0.745$. This result confirms the not rejecting the null hypothesis. Thus, seasonality can be expected in worked time, whereas no seasonal effect can be expected for the consumption of the two-component polysulfide sealant with anticorrosion protection.

# 5. Discussion

This article is devoted to testing the impact of seasonality on two aircraft maintenance factors in aviation enterprises engaged in aircraft maintenance and repair.

While previous studies have focused mainly on traffic demand, airport activity or aircraft downtime, this research provides empirical evidence that different maintenance resources exhibit distinct seasonal behavior. This finding contributes to a more detailed understanding of maintenance planning and resource management in aviation.

Data from real operations were used for testing seasonality. Seasonality was assessed by comparing predefined seasonal periods using the Kruskal–Wallis test. While more advanced time series approaches such as seasonal decomposition or SARIMA models can be used to detect recurring seasonal patterns, these methods typically require significantly longer time series. Given the limited number of observations and predefined seasonal classification, nonparametric comparisons of seasonal groups were considered the most appropriate approach.

The results show that a certain degree of seasonality can also be expected in aircraft maintenance and repair activities. The test results demonstrated that, in the examined maintenance organization, a seasonal pattern in the number of worked time during the summer months (in this case, June–September) was present. This finding corroborates previous studies that have demonstrated seasonality in air transport. In the present case, the observed pattern is likely explained by the scheduling of maintenance activities outside the summer months.

In contrast, seasonality did not manifest itself in the consumption of the two-component polysulfide sealant with anticorrosion protection during the summer months. This result is surprising given the generally known presence of seasonality in aviation, as well as the seasonality demonstrated in worked time in this study. The main reason for this result is likely the universality of the examined sealant and its possible use during unexpected aircraft failures, which can occur at any time. Another possible explanation is that material consumption is more strongly influenced by the type of maintenance performed than by the frequency of maintenance activities. Nevertheless, it cannot be excluded that the statistical power of the test was limited by the relatively small dataset. Since this material is not a spare part – whose supply is managed differently (e.g., according to maintenance schedules) – it is not recommended that management of the repair organization reduce supply volumes during the summer months. Conversely, the demonstrated seasonality in the number of hours worked may serve as a basis for optimizing workforce capacity planning, shift scheduling, and the planning of employee leave.

Since the analysis was based on data obtained from a single maintenance organization, the findings cannot be generalized to the entire aircraft maintenance sector without further research.

Further research should focus on systematic analysis and verification of the impact of seasonality also in the case of other inventory items used in maintenance and repair activities. Based on the acquired findings, inventory levels can be subsequently optimized and contractual relationships with suppliers can be efficiently adjusted.

To improve the accuracy of future analyses, it would be beneficial to use larger datasets, including multiple maintenance organizations, examine a wider range of material types, and investigate the influence of additional factors, such as aircraft type and climatic conditions. An equally interesting area for future research would be a comparison between civil and military aircraft maintenance.

# 6. Conclusion

The aim of this study was to determine if the seasonality characteristic of the aviation sector extends to aircraft maintenance resources. We analyzed two variables representing different aspects of the maintenance process.

The results show that seasonality affects different maintenance resources in different ways. While the worked time clearly followed the expected seasonal pattern, no statistically significant seasonality was found for material consumption. This finding suggests that maintenance workload and material demand should not be automatically considered interdependent.

Although this study is based on data from a single organization, the findings suggest that identifying seasonal effects using statistical methods can contribute not only to more efficient utilization of human resources but also to the optimization of logistics processes and inventory management.

The main contribution of this study lies in demonstrating that seasonality in aircraft maintenance is not a universal phenomenon that affects all resources in the same way.

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