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Shipping Methodologies and Shipping Delivery Performance

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Shipping Methodologies and Shipping Delivery Performance

Introduction

Currently, online shopping habits demand fast and reliable delivery. Recognizing the necessity for speed and reliability, Sahoo et al. (2021) highlighted the important role of shipping methodologies to ensure effective delivery. Transportation, including air, sea, and road, has different inherent transport risks and serves as key performance indicators affecting the time of arrival. Nie (2022) further proposed that these modes are chosen based on speed, safety, reliability, and cost-effectiveness. Hence, the transportation mode is an essential decision, especially for e-commerce. This research objective is to identify how different shipping methods affect delivery times by using hypothesis testing, such as one-way ANOVA and Kruskal–Wallis. The findings will benefit the e-commerce company to support their theories before putting them into action.

Research Questions

● Is there any significant difference between each shipment method affecting the delivery time?

Data Collection

The data was sourced from "Customer Analytics" on Kaggle. The dataset contains 10,999 observations across 12 variables. The variables provide comprehensive insights into customer behaviour, shipping methods, and product delivery performance. The two key factors used in the analysis:

- Mode of shipment: Ship, Flight, and Road are the three ways that the company transports its products.
- Reached on time: It is a target variable, indicating whether products arrived on time (0 for on-time, 1 for delayed).

This research's focus is on exploring the relationship between shipping strategies and delivery effectiveness. The following sections of this report will provide more details about methodology, statistical techniques, research findings, and recommendations and suggestions for future research.

Methodology, concepts, and approaches

The null and alternative hypotheses are defined below:

Hypothesis testing

● Null Hypothesis: The mode of shipment has no effect on the time of arrival of the order to the customer

● Alternative Hypothesis: the mode of shipment affects the time of delivery

Based on the research hypothesis, the dataset was divided into three groups: flight, ship, and road. This division allowed for the comparison of different shipping methods and their effects on on-time delivery using two-sided hypothesis testing. The datasets were investigated using a Box Plot to identify outlier data before the analysis process. Heumann and Shalabh (2016) demonstrated that hypothesis testing can be conducted by comparing the p-value to the significance level of 0.05 and the test statistic to confidence intervals. Assuming each shipping method works independently, so one doesn't affect the others' on-time delivery.

The datasets were initially analysed using ANOVA because it can test more than two sample groups (Kim, 2017). However, due to its limitations, the methodology was shifted to the Kruskal–Wallis test. ANOVA was used to examine differences between shipping methods because it met the assumption of independence between groups. Consequently, a one-way ANOVA compared the means of each shipping method since the data was categorised by shipping method only. An investigation is required

to test if on-time arrival means for flights, ships, and road transport are not different according to the null hypothesis.

One-way ANOVA was carried out using two different approaches: comparing the p-value to the chosen α value and the test statistic to the critical region to either retain or reject the hypothesis. Hypothesis testing using a critical region approach needs to find the degrees of freedom and among-group variation. Another significant aspect of ANOVA is that residuals should follow a normal distribution and equal sample sizes. The datasets were investigated using a Q-Q plot to identify this aspect. However, using ANOVA analysis may not be an appropriate approach to test this hypothesis due to the limitations, which could weaken the conclusion of the hypothesis.

The Kruskal-Wallis test was considered because the residuals do not follow a normal distribution, and the data sizes for each shipment method are unequal (McKight and Najab, 2010). The Kruskal–Wallis test, unlike traditional one-way ANOVA, does not rely on the assumption of a normal distribution for the residuals. In the Kruskal–Wallis test, hypothesis testing was conducted by comparing the p-value to a two-sided significance level. If the p-value falls within the two-sided significance level, the null hypothesis type can be retained; otherwise, the null hypothesis must be rejected.

Additionally, the data was analysed to identify a linear relationship between the mode of shipment and reach on-time by calculating the correlation matrix. A correlation value near zero means no connection, while a value near one indicates a strong relationship (Taylor, 1990).

Analysis, Findings, and Discussion

Analysis

In this analysis section, a comprehensive examination of the dataset has been undertaken by using various statistics to discern the potential association between shipping methods and delivery performance. Initially, descriptive analytics was conducted to see the basis for other statistical tests, such as central tendency of columns pertinent to the representative of the entire column. Moreover, univariate analysis was conducted, and Table 1 and the associated graph indicate that around 59% of products did not arrive on time, meanwhile, 40.3% were delivered on time.

Values	Percentage
1	0.596691
0	0.403309

Table 1 *Univariate analysis on reached on time variable*

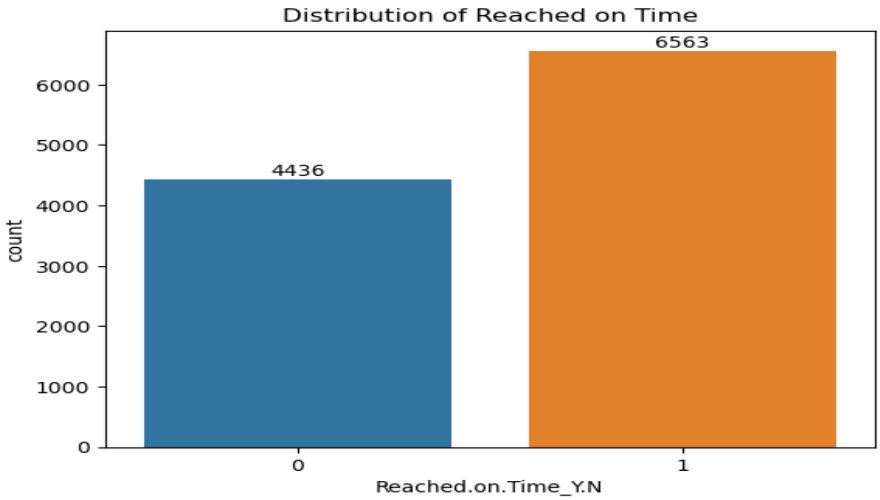

Figure 1 *Univariate analysis in distribution of products based on punctuality, with 0 and 1*

Figure 2 *Univariate analysis distribution of products by mode of shipment: flight, ship, and road*

Moreover, the shipment methodologies play a pivotal role in these figures, and maritime transportation is the highest amongst the others, accounting for 7,462 products, whereas the air and road have 1777 and 1760 products respectively. It is proven that sea transport has a significant portion of deliveries, as Fig. 1 and Fig. 2 present above.

Reached.on.Time	**0**	**1**
Mode of_Shipment		
Flight	39.842431	60.157569
Road	41.193182	58.806818
Ship	40.243902	59.756098

Table 2 *Percentage distribution of products based on their time arrival across different modes of shipment*

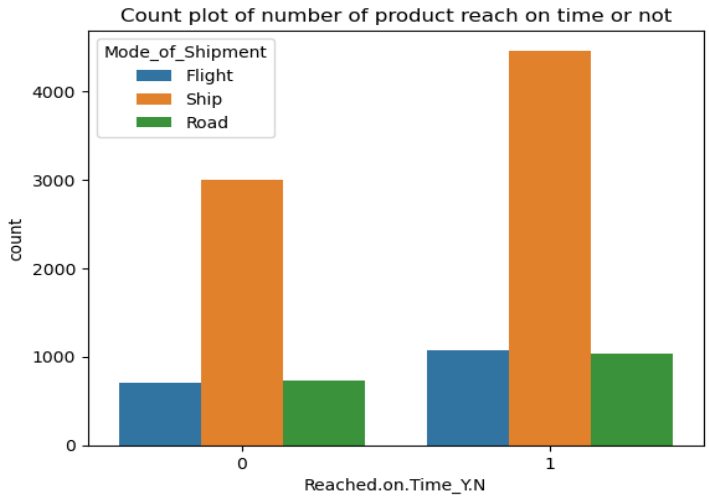

Figure 3 *Distribution of product deliveries by mode of shipment, comparing with on-time ('0') versus delayed ('1') arrivals*

A new pattern appears in Fig 3 and Table 2, as bivariate analysis. The highest percentage of delayed packages is the flight shipment. We indicate there is a complex interplay, even, air shipment statistically has the highest percentage and encounters more delays, ship delivery has bigger volume. Thus, there may be underlying confounding columns or factors in the dataset that affect the delivery time. In addition, to strengthen the previous analysis, Fig 4 presents the distribution in each shipment method has no outliers and the distribution of this data is abnormal. This reason leads us to test the hypothesis with one-way ANOVA and Kruskal-Wallis test, which is suit with our sample condition.

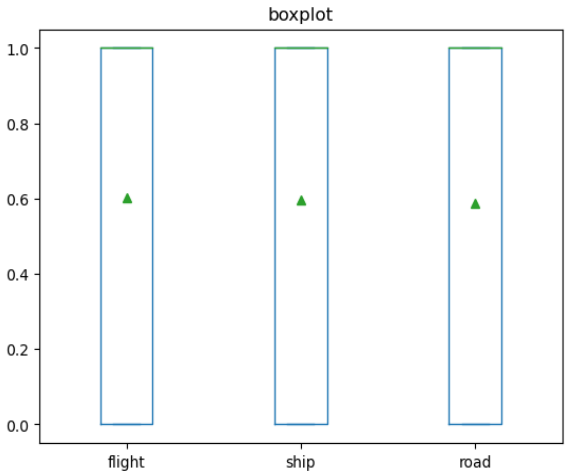

Figure 4 *Outliers checking, using boxplot, divided into each mode shipment*

Results

The group data is segregated into three categories: air, ship, and road. The one-way ANOVA produced a p-value of 0.6896, which exceeds the typical alpha level. In detail, there are no significant differences in the means across the three groups. Consequently, the null hypothesis is accepted. Then, One-way ANOVA was conducted using critical region. This involved the degree of freedom and was divided into 2 group variations. It resulted at 10.996 and the computations yield an upper critical value of 3.6901 and lower critical value is 0.0253. Variance analysis showed that Among-group variance (SSA) was 0.1789, Meanwhile, within-group variance (SSW) was 2646.7406. The result is 0.3716 did not fall within the critical region and null hypothesis is accepted, as appears in Fig 5.

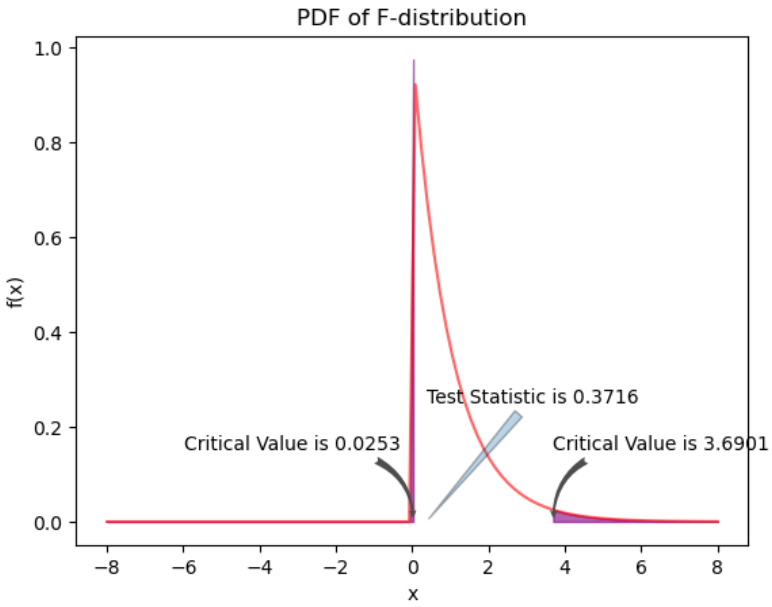

Figure 5 *One-way ANOVA critical region approaches*

A Kruskal-Wallis test was conducted and resulted in a p-value of 0.6896. It shows, there is no significant variance in the averages between the different shipping methodologies.

In conclusion, the hypothesis testing and the graphs (Fig 6 and Fig 7), indicate that there is no statistically significant relation, since there is no linear relationship between the shipment and the time of arrival.

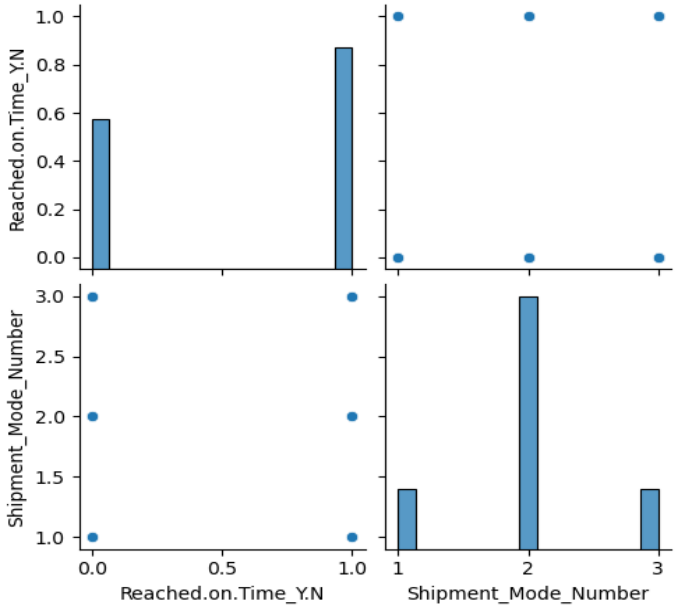

Figure 6 *Visualization of shipment mode numbers against on-time delivery*

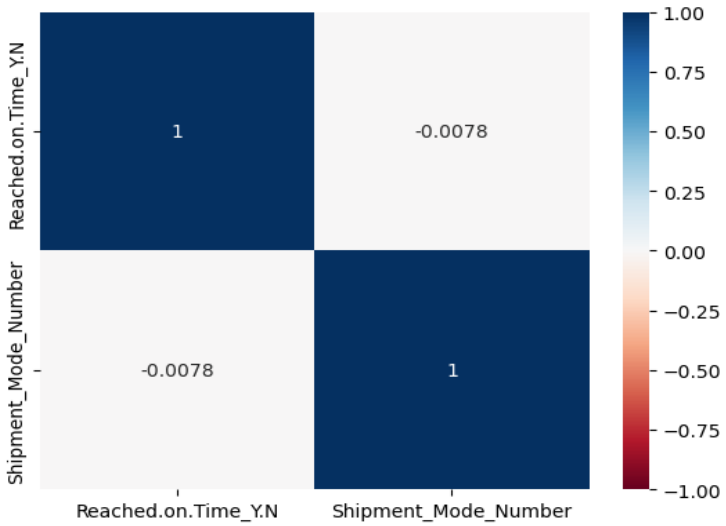

Figure 7 *Correlation between time-delivery and shipment modes*

Limitations, Discussion, Recommendation, and Appendix

Limitation

The limitations of the analysis arise from the dichotomous nature of our data, which categorises shipments as either "on time" or "delayed." The current representation fails to account for the subtle discrepancies in delivery durations among various means of transportation, wherein a delay in air shipping can significantly differ from a delay in sea shipping. Furthermore, the analysis did not extensively explore the origins of delays, including potential contributions from human factors or external factors outside our control. As a result, the ability to offer a full assessment of the fundamental elements influencing delivery performance is constrained.

Discussion and Recommendation for Further Research

Data exploration and hypothesis testing have identified confounding variables that may influence delivery times; it is Warehouse Block F, as appear in Fig 8, 9, and 10.

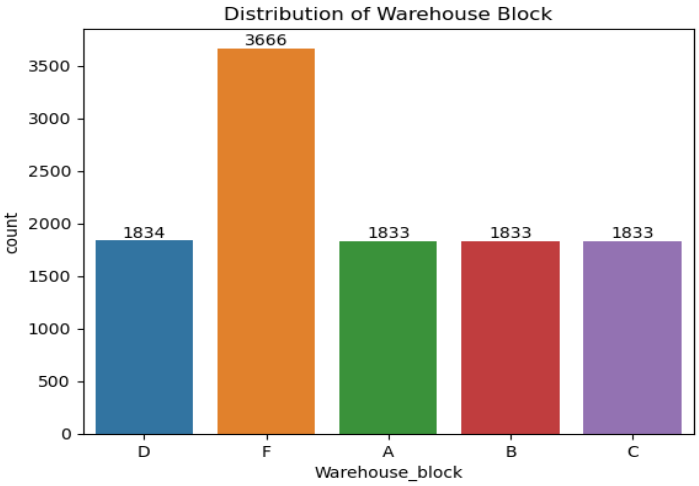

Figure 8 *Production of products by Warehouse Block*

The variance of pathway to the block F could stem from factors such as distance, cost efficiencies, or management strategies. In Further research, block F could be the main target of analysis or testing

to discern the main causes of the delay. This insight will benefit the operational division to enhance delivery consistency.

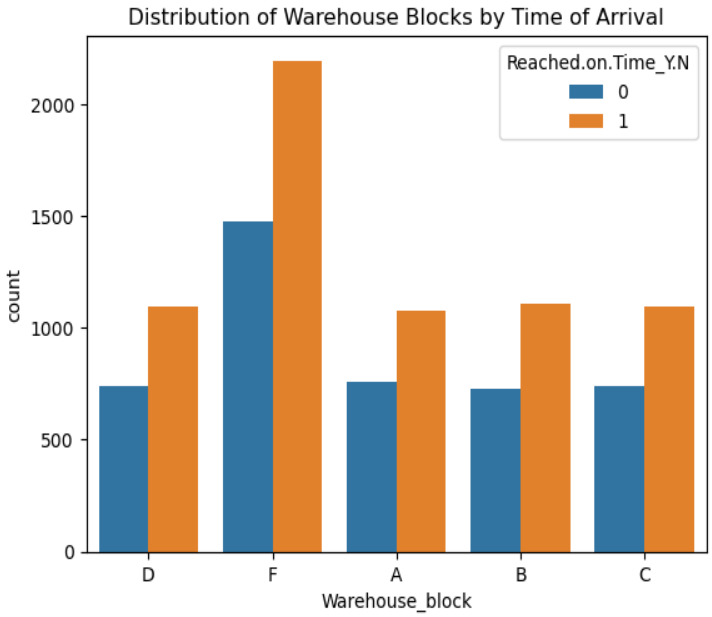

Figure 9 *Distribution of products by warehouse block categorised by arrival time which 0 indicating on-time and 1 indicating delayed*

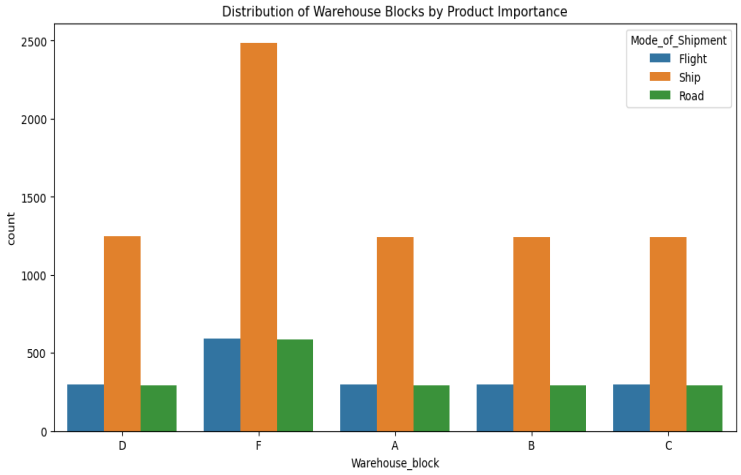

Figure 10 *Distribution of products across warehouse blocks, divided by mode of shipment*

Appendix

Data

The data source could be accessed at:
https://www.kaggle.com/datasets/prachi13/customer-analytics/data

One-way ANOVA
Hypothesis statement

$$H_0 = \mu_1 = \mu_2 = \mu_c$$

Degree of Freedom

- Between Groups = $C - 1 = 3 - 1 = 2$
- Within Groups = $n - c = 10999 - 3 = 10996$

Among Group Variation

- **SSA=**$\sum_{j=1}^{c} n_j(\hat{x}_j - \hat{x})^2$**=** 0.1789084957709865

Within Group Variation

- **SSW=**$\sum_{j=1}^{c}\sum_{l=1}^{n_j} n_j(x_{ij} - \hat{x})^2$=2646.740629643816

Test-Statistic

- $t(x)=\frac{\frac{SSA}{Degree\ of\ Freedom\ (SSA)}}{\frac{SSW}{Degree\ of\ Freedom\ (SSW)}} = 0.3176$

Upper Critical Value

- Upper Critical Value $= 3.690117256534697$
- Lower Critical Value $= 0.02531786627776257$

Bibliography

Heumann, C. and Shalabh, M.S., (2016) '*Introduction to statistics and data analysis*', Springer International Publishing Switzerland.

Kim, T.K., (2017) 'Understanding one-way ANOVA using conceptual figures.', *Korean journal of anesthesiology*, *70*(1), pp.22-26.

McKight, P.E. and Najab, J., (2010) 'Kruskal-wallis test.', *The corsini encyclopedia of psychology*, pp.1-1. Available at: https://doi.org/10.1002/9780470479216.corpsy0491.

Nie, X. (2022) 'Cross-border E-Commerce Logistics Transportation Alternative Selection: A multiattribute decision-making approach', *Mathematical Problems in Engineering*, 2022, pp. 1–7. doi:10.1155/2022/4990415.

Sahoo, R., Pasayat, A.K., Bhowmick, B., Fernandes, K. and Tiwari, M.K. (2021) 'A hybrid ensemble learning-based prediction model to minimise delay in air cargo transport using bagging and stacking', *International Journal of* Production *Research*, 60(2), pp. 644–660. Available at: https://doi.org/10.1080/00207543.2021.2013563

Taylor, R., (1990) 'Interpretation of the correlation coefficient: a basic review.', *Journal of diagnostic medical sonography*, *6*(1), pp.35-39. Available at: https://doi.org/10.1177/875647939000600106

Wahyudi, T. and Arroufu, D.S., (2022) 'Implementation of Data Mining Prediction Delivery Time Using Linear Regression Algorithm.', *Journal of Applied Engineering and Technological Science (JAETS)*, 4(1), pp.84-92. Available at: https://doi.org/10.37385/jaets.v4i1.918