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A study on Parametric and Non-Parametric Statistical Tools

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Abstract

This research report provides a brief overview of the most recent research techniques. The field of the research process has seen a resurgence of attention due to recent advancements in academia. Professors, Ph.D. candidates, researchers, investigative officers, and university students comprise the demographic of this research article. The article will become an essential part of your research papers, projects, and reports for citations due to future obligations. This study is distinct due to the researchers' discussion of all relevant software, almost all parametric and non-parametric tests, and statistical tools, such as central tendency, mean, median, variance, standard deviation, standard error, validity & reliability, co-efficient of variation, type I, II & III errors, skewness, kurtosis, and histogram. The statistical data analysis procedure, data cleansing, data mining, and data analysis and data gathering methods for mixed-method, qualitative, and quantitative research have also been discussed with the researchers. The foundation of each study is the proper application of research tools and techniques. Any study project starts with a statistical technique, and when these techniques are applied correctly, the results will be reliable and valuable for the world to consider. Researchers' lack of familiarity with the use of parametric and non-parametric techniques has been noted in a number of publications. The purpose of conducting this study is to ease the confusion or lack of knowledge among the researchers in application of various parametric and non-parametric technique. This paper is an attempt to simplify the statistical decision for future research scholar. This study is useful as it converts the complex theoretical concepts of parametric and non-parametric techniques into simplified summarized content. This will eventually lead to the research fraternity fostering effective solutions to the social issues. When data does not meet the assumptions needed for parametric testing, non-parametric statistical tools are crucial methods. These tools are applicable to nominal and ordinal data, and even to interval or ratio data when normality and homoscedasticity assumptions are violated. This chapter provides a comprehensive understanding of widely used non-parametric methods, their applications, assumptions, advantages, limitations, and interpretation. It is a useful manual for researchers in all fields. Before exploring specific tools and their applications, it is important to understand the foundation of non-parametric statistics within research methodology. Unlike parametric techniques, which rely heavily on assumptions such as normality of data distribution and homogeneity of variance, non-parametric methods are flexible and applicable to real-life business and social data, which may not always meet such ideal conditions. These tests are widely used in management and behavioural research because they efficiently analyse ranked, ordinal, or categorical data derived from surveys, field studies, and qualitative assessments.

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INTRODUCTION

IBM's statistical software for managing research data, multivariate analysis, and other purposes is called the Statistical Package for the Social

Sciences (SPSS). IBM SPSS Statistics is the most recent version. Originally created in 1968, SPSS was purchased by IBM and is currently only offered as a one-year trial, can be bought on a monthly or yearly basis. It is a popular software for social science statistical analysis. Software for data entry, analysis, tables, and graphs that runs on Windows is called SPSS. It can effectively handle massive amounts of data and carry out a variety of studies. For statistical analysis, SPSS is written in Java [1]. It is used by various industries such as market observation, healthcare, surveys, government, emergency preparedness, education, sports, advertising, weather forecasting, and data mining. All SPSS features can be accessed through menus or programming. According to experts, statistics in media research plays a vital role in collecting, explaining, presenting, interpreting, and analyzing data for results. Software like SPSS simplifies programming by placing constraints on file structure, data processing, types, and matching files. The table structure of SPSS datasets is two-dimensional. Cases are represented by rows, and metrics like age, sex, and wealth are represented by columns. Only text and numeric data types are defined by SPSS program. Case-by-case, sequential processing takes place. One-to-one or one-to-many file matching is possible, but many-to-many matching is not [2].

SPSS software widely used globally, especially in UK, USA, Canada, Netherlands, Fiji, Sweden, Australia, and Lebanon. In India, ‘Prof. Prasanta Chandra Mahalanobis’ known as ‘Father of Statistics’ and ‘Florence Nightingale’ as mother of statistics. SPSS has simple interface, perfect for data analysis. It allows data to be processed in various formats like XLSX and CSV for easy importing into data sets. Useful for exporting charts, tables, and graphs from SPSS to other programs. Offers data analysis for group identification, numerical outcome prediction, and descriptive and bivariate statistics. Can display open data in SPSS’s main view. SPSS has limitations in analyzing very large amounts of data. For large medical data sets, 'SAS' or 'R' software can analyze clinical data. Basic tests like T-test, F-test, Chi-square test, ANOVA test, regression analysis, and correlation coefficient analysis of variance can be used for comparison and data analysis. This software integrates many tools for data mining, surveys, and market research. Excel is a spreadsheet program, but SPSS is a robust statistical analysis program. Whereas Excel necessitates more effort, SPSS provides built-in data manipulation tools such as recording and manipulating variables. Data must be coded and entered into "variable view" prior to analysis. Missing values are defined by users as particular numerical values. Recent developments in academia have led to a renewed interest in the study of the research process. This research report's demographic consists of professors, Ph.D. holders, researchers, investigative officers, and college students. Future requirements will require the document to be cited in your research articles, theses, projects, and reports. The researchers covered almost every kind of parametric, including central tendency, mean, median, mode, variance, standard deviation, standard error, validity & reliability, and coefficient of variation [3]. The normal probability curve, parametric and non-parametric (paired and unpaired) tests, data mining, data cleaning, and data collection and analysis methods for mixed-method, qualitative, and quantitative research have also been covered by the scholars. Non-parametric statistical approaches emerged as vital analytical tools in situations where the assumptions of parametric tests cannot be fulfilled. These methods are frequently employed in behavioral and management research, where data frequently come from ordinal scales that don't follow a normal distribution, like Likert evaluations or ranks. Non-parametric statistics, also known as distribution-free statistics, are statistical methods that do not assume anything about the probability distribution of the population. When the sample size is small, these strategies are appropriate. The data are skewed or ordinal in nature. It is unknown what the underlying population distribution is. Data violate the assumptions of parametric tests.

RESEARCH SCALES

Date types: metric and non-metric. Metric data classified into intervals and ratios based on level of measurements. Non-metric data classified into nominal and ordinal variables. In SPSS software, two types of variables used: categorical and numerical. Numerical data can be discrete or continuous. Only quantitative data used for quality and quantity. Qualitative data used to explain qualities, words, meanings, ideas, thoughts, features, and characteristics of the data. This is not possible in SPSS. And in

SPSS, statistical analysis tools are specific for data collection, presentation, analysis, interpretation, and organization. Tools include mean, mode, median, range, standard deviation, dispersion, correlation coefficient, variation, and interquartile range. Mode has types like Unimodal, Bimodal, Trimodal, Multimodal, and mean.

To sum up, SPSS is versatile data-analysis software with various statistical tools. Anyone can learn descriptive analysis, data preprocessing, cleaning, visualization, and modeling. SPSS interface is easier than SAS. SPSS data files contain normal data and meta-data, while Excel includes non-data entries. Market research, government, healthcare, and education all frequently use SPSS. In SPSS, tools for data collection, presentation, analysis, interpretation, and organization are available. Tools include mean, mode, median, range, standard deviation, and correlation [5]. The software supports numerous analytic methods like descriptive statistics, inferential statistics, and tests such as T-test and ANOVA (Figure 1).

"R" is a statistical computing environment and language. R Foundation for Statistical Computing: R is a popular programming language used for statistical applications, data management, and visualizations (Figure 2).

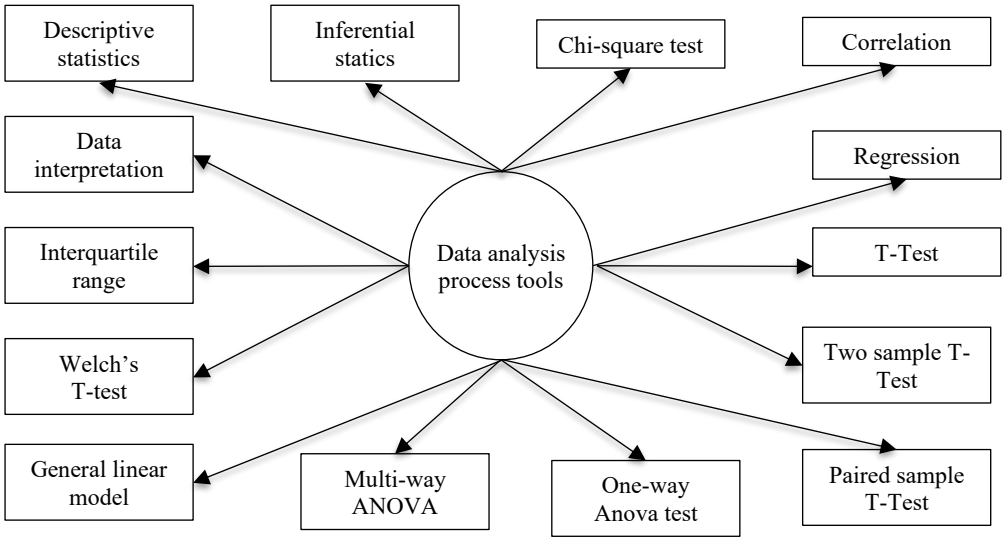

Figure 1. The statistical package for the social sciences software analyzes data using several tests [4].

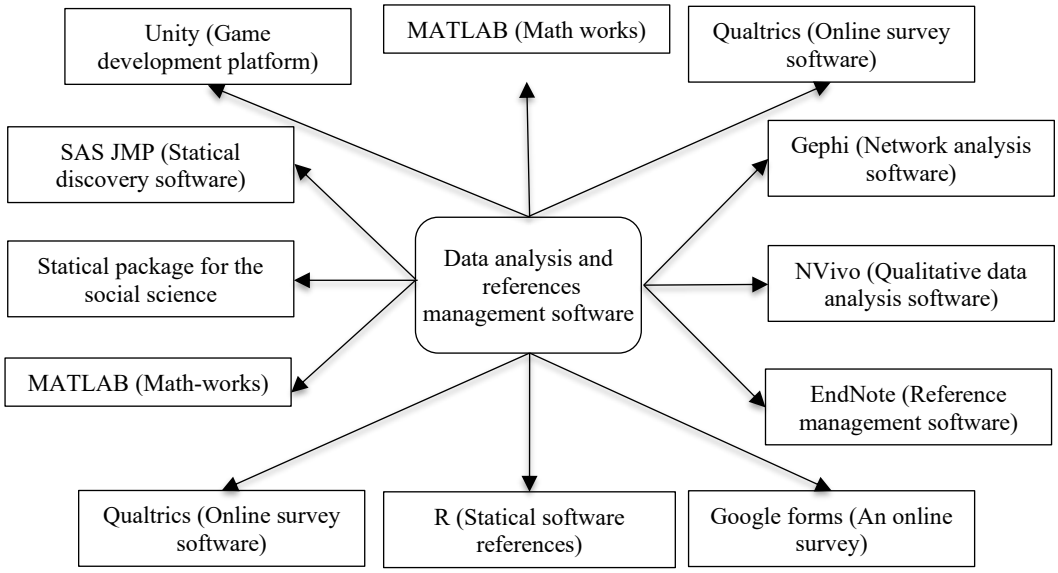

Figure 2. Used of data analysis and references management software [6].

Market research, customer experience, and more are powered by Qualtrics' survey platform, which grows with its goals. Gephi is an open-source, free program for network exploration and manipulation. Gephi is a Java program for network analysis and visualization. Heymann, S., Jacomy, and Bastian, M. are some of these programs. A commercial program called EndNote is used to organize references and bibliographies. When composing essays, papers, and articles, it facilitates the formatting of citations. Google offers an online survey tool called Google Forms for gathering research data. It can generate Google Drive quizzes and survey forms. "Global Organization of Oriented Group Languages of Earth" is the full name of Google. In 1998, while attending Stanford University, Larry Page and Sergey Brin started Google. Google Forms offers unlimited forms, questions, submissions, and collaboration. For free Survey Monkey, use Google account. Online survey is cheapest method for data collection. Formplus and Online Survey Builder increase responses. Popular online surveys: paper forms, mobile offline forms, SMS-based forms. Unity, a cross-platform game engine by Unity Technologies, was first announced in June 2005 at Apple worldwide development conferences as a Mac OS X game engine. It provides a system for designing games or app scenes in 2D, 2.5D, and 3D. SAS, also known as “John’s Macintosh Project”, was first released in 1989. In the early days, the project was used by scientists and engineers for experiments, quality support, and reliability modeling. JMP is like SAS, a smaller spreadsheet software for interactive use. One prominent use of JMP is designing and analyzing experiments. These methods are useful in situations where measurement is imprecise or based on subjective judgment, such as employee performance ratings, consumer satisfaction surveys, or customer preference rankings [7]. Do not require data to follow a normal distribution. Can be applied to ranked or categorical data. More robust to outliers and non-homogeneous variances. Useful for small sample sizes. Non-parametric tests offer flexibility and require fewer assumptions than parametric tests. However, they may be less statistically powerful when compared to parametric methods applied to normally distributed interval data. Simple computation and interpretation. Can handle outliers effectively. Less efficient and powerful.

Provide less detailed information. Some tests may be conservative.

RESEARCH TOOLS

Research tools include various instruments and resources used in the research process. Here is a diverse list of tools and software covering different research aspects.

Software for analyzing qualitative data is called NVivo. Mendeley is an academic social network and reference management. Zotero is an open-source, free reference management program. Software for managing references is called EndNote. Software for online opinion surveys is called Qualtrics. GitHub is used for collaboration and version control [9]. Atlas.ti is for qualitative data analysis. SAS JMP is for statistical analysis and visualization. Tableau is for creating interactive visualizations. Overleaf is for writing research papers. Trello is for organizing tasks and projects. Screencast is for creating video presentations. Grammarly is for grammar, format, and style checking. Toggle is for monitoring work activities (Figure 3).

VARIOUS PARAMETRIC STATISTICAL TOOLS

One-Sample t-Test

Examine the effects of variations between the sample and population means. Think about how sample size affects the sample mean's reliability.Examine how variance affects the population. To get the range of the population mean based on the sample mean, use confidence intervals.To ascertain if the observed differences are statistically significant, use hypothesis testing. Examine real-world scenarios in which comparing these means is crucial for decision-making [10]. Investigate the assumptions. underlying the sampling methods applied to minimize bias in comparison

- *Equation:*

$$t=\frac{\bar{x}-\mu}{s/\sqrt{n}} \quad (1)$$

- *Example:* Compare average IQ score of students to national average
- *Software implementation:* R, Python, SPSS paths

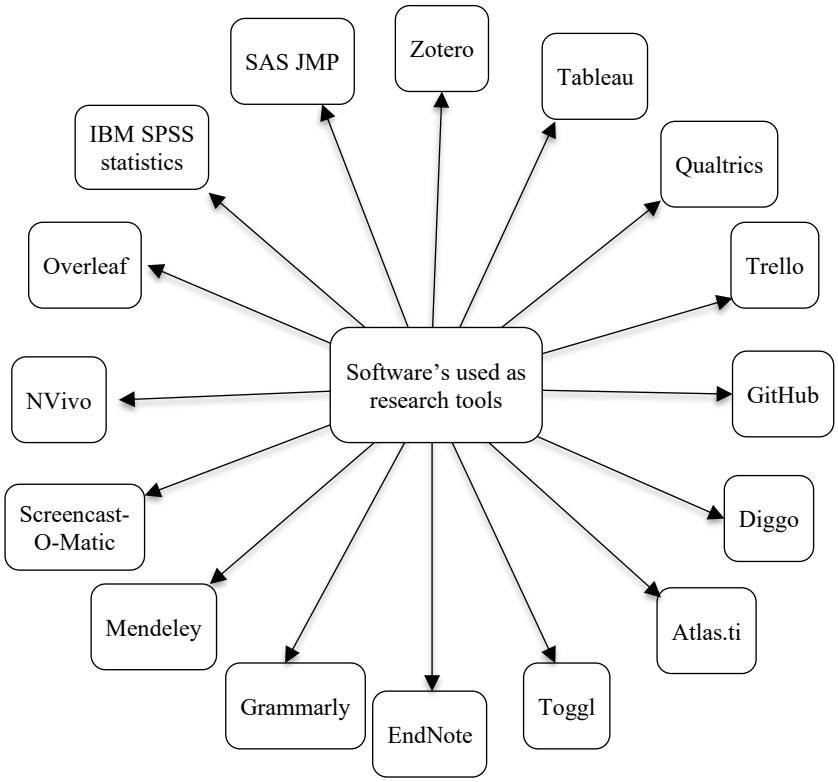

Figure 3. Software's used as research tools [8].

Independent Two-Sample t-Test

- *Purpose:* Compare means of two independent groups
- *Methodology:* Use statistical tests such as t-tests or Mann-Whitney U tests based on the data distribution. Ensure random sampling to maintain independence between groups
- *Assumptions:* Verify that the groups are normally distributed if using parametric tests. Check for homogeneity of variance when considering equal variances can improve validity.
- *Interpretation:* Analyze p-values to determine statistical significance. Report confidence intervals to provide a range of values for the difference in means.
- *Applications:* Utilize findings in fields such as psychology, medicine, and social sciences for informed decision-making [11]. Extend analysis to explore interactions or covariates among variables for a deeper understanding of relations.
- *Equation:*

$$t = \frac{\bar{x_1} - \bar{x_2}}{\sqrt{s_p^2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} \quad (2)$$

- *Example:* Male vs female performance comparison
- *Graphical representation:* Boxplot of two groups

Paired-Sample t-Test

- *Purpose:* Compare same group before–after or matched pairs
- *Methods:* Utilize statistical techniques for accurate analysis. Employ t-tests to assess differences between paired observations. Consider effect sizes to determine the magnitude of changes.
- *Applications:* Investigate the impact of interventions. Analyze pre–post data in clinical trials to evaluate treatment effectiveness. Use matched pairs in educational research to assess teaching methods.

- *Considerations:* Ensure validity in comparisons. Control for confounding variables that may affect outcomes. Ensure that the sample size is sufficient for reliable results [12].

- *Equation:*

$$t = \frac{\bar{d}}{s_d/\sqrt{n}} \tag{3}$$

- *Example:*
- *Output interpretation:* Mean difference and significance

F-Test (for Variance Equality)

When comparing the variances of two populations, the F-Test can be used to ascertain whether the variability in one group differs significantly from that of the other.

Testing the null hypothesis that the variances from two populations are equal is the primary goal of the F-Test for variance equality. This is crucial in assessing whether different methods, treatments, or conditions produce results with similar variability.

Equation: The equation for the F-Test when comparing variances of two samples is:

$$F = \frac{s_1^2}{s_2^2} \tag{4}$$

This F-value is then compared against a critical value from the F-distribution table (determined by the degrees of freedom of each sample and the chosen significance level) to decide if the difference in variances is statistically significant. If FFF is greater than the critical value, you can conclude that the variability in test scores differs significantly between the two teaching methods. If not, their variances are considered statistically equal [13].

Use Case Explanation

The F-Test can be applied when analyzing whether alternative teaching methods produce similar consistency in student performance an important aspect in education research, quality control, and experimental design. This process ensures that conclusions drawn about the effectiveness or reliability of a new method account for both differences in averages and differences in variability.

One-Way ANOVA

When there is only one independent variable involved, One Way ANOVA is a statistical test used to ascertain if the means of three or more independent groups differ significantly from one another. Testing the null hypothesis—that all group means are equal—against the alternative—that at least one group mean is different—is the primary objective of a One Way ANOVA. When comparing the impacts of several treatments, instructional strategies, or categories on a single continuous result, this is especially helpful [14].

- *Equation:*

$$F = \frac{\mathrm{MS_{Betwee}}}{\mathrm{MS_{Within}}} \tag{5}$$

- *Example:* Students' performance using three different teaching approaches Tukey's test for post-hoc analysis.

Two-Way ANOVA Technique

A statistical technique for figuring out how two independent variables affect a dependent variable is called two-way ANOVA. It analyzes if there is an interaction effect between the independent variables

as well as the individual impact of each one. This method allows a more thorough understanding of how independent variables interact to affect results in experiments when factors are tested concurrently. It investigates if the level of one independent variable affects the effect of another independent variable. It assesses each independent variable's primary effect on the dependent variable, enabling researchers to comprehend how each component affects the outcomes on its own [15]. All things considered, two-way ANOVA is a potent analytical method that is frequently used to investigate intricate interactions between variables in a variety of disciplines, including psychology, agriculture, and biology.

DECISION FRAMEWORK FOR CHOOSING THE RIGHT TEST

Step-by-Step Process:

Define hypothesis: A hypothesis is a specific, testable statement or prediction about the relationship between two or more variables. It serves as a tentative explanation that researchers evaluate through data collection and analysis.

1. Identify data type
2. Check assumptions
3. Apply appropriate test
4. Interpret p-value and effect size

Application Examples (Case Studies)

- *Case 1:* Comparing mean blood pressure of two treatments (Independent t-test)
- *Case 2:* Comparing average satisfaction across three branches (One-way ANOVA)
- *Case 3:* Relationship between study hours and exam scores (Correlation & Regression) Each case includes:
- Hypothesis
- Formula & Computation
- Graphical Output
- Interpretation of results

R Language Commands

- t-test, ANOVA, correlation, regression examples
- Output interpretation

Python (SciPy, Statsmodels)

- Code snippets for each test
- Example outputs

Output Interpretation

The results generated from the Toolpak will be presented in a new worksheet or in the same one based on your selection, where you can further analyze or visualize the data. Utilizing the Excel Toolpak greatly enhances your data analysis capabilities, making it invaluable for both beginners and advanced users in handling statistical tasks [16].

Maximum Likelihood Estimation (MLE)

- Concept of likelihood function
- *Equation:*

$$\hat{\theta}=\text{argmax}_{\theta} L(\theta) \tag{5}$$

- *Example:* Normal distribution parameter estimation

Method of Moments

- Derivation of parameter estimates using sample moments

Strengths and Limitations of Parametric Tests

Assume a specific distribution (usually normal), allowing for powerful statistical inference. Capable of providing more precise estimates for population parameters with larger sample sizes. Generally require fewer data points to achieve reliable results, making them useful in experiments with limited data availability. If the underlying data is not regularly distributed, distributional assumptions may produce unreliable conclusions.

Sensitivity to outliers, which can skew results and affect the validity of conclusions. Requires interval or ratio scales, limiting applicability to categorical data unless further transformed. Non-parametric tests can be used with ordinal data and are less dependent on distributional assumptions. bootstrap techniques that do not rely on parametric assumptions by resampling data to estimate the sampling distribution.Bayesian techniques can offer more adaptable modeling approaches to uncertainty since they take prior knowledge into account.

Communication Models

In our minds, models are conceptual frameworks that depict the outside world. They use pictures and diagrams to make ideas easier to understand. Models aid in understanding processes and drawing conclusions easily. Communication models help identify elements and understand communication relationships during research. These models represent new ideas on communication, helping us plan an effective system. Every model has five elements: sender, receiver, message, contextual factors, medium, and feedback [17]. Understanding these elements is crucial. A model works as transmission, describing communication as one-way or two-way process. Sender sends message via channel to receiver, who receives it mentioned Table 1.

Sample Commands Comparison with different parameters. Here is an important thing, which is transmission of the model that may face disruptions by noise or environmental issues. Communication model advantages include providing natural understanding of system or structure process of research, identifying whole components and complete relationship of communication process being studied overview of Statistical Tools mentioned Table 2.

Models visualize relationships in complex structures for discussion and analysis. They clarify events, frame scientific inquiry, and predict real-world outcomes. Aristotle, Lasswell, Shannon-Weaver, and David Berlo's models are included in communication models. Interactive models mediate internet-based communication with two-way customer feedback (Figure 4).

Table 1. Overview of Statistical Tools [19]

Tool	Function	Interface	Typical Use Case
SPSS	t-test, ANOVA, Regression	GUI	Social sciences
R	All tests & modeling	Command line	Academic & data science
Python	Parametric & ML integration	Code	Automation, visualization
SAS	Advanced modeling	Script + GUI	Industrial analytics
Minitab	Process analysis	GUI	Quality control
Jamovi / JASP	t-test, ANOVA, regression	GUI	Education, open-source
Excel	Basic analysis	GUI	Simple research projects

Table 2. Sample Commands Comparison with different parameters [20].

Test	R	Python	SPSS Path
t-test	t.test	stats.ttest_ind	Analyze → Compare Means
ANOVA	aov	stats.f_oneway	Analyze → One-Way ANOVA
Correlation	cor.test	pearsonr	Analyze → Correlate
Regression	lm	OLS	Analyze → Regression

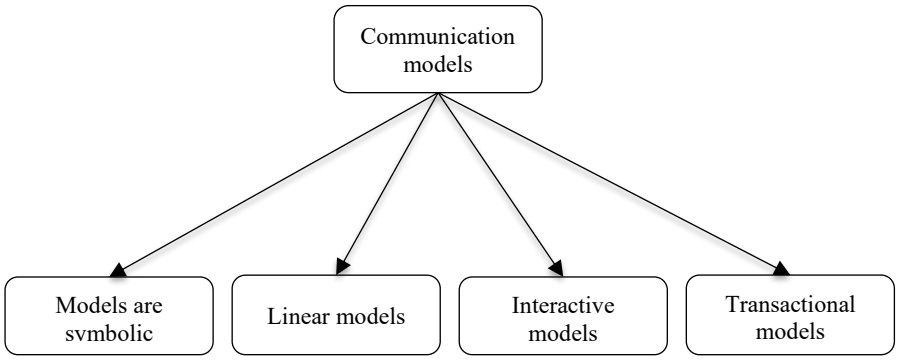

Figure 4. Type of Communication Model [18].

TECHNICAL TOOLS AND SOFTWARE FOR PARAMETRIC ANALYSIS

Table 1 shows the Overview of Statistical Tools

Comparative Advantages

- R and Python for automation
- SPSS for interpretability
- Minitab for industrial applications

Diagnostic & Visualization Tools

- Normality plots
- Residual plots
- Scatter diagrams
- Confidence intervals visualization

Best Practices and Ethical Use

- Verify assumptions before interpreting results
- Report effect sizes, not only significance
- Avoid overgeneralization
- Ensure reproducibility (share code/data if possible)
- Use open-source tools responsibly

Emerging Trends and Applications

- Integration with Machine Learning (parametric classifiers)
- Use in Health Sciences (clinical trials)
- Engineering & Quality Control (process optimization)
- Behavioral and Educational Research (experimental designs)

Parametric tools are utilized across a wide array of research and professional fields that require complex modeling, simulation, and optimization based on variable parameters and established rules.

THEORY

Another important document presents almost 100 communication theories and 12 models, titled “Hundred Theories and Models of Mass Communication," available at Google Scholar and "www.amazon.com." A theory is needed to understand the world.

Theory is rational thinking about a phenomenon or its results [21]. The word theory means neutral thinking about something. Theory supports studies logically, while research provides empirical support. Theories can be scientific, non-scientific, or discipline-free. Theoretical frameworks involve conceptualization, testing, and analysis. Theories should be testable, falsifiable, stable, and replicable.

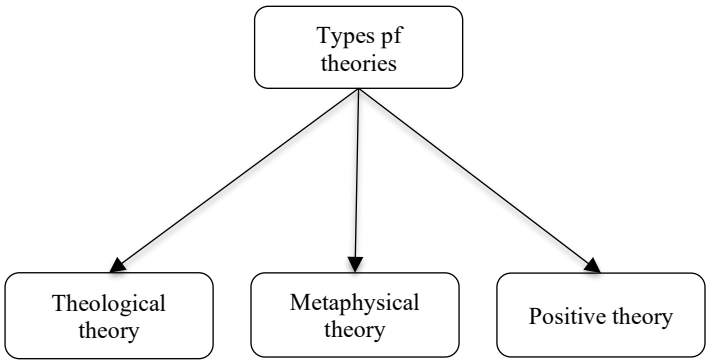

Figure 5. Types of theories [22].

Types of Theory

AAs a structure development, a theory has three stages: theological, metaphysical, and positive. Types of theories include normative, social scientific, working, and common sense. The theory helps researchers predict observations. Theorists say scientific theory develops through scientific method, observation, research, and hypothesis testing (Figure 5).

The Major Role of Theories in Academic Research

Most recent studies explain the major role of theories in academic research for prediction and understanding of phenomena. Theories challenge existing knowledge within critical assumptions, explain theoretical framework, and support research study theory. Theories explain phenomena, draw connections, predict future research based on new ideas, observations, and existing knowledge [23]. Main role of theory is to explain results, predict future outcomes, guide future research, and avoid becoming facts.

A Relationship between the Theory, Hypothesis, and Research Question

There is a close relationship between theory, research problem, research question, hypothesis, objectives, literature review, and research methodology. A theory expands existing knowledge to create new knowledge, while a hypothesis is an assumption written by the researcher before starting the research work. A theory explains things shown in collected data.

Conceptualization of Theory

The theory is an abstraction of social reality, not a collection of notions for understanding behavior, but an abstract concept. Everyone develops common-sense beliefs to make sense of their existence. Communication researchers apply academic backgrounds to make sense of communication. We will study the nature of theory by exploring theory in academic circles and the foundation for theory production and application. Theory must "look beyond" social facts.

STATISTICAL TOOLS

Variance and Standard Deviation

Studies show that variance, which stands for difference, is used to calculate the average squared deviation from the mean during data analysis; the square root of this figure is called the standard deviation. The standard deviation is reported in the same units as the original values, but both measurements show data variability [24]. The standard deviation is the square root of the variance, which is the average of squared deviations from the mean. Due to squaring, the variance is no longer in the same unit of measurement as the original data, resulting in a standard deviation of roughly 3.03. A square root is a factor of a number that yields the original number when multiplied by itself. For example, +3 and -3 square roots are 9, and 25 square root is 5 since 5 multiplied by 5 equals 25. Squared deviation measures the difference between two variables. MSD between variables X and Y is Σ (X−Y)2/N, where N is the number of observations. Deviation from a norm or standard is called a deviation. It is common in mathematics, science, and nature, playing a role in evolution.

Measure of Central Tendency

A measure of central tendency is a singular value employed to encapsulate the central characteristic of a dataset, and it encompasses three principal forms: the mean, median, and mode.

Mean, Median and Mode

In statistical data analysis, 'mean' is the average calculated for quantitative data. Continuous Variable has infinite values. Sample mean gives average of data set. Mode is most repeated value in data after arranging in order. The most repeated value in data is the mode. If all values appear with the same frequency, there is no mode. Mode can relate to non-numerical data like colors, flavors, or size [25]. Data sets can have single or multiple modes: Unimodal, Bimodal, Trimodal, and Multimodal. Unimodal means a single line in the curve or only one value is repeating; Bimodal means two equal lines in the curve or twice as many values are repeating; Trimodal means three equal lines in the curve or three values are repeating. The median is a middle value in your data ordered from smallest to largest; for example, 50% of data points are above and 50% are below. Previous studies found mean and median used in quantitative data, mode in qualitative and quantitative data. Mean only for interval and ratio level due to equal spacing requirement [26]. The median is used for ordered data like ordinal, interval, and ratio levels. The mode is used for any level, but it's most meaningful for nominal and ordinal levels. Mean, median, and mode values always stay the same and are at the central point on the curve.

Standard Deviation and Standard Error

Standard error measures how accurately a sample represents a population, indicating the consistency and reliability of the sample mean. It helps construct confidence intervals and assess how close the sample mean is to the true population mean. A higher standard error means sample means are more spread out and less likely to represent the true population mean. Standard deviation measures variation within one dataset, while standard error measures variation among sample means. While standard deviation shows how data points spread from the mean, standard error shows how sample means spread from the overall mean—and it is always smaller than the standard deviation.

The standard error of the mean (SEM) is an inferential measure of uncertainty, while standard deviation (SD) is descriptive and shows data variability. A high standard error indicates greater prediction error and uncertainty in the model. Standard error is a key inferential statistic that shows the accuracy of a sample estimate. A zero standard error means no random error, while a larger one indicates less accuracy due to greater random variation. Previous studies note that sampling error differs from standard error: sampling error is obtained by multiplying the standard error by the Z-score for a confidence interval, while standard error is calculated by dividing the standard deviation by the square root of the sample size [27]. The standard error measures how far a sample mean is from the true population mean, often shown as a percentage. The standard error indicates how accurately the sample represents the population, whereas the margin of error indicates the extent of mistake based on sample data. The standard deviation is 3.03, the crucial Z-value for a 95% confidence range is -1.96, and the margin of error is 5% (0.05). Keep in mind that the standard error determines the confidence interval.

The symbol for standard deviation is “σ” (Sigma), representing the data’s spread from the mean within the range of -3σ to +3σ. A smaller σ means data are closely clustered around the mean, while a larger σ shows greater dispersion. An ‘asymptotic’ curve means both sides approach but never meet, while the ‘point of inflection’ marks where the curve changes direction around ±1σ above and below the mean. Studies report that variance is the average of squared distances from the mean, with higher variance indicating data points are more widely spread. Studies show that low variation is ideal, indicating more reliable predictions from sample data, while high variation reduces consistency. When observations differ, the standard deviation—the positive square root of the mean squared departures from the mean—is always positive. If all observations are equal, the standard deviation is zero; otherwise, it is always positive. Standard error measures the expected discrepancy of a sample mean from the true population value, with smaller values being better and zero indicating an exact estimate.

The coefficient of variation and Concept of Residual

The ratio of the standard deviation to the mean is called a coefficient of variation (CV). A higher CV indicates more dispersion, while a lower CV shows greater precision, usually expressed as a percentage. A CV of 5% or less is generally considered good, while 10% or higher is considered poor. However, the mean should be considered, as low concentrations can yield high CVs and high concentrations can yield low CVs. The remaining sum, balance, or difference is represented by a residual (e). In regression analysis, it is the difference between the dependent variable's observed value (y) and its projected value (ŷ), which is computed as e = y - ŷ.. Every data point has a single residual, and the mean and total of all residuals are always equal to zero.

Validity and Reliability Tests

Validity measures how accurately a method assesses what it is intended to. High validity means results reflect real-world properties, while reliability indicates the consistency of a valid measurement. In short, both validity and reliability evaluate research quality. Reliability means results can be consistently reproduced, while validity ensures the measurement reflects the intended concept. Validity focuses on accuracy, and reliability on consistency. Validity measures how well a scale assesses what it is intended to, while reliability refers to its consistency across occasions. Reliability can be assessed through stability, internal consistency, and equivalence [28]. Establishing validity and reliability ensures data are replicable and results accurate, maintaining measurement integrity. Validity can be improved by controlling variables, refining measurement techniques, increasing randomization, using blinding, and including control or placebo groups. There are four main types of reliability, estimated by comparing results from the same method.

Reliability Test

A reliability test measures the consistency of a test whether a person gets similar scores on repeated attempts. It is commonly assessed in three ways: test-retest reliability (over time), internal consistency (across items), and inter-rater reliability (across researchers). In research, checking data reliability is crucial. Researchers can ensure reliability in content analysis using the test-retest method, repeating the test on the same sample and comparing results consistent results indicate good reliability. In SPSS, go to Analyze → Scale → Reliability Analysis, move the required variables into the items box, select the desired options, and click OK. The results will appear in the output window (Figure 6).

DATA ANALYSIS METHODS

Data analysis involves six steps: ask, prepare, process, analyze, act, and share (Figure 7).

Following steps are used to analyze the data properly (Figure 8):

Prescriptive Analytics

Prescriptive analytics recommends the best decisions to capitalize on future opportunities and manage risks, using advanced tools to analyze data and show the implications of each option. Simply put, prescriptive analytics answers “What should we do in the future?” by predicting likely outcomes and recommending actions to influence them [32].

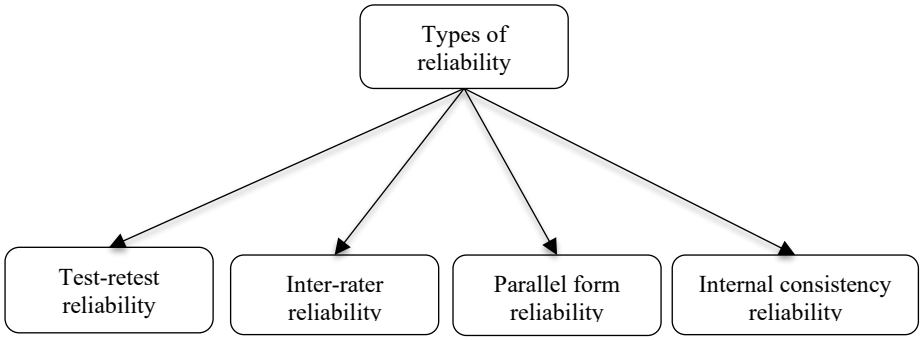

Figure 6. Various types of reliability [29].

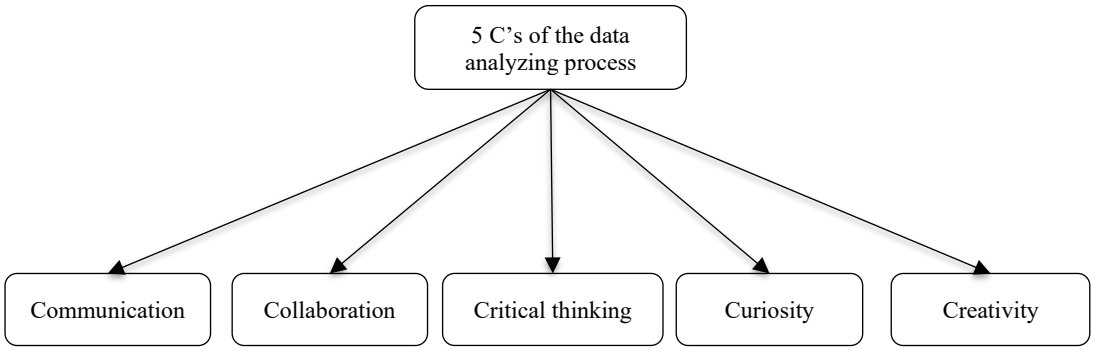

Figure 7. 5 C's of the data analyzing process [30].

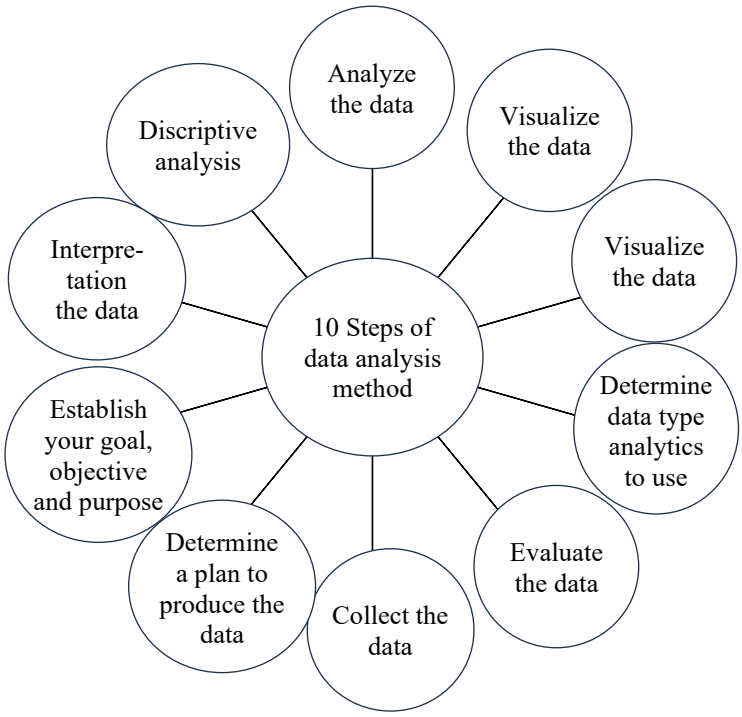

Figure 8. 10 steps of data analysis method [31]

Data collection Instrument

Data-collection instruments are tools used to gather research data, such as tests, questionnaires, interviews, rating scales, checklists, or surveys from at least 10 respondents. Instruments collect data for storage, analysis, or monitoring, while tools measure, manipulate, or process the data. Measurement tools help researchers and practitioners assess subjects, clients, or patients. They collect data on variables from physical functioning to psychosocial well-being and include tests, scales, surveys, questionnaires, checklists, and mechanical devices. In the course of a research study, the researcher employs a diverse range of data collection tools and sources to ensure comprehensive and reliable findings. While interviews provide in-depth investigation of participants' experiences and perspectives, questionnaires are used to effectively collect quantitative data from a large number of respondents. A case study provides contextual insights through a thorough analysis of a particular person, organization, or circumstance. Surveys are a methodical way to gather standardized data, which is frequently used to spot trends or patterns [33]. Through observations, researchers record behaviors and events as they occur naturally, ensuring authenticity. Focus group discussions encourage interactive dialogue among participants, yielding rich qualitative data and diverse perspectives. In addition to primary data, researchers rely on secondary data such as books, journal articles, dissertations, and databases, which provide established theories, prior research findings, and credible background information. Modern

research also utilizes technological tools such as cameras, audio/video recorders, and other mechanical devices to capture real-time data and ensure accuracy. Moreover, internet search engines and websites serve as vital resources for accessing up-to-date information, reports, and global perspectives. Collectively, these instruments and sources enable researchers to gather, analyze, and interpret data effectively, leading to valid and meaningful research outcomes. Five statistical tools are used in the data analysis process and are available below: As a statistical tool, ‘mean" is used for average, standard deviation, regression analysis, hypothesis testing, and sample size determination

PARAMETRIC TESTS & NON-PARAMETRIC TESTS

Statistical Tests

Different statistical tests have varying assumptions and produce different statistics. Researchers must choose a test that fits their data and the effect or relationship being studied, with the number of independent variables affecting the test statistic needed for the same p-value [34]. Studies show that in research, ‘tests’ refer to questionnaires or instruments assessing abilities, attitudes, aptitudes, performance, social phenomena, and physical or psychological states, distinct from medical laboratory tests. Studies indicate that statistical tests use standardized instruments like questionnaires, inventories, and scales to measure constructs in social sciences, mainly for data assessment, analysis, diagnosis, and research.

Usage of the Tests

Studies indicate that statistical tests use standardized instruments—like questionnaires, inventories, and scales—to measure constructs in social sciences, mainly for data assessment, analysis, diagnosis, and research. If groups come from one population, use a paired sample t-test; if from two populations, use a two-sample t-test. The choice depends on whether you are comparing one group or two. Use a two-tailed test to check if any difference exists between groups, and a left- or right-tailed test to see if one group’s mean is specifically greater or smaller than the other [35].

Selection of the Test

Using the wrong statistical test can lead to invalid or unreliable results. Although software like R, Stata, Minitab, and SPSS simplifies testing, selecting the correct test remains the researcher’s responsibility. Statistical test selection depends on three key factors: (1) number of variables, (2) data type or measurement level (continuous, binary, categorical), and (3) study design (paired or unpaired). Non-parametric tests handle skewed, non-normal data based on qualitative, nominal, or ordinal scales. They are less powerful and compare percentages or proportions with limited population information, such as the Chi-square and Kruskal tests.

Classification of Non-Parametric Tests [36]

Non-parametric tests may be classified based on:
Type of data: Nominal or Ordinal.
Number of samples: One-sample, Two-sample, or K-sample.
Independence or dependence of samples.
Categories:
Tests for One Sample
Tests for Two Independent Samples
Tests for Paired Samples
Tests for K Independent Samples
Tests for K Related Samples
Tests of Association

Commonly Used Non-Parametric Tests [37]

The major non-parametric statistical tools include:
Chi-Square Test

Sign Test
Wilcoxon Signed-Rank Test
Mann-Whitney U Test
Kruskal-Wallis H Test
Friedman Test
Kolmogorov-Smirnov Test
Spearman's Rank Correlation

Assumptions of Non-Parametric Tests [38]

Compared to parametric tests, non-parametric statistical techniques rely on fewer assumptions; yet, their application is still guided by a few fundamental assumptions:

- The data should at least be ordinal, if not interval or ratio.
- The observations should be independent, unless the test is designed for paired samples.
- The measurement scale should permit ranking or frequency analysis.
- In case of tests based on ranking, the distribution of rankings should reflect the underlying data behavior.
- Random sampling from the target population should ideally be ensured.
- In business and management research, these assumptions are particularly relevant where human behavior, preferences, and perceptions dominate data collection.
- Often such data are ordinal in nature and collected through Likert scales, rating techniques, ranking surveys, and attitude measurement instruments.
- This makes non-parametric tools practical and meaningful for management researchers.

Selection Criteria for Non-Parametric Tests [39]

Choosing an appropriate non-parametric statistical tool depends on several factors:

- Objective of the study: comparison, association, or goodness of fit
- Type of data: nominal or ordinal
- Number of samples: one sample, two samples, or k samples
- Independence of samples: related/paired or independent
- The selection framework is as follows:
- One sample tests: Kolmogorov-Smirnov One Sample Test, Chi-Square Goodness of Fit Test
- Two independent samples: Mann-Whitney U Test, Kolmogorov-Smirnov Two Sample Test
- Two related samples: Wilcoxon Signed Rank Test, Sign Test
- K independent samples: Kruskal-Wallis H Test
- K related samples: Friedman Two-Way ANOVA by Ranks
- Tests of independence/association: Chi-Square Test of Independence, Spearman Rank Correlation, Kendall's Tau

MAJOR NON-PARAMETRIC STATISTICAL TOOLS

This section provides detailed explanation of widely used non-parametric tools along with formulas, assumptions, and applications in business and management research.

Chi-Square (χ^2) Test [40]

One of the most popular non-parametric tests is the Chi-Square test. It is used to determine if an observed frequency distribution deviates from an expected distribution (Goodness of Fit assess) or to assess the relationship between categorical variables (Test of Independence).

Formula:

$$\chi^2 = \sum((Q_i - E_i)^2/E_i) \quad (7)$$

Where:
Q_i = Observed frequency
E_i = Expected frequency

Assumptions:

- Frequency-based data is required.
- Independent observations are necessary.
- Generally speaking, each cell's expected frequency should be five or higher.
- For instance, in the context of business research:
- A marketing researcher seeks to determine whether brand preference is gender-neutral. One hundred customers were surveyed as a sample. The association can be tested using the chi-square test.
- Decision Rule: Reject H_0 if the computed $\mathcal{X}^2$ value is greater than table $\mathcal{X}^2$ at (r-1)(c-1) degrees of freedom and the selected significance level (α).

Mann-Whitney U Test

A non-parametric substitute for the independent samples t-test is the Mann-Whitney U Test, sometimes referred to as the Wilcoxon Rank-Sum Test.When the dependent variable is ordinal or not normally distributed, it compares the differences between two independent groups. Two groups don't depend on one another [41]. The dependent variable is not normally distributed, but it is ordinal or continuous. A researcher want to compare the degree of job satisfaction among workers in the public and private sectors.A 5-point Likert scale is used to gauge satisfaction. The Mann-Whitney U test is suitable for comparing the groups because the data is ordinal.

Wilcoxon Signed Rank Test

The non-parametric counterpart of the paired samples t-test is the Wilcoxon Signed Rank Test. To determine whether the population mean ranks of paired or matched samples differ, it is utilized.The same participants provide the matched data. There are either continuous or ordinal differences between matched observations. Determine the difference between every pair. Sort the differences in absolute terms [42]. Using the original difference signals as a guide, apply signs to rankings. Before and after a motivating program, a training manager assesses how employee productivity scores have changed. The Wilcoxon Signed Rank Test is appropriate since the data are paired and could not have a normal distribution. Decision Rule: If computed W is less than critical W at selected α, reject H_0.

Sign Test

A straightforward non-parametric test for testing the median difference hypothesis using paired data is the Sign Test. It simply considers the direction of differences rather than their amount. Determine how many indicators from paired differences are positive and negative [43]. For analysis, use the binomial distribution. By analyzing sales data for ten stores before and after adoption, a researcher determines whether a new advertising technique boosts sales. The sign test can be used since the data might not be properly distributed. Decision Rule: If the quantity of positive or negative signals is substantially different from what would be predicted by chance, reject.

Kruskal–Wallis H Test

The Kruskal–Wallis H Test is a non-parametric alternative to one-way ANOVA. It is used when three or more independent groups need to be compared based on an ordinal or non-normally distributed continuous variable [44].

Assumptions:

The samples are independent.

The observations are at least ordinal.

The distributions of the populations have similar shapes.

Formula:

$H = (12 / (N(N+1))) * \Sigma(R_i^2 / n_i) - 3(N+1)$

Where:
N = total number of observations across all groups
R_i = sum of ranks for group i
n_i = sample size of group i

Example (Business Context):

A human resource manager wants to compare employee engagement scores across three departments: production, finance, and marketing. Since engagement scores are based on ordinal Likert-scale responses, the Kruskal–Wallis test is suitable.

Decision Rule:
Compare calculated H with critical chi-square value at (k – 1) degrees of freedom.

Friedman Test [45]
The Friedman Test is a non-parametric alternative to repeated measures ANOVA. It is used when the same subjects are measured under three or more different conditions.

Assumptions:
Data consist of repeated measures from the same individuals.
The dependent variable is ordinal.
Samples are related.

Formula:
$\chi^2_r = (12 / nk(k+1)) * \Sigma(R_i^2) - 3n(k+1)$

Where:
n = number of subjects
k = number of conditions
R_i = sum of ranks for each condition

Example:
A company introduces three incentive plans sequentially and evaluates sales performance. The Friedman Test determines if there is a significant difference between the plans.

Decision Rule: Reject H_0 if χ^2_r calculated > table value.

Spearman's Rank Correlation (ρ) [46]
Spearman's correlation measures the strength and direction of association between two ranked variables.

Formula:
$\rho = 1 - (6 \Sigma d_i^2) / (n(n^2 - 1))$

Where:
d_i = difference between paired ranks
n = number of paired observations

Example:
A study examines whether employee satisfaction ranks correlate with employee productivity ranks.

Kendall's Tau (τ) [47]
Kendall's Tau is used to measure ordinal association and is preferred when sample sizes are small.

Formula:
$\tau = (C - D) / (0.5\ n(n - 1))$

Where:
C = number of concordant pairs
D = number of discordant pairs

Example:
Used to measure agreement between two supervisors ranking the same employees.

Kolmogorov–Smirnov Test [48]
This test compares the distribution of a sample with a reference distribution or compares two sample distributions.

Test Statistic:
$D = \max |F_1(x) - F_2(x)|$

Example:
Used to test if customer waiting times follow a normal distribution.

Runs Test for Randomness [49]
This test evaluates whether data occur randomly over time.

Example:

Applied in stock market analysis to test if price changes are random.

APPLICATION OF NON-PARAMETRIC TESTS USING SOFTWARE TOOLS

With the advancement of statistical software, non-parametric tests have become easier to compute and interpret. Researchers in business and management frequently use software such as SPSS, Microsoft Excel, and R to perform non-parametric analysis efficiently.

Application Using Microsoft Excel [50]
Although Excel is not as advanced as SPSS for statistical analysis, non-parametric tests can still be performed using formulas and add-ins.

- *Chi-Square Test:* Use CHISQ.TEST function
- *Rank calculations:* Use RANK or RANK.AVG function
- *Mann-Whitney U Test:* Performed manually using ranks

Application Using R Software [51]
R is widely used in academic research due to its powerful statistical capabilities and open-source nature.

Example R Commands:
Mann-Whitney U Test:
wilcox.test (group1, group2)

Wilcoxon Signed Rank Test:
wilcox.test (before, after, paired = TRUE)

Kruskal–Wallis Test:
kruskal.test (values ~ groups)

Spearman Correlation:

cor.test (x, y, method = "spearman")

Table 3 illustrate the Worked Examples of Major Non-Parametric Tests and table 4 summarizes the purpose, data type, and application of major non-parametric tests used in business and management research.

Non-parametric statistical tools play a crucial role in research, particularly when the assumptions of parametric tests are violated or when the data are ordinal or nominal in nature [54]. These methods are widely used in business and management studies for hypothesis testing, group comparisons, and correlation analysis. They are flexible, robust, and suitable for real-world data, especially survey-based research and behavioral studies. Despite being less powerful than parametric tests, their importance lies in their ability to handle non-normal data without violating statistical assumptions.

Table 3. Worked Examples of Major Non-Parametric Tests [52]

S.N.	Techniques	Examples
1.	Chi-Square Test of Independence	A researcher wants to test whether customer satisfaction level is independent of service type (Online vs. In-store). A sample of 80 customers was collected. After preparing the contingency table and computing expected values, the chi-square value was calculated as $\chi^2 = 6.21$ with df = 1. Since χ^2 table value at $\alpha = 0.05$ is 3.84, χ^2 calculated > χ^2 table, hence H_0 is rejected. Conclusion: Satisfaction depends on service type.
2.	Mann–Whitney U Test	Two groups of employees from private ($n_1 = 6$) and public sector ($n_2 = 6$) firms were compared on job satisfaction scores. After ranking combined scores, U_1 was calculated as 8. Since U critical ($\alpha = 0.05$) = 5, and U calculated > U critical, there is no significant difference in satisfaction.
3.	Wilcoxon Signed Rank Test	Productivity scores before and after training for 8 employees were compared. After ranking absolute differences and summing positive ranks ($T+ = 29$) and negative ranks ($T- = 7$), W = 7. Since W < W critical (10), H_0 is rejected, indicating training improved productivity.
4.	Kruskal–Wallis	Test Employee engagement scores from three departments—HR, Production, and Marketing—were compared. After ranking all scores, H was calculated as 5.87. Since H critical = 5.99 at df = 2 and $\alpha = 0.05$, H < H critical, hence no significant departmental difference.
5.	Spearman Rank Correlation	Performance rank and motivation rank of 10 employees yielded $\rho = 0.82$. This indicates a strong positive relationship between motivation and performance.

Table 4. The following table summarizes the purpose, data type, and application of major non-parametric tests used in business and management research [53].

Test	Purpose	Data Type	Research Application
Chi-Square Test	Association between variables	Nominal	Customer preference vs. brand type
Mann–Whitney U Test	Difference between two groups	Ordinal	Job satisfaction public vs. private sector
Wilcoxon Signed Rank Test	Paired comparison	Ordinal	Before-after training performance
Sign Test	Paired comparison (median)	Ordinal	Effect of new policy on sales
Kruskal–Wallis Test	Compare 3+ groups	Ordinal	Departmental engagement comparison
Friedman Test	Related samples	Ordinal	Ranking incentives by effectiveness
Spearman Rank Correlation	Association measure	Ordinal	Motivation vs. performance
Kendall's Tau	Rank association	Ordinal	Agreement between raters
Runs Test	Randomness	Nominal	Stock price trend pattern
Kolmogorov–Smirnov Test	Distribution comparison	Continuous	Normality of sales data

CONCLUSION

The significance of the Application of Statistical Testing as a manual for fundamental parametric statistics in educational research is observe by the study's findings. The importance of statistical testing software in carrying out efficient research, choosing methodologies, reaching judgments, and assessing outcomes was underlined by respondents. With its ability to facilitate areas for improvement and enhancement of education, evaluate teaching techniques, track student achievement, optimize resource allocation, and assess policy impacts, statistics has become a vital instrument in education. Using the right statistical methods is crucial to carrying out successful social and behavioral research. The study also found that using the appropriate statistical test is crucial to drawing precise. Therefore, statistical analysis is essential to the effectiveness, efficiency, and flourishing of educational research in order to achieve the specified goals. The important need to make parametric and non-parametric statistical methods simpler for researchers to understand and use is successfully addressed in this study. By shedding light on the differences, assumptions, and appropriate uses of various tests, this study aims to improve the precision and reliability of research findings.

A deeper comprehension of these statistical methods can help researchers make better choices and conduct higher caliber research. In the end, this will contribute to the production of sound research that can direct business operations, legislative decisions, and societal developments; in other words, it will direct the researcher's fruitful approaches to social issues. Non-parametric statistical tools, which hold significant relevance in research situations where parametric test assumptions are not met. In fields such as management, behavioural sciences, economics and social research, the data collected is often ordinal in nature, skewed, or derived from small samples, making non-parametric approaches more appropriate and reliable. The chapter covered major non-parametric techniques including Chi-Square, Mann–Whitney U, Wilcoxon Signed Rank, Sign Test, Kruskal–Wallis, Friedman Test, Spearman Rank Correlation, Kendall's Tau, Kolmogorov–Smirnov and Runs Test. Each method was explained with assumptions, business applications and decision rules. The advantages of non-parametric tests such as flexibility, robustness and minimal assumptions make them valuable analytical tools. However, the limitations including lower statistical power compared to parametric tests must also be considered. Selection of the right test depends on research design, type of data, number of groups, and dependency of samples. With the increasing availability of statistical software like SPSS, Excel and R, application of these methods has become more accessible to researchers. Non-parametric tests are essential in empirical research and add analytical strength to studies dealing with real-world data complexities. Researchers must be familiar with these tools to ensure accurate statistical inference and meaningful interpretation of findings.

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