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A Comprehensive Review of Classical and Modern Statistical Methods in Research

Dr. Charudatta Dattatraya Bele[1*]

[1]*Associate Professor*

Abstract

Studies are significantly influenced by research methodologies. Quantitative research necessitates the utilisation of statistical methodologies. Advanced statistical analysis is essential to contemporary research in a number of fields, such as engineering, economics, social sciences, and healthcare. The literature on both traditional and contemporary statistical research methodologies is reviewed in this article. This review highlight that statistical methods remain foundational to research, evolving significantly with advancements in technology and data science. While classical techniques still hold value, the rise of big data, machine learning, Bayesian methods, and network analysis demands modern, adaptive approaches. The integration of statistical software such as SPSS, R, MATLAB, and Excel has revolutionized data analysis, making it more efficient and accessible. Researchers must carefully select software based on application needs to ensure accurate and meaningful results. As the digital age advances, understanding and applying both traditional and modern statistical methods is essential for reliable, insightful, and impactful research across disciplines.

Keywords: Research Methods, Social Science Research, Modern Statistical Methods, Digital Age, Artificial Intelligence, Traditional Statistical Methods.

1 Introduction

It is a phrase used in daily life to describe a variety of activities, such as gathering data, researching arcane ideas, and creating new inventions. In everyday speech, "research" may be used to describe occurrences that are often not true to its definition, and in certain delicate contexts, the word can be used

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to describe sensitive topics [1]. The term "research" often alludes to the pursuit of knowledge, but it may also mean a methodical and scientific search for relevant data on a certain subject [2]. A specific area or topic is the subject of scientific investigation, which is the art of research. A thorough investigation or inquiry, particularly through the pursuit of new facts in any field of knowledge, as defined by the Advanced Lerner's Dictionary of Current English. Some individuals believe that research is a kind of voyage that takes one from the known to the unknown; it may be thought of as the process of discovering new things. Being curious is the foundation of knowledge, and the method that humans use to learn about everything unfamiliar is called study [3]. Research is a scholarly endeavour that involves redefining and safeguarding issues, formulating hypotheses or offering solutions, gathering, organising, and evaluating data, drawing conclusions, and then carefully testing those conclusions to determine whether they can be turned into a hypothesis [4]. A distinctive contribution to the current state of information production is research, which is essential for its advancement. Contrast, experimentation, observation, and study are employed to ascertain the truth. In other words, the process of gathering data in order to solve a research issue via the use of objectives and a systematic approach. This systematic process of overview and theory formation is also research. Thus, the term "research" refers to the methodical process that includes stating the issue, developing a hypothesis, gathering information, evaluating that information, and drawing findings that either provide answers to the issue or take the shape of theoretical interpretations [5], [6].

A. Classical statistics

Under certain assumptions, there are many conventional statistical methods for measuring parameters. It is frequently assumed that these methods are precise; however, this is only accurate if the statistical model's assumptions are appropriate. A normal (Gaussian) or binomial model has often been assumed in traditional statistical models. Under some circumstances, often when the mean is far greater than the standard deviation, the normal distribution does, in fact, very nearly resemble a large number of distributions. For this reason, these traditional statistical methods have found extensive use [7], [8]. Nevertheless, it is imperative to exercise caution when employing them in situations where the assumption of normality is not strictly adhered to, as it is frequently challenging to identify the extent of inaccuracy that is introduced by such an approximation. Given that they begin with a set of presumptions selected by the analyst, it should be noted that even the most traditional statistical methods are subjective. A totally objective statistical analysis does not exist since all methods need some kind of probability model in order to function [9], [10].

B. Modern statistics method

Innovative techniques and instruments are constantly being introduced to modern statistics, which is a dynamic field. Here, we look at popular software programs, new data analysis methods, and industry trends. Recent developments in data science and statistics have produced techniques that tackle the complexity of contemporary data [11]. These include:

- **Machine Learning Integration:** combining machine learning methods with conventional statistical models.

- **Bayesian Networks:** Enabling the graphic representation of relationships among variables through a probabilistic approach.
- **High-Dimensional Data Analysis:** addressing issues in which there are much more characteristics than observations.

Once thought to be too complicated to analyse, these advancements enable analysts to extract valuable insights from data.

C. Types of statistical research methods

Finding patterns or trends in data samples via statistical analysis enables researchers to predict outcomes and draw relevant conclusions [12]. Statistical analysis fall into one of the following categories depending on the kind of data:

- **Descriptive Analysis:** Tables and graphs may be created by organising and summarising the vast amounts of data using descriptive statistical analysis. A number of procedures are used in descriptive analysis, including skewness assessments, measures of central tendency, measures of variance or dispersion, and tabulation.
- **Inferential Analysis:** The data obtained from a small sample size may be extrapolated to the whole population via inferential statistical analysis. Based on sample data, this analysis aids in inferences and decision-making for the whole population. For research initiatives that use a limited sample size and aim to extrapolate results for a broad population, this statistical approach is highly recommended.
- **Predictive Analysis:** Future events are predicted via predictive analysis. Financial enterprises, internet service providers, insurance companies, marketing firms, and data-driven marketing all use this study.
- **Prescriptive Analysis:** Data is examined using prescriptive analysis to determine the next course of action. To determine the greatest probable conclusion for a problem, it is often used in business analysis. It is quite closely associated with predictive and descriptive analysis. On the other hand, prescriptive analysis focusses on making suitable recommendations based on the preferences that are provided.
- **Exploratory Data Analysis:** Before using any other statistical analysis approach, EDA is often the initial step in the data analysis process. It entirely focusses on examining data patterns to identify possible connections. EDA is used to examine missing data from acquired data, find undiscovered relationships within data, and get the most insights possible.
- **Causal Analysis:** The use of causal analysis aids in comprehending and identifying the "why" underlying events as they seem to occur. This examination assists in the identification of the actual cause of disasters or in the discovery of the fundamental reason for an event. To determine what will happen to the given variable in the event that another variable changes, for instance, causal analysis is used.
- **Mechanistic Analysis:** The least popular kind of statistical analysis is this one. In biological science and big data analytics, mechanistic analysis is used. It makes advantage of the idea that,

when external factors are taken out of the equation, changes in one variable may lead to changes in other variables.

D. Important statistical tools in research

The most daunting part of doing research, according to biological scientists, is statistical analysis. Statistical tools, on the other hand, may make this process as simple as possible by assisting researchers in understanding how to handle data and interpret analysis [13].

- **Statistical Package for Social Science (SPSS):** This software program is often used in studies of human behaviour. Both graphical representations of the results and descriptive statistics may be generated using SPSS. Additionally, it offers the ability to write scripts that do more complex statistical processing or automate analysis.
- **R Foundation for Statistical Computing:** Among other domains, human behaviour research makes use of this software suite. Despite its high learning curve, R is a very powerful program. In spite of this, it necessitates a certain degree of programming proficiency. There is also a vibrant community involved in developing and improving the program and related plugins.
- **MATLAB (The Mathworks):** It is both a programming language and an analysis platform. This program is used by engineers and researchers to write their own code and contribute to the solution of their research questions. Although novices may find MatLab challenging to operate, it provides researchers with the flexibility they require.
- **Microsoft Excel:** MS Excel has many capabilities for data visualisation and basic statistics, however it is not the ideal option for statistical analysis in research. It is effortless to produce customisable graphs and figures that consist of summary information. The easiest way to get started with statistics is using Microsoft Excel.
- **Statistical Analysis Software (SAS):** It serves as a statistical platform that is employed in the fields of healthcare, business, and human behaviour research. It can do sophisticated analyses and provide figures, tables, and charts that are suitable for publishing.
- **GraphPad Prism:** Researchers studying biology are the main users of this expensive program. However, it provides a selection of options that can be applied to a variety of other fields. GraphPad has the same scripting capability as SPSS to automate analyses and perform intricate statistical computations.
- **Minitab:** Biology researchers are the primary users of this premium software. However, it provides a selection of options that can be applied to a variety of other fields. A scripting option is provided by GraphPad, which is similar to SPSS, to automate analyses and perform complex statistical calculations.

2 Literature Review

(Ugah et al., 2025) [14] This study examines advanced statistical methods such as time series analysis, machine learning algorithms, Bayesian inference, and regression analysis. However, the analysis of regionally connected data and the development of spatial models of environmental phenomena depend on spatial statistics. Furthermore, the use of Bayesian statistics in decision-making and uncertainty

quantification is growing in importance. These statistics take into account past knowledge and update forecasts as new information becomes available. In environmental studies and climate change, sophisticated statistical analyses are essential for comprehending the complex problems brought on by changes in the global environment. In order to make better decisions, make more accurate forecasts, and respond more effectively to the urgent issues posed by climate change, sophisticated statistical analyses are thus essential to contemporary climate and environmental research. The significance of multidisciplinary cooperation and suggestions for further study are discussed in the paper's conclusion.

(Dr. Sandhya Choudhary et al., 2024) [15] The core of scientific inquiry has been statistical analysis, which offers vital instruments for interpreting data, making decisions, and testing hypotheses. The statistical approach has been pushed towards more adaptable, data-driven techniques by advances in machine learning algorithms and processing capacity. This study examines new techniques including network analysis, Bayesian methods, deep learning, and machine learning. It focusses on how these techniques may be used in a variety of domains and have the potential to significantly alter statistical analysis. Through a comparison of conventional and new approaches, this paper shows how innovations enhance rather than replace statistical analysis's capabilities, influencing research in this dynamic setting.

(Cheong et al., 2023) [16] This study suggests a novel, sequential approach to secondary qualitative investigation using publicly accessible internet interview data. This kind of procedural approach may aid in expanding the datasets available to the research community, increasing rigour, and explicitly considering and mitigating possible hazards. To filter the gathered data, one of the suggested procedures is data quality evaluation, which includes evaluating the context and substance of the data using a total of 16 quality characteristics. Content analysis is used to categorise the dataset, and theme discourse analysis is used to address the predetermined research topics. The technique also discusses the legal and ethical issues surrounding the publication of research results derived from secondary web data. We illustrate how the technique gives secondary qualitative research structure by using the topic of forced migration as an example.

(Kotronoulas et al., 2023) [17] To provide a summary of the three sequential steps—data management, analysis, and interpretation—that go into processing quantitative research data, using real-world examples to promote better comprehension. Numerical research data that necessitate analysis are typically collected in substantial quantities. Data must be thoroughly examined for mistakes and missing values upon introduction into a data collection. As part of data management, variables must then be established and coded. Statistics are used in the analysis of quantitative data. The variables in a data set are summarised by descriptive statistics to demonstrate the typical characteristics of a sample. Measures of dispersion (standard deviation), central tendency (mean, median, mode), and parameter estimate (confidence intervals) may all be computed. Testing theories on the likelihood of a proposed impact, link, or difference is made easier with the use of inferential statistics. The P value is the probability value obtained from inferential statistical tests. Whether an impact, link, or difference could really exist in reality is indicated by the P value. Importantly, it has to be accompanied with an effect size measure to assist evaluate the extent of this impact, link, or difference.

(Sharma et al., 2022) [18] In this work, we examine the effect of WhatsApp usage on academic achievement using multivariate statistical approaches. Using chi-square, factor, principal component, and correlation analyses, we discovered a positive relationship between students' grade point average (GPA) and the amount of time they spent on WhatsApp. The app's capacity to support students' learning is linked to their ability to respond to questions during class. A lower GPA results from using the app more often in class. On occasion, however, pupils may benefit from utilising the app in terms of learning and performance. We have determined that a significant number of students utilise the application to disseminate academic materials, which subsequently enhances their academic performance. Additionally, they communicate with their professors via this app. R and SPSS were used to do the computations.

(MHATRE & Sananse, 2020) [19] In the digital age, using statistical software for research methods is essential. With the introduction of user-friendly software and potent personal computers, researchers can now work on computers that are conveniently located on their workstations. The kind of applications, the statistical, computational, and user-friendly nature of the study must all be taken into consideration when evaluating the software requirements. Research institutions and commercial organisations are constantly releasing new and updated tools for data analysis, so researchers may choose based on their specific needs. Statistical software may be used to analyse almost all research statistical methodologies. The nation has access to a variety of helpful software programs, including MATLAB, MINITAB, SAS, SYSSTAT, and SPSS. There are some that must be bought and those that are free. Statistical software makes it easy to analyse the frequently used research methodologies, which include descriptive statistics, ANOVA, test of significance, multivariate analysis, parametric and non-parametric approaches, etc. Statistical software is improving data analysis quality in the digital age.

(Hazarika, 2019) [20] Innovative computerised software for statistical analysis, SPSS (Statistical Package for the Social Sciences) was specifically designed for social sciences research. It is now frequently utilised, especially in the processing of large amounts of data. SPSS is a tool that enables researchers to gain a scientific understanding of human behaviour, the function and influence of organisations, and the analytic reasoning of various societal indicators. These days, the government itself, as well as commercial centres, market research firms, and educational institutions, use this software extensively. In short, we can say that it helps the researcher with data documentation. The program is a complete package that includes all statistical analysis methods and can effectively transform quantitative data into qualitative analysis. This study aims to comprehend the SPSS software's usefulness, challenges, and limitations in social science research.

(Zhang et al., 2018) [21] The results demonstrated that the kinds of statistical techniques used varied depending on the application areas. Parametric and nonparametric inferential methods were more frequently used in studies pertaining to information organisation and retrieval, whereas correlation and regression methods were more frequently used in studies pertaining to information use, dissemination, creation, and selection and control. These results support the development of relevant quantitative

research technique courses by researchers and enable educators in the area better comprehend the statistical method orientation of library and information science studies.

3 Conclusion

In conclusion, statistical methods have evolved significantly, driven by technological advancements and the increasing complexity of data in modern research. While classical techniques remain foundational, their limitations in handling large-scale and unstructured data have led to the rise of modern approaches such as machine learning, deep learning, Bayesian inference, and network analysis. These methods enable predictive modeling, anomaly detection, uncertainty quantification, and understanding of complex systems, making them highly relevant across diverse research fields. The integration of big data analytics and cloud computing has further revolutionized statistical analysis, allowing real-time processing and collaborative research on massive datasets. Moreover, the availability of a wide range of statistical software has democratized access to powerful analytical tools. Packages such as SPSS, R, MATLAB, SAS, and MINITAB offer comprehensive environments for statistical computation, while specialized software like SIGMAPLOT, STATGRAPHICS, and EXCEL provide tailored functionalities for specific research needs. The choice of software should align with the research objective, data type, and user expertise. As analytical technologies continue to evolve, researchers must stay updated on both classical and modern methodologies to ensure accurate, efficient, and insightful data analysis. Ultimately, the effective use of statistical tools enhances the credibility, reliability, and impact of research in the digital age.

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