MODELLING HOMICIDE IN KENYA USING TIME SERIES

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A research project submitted in partial fulfillment of the requirements for the Bachelor's degree in Mathematics and Economics with IT of Masinde Muliro University of science and Technology.

DECLARATION

We declare that this research project is our original work and effort and that it has not been submitted in any University or college for any award. Where other sources of information have been used, we have acknowledged them.

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ABSTRACT

Understanding and predicting homicide trends is crucial for effective law enforcement,public safety initiative, and policy formulation. This study aimed at modelling homicide occurrences in Kenya using time series analysis techniques. Leveraging historical data on homicides in Kenya spanning 20 years, the study will employ advanced statistical methods to identify trends, patterns and factors influencing homicide rates.

The research began by collecting and processing crime related variables. The time series analysis methods such as ARIMA and SARIMA will be used to model the temporal nature of homicide occurrences. The project aims to provide insights into the temporal patterns and underlying factors driving homicide rates in Kenya. By accurately forecasting future homicide trends, law enforcement agencies and policy-makers can develop a proactive strategies to prevent and address violent crimes effectively. The findings of this research will contribute to the advancement of public safety, measures and aids in the development of targeted interventions aimed at reducing homicides rates in Kenya.

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1 CHAPTER ONE

1.1 INTRODUCTION

In recent years, Kenya has been grappling with an alarming increase in homicide rates, presenting a significant challenge to public safety and societal stability. The surge in violent crime not only threatens individual lives but also undermines the country's socio-economic development and tarnishes its global image. Addressing this pressing issue requires a comprehensive understanding of the underlying factors driving these homicides and effective strategies to mitigate them.

Traditional approaches to crime analysis often rely on simplistic models or anecdotal evidence, which may overlook the intricate temporal patterns and dynamics inherent in homicide data. Time series analysis, particularly Autoregressive Integrated Moving Average (ARIMA) model, offers a robust framework to capture the complex interplay of seasonal, trend, and irregular components in crime data.

The rationale behind employing ARIMA modelling in studying homicide rates in Kenya lies in its ability to uncover hidden patterns, detect outliers, and generate accurate forecasts, thereby providing valuable insights for law enforcement agencies, policy-makers, and researchers. By leveraging ARIMA's capability to handle seasonality and time-varying trends, we aim to identify the underlying drivers of homicide rates and develop predictive models to anticipate future trends.

This study seeks to outline the objectives, methodology, and potential implications of employing ARIMA modelling in analysing homicide data in Kenya. By delving into the temporal dynamics of homicide rates, we aspire to shed light on the root causes of violent crime and devise evidence-based strategies to prevent and mitigate its occurrence.

Additionally, this research endeavour aims to contribute to the broader discourse on crime prevention and criminal justice reform in Kenya, fostering a safer and more secure environment for all its citizens.

1.2 BACKGROUND OF THE STUDY

The study revolves around the pressing issue of homicide in Kenya, a challenge that has significant social, economic and political implications. Kenya, like many other countries, Kenya grapples with various forms of criminal activities, including theft, homicide, Breaking, Robbery Assault and many other crimes. Understanding the factors contributing to these occurrences is crucial for effective policy formulation and targeted intervention strategies.

This study aims to employ time series as a methodological tool to model and analyse homicide patterns in Kenya. By utilizing ARIMA models, the study intends to explore the relationships between the incidences of homicide.

The study was motivated by the need to provide evidence-based insights into the dynamics of homicide in Kenya, allowing policy-makers to develop targeted interventions and allocate resources more efficiently. Additionally, it seeks to contribute to the existing body of knowledge on crime modelling with a specific focus on the Kenya context. Ultimately, the findings of this research endeavour aim to inform policies that can mitigate the prevalence of homicide, fostering a safer and more secure environment for the citizens of Kenya.

1.3 OBJECTIVES OF THE STUDY

1.3.1 GENERAL OBJECTIVES

To model and predict homicide crimes using ARIMA models.

1.3.2 SPECIFIC OBJECTIVES

1. To identify trends of the crime.

2. To forecast future homicide rates in Kenya.

3. To analyse and forecast impact of socio-economic factors, government or any other external factors on homicide.

1.4 SIGNIFICANCE OF THE STUDY

The study holds substantial significance in addressing the pervasive issue of homicide in society.

It contributes to the academic field by employing ARIMA to model and understand the complex dynamics of crime, providing valuable insights into the factors influencing its occurrence. The findings have the potential to enhance existing criminological theories and methodologies, contributing to the broader knowledge base in the field.

Beyond academia, the study holds practical implications for policy-makers and law enforcements agencies. By identifying key determinants of crime, it offers a data-driven foundation for the development of targeted interventions and policies. Such insights enable the allocation of resources to areas most in need, fostering more effective homicide prevention and reduction strategies. Additionally, the study can aid in the formulation of socio-economic policies aimed at addressing root causes, such as unemployment or economic inequality thereby contribution to broader societal improvements.

Ultimately, the significance of this study extends to well-being of Kenyan communities. By informing evidence-based strategies, the study aims to contribute to the creation of safer environments, enhancing the quality of life for citizens and fostering sustainable socio-economic development in the face of the challenges posed by crime and violence.

2 CHAPTER TWO

2.1 LITERATURE REVIEW

2.2 INTRODUCTION.

The chapter reviews empirical and theoretical literature that is relevant to the study and also presents the conceptual framework.

2.3 HOMICIDE IN KENYA.

According to Mushanga (2011), homicide refers to the killing of a human being through an act or omission of another person whether deliberate or not. These are killings that are committed with malice aforethought, planned, prior intention or when the person dies due to the action or inaction of persons other than the victim (Mushanga, 2011). Ghuneim (2013) explains that a homicide is justified when the killing is done in self-defence or when the killer does so to stop the commission of a felony or serious offence. Thus, a policeman who shoots to kill a felon is not guilty of criminal homicide. He further explains that excusable homicide is committed when a person without negligence or intention accidentally kills another person. A homicide becomes criminal if it is done without lawful justification or excuse; then it is either murder or manslaughter.

According to the Kenyan Penal Code chapter 63 Laws of Kenya, murder is categorized as:

1. Manslaughter: this applies to any individual who by means of an illegal act or inactions causes the death of another individual is responsible for the felony termed manslaughter. In Kenya any individual who commits manslaughter if found guilty is liable to life imprisonment.

2. Murder: Any individual who with criminal intent causes the death of another person through unlawful act/or omission is guilty of murder. In Kenya, if found guilty the mandatory sentence for murder is death sentence.

In all homicide cases, criminal intent is proven through one of the following ways:

- An intention to kill or cause grievous harm to any individual, whether that individual is the one actually killed or not;

- With knowledge that action or omission inflicting loss of life will likely result in the demise of or brutally harming the individual whether the individual is actually murdered or not, despite the fact that such know-how is followed by lack of concern whether death or bodily harm is caused or not or by wish that it could not be have happened;

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- Intention to perpetrate a serious offence;

- An intention through the act or omission to assist the flight or escape from custody of any individual who has committed or attempted to commit a crime.

Killing on provocation: when someone who intentionally murders another in the circumstances which lead to loss of life because does an action which causes death under the sudden uncontrollable state of mind before his mind fully settles is guilty of manslaughter only. Suicide pacts: this is a form of manslaughter, and not murder if someone undertaking suicidal act in conjunction with another person to murder the other or help another person commit suicide or him murdered by the third party. Infanticide: any female adult knowingly or by omission kills her infant (less than 12 months), however, during the period of her action or omission she had mental instability brought about by the effect of her giving birth, then, notwithstanding that the situations, for the provisions of this section, the act amounts to murder and will be responsible for an offence called infanticide and may be dealt with as if she has committed the manslaughter of an infant.

The president of Kenya, his Excellency, Uhuru Kenyatta, commuted all persons sentenced to death to serve life imprisonment early 2018 and in 2016, whereby death sentences of 2,747 inmates on death row were commuted to life imprisonment, as was done by President Mwai Kibaki 7 years earlier, where he commuted the sentences of 4000 inmates on death row to life imprisonment in 2009. The move was made to compel these prisoners to work, something condemned men are exempted from. Despite the lack of executions, death sentences are still passed in Kenya by Kenyan Courts (KNCHR, 2018).

2.4 HOMICIDE TRENDS IN KENYA.

According to the National Police Service Crime situation report (2016), there were 2,648 reported homicides cases in Kenya in the year 2015; of which 1,777 were murders, 62 were manslaughters, 51 were infanticides, 51 were abortions, 80 were concealing of Births, 320 were Suicides and 301 were deaths caused by dangerous driving (NPS, 2016).

Almost all kinds of homicide are a consequence of the goals of perpetrators. According to Daly (2016), the rate of transitional elements of different types motivates an individual committing homicide. The means used in perpetrating homicide depends on various factors such as the desires of offenders, demographic features of the victims and offenders and the availability of the weapon and laws governing them.

According to Allison (2013), criminal homicide divulges very interesting patterns in reference to sex, age, an association of the victim and the offender, the motives for the homicide and the methods of inflicting fatal injury and the weapons used.

He further observed that men aged between 25-30 years committed homicide more frequently against other men than women mainly due to property disputes. This study further revealed that there was a greater possibility for women to be killed by intimate partners or by people they are more familiar with than by their male counterparts.

2.5 GLOBAL HOMICIDE TRENDS.

Globally, no less than 560,000 individuals were murdered brutally in 2016, this represents approximately 8 violent killings for every 100,000 population (UNODC, 2017). The rate to some degree reduced in 2015 (7.7) and 2014 (8.1). Worldwide, in 2016, around 385,000 deliberate homicides were recorded. These homicides represented more than 66 percent of all fatalities of the deadly violence. The primary rise in the worldwide homicide rate since 2004 occurred in the year 2016 (WHO, 2017). In the midst of 2015 and 2016, the homicide rates raised from 5.1 to 5.2 murders for every 100,000 13 population. Direct conflict killings represented 18 percent of the aggregate violent homicides in 2016, an insistence that a major number of victims of deadly violence keep on losing their

lives outside of the war zone. Armed conflicts existed in nine out of the 23 nations with the most noteworthy brutal homicides rates in 2016 (UNODC, 2017).

Broadly, 99,000 individuals died in armed conflict internationally in 2016 (Small Arms Survey, 2017). This number is lower than in 2015 (119,000), after a peak in 2014 (143,000), moreover, this was two times higher than in 2004 (42,000). Syria, El Salvador, Venezuela, Honduras, and Afghanistan were the five most violent nations in 2016 regarding recorded violent death rates (UNSD, 2017).

Continuity of the present local patterns infers that violent deaths every year are probably going to rise from around 560,000 in 2016 to more than 610,000 by 2030.in connection to the anticipated development in populace, the homicide rate will rise every year from very almost 385,000 to 421,000 while the rates of homicide universally may diminish marginally between 2016 and 2030, from 5.15 to somewhat lower than 5.0 for each 100,000 populace (Small Arms Survey, 2017). Yearly, killings that result from direct conflicts are foreseen to surpass 100,000 in number by 2030. A decrease in the yearly number of violent killings to around 408,000 by 2030, down from 560,000 is the more positive situation in 2016. In a more negative situation, the entirety of brutal killings is probably going to rise to around 819,000 by 2030. In the event that nations could forsake the 'business- as -usual' practice for the positive situation, possibly 1.35 million lives are probably going to be spared between the period of 2017 and 2030. In contrast to the negative situation, the positive one predicts roughly 2.6 million spared lives (Small Arms Survey, 2017). As far as homicides alone, nations could save 825,000 lives 14 between 2017 and 2030 in the event that they

continuously upgrade their crime control and prevention techniques to accomplish the violence reduction levels of the most affected countries in specific world regions. In this manner, nations in the sub-region of Latin America and the Caribbean would profit most, saving at least 489,000 lives altogether by 2030, followed by states in South-Eastern Asia (86,000 lives) and Eastern Africa (56,000 lives) (UNSD, 2017).

3 CHAPTER THREE

3.1 METHODS

3.1.1 DATA SOURCE

The data utilized in this analysis is a synthetic time series dataset generated for the purpose of exploring homicide trends I Kenya over the past decade. While the data does not represent actual data reported incidents, it serves as a proxy for understanding potential dynamics in homicide rates. This synthetic dataset was created to facilitate to the exploration of various analytical technical, including ARIMA modelling, to forecast future trends and identify potential factors influencing homicide rates in Kenya. While the data itself is not sourced from real-world records, the analysis aims to offer valuable insights and inform discussions on strategies for addressing and mitigating homicides-related challenges in Kenya

3.1.2 TOOLS

The study employs R programming language for data analysis, utilizing packages such as forecast for time series analysis and visualization. Statistical techniques including ARIMA models are applied to understand and forecast homicide trends. Additionally, exploratory data analysis methods such as histogram, density plots and autocorrelation functions are employed to gain insights into the underlying patterns and dynamics of the data.

3.1.3 MODELS

In an ARIMA model, AR(Autoregressive) and MA (Moving Average) components represent the temporal dependencies within the time series data.

Autoregressive (AR) Component.

The AR component represents the relationships between the observation and a number of lagged observations in the past. Mathematically, it can be represented as:

$$Y_t = c + \phi_1 \cdot x_{t-1} + \phi_2 \cdot x_{t-2} + \cdots + \phi_p \cdot x_{t-p} + \varepsilon_t$$

Where:

- x_t: Value of the time series at time t.

- c: Constant term.

- $\phi_1, \phi_2, \ldots, \phi_p$: Autoregressive parameters.

- $x_{t-1}, x_{t-2}, \ldots, x_{t-p}$: Lagged values of the time series.

- ε_t: White noise.

Moving Average (MA) Component.

The MA component represents the relationship between the current observation and a number of lagged forecast errors. Mathematically, it can be represented as:

$$Y_t = \mu + \varepsilon_t + \theta_1 \cdot \varepsilon_{t-1} + \theta_2 \cdot \varepsilon_{t-1} + \cdots + \theta_q \cdot \varepsilon_{t-q}$$

Where:

- ε_t: Error term at time t.

- μ: Mean of the time series.

- $\theta_1, \theta_2, \ldots, \theta_q$: Moving average parameters.

- $\varepsilon_t, \varepsilon_{t-1}, \varepsilon_{t-2}, \ldots, \varepsilon_{t-q}$: Lagged forecast parameters.

The AR and MA components along with differencing (1) component, constitute the ARIMA model and crucial for capturing the temporal dependencies and patterns in time series data, including homicide rates.

4 CHAPTER FOUR

4.1 DATA ANALYSIS AND INTERPRETATION

4.1.1 PAST TRENDS OF HOMICIDE NUMBERS.

The analysis employed the Autoregressive Integrated Moving Average(ARIMA) model to examine the patterns and trends in homicide data over the last 20 years. The data was processed using R programming, facilitating comprehensive exploration and prediction. The plot of the last 20 years of homicide data in Kenya revealed fluctuating

patterns with discernible peaks and troughs, indicating potential seasonal or cyclical influences. Such visual insights serve as the foundation for understanding the underlying dynamics of the data.
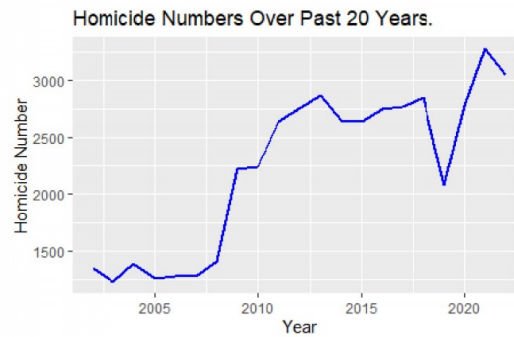

Figure 1: Number of Homicide over the last 20 years

4.1.2 MODEL SUMMARY AND INTERPRETATION.

The ARIMA model, applied to the dataset yielded valuable insights into the temporal patterns and potential future trajectory of homicide occurrences. A detail summary of the models parameters and diagnostics statistics is as shown on figure 2 below.


```
        Point Forecast    Lo 80     Hi 80     Lo 95      Hi 95
2023            3056  2383.697  4089.699  2118.184   4883.101
2024            3056  2171.798  4690.768  1857.613   6207.394
2025            3056  2028.794  5253.609  1690.551   7661.011
2026            3056  1919.523  5816.665  1567.523   9359.972
2027            3056  1830.809  6396.846  1470.520  11415.877
```

Figure 2: Summary of the Model

From the summary table above, the estimated variance of the residual errors from the model depicted as sigma squared, indicates the how much the actual points deviate from the predicted values on average. Since the model suggests a smaller sigma squared = 3.286e-06 indicates that the residuals are more clustered around the predicted values, thus indicating a better fit of the model to the data.

On the hand the Log Likelihood indicates a measure of how well the model fits the data. In the case of model analysis, higher values indicate better fit. For the case of this homicide analysis the log likelihood = 98.31 which indicates a good fit for the model.

Based on the
AIC(Akaike Information Criterion)= -194.62,
AICc(Correlated Akaike Information Creterion) = -194.4
and BIC(Bayesian Information Criterion) = -193.63.
Since all the values are lower therefor indicates a better model fit.

Training Set Error Measures;
ME(Mean Error),The average errors;positive values indicate on average:model under predicts, negative values indicate over prediction.
RMSE(Root Mean Squared Error),provides measure of the typical magnitude of the errors.
MAE(Mean Absolute Error), Average of absolute error,provides measure of the average magnitude of errors.
MPE(Mean Percentage Error),Average percentage difference between predicted and observed values.
MAPE(Mean Absolute Percentage Error),Simalar to MPE but absolute value are used.
MASE(Mean Absolute Scaled Error),Compare the models performance to that of naive baseline model, values close to 1 indicate models performs similarly to the

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baseline.

ACFI(Autocorrelation Function Inequality), measure of models ability to capture the autocorrelation structures of the data. values close to zero indicate good fit.

The error measures(RMSE, MAE, MAPE,..) provides insight into the accuracy and direction of the model's prediction. In this case, the RMSE and MAE indicate that average magnitude of errors, while MAPE and MPE provide insights into the percentage differences between predicted and observed values. The ACFI value indicates how well the model captures the autocorrelation structure of the data. In the case of this study ACFI suggests the model is fit as its close to 0 since it is -0.1969932. Based on the statistics and errors measures, the ARIMA model appears to provide a reasonable fir to the homicide data, it has captured the underlying patterns and dynamics. Rather its essential to interpret the output considering potential limitation of the model.

4.1.3   PREDICTED VALUES AND TRENDS.

The ARIMA model generated predicted values based on historical data and trend analysis. The predictions offer valuable foresight future and trends in homicide occurrences. The predicted values are as shown in the table below.
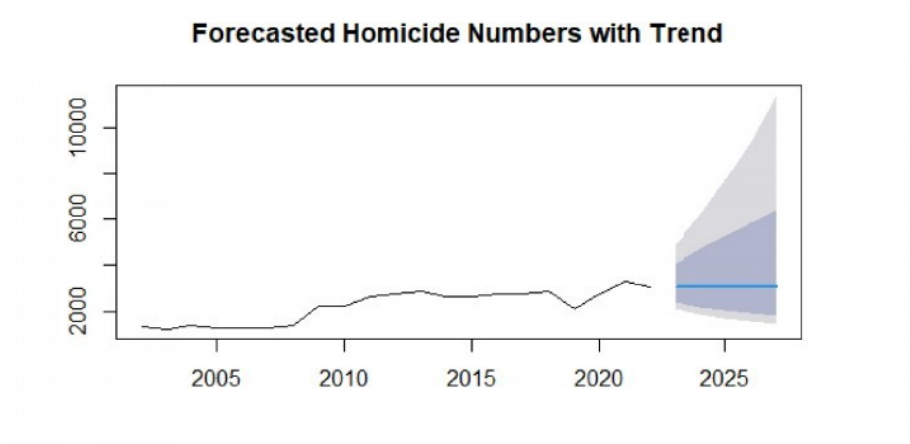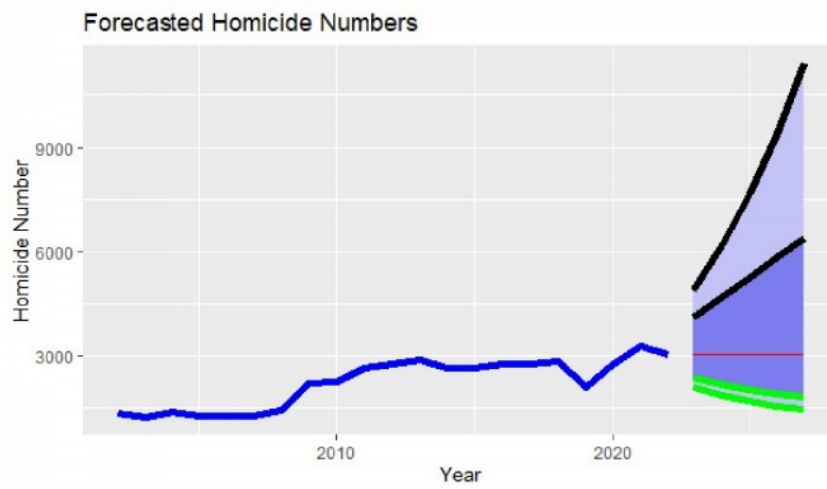
Figure 4: Trend of the predicted values

Figure 3: Predicted values in the next 5 years

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5 CHAPTER FIVE

5.1 CONCLUSION AND RECOMMENDATIONS

Based on the results of the analysis it can be concluded that there might be a surge or potential increase in the number of cases in the future years. Therefore its essential for the law enforcement and policy-makers to address the issue.

5.1.1 RECOMMENDATIONS.

From the above findings and conclusions, the study suggests the following recommendations.

1. The government should roll out a program to ensure that all pupils who complete primary education can transition to secondary schools or vocational training schools smoothly. This will give them better chances of progressing in life and provide opportunities for employment to reduce their involvement in criminal activities like homicide or forming criminal gangs.

2. The Kenyan government through NACADA (National Campaign Against Drug Abuse), Non-governmental and Religious organizations to should roll out awareness campaigns on substance abuse especially enforcement of Alcohol related laws and conflict management at family and community level targeting the youth so as to address the issues of alcoholism which may results to domestic disputes and thereafter leading to commission of crime like homicide.

3. Through non-governmental and Religious organizations communities and families should be provided with counselling on how to handle disputes amicably especially among family members and promotion of traditional alternative dispute resolution mechanism to deal with emerging disputes among families, neighbours, and community at large who have disagreements over land, marital problems, property disputes etc.

4. The Kenyan government needs to address the risk of illegal firearms by aggressively fighting the proliferation of small arms mostly to urban centres and other parts of the Country. They should also start security and community driven initiatives to recover the illegal arms that are already in the hands of criminals.

5. Further, the government through law enforcement agencies especially National Police Service (NPS) should Promote and facilitate increase in night patrols 99 especially in urban areas since homicide offences are mostly committed at night according to this study.

5.1.2 RECOMMENDATIONS FOR FURTHER RESEARCH.

1. The current study assessed the the number of reported homicide offences in Kenya. Further research is recommended on assessment of criminal offence of gender Homicide convicts of gender related homicide cases in Kenya.

2. The current study gives the need for further study on the homicide rates, relationship between homicide and other crimes reported and regional homicide cases.

3. Future research should also be conducted on the relationship between the use substance abuse like Alcohol and the increase in homicide cases in Kenya.

4. Further studies are recommended to examine the correlation between the commission of homicide offences and education level of male homicide convicts in Kenya.

5. Finally, future studies should attempt to re-examine the themes found in the current study using a larger sample size to refine criminal profiles of male homicide convicts in the entire Country. The current study was a case study of only data of last 20 years (2002-2022).

REFERENCES

1. Crime Analyses Using R - CHAPTER 13: Anindya Sengupta*, Madhav Kumar*, Shreyes Upadhyay *Fractal Analytics, India, Diamond Management and Technology Consultants, India.

2. Introductory Time Series with R - Paul S.P. Cowpertwait · Andrew V. Metcalfe

3. International firearm injury prevention and policy (GunPollicy.org).

4. Kenya National Police Service Annual Reports.

5. Kenya National Bureau of Statistics.

6. STA-445 Class Notes

7. Time Series Analysis and Its Applications - Robert H. Shumway • David S. Stoffer, Third Edition.

8. World Bank (data.worldbank.org),intentional homicides.

BUDGETING AND PLANNING

The following table shows the team planning and expenses that have been incurred since the start of the project till now.

Serial No.	Date	Printing	Computer	Time(Hrs)
1	25/11/2023	200	22,700	2
2	18/12/2023	500	-	5
3	14/01/2024	220	-	3.5
4	20/02/2024	560	-	4
5	25/02/2024	450	-	5
6	19/03/2024	700	-	4
Total	-	2630	22,700	23.5

Table 1: Table showing the projects expenditure.