Grenze International Journal of Engineering and Technology, January Issue

From Data to Action: Improving Police Resource Allocation and Performance Management

Kavita R Singh[1], Shantanu Naresh Shinde[2], Durvesh Balkrushna Wath[3], Gargi Rajendra Magarde[4], Shatayu Shashikant Sakharkar[5], Aditya Narayan Ghatol[6] and Hawraa H.Abbas[7]
[1]Yeshwantrao Chavan College of Engineering, Department of Computer Technology, Nagpur, Maharashtra, India
Email: singhkavita19@gmail.com
[2-6]Yeshwantrao Chavan College of Engineering, Department of Artificial Intelligence and Data Science, Nagpur, India
Email: {sshantanu461, durveshwath7, gargimagarde, shatayusakharkar, adighatol4}@gmail.com
[7]College of Information Technology Engineering, Al-Zahraa University for Women 56001 Karbala, Iraq
Email: Hawraa.h@alzahraa.edu.iq

***Abstract*—Along with being under public surveillance, having budget limitations, and maintaining safety, one of the crucial responsibilities of the police force includes enhancing police performance and optimize resource allocation. It has been observed that a major issue faced to improve the performance is improper utilization of police resources. This study offers a data-driven approach that integrates live data using Firebase and StreamLit along with Microsoft Power BI to improve police performance and resource allocation. Using data from the Karnataka Hackathon, and deriving visualizations for the analysis of the data can further help for proper police resource allocation. The main aim of the analysis of these visualizations is to identify the various factors that can help to increase the efficiency of police and for proper resource allocation in real time. Proper police allocation can lead to reduced response time, the presence of officers in critical areas, and therefore reducing the crime rates, ultimately increasing police performance. This research emphasizes how data analysis using live data can help to make informed, evidence-based decisions.**

***Index Terms*— Microsoft Power BI, Police Resource Optimization, Police Performance Strategies, Evidence-based decisions.**

I. INTRODUCTION

Effective resource allocation and performance optimization, although challenging is important for law enforcement agencies to enable responses in a prompt manner towards incidences of criminal activities. This issue is majorly dealt by the police department by three broad perspectives of preventing crime:
Behaviour Modification: Attempts to encourage individuals not to commit crimes, despite its theoretical attractiveness it proven ineffective in practice because of the complexity and resistance faced for changing behaviours.
Increasing Resources: Substantively increasing police resources may seem convincing; however, the bottom line is that it requires a significant amount of funding—resources that may exceed the financial allotments available, and likely present logistical issues.
Optimizing Existing Resources: It maximizes the use of analytical methods and technological solutions to the maximum extent with regard to available police resources. This approach would be data-driven and technically

Grenze ID: 01.GIJET.11.1.539_1

advanced framework—a base where law enforcement is certain to make decisions based on the evidence available to them, in both effective resource allocation and performance management.
The last approach would be the most challenging because it aims to develop an overarching solution to meet the particular needs of law enforcement. This paper draws real-world data available through the charge-sheeted cases dataset provided by Karnataka state Hackathon to provide actionable insights beyond the use of descriptive analytics. It combines the powerful capabilities of Microsoft Power BI and the robustness of data storage and retrieval offered by Firebase with the potential to create online interactive dashboards that can be deployed in real-time by StreamLit.
The proposed approach will improve operational efficiency by optimizing resource allocation to enhance its influence on public safety. In addition, transparency and data-driven decision-making will improve public trust and further strengthen public relations—a foundation of modern and democratic police force. This research, therefore, contributes to the encouragement of responsibility, responsiveness, and evidence-based practices of the law enforcement agency that will guide them for more efficient, unbiased, and public-centred resource management as well as performance management.

II. Literature Review

Efficient resource allocation and optimization are critical challenges for modern law enforcement agencies. This literature review synthesizes key findings from various studies on police resource allocation and performance optimization, emphasizing data-driven approaches and technological solutions.
“Ref. [1]” Hotspot analysis has been a cornerstone of crime mapping, indicating areas with high crime concentrations and high Police resource requirements. Early work by Sherman et al. (1989) laid the foundation by examining crime concentration at specific locations and introduced the concept of "hotspots”. The City Clustering Algorithm (CCA) constructs these clusters by considering two key parameters: a crime density threshold (C*) and a distance threshold (δ). The crime density Ci is calculated as the number of cases per unit area or population, and its geographic centroid is used as the reference point. If Ci > C*, then the district or police unit is considered a potential crime hotspot. The distance threshold δ represents the maximum distance between districts or police units to consider them as spatially contiguous, i.e., all nearest neighbouring districts or units that are within a distance smaller than δ will be clustered together. The crime density threshold C* can be quantified as the number of cases per square kilometre, while the distance threshold δ can be expressed in kilometres or any other suitable distance measure. Analysing Crime Hotspots for Police Allocation is one of the most required features.
“Ref. [2]” Risk Terrain Modelling (RTM) represents a significant advancement in predictive policing by integrating place-based risk factors into crime forecasting models. Developed by Caplan et al. (2010), RTM shifts the focus from merely identifying crime hotspots to understanding the underlying risk factors that contribute to crime emergence. This method involves creating risk maps that combine various environmental and social data layers to identify areas at higher risk for future crimes. Kennedy et al. applied RTM to understand the spatial dynamics of shootings in Newark, demonstrating its effectiveness in forecasting crime by incorporating risk factors such as the presence of bars, schools, and previous crime incidents. This approach aligns with the principles of environmental criminology, which posits that both social and physical characteristics of community influence crime patterns. This makes predictive policing or risk factor analysis an important factor for police resource allocation.
“Ref. [3]” The application of big data technologies in public security has gained significant attention, as these methods enable the effective analysis and utilization of vast amounts of data. According to Wen et al., the integration of big data in public security facilitates the development of systems that can predict potential criminal activities and optimize the deployment of police resources accordingly. This approach not only enhances the efficiency of resource allocation but also improves the responsiveness of law enforcement agencies to emerging threats. The use of machine learning algorithms, such as decision trees and random forests, has shown promise in predicting criminal behaviour and optimizing police resource allocation. Wen et al. describe a system that employs these algorithms to analyse various factors influencing crime, such as income levels, education, and previous criminal records. By predicting the characteristics and locations of potential criminals, the system enables the proactive deployment of police resources to high-risk areas, thereby enhancing public safety and resource efficiency. For example, a study on the Colombian National Police's command and control system demonstrates the effectiveness of using real-time data to manage police resources in urban environments. This system leverages a combination of genetic algorithms and local search optimization to dynamically adjust patrol routes and resource allocation based on current crime data.

“Ref. [4]” Big data analysis has transformed crime prediction and prevention, enabling the identification of trends and patterns through methodologies like Social Network Analysis (SNA), CRISP-DM (Cross-Industry Standard Process for Data Mining), and AMPA (Actionable Mining and Predictive Analysis). Key techniques include distributed programming frameworks, non-relational databases, homomorphic encryption, secure multiparty computation, and attribute-based encryption. These methodologies improve crime forecasting and patrol optimization for police Resource allocation.
“Ref. [1]” Similarly, Caminha et al. highlight the benefits of using big data for police resource allocation by comparing two strategies: Resident Population Allocation (RPA) and Floating Population Allocation (FPA). Their study demonstrates that FPA, which allocates resources based on the dynamic clustering of populations, is more effective in targeting high-crime areas compared to traditional methods that rely on static population data.
“Ref. [5]” “Ref. [6]” The McKinsey 7S framework suggests that organizational effectiveness stems from the interaction of seven factors: strategy, structure, systems, shared values, style, staff, and skills.
“Ref. [7]” “Ref. [8]” The framework highlights the importance of aligning these factors, including resource allocation, for effective strategy implementation.
The literature underscores the evolution from traditional hotspot analysis and identifying the risk factor to more sophisticated predictive models like RTM, which incorporate environmental and social factors into crime forecasting. The integration of advanced analytical tools like ETL, Power BI, StreamLit etc further enhances the ability of law enforcement agencies to allocate resources efficiently and respond proactively to crime. These developments not only improve operational efficiency but also foster transparency and data-driven decision-making, essential for building public trust and enhancing community safety.
By incorporating these insights into the proposed study, the aim is to develop a comprehensive system that leverages the latest technological advancements and predictive models to optimize police resource allocation and Management. This approach aligns with the overarching goal of promoting accountability, responsiveness, and evidence-based practices within law enforcement agencies.

III. Limitations

A. Data Quality and Cleaning:

Indeed, the poor quality of data, apart from unavailability of reliable ETL or Extract, Transform, Load has been pointed out by many studies as some major concerns for police resource allocation. Poorly cleaned data results in inaccurate and unreliable analysis.

B. Integration of Live Data:

Traditional crime analysis uses static datasets, which naturally cannot capture the dynamic changes in patterns of crime. This lag in the integration of data itself has inherent limitations in terms of law enforcement agencies responding in real-time to emerging threats.

C. User-Friendly Data Visualization and Interaction

Most existing research and tools lack the availability of interactive, user-friendly dashboards that would help non-technical users to easily explore and analyse data. Because of that, police departments might be restricted from adopting and using the collected data-driven insights.

D. Holistic Analysis and Decision Support

Most of the available solutions lack the integration of better analytics tools with integrated decision support systems to support decisions. They are mostly based on providing descriptive analytics without facilitating the entire process more amply by incorporating predictive or prescriptive analytics.

IV. Motivation

Together with the inability of tools to offer interactive visuals, the limitation in the integration of live data is among the major causes of the ineffectiveness of police resource allocation. The traditional approaches of data analysis normally tend to take static datasets, which are not dynamically changed in real-time as patterns of crime change. This, therefore, makes it difficult for the departments of law order to have an immediate response to the emerging threats. Some research and tools also lack easy-to-use and interactive dashboards, coupled with friendly adoption and usage of insights by police departments.
From the above-mentioned limitations, we were motivated to work on this problem which is a challenging issue in the domain of resource allocation for the police departments. As is evident from the statistics available:

“Ref. [9]” Static Datasets Limitation: Traditional policing methods that run on static data sets tend to fail while predicting real-time crime incidents. Since real-time data sets are not integrated, law enforcement agencies tend to fail dynamic resource allocation and, hence, couldn't efficiently tackle emerging crime hotspots.
“Ref. [10]” Need for Interactive Visualization: Most of the police departments lack interactive and user-friendly data visualization tools which makes it difficult to apply data-driven insights into real-world policing practices. Advanced data visualization tools along with predictive analytics can considerably improve the decision-making motives as well as operational planning methods in police forces.
" Designing an Effective Law Enforcement Data Dashboard ". This illustrates how essential it is to address these issues to achieve the best police performance.
In this paper, we propose a strategy specifically to address the above limitations. Here, we present a framework for police resource optimization based on the insights derived from Power BI visuals. Using the Advanced data visualization capabilities of Power BI, we aim to create interactive dashboards that integrate live data from StreamLit so that users may have actionable insights in real time. These insights help in designing policing strategies that can potentially optimize resource allocation, are operationally effective and efficient, and enhance public safety.

V. Proposed Work

In the present study, data were utilized from official records of charge-sheeted cases in the Karnataka state police Hackathon. The dataset contains 172,303 case records from various districts in the state of Karnataka, containing complete details related to FIR (First Information Report) registration since 2016. The dataset contains attributes like 'District Name', 'UnitName', 'FIRNo', 'RI', 'Year', 'Month', 'Report_Type', 'FIR_ID', 'Unit_ID', 'Crime_No', 'FIR Type', 'FIR_Stage', 'Complaint_Mode','Latitude', 'Longitude', 'Village_Area_Name', 'Male', 'Female', etc.
As illustrated in Figure 1, the following is the correlation matrix, where the correlation coefficients are provided for each pair of attributes: The nearer the value of any two attributes is to 1 or -1, the linear relationship between the two is strong. The nearer it is to 0, the linear relationship is weak. We set a threshold value to consider the most related features, in this case, 0.7. All pairs of the features were taken into account in such a way that the absolute value of the correlation coefficient was more than 0.7, because these two values were most relevant for our study.
Figure 2 reveals the rest after applying this threshold that filters out high collinearity in attributes; high multi feature collinearity produces multicollinearity and distorts results in regression analysis and all statistical models. Hence, full proofing our analysis against such concerns by filtering features exhibiting significant correlations above the threshold.
The ones that passed this criterion and remained in our study are: ‘District_Name’, ‘UnitName’, ‘FIRNo’,’ RI’, ‘Year’, ‘Month’, ‘Report_Type’, ‘FIR_ID’, ‘Unit_ID’, ‘Crime_No’, ‘FIR Type’, ‘FIR_Stage’, ‘Complaint_Mode’, ‘Latitude’, ‘Longitude’, ‘Village_Area_Name’, ‘Male’, and ‘Female’. We selected these because the correlations hold between them, representing severe relationships, meaningfully important to be considered for the creation of the skeleton key or inter-relationship discovered in our dataset.
Figure 2 presents a heatmap of the correlation matrix makes this very visual. Of course, it preserves the characteristics that drive its selection and points out the main correlations between these. With this so tightly managed and logical approach to feature selection, our next analysis will be both extremely focused yet exhibit extreme breadth in capturing important patterns and trends in data, without suffering from the perils that come with multicollinearity.
This feature selection process and the considerations involved therein thus constitute an important part of our data preprocessing phase, upon which basis the subsequent analyses rest.

VI. Visual Aid References

An ETL process *i.e.*, Extract, Transform and Load, is used for data preparation to create a visualizing dataset as depicted in Figure 3. This takes place in several steps. First of all, the process of feature extraction has been undertaken where the most relevant variables to the analysis at hand have been identified and retained. Irrelevant variables and columns with redundant information were removed from the dataset to make it and its analysis, and related computations less complex. After that, the missing values have been treated either by imputing values or by deleting incomplete records so that data is complete to draw accurate inference and conclusion. At last, the duplicate entries were also diagnosed and deleted because their place permits biased analysis and also damages the result.

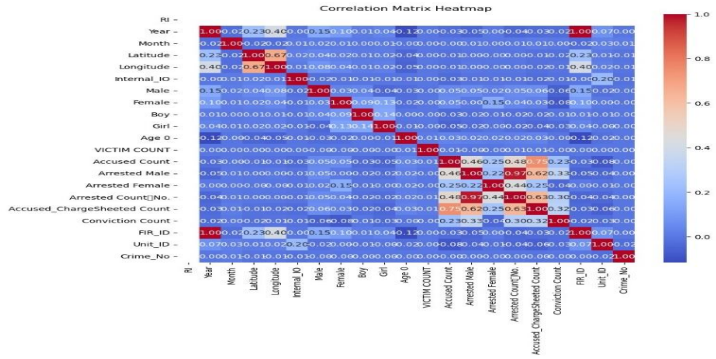

Figure 1:Correlation matrix for all 20 numerical attributes in the dataset

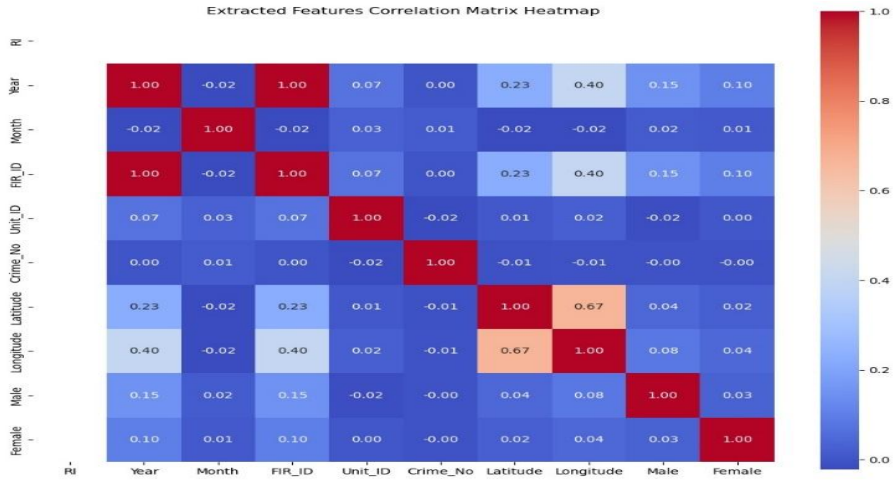

Figure 2: Correlation matrix heatmap for the selected attributes with significant correlations above the threshold of 0.7

The dataset, after preprocessing, was left with the 18 attributes selected and was reduced to 28,000 rows. Then it was put forward to Firebase so that from now, data will be updated constantly. In this, way, the Karnataka Police will input new data without much hassle and it will make sure live-like and update data in the dataset. With Firebase, the police can access as well as manipulate data in real-time, making it work more dynamically with data analysis.

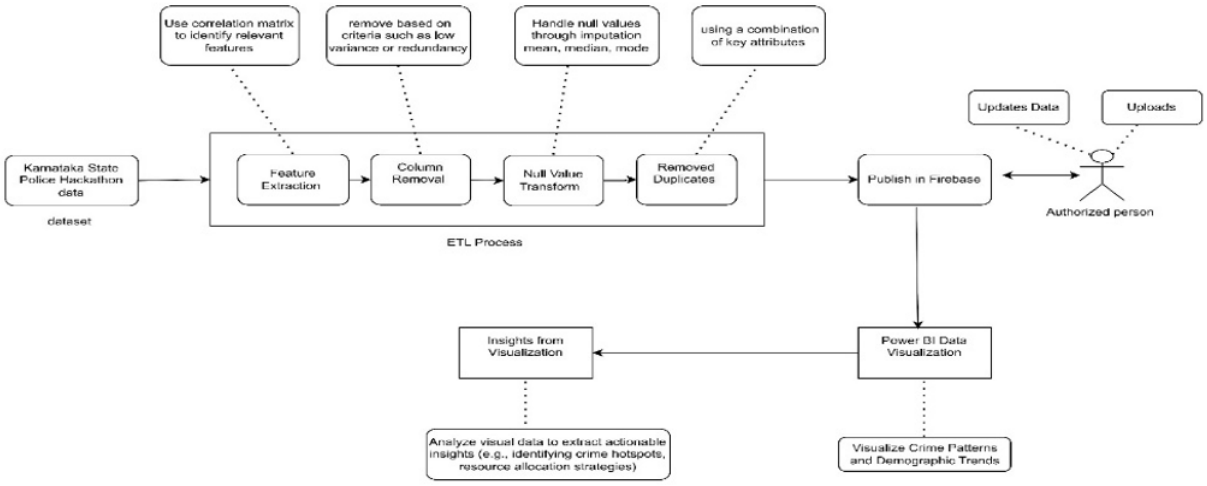

Figure 3: Flow Diagram of the system

VII. Data Visualization

We use StreamLit for integrating data in a real-time manner and Microsoft Power BI as a visual platform to interpret results such that all said information together provides police performance and resource allocation to inform better decision-making. Visual usage provides different tools: from heat maps to bar charts, visual tools provide where and how crimes are distributed, with the hotspots showing where the density of crime is high and quantitatively viewing the crime rate across districts. The visualization of data leads to the ease of resource allocation to police departments, prioritization of high-crime areas, and the socio-economic underpinnings that affect crime patterns. These promise the ultimate increase of efficiency in police operations and public safety through data-driven, precision, and adaptive resource management.

Well, we use StreamLit to bring in live data and Microsoft Power BI helps to yield interactive visuals. This combination helps us achieve effective real-time result interpretation toward enhanced police performance and resource reallocation. The dynamic visualizations Power BI is helping to generate allow for the policing of resources in data-driven decisions so that the police may optimally use these resources to enhance public safety and operational efficiency. These and more advanced tools are leveraged so that they can give insights to help in proactive and informed policing strategies.

VIII. Experimentation and Result Analysis

Following the cleaning of charge-sheeted cases dataset provided by Karnataka state Hackathon, we utilized Microsoft Power BI to generate various visuals aimed at providing actionable insights for enhancing police performance and optimizing resource allocation.

A. Heat Map

One of the pivotal visuals created is the heat map depicted in Figure 4, which elucidates the spatial distribution of crime incidents across Karnataka. The heat map uses a colour intensity scale (red, yellow, green) to represent the severity and frequency of reported incidents, with red areas denoting high-density crime hotspots. The heat map reveals several critical insights. Bengaluru City displays the highest concentration of crime incidents, indicating a critical need for substantial police resources to address the elevated crime rates effectively. In Belagavi District, several red and yellow clusters are evident, highlighting multiple high-crime areas that necessitate targeted police interventions. Additionally, the regions of Ballari and Bagalkot show notable crime hotspots, though these are less intense compared to Bengaluru and Belagavi, suggesting a requirement for moderate resource allocation.

This heat map serves as an instrumental tool for improving police performance and resource allocation strategies. By visually identifying regions with high crime concentrations, law enforcement agencies can prioritize the deployment of resources to the area's most in need. This targeted approach ensures that police presence is concentrated where it is most necessary, thereby enhancing public safety and operational efficiency. The insights gained from this heat map can inform strategic planning and decision-making processes, enabling a data-driven and effective response to crime trends across Karnataka.

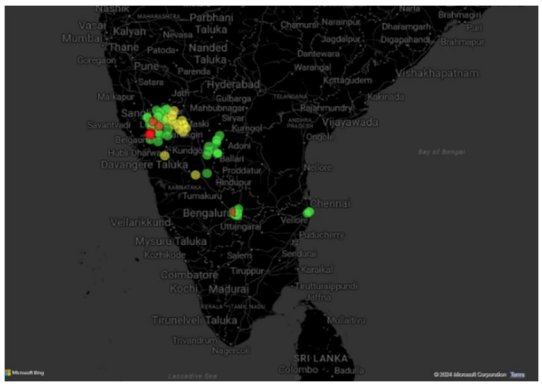

Figure 4: Heat Map of Crime Incidents Across Karnataka

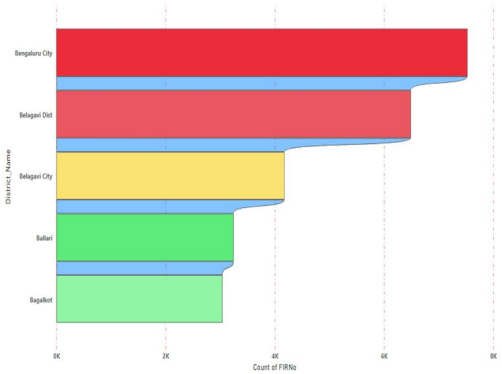

Figure 5: FIR Count by District

B. Stacked Bar Chart

Figure 5 shows the stacked bar diagram showing the distribution of First Information Reports (FIR) across different districts. Values of x axis denote the count of FIRs and y denotes the names of the district in the state:

Bengaluru city, Belagavi district, Belagavi city, Ballari, Bagalkot. The data supported the inequity amongst the available districts with the maximum count of FIRs in Bengaluru City followed by Belagavi District and Belagavi City.

Such information is important in the analysis of the performance of the police and in appropriately apportioning of law enforcement resources. The higher number of FIRs in Bengaluru City would, therefore, resemble the high demand for the law enforcement resources in a strategic planning manner in order to be able to effectively contain the high crime rates. In the process, the districts like Bagalkot and Ballari, which may not count so high in their FIRs, and as such may be indicative of the reverse nature, that fewer resources may be needed, or completely a different style of policing. These trends point to the fact that a tailor-made allocation should be enforced to get police performance and public safety. Targeted allocation will allow police authorities to allocate better the prestigious areas, which are crime-infested and optimize the crime and resources.

C. Bar Chart

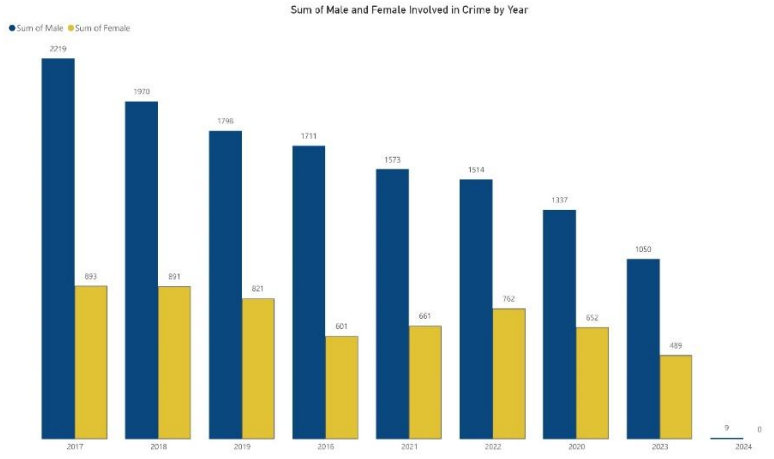

Figure 6: Bar Chart Representing the Sum of males and female involved in crime by year

Figure 6 presents a bar chart that indicates the annual totals for all the years a male and a female are criminally involved with crimes from 2016 up to 2024. On the x-axis are the years, while on the y-axis are the totals for male and female years of engagement in criminal activities. This figure depicts trends for criminal involvement by gender, which are important in coming up with implications of these results on police performance and resource allocation.

From year 2016 to 2023, there is a trend noted where males are more involved in crimes than females. The most involving year for males was in the year 2017, having 2,219 individuals, and for the females, it was in 2017 with a high of 893 individuals. More than two years later, based on the numbers, in 2021, the figures portray a severe drop with 1,573 being males and 661 being females involved in crime. Data for 2024 is incomplete, but quite obviously, through resource efficiency and strategic efforts, it is also likely to follow the trend of further reduction in the coming years.

Statistical record analysis proves this factor to be decreasing the involvement of both genders in crime; hence, the rates can be brought down further by the proper allocation of police and task force teams with strategically set initiatives. Proper allocation of resources will also aid in properly directing the police forces in areas where the crime is highest. In return, such practice will not only bring the rates of crime down but will also increase the overall performance and effectiveness of the policy service making the community much safer.

IX. Conclusion

This fact makes the current study quite relevant: it is in practicing data-driven techniques that the police could use in allocating resources and monitoring changes in the efficacy of their resources. Microsoft Power BI and StreamLit will enable the police to get the most up-to-date insights into the trends of crimes and resources for a more strategic way of action.

They also provide visualization through the use of heat maps and bar-graph representations that could help unveil relevant crime trends, besides enabling the identification of important socio-economic factors affecting crime rates.

The analysis brings to light notable differences in crime rates among various districts, with regions such as Bengaluru City and Belagavi displaying higher crime incident concentrations. These findings indicate the need for targeted interventions and flexible resource distribution to address the distinct requirements of each district. For example, areas with consistent crime patterns, like Bagalkot, may maintain existing resource levels, while high-crime regions like Bengaluru City may necessitate increased police presence and well-thought-out plans to effectively manage elevated crime rates. The use of a resource control system through which the distribution is easily responsive to the changes in the crime stock can then take the character of something that eventually brings efficiency in the way that police forces are deployed with the intent to enhance public safety and operational efficiency. Through apps such as Firebase, which have allowed integration with real-time data, agencies can accord continuously adaptive strategies with the most current information and hence give birth to a proactive approach to crime deterrence.

In a nutshell, this research will lay a good foundation for the optimization of police resources. Law enforcement agencies could employ the help of these advanced technical tools and information-oriented strategies for attaining operational efficiency, and at best, these may foster the cause of transparency and betterment of relationships with the community. The research outlines the steps on which future commercial work can be approached to further develop these methods and consider additional factors that can affect police performance and resource allocation.

REFERENCES

[1] Caminha, C., & Furtado, V. (2017). Impact of human mobility on police allocation. https://doi.org/10.1109/isi.2017.8004886

[2] Kennedy, L. W., Caplan, J. M., & Piza, E. (2010). Risk Clusters, Hotspots, and Spatial Intelligence: Risk Terrain Modeling as an Algorithm for Police Resource Allocation Strategies. Journal of Quantitative Criminology, 27(3), 339–362. https://doi.org/10.1007/s10940-010-9126-2

[3] Wen, S., et al. "A Police Resource Optimization System Based on Intelligence Research, Judgment, and Analysis." Guangdong Police College, Year.

[4] Al-Rummana, Galal & Al-ahdal, Abdulrazzaq & Shinde, Ganeshchandra. (2021). The Role of Big Data Analysis in Increasing the Crime Prediction and Prevention Rates. 10.1002/9781119711629.ch10.

[5] Peters, T., & Waterman, R. (1982). In Search of Excellence. New York, London: Harper & Row.

[6] Wernerfelt, B. (2004). A Resource-Based View of the Firm. Strategic Management Journal, 13(2), 171-180.

[7] Simiyu, N. (2013). A study to investigate challenges affecting strategy implementation in government corporations (Unpublished MBA Project). School of Business, Kenyatta University, Nairobi, Kenya.

[8] Dunphy, D. C., & Stace, D. A. (1988). Transformational and coercive strategies for planned organizational change. Organizational Studies, 9(3), 17-34.

[9] O. Kounadi, A. Ristea, A. Araujo, and M. Leitner, “A systematic review on spatial crime forecasting,” Crime Science, vol. 9, no. 1, May 2020, doi: 10.1186/s40163-020-00116-7

[10] Jacobson, Michael, Mark Perbix, and Karen Lissy. 2023. Developing a Concept of Operations Document. Designing an Effective Law Enforcement Data Dashboard. Washington, DC: Office of Community Oriented Policing Services.