Explorative Analysis for Predicting Direct and Indirect Affected Population due to Alcohol Abuse in Karnataka using Machine Learning Techniques

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The objective of the work is to predict directly and indirectly affected population in Karnataka, India, due to alcohol consumption by considering five years (2017-2022) of government data on alcohol licensing, sales, consumption, population trends, and treatment centers. Districts are grouped into 7 divisions as recommended by the state excise department. It is observed that the alcohol sales rose by 7.3%, impacting direct (13.6%) and indirect (13.7%) affected populations. The average alcohol consumption of an alcohol dependent person per day is around 239. 5ml.During the period 2020-23 the alcohol consumption increased by 3.7%, signifying high risk. The directly affected population with high-risk is around 53.2 lakhs. The existing treatment infrastructure comprises of 427 centers, encompassing private, IRCAs, and outpatient hospitals. Each treatment center, when compared against the directly affected population, attends approximately 18,300 individuals annually. On a monthly scale, this equates to 1,531 individuals per hospital, assuming a modest 20-bed capacity. This leaves a staggering 52.17 lakh people untreated annually, highlighting a substantial gap between those seeking treatment and the available resources. With only 34 IRCAs, our findings stress the need to expand rehabilitation facilities to effectively combat alcohol addiction. We have also employed Machine Learning algorithms i.e. the Linear Regression model to predict directly and indirectly affected population. The model predicted the directly and indirectly affected population with an accuracy of 96% and 94% and RMSEs of 0.0206 and 0.052, respectively. Finally, we substantiate our findings and provide recommendations to expand rehabilitation facilities, also enhancing public awareness on responsible drinking, and advocating policy reforms to address the treatment gap effectively.

Keywords: Licenses, Sales, De-addiction center, Directly affected population, Indirectly affected population, Policies.

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1 Introduction

Alcohol consumption in India has been steadily rising, leading to a significant burden on public health and societal well-being [1]. This issue closely aligns with Sustainable Development Goal 3.5, which aims to address substance abuse [2], including alcohol addiction [3]. In Karnataka, specifically, alcohol sales have surged over the past decade, with a 43.5% increase from 2007 to 2017, contributing substantially to the state's tax revenue [4]. However, this increase in sales correlates with a rise in alcohol addiction cases, highlighting the urgent need for preventive measures and treatment facilities. Statistics reveal a concerning trend, per capita alcohol consumption has nearly tripled over the past two decades, reaching 5.5 liters consumption per adult per year in 2021 [5]. Approximately 32% of Indians consume alcohol, with a notable increase in daily consumers. In Karnataka alone, around 14% of the population, totaling 9.45 million people, is alcohol consumers. This escalating consumption is attributed to various factors, including societal norms, celebratory occasions, and coping mechanisms for stress and hardships. Financial implications of alcohol consumption are significant, particularly for disadvantaged households [4]. On average, these house-holds allocate 5% of their monthly budget towards alcohol expenses, affecting their overall economic stability. Moreover, increased alcohol consumption poses severe health risks, including coronary heart disease, brain damage, pancreatitis, and mental health disorders. To address the growing challenge of alcohol addiction, the Indian government has established drug dependence treatment centers across the country, including 34 in Karnataka [6]. These centers offer rehabilitation programs aimed at the socio-economic recovery of individuals struggling with addiction. However, the capacity of these centers remains limited, with each facility accommodating a maximum of 15 to 60 beds and a 90-day stay limit per inmate. Government policies regarding alcohol regulation vary across states and localities, influencing production, consumption, taxation, and legal drinking age [7]. In Karnataka, the minimum drinking age ranges from 21 years, depending on specific regulations. Recent budget initiatives have aimed to curb alcohol consumption by increasing excise duties, yet challenges persist in effectively mitigating addiction rates. Dry days, during which alcohol sales are prohibited, represent another policy approach to reduce consumption. However, the average affected population in Karnataka remains at 11%, indicating the need for more comprehensive strategies to address alcohol-related issues. The rise in alcohol consumption in Karnataka poses significant challenges to public health, social well- being, and economic stability[8]. While government efforts to establish treatment centers and implement regulatory measures are commendable, they fall short of addressing the scale of the problem. More comprehensive approaches, including increased access to treatment facilities, targeted prevention programs, and stricter regulations, are essential to mitigate the harmful effects of alcohol addiction and promote a healthier society [9].

2 Related Works

2.1 Review of Literature

Benegal, V. et al. [10], the authors examined the social cost of alcoholism in Karnataka based on a study of 113 patients at a de-addiction center. They calculated the annual loss faced by alcohol-dependent individuals due to absenteeism to the work, alcohol expenditure, and loans. They also evaluated the state's revenue from alcohol taxation and health payments, along with hospital costs. The study found that alcoholism's social costs outweighed benefits from alcohol sales and taxation, imposing a significant economic burden. They also noted policy limitations leading to illicit liquor tragedies, suggesting the need for improved cost estimates, and addressing public health aspects of alcohol.

Gupta, S. et al. [5] analyzed alcohol consumption in India by using the data of the National Survey on the magnitude of substance use in India in 2019.Their study shows that Karnataka represents an excess of 45 percent of all the alcohol sold in India, which can cause a significant burden on public health.

Aditya Sharma and Dikshant Sharma [6] conducted a review of 32 papers and stated that counseling and treatment practices play an important role during drug de-addiction in rehabilitation centers. Their study suggests incorporating drug abuse education in schools, interconnecting rehabilitation centers, and implementing better monitoring systems.

Murthy, P. et al. [11] has emphasized alcohol use among adolescents in India. Their study describes how alcohol usage among adolescents and the initiation of use at an early age is risking their health. They have conducted a systematic review of fifty-five peer-reviewed papers and relevant online databases. Based on narrative synthesis they concluded that the mean age of initiation of drinking was between 14.4-18.3 years. There is still a lot of scope in understanding the reason for the use of alcohol in adolescents and might provide a direction to policymakers.

National Institute on Alcohol Abuse and Alcoholism [12] examines alcohol use in India, emphasizing a scientific approach to understanding and addressing related problems. It highlights the increased risk of road accidents, poisoning, and injuries due to intoxication, as well as the negative impact on family conditions. The research underscores the shortcomings of current policies and advocates for a more scientific approach in policy design to effectively address these issues.

Gururaj, G. et al. [13], the focus is on alcohol-related harm to public health and the necessity for effective control policies in India. The report highlights the escalating risk due to increased availability and consumption of alcohol. It advocates for a scientific, systematic, and coordinated approach to tackle this issue. Strategies proposed include reducing availability and demand, early risk recognition, community empowerment, and implementing a national alcohol control policy. The report underscores the importance of evidence-based, culturally specific, and sustainable policies with an integrated approach to address alcohol-related harm and risks effectively.

Neha D. Sirur et al. The Public Health Foundation of India report [14] delves into alcohol marketing and regulatory policies in India, covering production, distribution, sales, and consumption trends. Notably, it underscores the shifting of drinking patterns, particularly the increased alcohol consumption among women and youth. The report advocates for national-level legislation to address fragmented policies. Key strategies proposed include regulating alcohol marketing, enforcing stringent drink-driving laws, modifying drinking contexts, promoting education and community engagement, and improving treatment and intervention services.

Ambedkar,A. et al. [15], a survey on substance use in India found a significant prevalence, mainly alcohol consumption. The study employed House-hold Sample and Respondent Driven Sampling Surveys. Shockingly, the survey revealed a ratio of 1 woman to 17 men consuming alcohol. This highlights a substantial population affected by substance abuse, urging the need for urgent intervention. However, treatment services are inadequately covered, emphasizing the necessity for policies and programs to address this public health concern. State-level surveys are recommended to identify priority districts for targeted interventions.

As evidenced by the literature survey, numerous studies have explored various facets of alcohol use in India, including its social costs, treatment practices, adolescent consumption, prevalence, and regulatory environment. In this study, we gathered data on alcohol licenses, sales, consumption, impact, affected population, and the number of hospitals and de-addiction centers in Karnataka. Through analyzing alcohol sales, licenses, and evaluating treatment centers, we assessed the affected population. Calculating the ratio of individuals undergoing treatment to those without access highlights the urgency for effective policy interventions.

3 Methodology

In this section, methodology of proposed work is discussed. The process was executed using Jupyter Notebook, utilizing Python version 3.10.9 as the chosen programming environment.

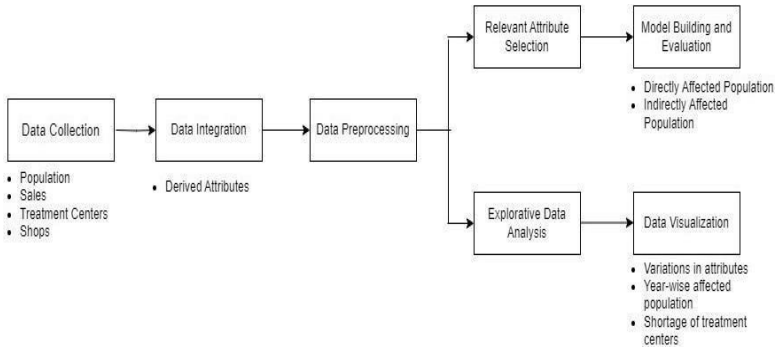

Figure 1. Proposed System Model

The proposed system model is as shown in Figure 1. It illustrates the steps involved from data collection to model building. The process begins with collecting data from various sources, such as population statistics, sales records, treatment centers, and shops. This data is then integrated into a cohesive dataset, which is subsequently pre-processed to ensure its quality.

Pre-processing transforms raw data into high-quality data suitable for further analysis. This stage, facilitates both, model building through attribute selection and data visualization. Relevant attributes are selected for building predictive models to estimate the directly and indirectly affected population.

Exploratory data analysis is also conducted to visualize variations in attributes, track the year-wise affected population, and identify shortages in treatment centers. The outcome of this process includes building and evaluating predictive models and generating insightful visualizations to aid decision making. The predictive models used in this system include Linear Regression, Random Forest, and KNN[K-Nearest Neighbors].

3.1 Data Source and Preprocessing

The data collected is publicly released data from the government of Karnataka's official website[16]. The data includes shops, licenses given, and variation of alcohol sales, the total population, Risk level according to the per day consumption, the treatment centers which include the government and private health facilities over the 5 years in Karnataka. The State-wise population and the affected population are considered first. Then it is drilled down to the data of Karnataka State. Sales data is taken from the Karnataka state excise website [17]. This data consists of year-wise sales of IML [Indian Made Liquor] and growth percentage from the year 2017 to 2023 in each of the districts. The individual growth of each year is specified in the raw data.

The data regarding alcohol licenses are obtained from the Karnataka State Beverages Corporation Limited website. This consists of data regarding different types of licenses along with the retailer's name, retailer's address, PIN code, and city in each district. The data on population of each district is taken from the India census website. The percentage of affected people by consumption of alcohol is taken from the ground report. On an average, the percentage of the population consuming alcohol in

Karnataka is 11 percent. Per day consumption indicates the volume of alcohol consumed by an individual per day.

The district-wise data on per-day consumption is not available. So, to derive this attribute, pre-existing attributes from the dataset like sales, directly affected population [18] and percentage of population consuming alcohol are used. Hence per day consumption can be derived. Considering that each carton box contains 12 bottles of liquor and average liquor sold in a bottle is 750ml[19], THE formula for the affected population can be calculated using following equations.

$$\text{Directly affected population [X]} = \text{district population} \times 0.11 \tag{1}$$

$$\text{Yearly consumption of Alcohol in ml(Y)} = \text{number of carton boxes} \times 12 \times 750\ \text{X} \tag{2}$$

$$\text{Per day consumption in ml(D)} = \text{Y} \tag{3}$$

For instance, the total population of Dharwad district is 2,104,129.

$$\text{Affected population(X)} = 2104129 \times 0.11 = 231454 \tag{4}$$

$$Yearly\ consumption\ of\ Alcohol\ in\ ml(Y\ ) = \frac{1687791 \times 12 \times 750}{231454} = 65629.1\ \text{ml} \tag{5}$$

$$Per\ day\ consumption\ in\ ml(D) = \frac{65629.1}{365} = 179.8\ ml \tag{6}$$

Data on total treatment centers which include hospitals and the de-addiction centers consisting of IRCAs and private rehabilitation centers are obtained from rehabs.in and justdial.com.

The total missing value percentage is 3.33% in two of the columns. The missing values of the attributes are filled by the backward fill or ”bfill” method. The bfill method is a vectorized operation in pandas, which takes advantage of underlying optimized implementation in NumPy. In the bfill method, the missing values are replaced by the values in the next row. For example, in the attribute sales 2019-20, the value of Bagalkot district is missing. Nan is the missing value which must be replaced by the value in the next row i.e., Vijayapura District which has value 1275876. As a result of using ’bfill’ method the sales 2019- 20 of Bagalkot District will be 1275876. After data cleaning, the datasets of population, sales, and licenses are integrated to form a single dataset. After integration, the data is normalized using ‘z-score’ normalization technique so that all the values fall under the same range. As there are negative values in the dataset hence ‘z-score’ is used as it ranges from -3 to +3.

3.2 Exploratory Data Analysis and Interpretation

According to the guidelines provided by the State Excise Department of Karnataka, the state is divided into 6 divisions to ease the data visualization and analysis. Table 1 depicts the divisions and their respective districts.

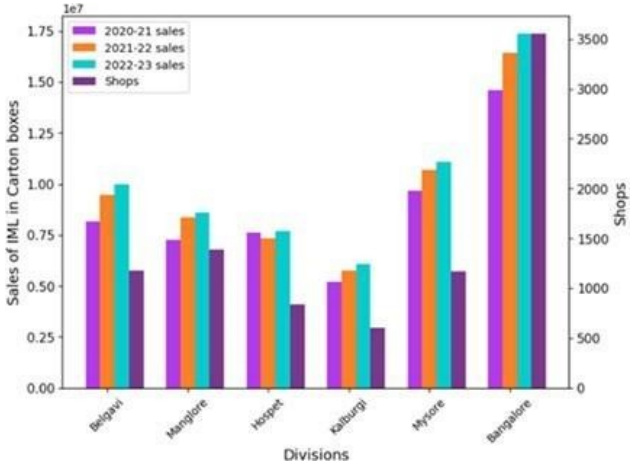

Figure 2. Number of shops and sales of IML in each division

Table 1. Division and Associated Districts

Division	Name of Districts
Belagavi	Belagavi, Dharwad, Vijayapura, Haveri, Bagalkot
Mangalore	Dakshina Kannada, Kodagu, Shivamogga, Udupi, Uttar Kannada
Hospet	Bellari, Chitradurga, Davangere, Gadag, Koppal
Kalburgi	Kalburgi, Yadgiri, Bidar, Raichur
Mysore	Chamarajanagar, Chikkmangaluru, Hassan, Mandya, Mysuru
Bangalore	Bangalore Urban, Bangalore Rural, Kolar, Ramnagara, Tumkuru, Chikballapur

Figure 2 shows the total number of shops in each division of Karnataka when compared to sales each year. In Belagavi division, around 8400 carton boxes were sold in 2022-23 similarly 6200, 9100, 9900 and 9400 carton boxes were sold in Mangalore, Hospet, Kalburgi and Mysore divisions respectively while 4800 carton boxes per shop were sold in Bengaluru division in 2022-23 which has 3557 shops. Figure2 also depicts the sales trends for the past 3 years from 2020-23,

Which has a linear growth. In the year 2022-23 growth accounts for 5.3% for the Belagavi division, 3.1% for the Mangalore division 5.03% for the Kalburgi division, and 3.6% for the Mysore division, and 5.52% for the Bangalore division but in Hospet division the sales have dropped in the year 2021-22 to 3.4% and again increased 3.6% in 2022-23. The growth in sales indicates the varying strata of consumption of alcohol across all the divisions from 2020-2022.

Table 2. Divisions and Consumption Growth

Division Consump	Ption Growth 2020-21[%]	Consumption Growth 2021-22 [%]
Belagavi	-3.34	15.2
Mangalore	-3.5	12.5
Hospet	-23.5	-4.9
Kalburgi	-20.8	10.7
Mysore	2.1	10.2
Bengaluru	5.3	9.8

Table 2 shows that the per capita consumption growth for the year 2020-21 was predominantly negative. This decline is attributed to people reducing their alcohol consumption due to the corona virus pandemic, except for the Mysore and Bangalore divisions. The per capita consumption for the year 2021-22 has rapidly increased in all the divisions except the Hospet division. This interprets that the per capita consumption of alcohol is having an upward trend which can be the result of one of two things: More population has started drinking alcohol or the existing population is drinking more than they used to. As consumption increases, the limit risk level also increases and vice-versa. According to World Health Organization [WHO] the risk level is categorized into four categories: low [1-40g], Medium [41-60g], High [61-100g], Very high risk[greater than or equal to 100] for males. Usually, Risk level is measured in grams according to a mathematical formula determined by World Health Organization.

$$\text{Risk Level} = \text{Average Quantity of Consumption} * \text{Ethanol Content} * \text{Density of Ethanol} \quad (7)$$

Above Equation 4 shows the risk level in ranges. For instance, consider the Dharwad district:

- The average quantity of alcohol consumption = 207.58 ml
- Ethanol Content = 0.400
- The density of Ethanol = 0.789g/ ml

Hence Risk Level = 207.58 * 0.400 * 0.789 = 65.64 grams which shows that Dharwad district lies in High-Risk Zone. The affected population includes the people who drink above the mentioned limit which is set by the World Health Organization which depicts that for women high risk is defined as drinking more than 2.9 drinks and for men, more than 4.3 drinks a day. The people who are at high or very high- risk levels require medical health facilities and treatment centers. Treatment centers include hospitals, private rehabs as well as government IRCAs.

Table 3. Division-wisedata

Division	Directly affected population (in Lakhs)	Indirectly affected population (in Lakhs)	Risk level	Treatment centers
Belagavi	15.4	46.2	Medium	61
Mangalore	8.2	24.6	High	74
Hospet	10.6	31.5	High	47
Kalburgi	9.8	28.2	Medium	27
Mysore	10.2	30.6	High	72
Bangalore	24.2	72.6	High	146

Table3 shows the data regarding the directly affected population due to alcohol consumption in 2022 and indirectly affected population in the year 2022, risk level, and number of treatment centers in each division. The calculation for the directly impacted population, referring to Equation 1, where, directly affected population = district population x 0.11 where the factor 0.11 is employed, accounting for the 11% prevalence of the issue according to the National Family Health Survey. In the context of Karnataka, considering an average household size of 4 members, it is assumed that a single family member is directly affected. This exclusion leads to 3 additional individuals being indirectly affected. Therefore,

$$\text{Indirectly affected population} = \text{Total population Directly affected population} \quad (8)$$

Having explored the information about per capita consumption of alcohol, the consumption of alcohol is due to the alcohol consumers and shops. The number of alcohol consumer per shop in each division depends on the number of people who are going to buy alcohol from each shop.

Table 4. Divisions and Shops and Hospitals

Division	Alcohol consumers per shopper year (Lakhs)	Directly affected population (in Lakhs)	Alcohol consumers getting treated per hospital per year (Lakhs)	Alcohol consumers One Year (in Lakhs)
Belagavi	1305	15.4	27086	15.1
Mangalore	590	8.2	12736	8
Hospet	910	10.6	24345	10.3
Kalburgi	1543	9.8	36706	9.4
Mysore	863	10.2	16177	10
Bangalore	680	24.2	15804	24.1

From Table4, it is evident that the number of alcohol consumers per shopisin multiples of hundreds, while the number of alcohol consumers for each hospital in one year varies from several thousand to lakhs. This indicates that the number of people who are left untreated is more than 75% in each division. In the Bengaluru division, the proportion of people who are left untreated is 95%. This suggests that the present treatment centers are not sufficient to treat even 50% of the total affected population, which implies that:

- Either the number of beds in each of the treatment centers can be increased, or
- The number of treatment centers can be increased.

4 Results and Discussion

The relevant attributes for model building were selected based on a pair plot and Pearson's correlation matrix, considering correlations greater than 0.7. The chosen attributes include IML sales from 2017-18 to 2022-23, directly affected population, indirectly affected population from 2020 to 2023, total licenses, number of shops, and risk level.

Table 5. Model and their parameters

Affected	Population	Type	Method	Accuracy	RMSE
Directly	affected	population	Linear Regression	96%	0.0205
Indirectly	affected	population	Linear Regression	94%	0.052

Data was normalized using the Standardization method and divided into 80% training and20% test data. A heat map was used to extract15 features based on correlation. The target variables were 'Directly affected population 2023' and 'Indirectly affected population 2023'. Linear regression was employed for both, as the directly and indirectly affected populations are linearly proportional to population growth. The linear regression models achieved an overall accuracy of 96% for directly affected population prediction and 94% for indirectly affected population prediction, with an RMSE of 0.0205 and 0.052 respectively as given in Table 5.

4.1 Comparison with other Models

To validate the robustness of the Linear Regression model, its performance was compared with Random Forest and K-Nearest Neighbors [KNN] models.

Random Forest:

- Directly affected population : Accuracy = 84.6%, Loss = 0.2
- Indirectly affected population : Accuracy = 85%, Loss = 0.11

K-Nearest Neighbors [KNN]:

- Directly affected population : Accuracy = 75%, Loss = 0.85
- Indirectly affected population : Accuracy = 75%, Loss = 0.7

Linear Regression outperformed both Random Forest and KNN models in terms of accuracy and RMSE for predicting the affected populations. This is primarily because Linear Regression provides a straightforward relationship between variables, making results easy to interpret. Its high accuracy and low RMSE indicate effective trend capture with minimal error. Additionally, its well-suited for linearly related data and is computationally more efficient compared to the other models.

4.2 Prediction for Impact of Alcohol Consumption

The linear regression model predictsthatthedirectlyaffectedpopulationin2023 will continue to rise, impacting approximately 13.6% more individuals. Similarly, the indirectly affected population is expected to increase by 13.7%. This growth highlights a significant public health concern, as the trend indicates an escalation in the number of individuals directly and indirectly suffering from alcohol-related issues.

5 Conclusion

Addressing the growing issue of alcohol addiction in Karnataka demands urgent action aligned with Sustainable Development Goal [SDG] 3.5. Statewide alcohol sales surged by 26.38% from fiscal year 2019-2020 to 2022-23, contributing to a 9.3% increase in per capita consumption. This economic trend, however, conceals a critical public health concern affecting directly 53.2 lakhs and indirectly 1 crore 59 lakhs, leading to physical and mental health issues [20]. The existing treatment infrastructure of 427 centers is inadequate, with each center handling around 18,300 individuals annually, leaving approximately 76.9 lakh untreated each year. As the population grows by 1.1% annually, an estimated 1.2 lakh individuals annually will enter the high-risk zone. Urgent measures are needed to bridge this treatment gap and meet evolving community needs.

Recommendations include strengthening alcohol serving restrictions, prioritizing public health concerns, expanding treatment center capacities, and implementing comprehensive awareness campaigns [13]. By enhancing policies, allocating more resources to prevention and treatment, expanding treatment facilities, and advocating for legislative changes to support rehabilitation and community programs, Karnataka can effectively combat alcohol addiction and mitigate its impact on the population. Looking ahead, Karnataka has as significant opportunity to expand its efforts in addressing alcohol addiction through innovative approaches. Future initiatives could focus on integrating technology into treatment delivery, enhancing community-based support systems, advancing research into addiction prevention and treatment, and advocating for evidence based policies that prioritize public health [21]. By leveraging these strategies, Karnataka can foster a more comprehensive and effective response to alcohol addiction, ensuring better outcomes for individuals and communities across the state.

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