Bangalore traffic insights

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1.0 Introduction

This project aims to visualize urban traffic patterns in Bangalore using an interactive R Shiny application. Bangalore is a densely populated metropolitan city with chronic traffic congestion. Through this project, we explore traffic patterns and investigate factors impacting congestion and travel time using a range of visual analytics. The goal is to uncover hidden patterns in the data that may help decision makers in finding data driven solutions to alleviate the traffic problem in the city

Our approach is rooted in storytelling through data. We designed our presentation and application in a logical sequence that starts with exploratory data visualizations to understand the dataset's structure and relationships. This is followed by a focus on compliance, traffic patterns, roadwork influence, year-on-year trends, and weather impact. This structured order was chosen to gradually shift from general traffic behavior to external and long-term influencing factors.

The final output is a functional, accessible web-based dashboard that empowers users—planners, residents, and analysts—to explore Bangalore's traffic dynamics visually.

2.0 Dataset Selection and Relevance for Data Visualization

The dataset we used titled **"Bangalore's Traffic Pulse"**, was sourced from Kaggle, it contains 8936 record and 16 features. The dataset offers a comprehensive view of traffic patterns across major roads and intersections in Bangalore, India. It encompasses metrics such as traffic volume, speed, and congestion levels, providing valuable insights into urban mobility challenges.

2.1Complexity:

- **Data Granularity:**
  The dataset provides fine-grained details such as individual road segment measurements, specific dates, and location identifiers. This enables both localized analyses (e.g., specific intersections) and broader city-wide patterns.

- **Multivariate Relationships:**
  The dataset includes multiple features (e.g., congestion level, road capacity utilization, number of vehicles, and pedestrian/cyclist counts). Exploring interactions between these variables requires multivariate analysis and visualizations that go beyond basic plots.
- **Spatial Complexity:**
  Because traffic is inherently spatial, the dataset's geographical components (like junction names and road segments) demand visualizations such as geospatial heatmaps, network graphs, or map overlays using tools like leaflet or ggmap.
- **Dynamic and Non-linear Behavior:**
  Traffic flow is influenced by numerous unpredictable factors such as roadworks, accidents, and weather conditions. This introduces non-linearity, making visualization and interpretation more challenging.
- **Categorical and Continuous Mix:**
  The dataset features both categorical data (e.g., compliance type, junction names) and continuous variables (e.g., speed, vehicle count), requiring thoughtful visualization choices that effectively communicate mixed data types.

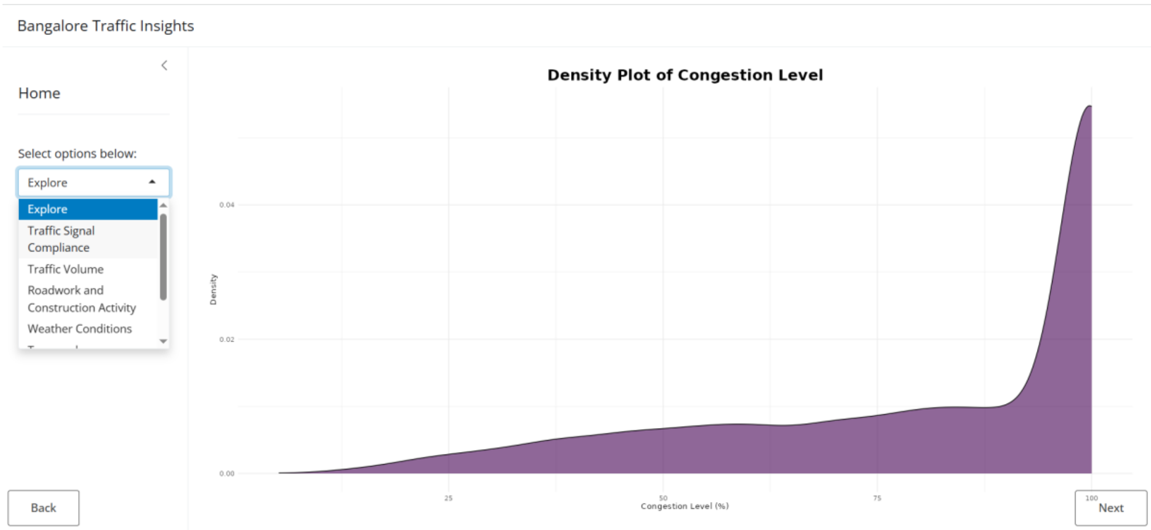
2.2 Appropriateness:

- **Urban Planning and Policy Analysis:** The dataset's detailed traffic metrics are instrumental for urban planners and policymakers aiming to understand congestion hotspots and devise mitigation strategies.
- **Academic Research:** Researchers focusing on transportation engineering, urban studies, or data science can leverage this dataset to model traffic behaviors and assess the efficacy of traffic management interventions.
- **Public Awareness:** Visualizations derived from this data can inform the public about traffic trends, promoting informed commuting decisions and fostering community engagement in traffic solutions.

3. GUI Design and Functionality

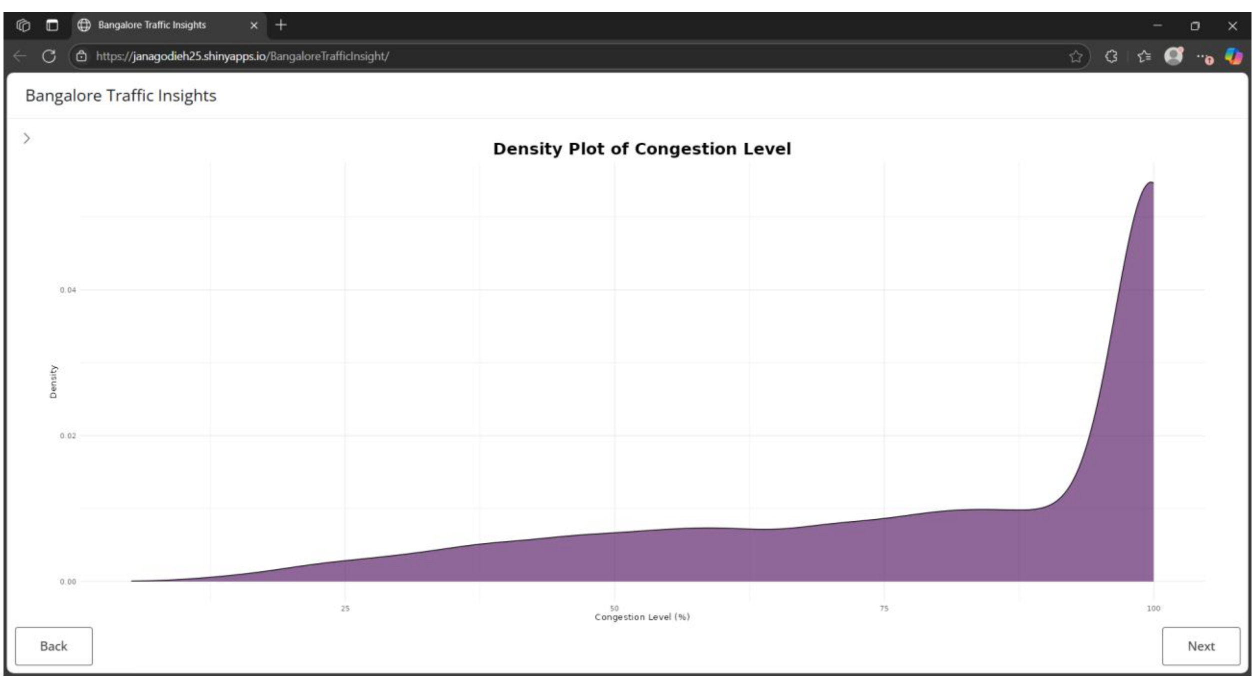
The graphical user interface (GUI) for the project was built using the **R Shiny** framework. This framework was selected due to its capability to produce interactive web applications with a responsive and user-friendly design.

Our Shiny app provides a clean, structured, and interactive dashboard that allows users to explore multiple traffic-related visualizations. The interface includes a side bar containing a drop down menu, each item in the menu is dedicated to a specific type of analysis or visualization. The app includes **30 plots**, categorized under 8 main sections:
Data Exploration, Compliance, Traffic Volume, Roadwork, Yearly Trends, and Weather Effects, Deeper Dive and Expanded Analysis.

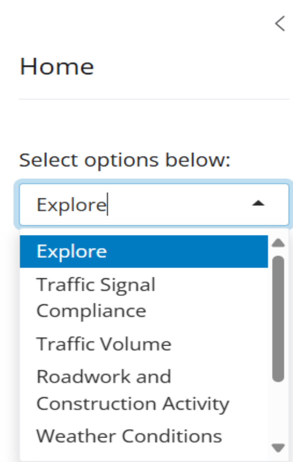


User manual

Main Graphical User Interface



The **Bangalore Traffic Insights** dashboard provides an interactive and user-friendly interface for exploring traffic data across the city. When you open the application through the link : "Bangalore Traffic Insights", you'll see a clean layout with the title at the top, a sidebar on the left only triggered when clicking on the small arrow in the top left corner , a central plot area for visualizations, and navigation buttons at the bottom. The dashboard is responsive, and plots are dynamically updated based on user selections.



Select Options Panel (Sidebar)

On the left side of the screen, you'll find a dropdown menu labeled "Select options below:" This is the core control for what data is displayed. By clicking the dropdown, you can scroll and choose from several traffic-related indicators, including:

- Traffic Signal Compliance
- Traffic Volume
- Roadwork and Construction Activity
- Weather Conditions
- Temporal
- Deeper Dive
- Expanded Analysis

Once an option is selected, the main display will automatically refresh to show a plot or graph relevant to that metric. This selection panel allows you to explore different aspects of the traffic system with just a single click.

Navigation Buttons (Bottom)

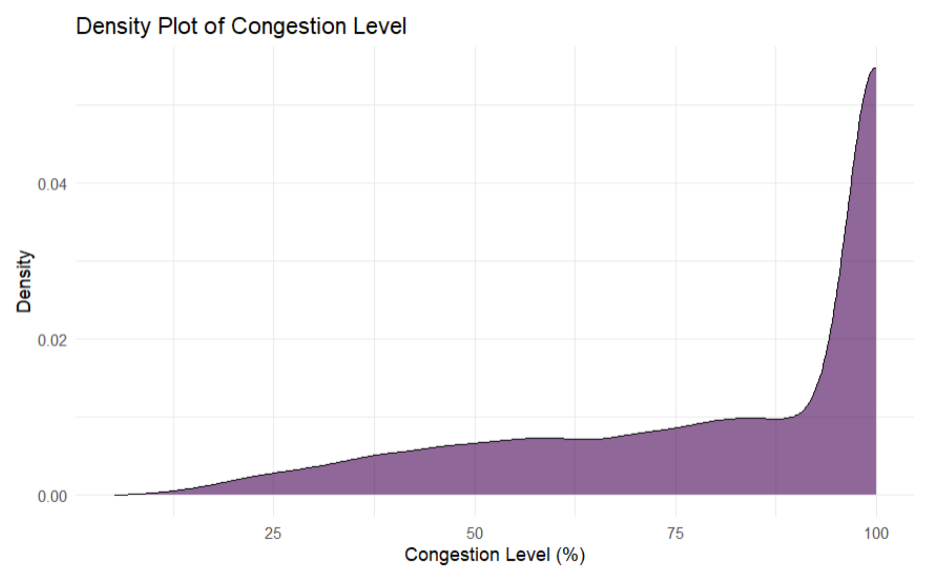
At the bottom corners of the interface, you'll see **Back** and **Next** buttons. These let you move through the dashboard's visualizations in sequence. Clicking **Next** advances to the following plot, while **Back** returns you to the previous one. This allows users to follow the data narrative at their own pace.

4.0 Technical stack:

Data visualization analysis

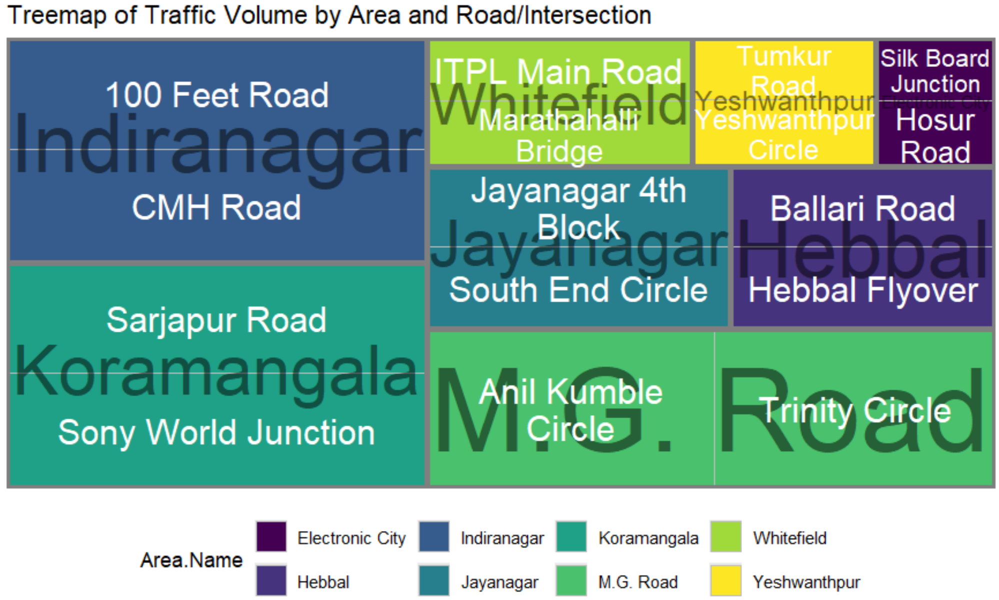
(Exploration plots)

1.Density plot of congestion level:



Most of the data is concentrated around a very high congestion level, close to 100%, indicating that severe traffic congestion is the most common pattern in the city. This suggests that the city of Bangalore frequently experiences heavy traffic jams, as the majority of the values appear on the right side of the curve (High Congestion Levels).

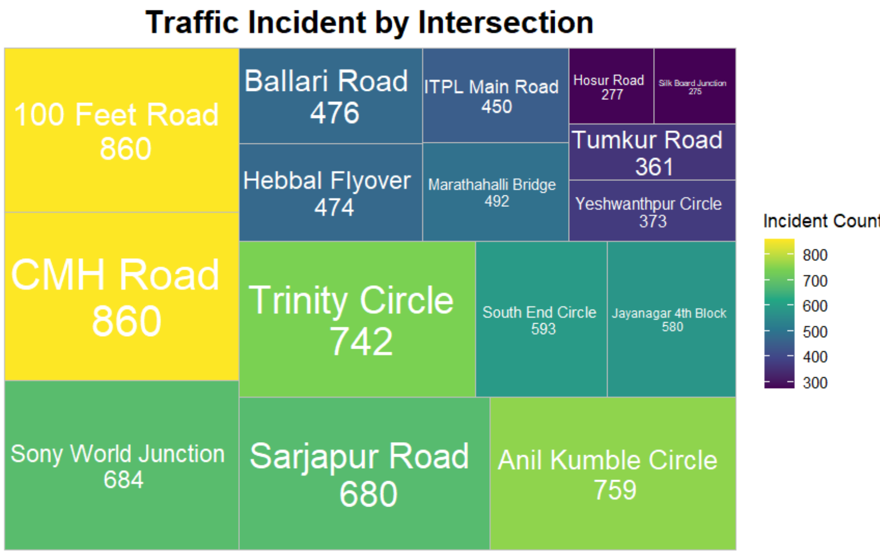
2. TreeMap of traffic volume by area and Road/ Intersection:



The tree map in the image illustrates the distribution of traffic volume in Bangalore by area and main roads. It is clear that areas such as Indiranagar (especially 100 Feet Road and CMH Road), Koramangala (including Sarjapur Road and Sony World Junction), and M.G. Road (Anil Kumble Circle and Trinity Circle) have the highest traffic volumes compared to other regions.

This suggests that these areas are major hubs of traffic congestion in the city and should be considered critical points when planning solutions for traffic management and regulation in Bangalore. In contrast, areas like Electronic City, Yeshwanthpur, and Whitefield appear with smaller sizes, indicating that their traffic volumes are relatively lower.

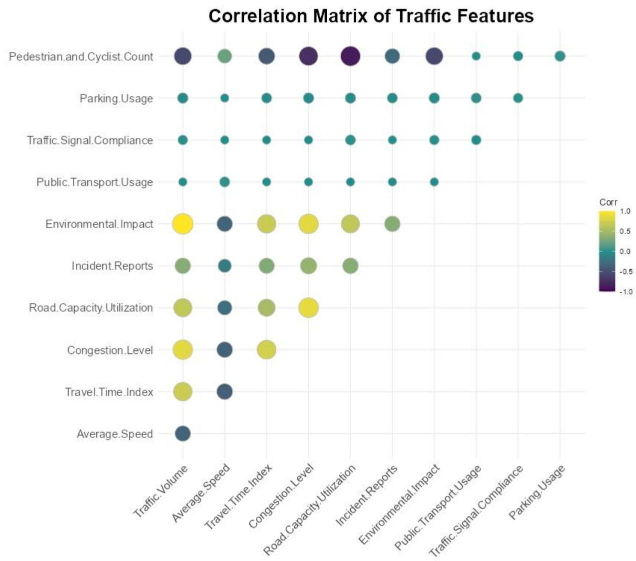
3.TreeMap of traffic incident by intersection:



The treemap shows the distribution of traffic accident counts across major intersections in the city of Bangalore. By observing the size and color of the boxes, it is evident that intersections with high traffic density—such as "100 Feet Road" and "CMH Road" (with 860 accidents each), followed by "Anil Kumble Circle" (759 accidents) and "Trinity Circle" (742 accidents)—record the highest number of accidents. This indicates a clear positive correlation: the higher the traffic volume at an intersection, the greater the number of accidents recorded.

In contrast, intersections like "Silk Board Junction," "Hosur Road," and "Yeshwanthpur Circle" reported fewer accidents, which may lower traffic density in those areas.

4.Correlogram



The diagram shows the relationship between each pair of features. There is a strong positive correlation between traffic volume and the following:

- Incident reports
- Congestion level
- Road capacity utilization
- Travel time index

This means that as traffic volume increases, environmental impacts, the number of incidents, road utilization, congestion, and travel time all increase as well.

#There is a clear negative correlation between average speed and both:

- Congestion level
- Travel time index

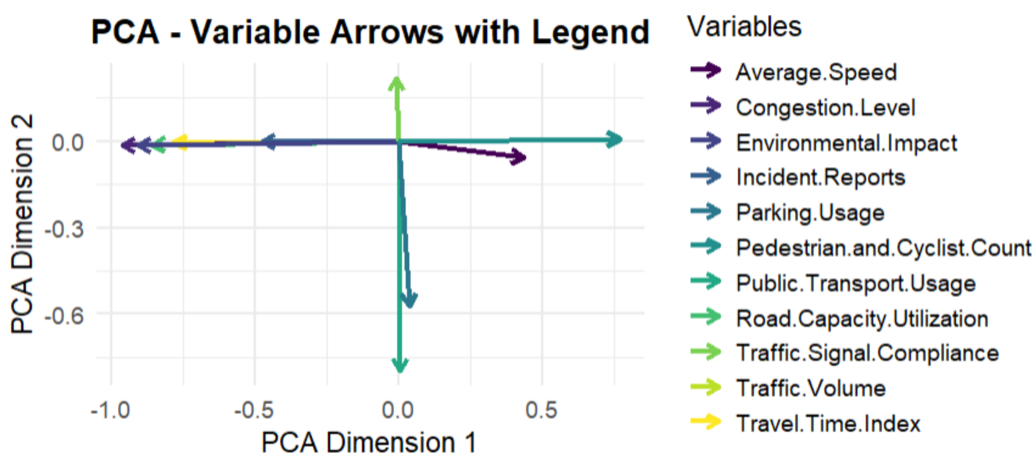
In other words, as congestion or travel time increases, the average speed of vehicles decreases.

There is a weak or almost negligible correlation between some indicators, such as:

- Parking usage
- Traffic signal compliance
- Public transport usage

and the other features. This suggests that their impact on congestion, incidents, and environmental effects is limited in this context.

5.PCA



- PCA Dimension 1:

  Most variables (such as traffic volume, environmental impact, incident reports, road capacity utilization, congestion level, and travel time index) strongly point to the left on the horizontal axis, indicating that these factors are highly correlated and collectively explain the main variance in the data. One of them is associated with the increase of the other features, and they all move in the same direction, suggesting that an increase in traffic volume is linked to increases in the other features.

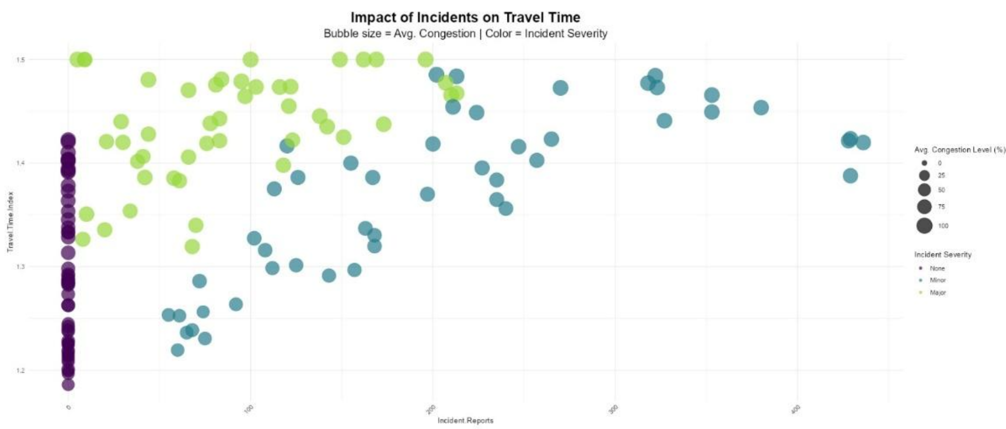
  The arrow representing average speed points almost in the opposite direction to the cluster of variables related to congestion and traffic volume, confirming a strong inverse relationship: as congestion and traffic volume increase, the average speed decreases.

- PCA Dimension 2:

  Some variables, such as public transport usage and pedestrian and cyclist count, point downward, indicating that they explain a different variance than the other variables. This suggests that changes in these factors may not have a direct impact on traffic flow or congestion.

Some variables, such as traffic signal compliance and parking usage, have short arrows or arrows overlapping with the axis, indicating that their impact on the main variance in the data is less significant compared to other factors.

6.Bubble Plot

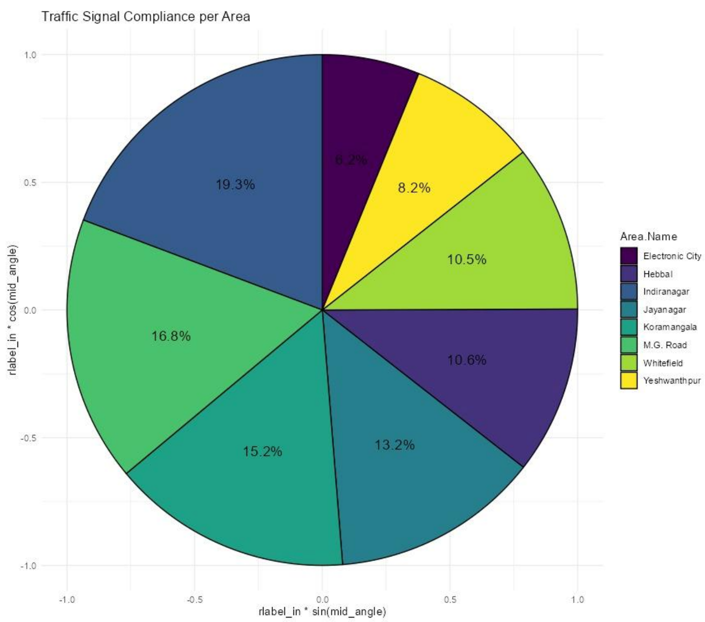


Relationship between Incidents and Travel Time:
The chart shows a positive correlation between the number of incident reports and the travel time index, where the travel time index increases as the number of incidents rises. This means that traffic incidents lead to longer travel times.

-Incident Severity:
Colors are used to represent the severity of traffic incidents.
It is observed that minor incidents (green color) are not concentrated in a specific location but rather spread across multiple areas. Additionally, in cases where there were no incidents or only low-severity incidents (red color), the travel time index still varied.
This suggests that incident severity does not have a impact on the travel time index.
The number of incidents increases, especially minor incidents, travel time and congestion levels also increase.
This indicates that the frequency and number of incidents have a greater impact on traffic volume in Bangalore than the severity of the incidents.

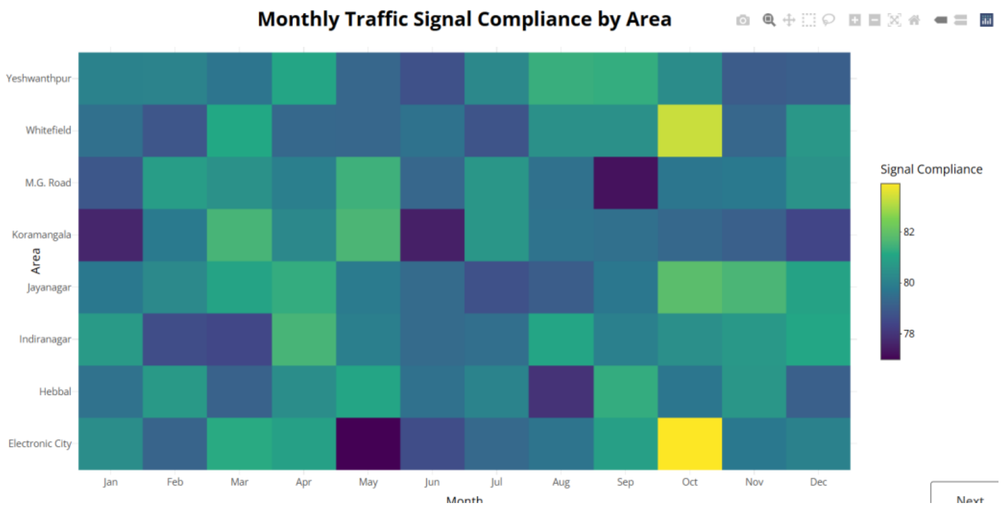
(Traffic Signal Compliance)

1. Pie chart



This pie chart visualizes the distribution of traffic signal compliance across different areas in Bangalore, highlighting which zones contribute most to overall compliance levels. **Indiranagar** leads with the highest share at **19.3%**, followed by **M.G. Road (16.8%)** and **Whitefield (15.2%)**, suggesting that these areas have a relatively strong culture of adherence to traffic signals or possibly better enforcement mechanisms. On the other end of the spectrum, **Electronic City** records the lowest contribution at **6.2%**, raising concerns about potential non-compliance issues in that zone. **Jayanagar**, **Koramangala**, and **Yeshwanthpur** show fairly balanced contributions, ranging between 8% and 13%. Overall, the chart underscores significant variation in traffic discipline across neighborhoods, which could influence both congestion levels and safety outcomes. These insights could guide targeted interventions, such as signal optimization or awareness campaigns, in lower-performing areas.

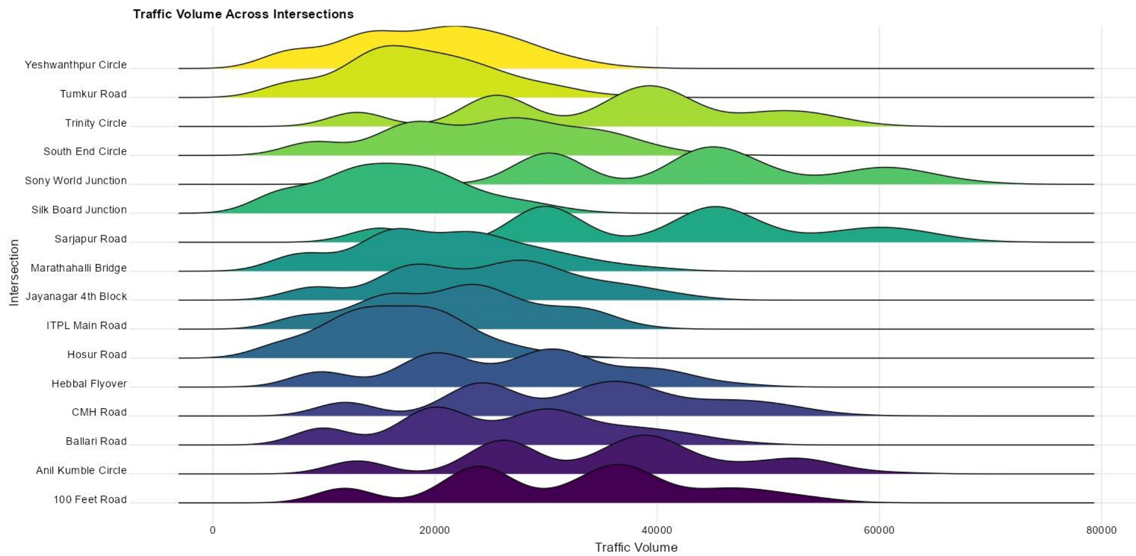
2. Heatmap



This heatmap reveals that while traffic signal compliance across Bangalore generally remains within a stable mid-range (around 78–82%), several areas experience **isolated monthly dips** that suggest short-term disruptions rather than persistent non-compliance. For instance, **Electronic City** shows a sharp drop in May, likely due to temporary enforcement lapses or traffic rerouting from nearby construction. **M.G. Road** experiences a notable decline in September, which may coincide with festival-related congestion or shifting traffic patterns. **Koramangala** sees low compliance in January and June—potentially tied to seasonal events or peak commuting stress. Similarly, **Hebbal** records a dip in August, and **Indiranagar** in March and June, both of which may reflect transient roadwork or traffic interventions. These fluctuations contrast with more stable areas like **Jayanagar** and **Yeshwanthpur**, which maintain consistent compliance throughout the year. Overall, the data suggests that **compliance issues are largely episodic and influenced by local context**, reinforcing the value of targeted, time-sensitive traffic management strategies.

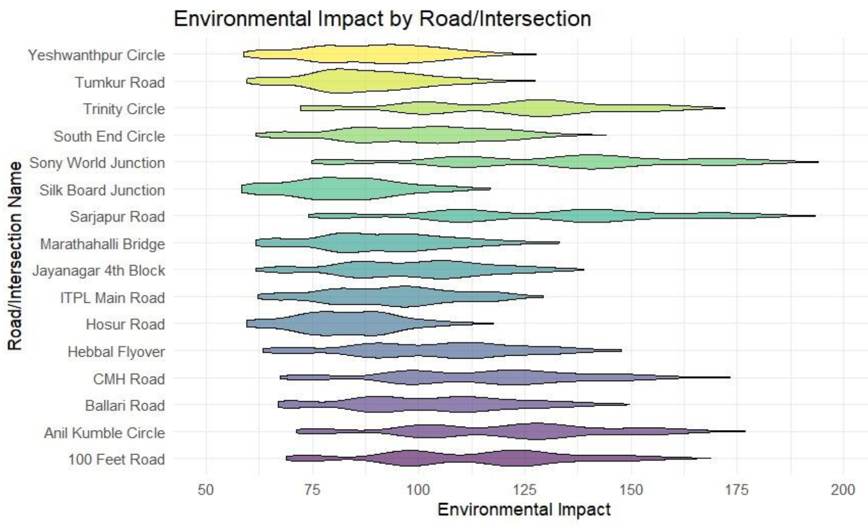
(Traffic Volume)

1. Ridgeline Plot



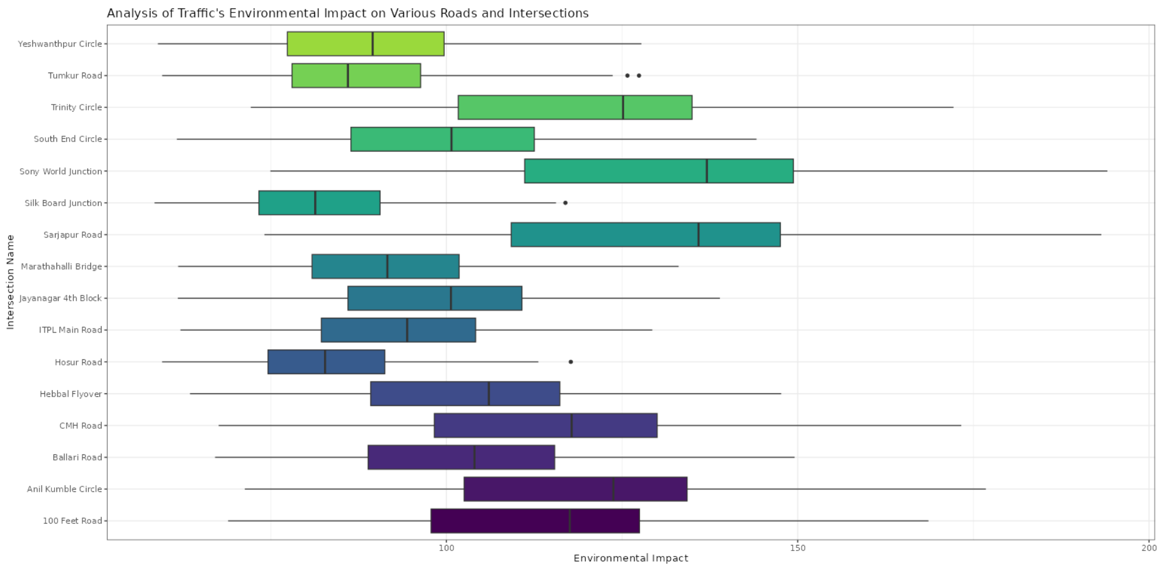
This ridgeline plot highlights the variation in traffic volume across major intersections in Bangalore, revealing both intensity and distribution patterns. Intersections such as Yeshwanthpur Circle and Tumkur Road exhibit consistently high traffic volumes, with broad peaks extending beyond 60,000 vehicles, underscoring their role as major city entry points. Similarly, Silk Board Junction, Sony World Junction, and Marathahalli Bridge also show sustained high traffic flow, marking them as critical congestion zones. In contrast, intersections like Trinity Circle and South End Circle display narrower or multi-peaked distributions, suggesting fluctuating traffic likely driven by time-of-day patterns or localized disruptions. ITPL Main Road and Hosur Road show long-tailed distributions, indicating regular traffic surges, while smoother, more symmetric curves at 100 Feet Road and Ballari Road suggest stable and predictable flow. Overall, the chart emphasizes which intersections are persistent hotspots and which face intermittent pressure, providing valuable guidance for targeted traffic management and infrastructure planning.

2. *Violin Plot*



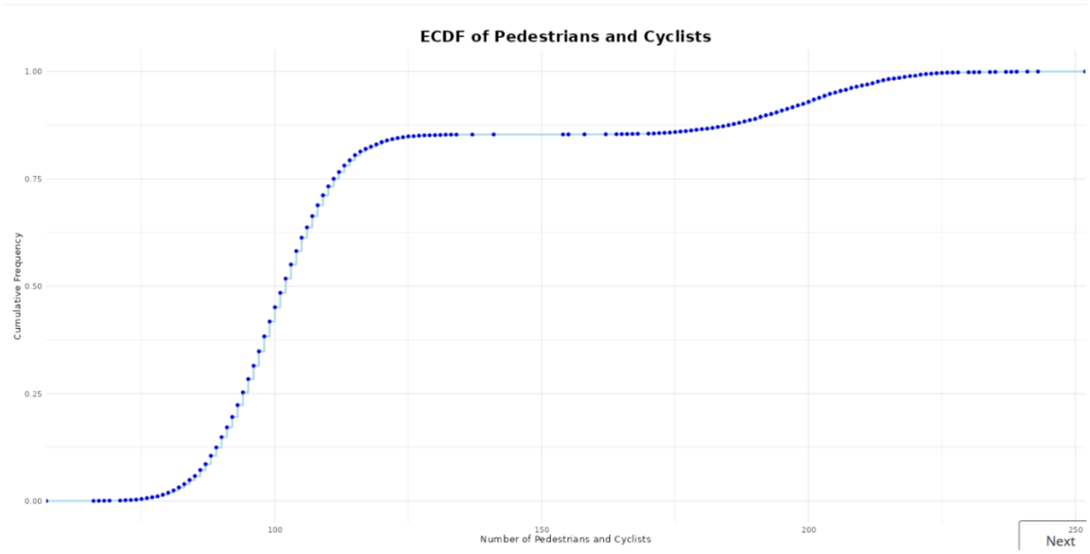
This violin plot presents the distribution of environmental impact scores across major intersections in Bangalore, offering insights into how traffic activity affects local environmental conditions. Intersections like Yeshwanthpur Circle, Tumkur Road, and Trinity Circle show the highest environmental impact levels, with tightly packed distributions concentrated around higher values—indicating consistently elevated pollution or emissions likely due to heavy and persistent traffic. In contrast, intersections such as 100 Feet Road, Anil Kumble Circle, and Ballari Road display wider, more varied distributions that extend into lower impact ranges, suggesting occasional but not sustained environmental stress. Mid-range areas like Silk Board Junction, Sarjapur Road, and Marathahalli Bridge exhibit broader distributions with moderate peaks, pointing to fluctuating traffic-driven environmental conditions. Overall, the plot highlights that intersections with high traffic volumes tend to correlate with greater environmental impact, though variability in some areas suggests that infrastructure design, signal timing, or vehicle types may moderate these effects.

3. Box Plot



This boxplot analysis provides a detailed comparison of the environmental impact caused by traffic across different roads and intersections in Bangalore, showcasing the distribution, central tendency, and variability in impact levels. Intersections such as Sarjapur Road, Trinity Circle, and Sony World Junction exhibit both high medians and wide interquartile ranges, indicating not only elevated pollution levels but also considerable fluctuation—possibly due to inconsistent traffic flow or localized environmental factors. In contrast, locations like Yeshwanthpur Circle and Tumkur Road have more compact distributions, reflecting consistently high environmental impact with minimal variability. A few intersections, including Silk Board Junction, Hosur Road, and Tumkur Road, show outliers, pointing to instances of extreme impact that could coincide with peak traffic hours, construction, or weather-related stagnation. Meanwhile, roads like 100 Feet Road, Ballari Road, and CMH Road exhibit relatively moderate and stable environmental profiles, suggesting better ventilation, infrastructure, or traffic regulation. Overall, the plot highlights that environmental impact is not solely a function of volume but also of traffic regularity, road design, and area-specific conditions.

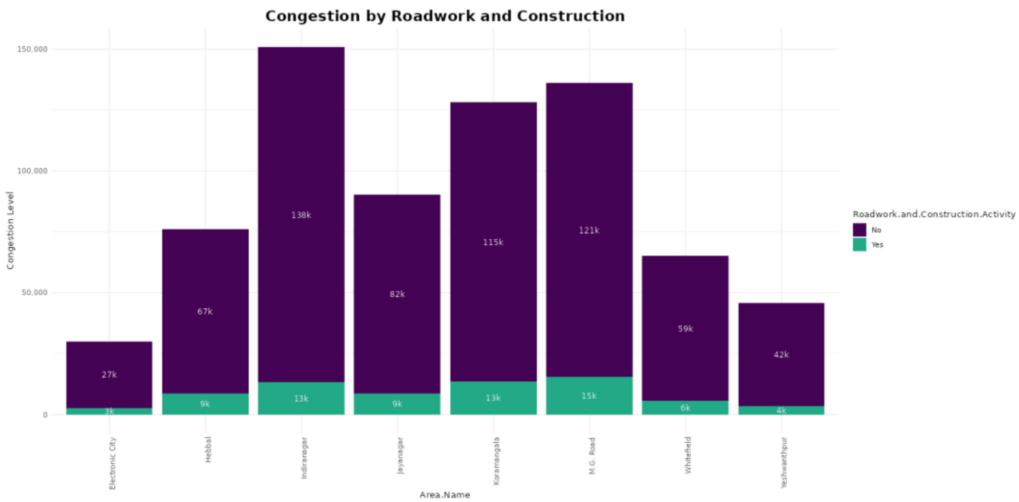
4. *ECDF*



This ECDF (Empirical Cumulative Distribution Function) plot provides a detailed view of the distribution of pedestrian and cyclist counts across Bangalore's intersections. The steep curve between roughly **90 and 130** indicates that most intersections report pedestrian and cyclist activity within this range—specifically, about **75% of the data** lies within this band. The gradual flattening beyond 130 suggests that **higher pedestrian and cyclist counts are relatively rare**, while the shallow slope at the beginning shows that very low activity levels (below 75) are also uncommon. This implies that pedestrian and cyclist traffic in Bangalore is moderately concentrated around a middle range, with only a few areas experiencing either extremely low or exceptionally high foot and cycle traffic. Such insight supports targeted infrastructure planning, indicating that most locations would benefit from moderate pedestrian/cyclist facilities, while a smaller number may require high-capacity walkways or safety interventions.

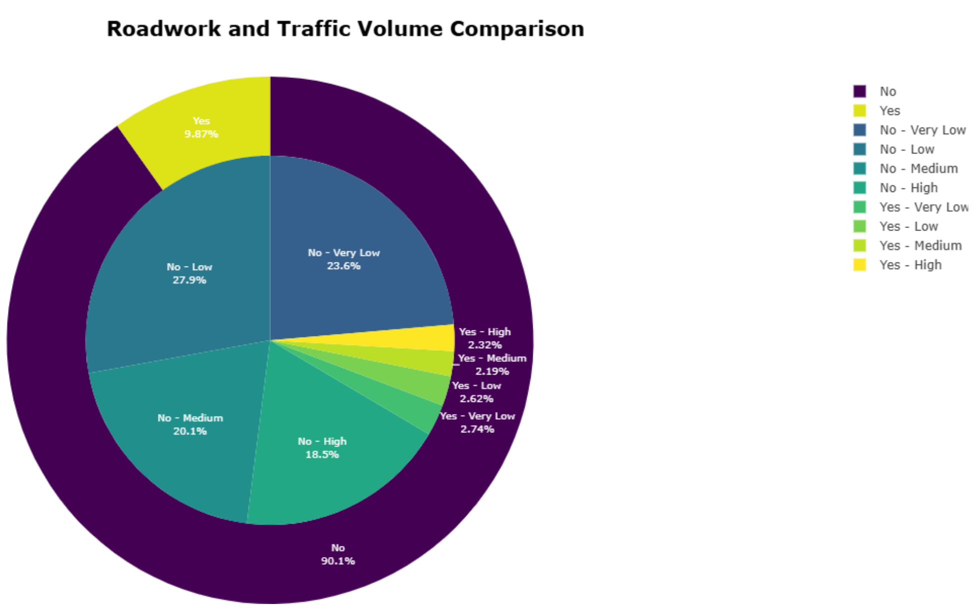
(Roadwork and Construction Activity)

1. *Stacked Bar Plot*



The chart indicates that in most areas, traffic congestion tends to arise even when there is no ongoing roadwork or construction. This implies that there are additional underlying causes that may be contributing significantly to the overall congestion.

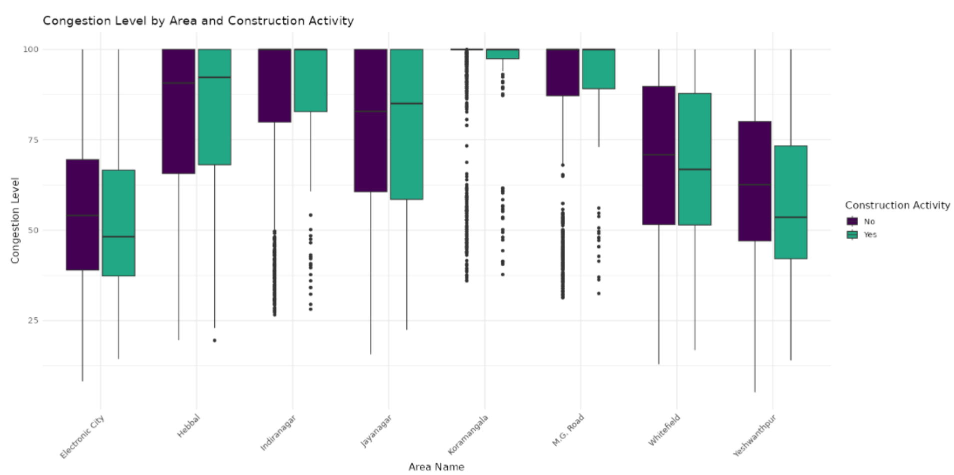
2. Nested Pie Chart



Roadwork is rare but impactful: Only **9.87%** of the records involve roadwork (outer yellow segment), yet within this small portion, there is a **disproportionate share of high congestion levels**—with **3.32% of total cases** being “Yes – High” congestion despite roadwork representing less than 10% of the data. **Most congestion occurs without roadwork**: The vast majority of observations (**90.1%**) show **no ongoing construction**, but even then, a significant portion still falls under **high (18.5%) or medium (20.1%) congestion**, indicating that roadwork is not the sole contributor to traffic problems. **Roadwork increases the risk of high congestion**: Within the "Yes" segment, the relative concentration of **high congestion** (3.32% of total) is higher than in the "No" segment, suggesting that even though roadwork is less frequent, it tends to **elevate congestion levels when present**.

Very low congestion rarely coincides with roadwork: “Yes – Very Low” comprises just **2.74%**, reinforcing the expectation that roadwork and low congestion seldom occur together.

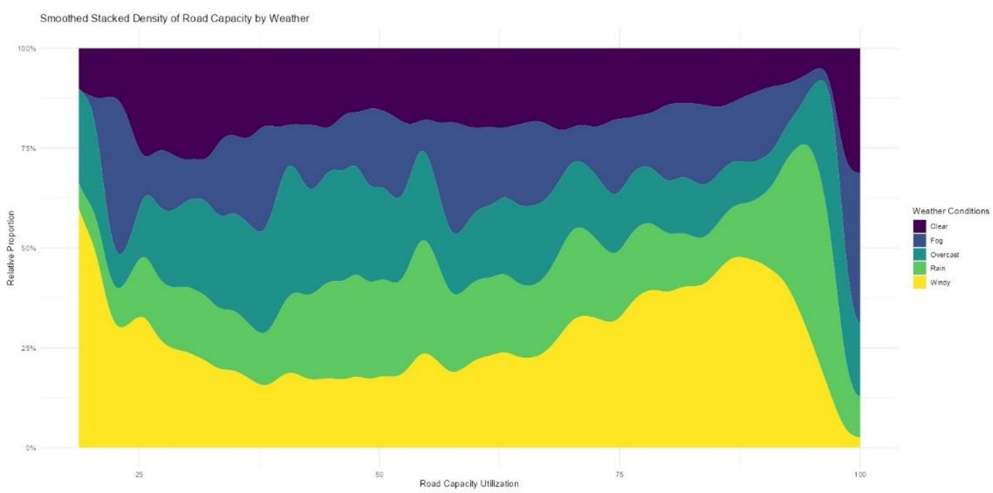
3. Box Plot



This plot provides a comprehensive understanding of traffic behavior in Bangalore by differentiating between long-term structural changes and short-term fluctuations in traffic volume. The long-term trend, as evidenced by the downward-sloping trend line, may reflect broader socio-economic or infrastructural factors such as policy changes, improvements in public transportation, or shifts in commuting patterns. Meanwhile, the detrended data offers a clearer view of high-frequency variations and potential anomalies—such as traffic spikes during festivals, holidays, or construction work—that could be obscured in the raw dataset. This kind of analysis is particularly valuable for urban planners, traffic engineers, and policymakers to make data-driven decisions aimed at improving traffic flow and reducing congestion over time.

(Weather Conditions)

1. Stacked Density Plot



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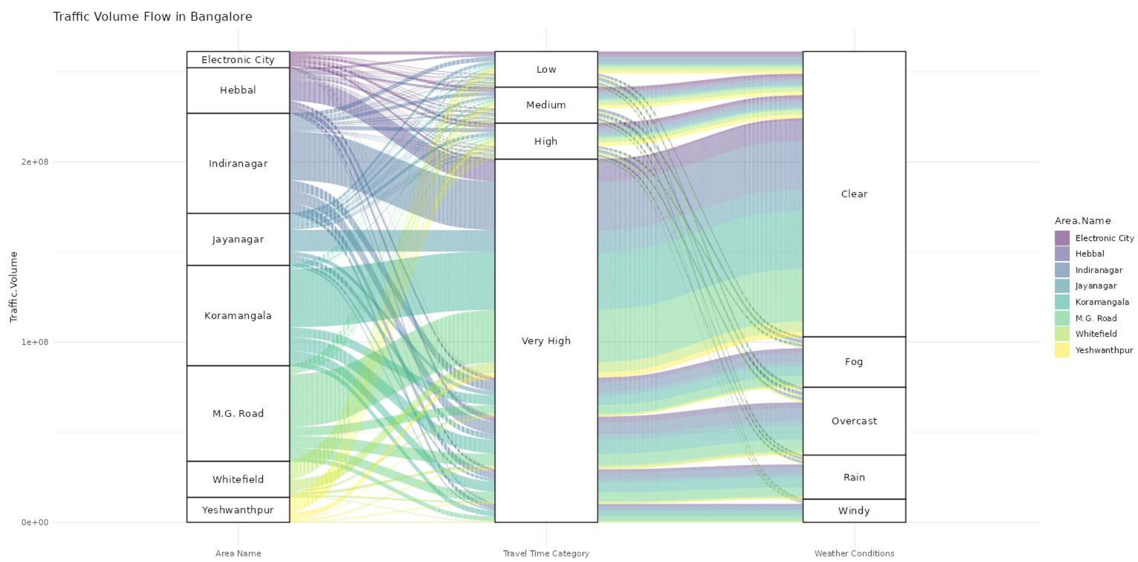
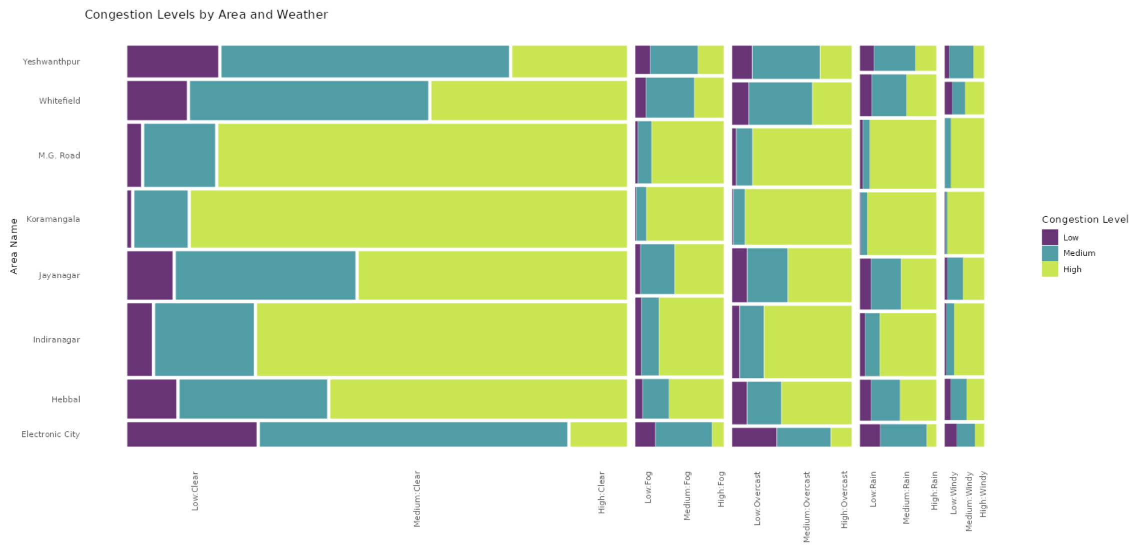
utilization levels. While clear weather is present throughout, it occupies a smaller proportion of total usage, suggesting that windy days are either more frequent or coincide with periods of heavier travel. This may reflect Bangalore's typical climate, where mild wind is common and does little to disrupt driving patterns. Unlike rain or fog, which reduce visibility and road safety, wind appears to have minimal behavioral impact on drivers. Notably, rainy conditions are concentrated in the mid-range of capacity, indicating cautious but ongoing travel, whereas fog and overcast conditions diminish at higher utilization levels putting off non-essential movement. The dominance of windy weather across capacity levels suggests that it represents not just common climate condition, but also a stable operational environment for Bangalore's traffic, where movement remains largely unaffected by external factors.

2. *Parallel Plot*



This diagram maps the flow of traffic volume across Area, Travel Time Category, and Weather Conditions, giving a comprehensive picture of how different zones in Bangalore behave under varying road stress and climate conditions. The most apparent insight is that areas like M.G. Road, Indiranagar, and Koramangala feed heavily into the "Very High" travel time category, suggesting consistently congested or slow-moving corridors. These are central zones known for commercial density, narrow lanes, and mixed-use land development, which naturally leads to traffic bottlenecks. Furthermore, this high travel time is heavily associated with clear weather, reinforcing the idea that volume, not bad weather, is the main cause of delays in these regions. In contrast, peripheral areas like Electronic City and Yeshwanthpur contribute more traffic to low and medium travel time categories, indicating that either infrastructure is better or traffic is more dispersed. These f lows are also more mixed across weather types, suggesting less sensitivity to environmental changes, perhaps because they feature more planned roads or better drainage systems. Overall, this plot highlights that infrastructure quality and land use patterns are stronger predictors of travel delays than weather alone, especially in core urban centers.

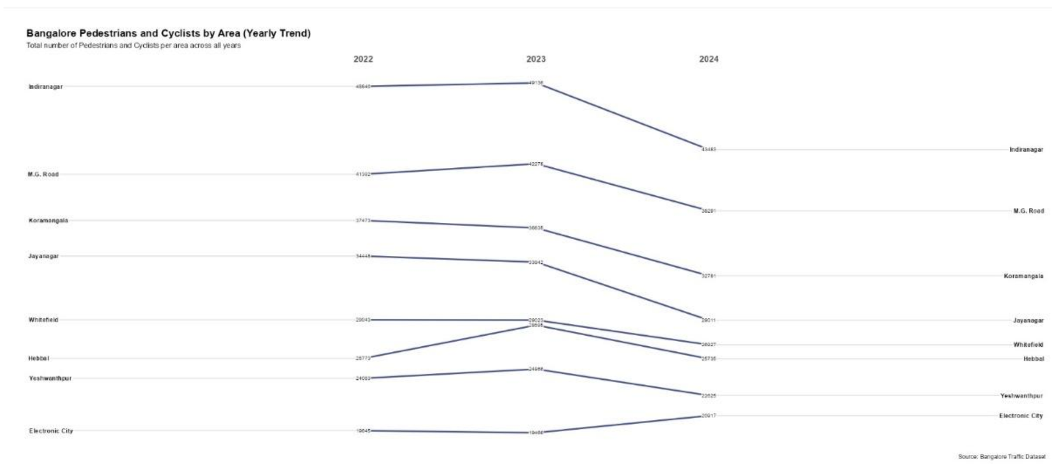
3. *Mosaic Plot*



This mosaic bar plot breaks down congestion levels to low, medium, and high by area and weather condition combinations. One of the most revealing patterns is the dominance of high congestion across most areas during clear weather, especially in regions like M.G. Road, Koramangala, and Indiranagar. This again points to the idea that good weather encourages higher traffic flow, which leads to worse congestion in zones that already suffer from infrastructure constraints. Conversely, in Electronic City and Hebbal, we observe a more even distribution across low and medium congestion levels, especially under overcast and rainy conditions, implying better traffic absorption or behavioral shifts such as rescheduling trips or remote work adoption. Another subtle but meaningful pattern is the near absence of high congestion during foggy or windy conditions in most areas, likely because drivers avoid non-essential travel or reduce travel time during those days. In this plot, weather acts as a natural regulator, moderating traffic extremes and influencing how people use urban space. What stands out overall is that congestion in Bangalore is less about weather disruption and more about behavioral response to favorable or unfavorable driving conditions. People take to the roads when it's sunny, creating the biggest problems.

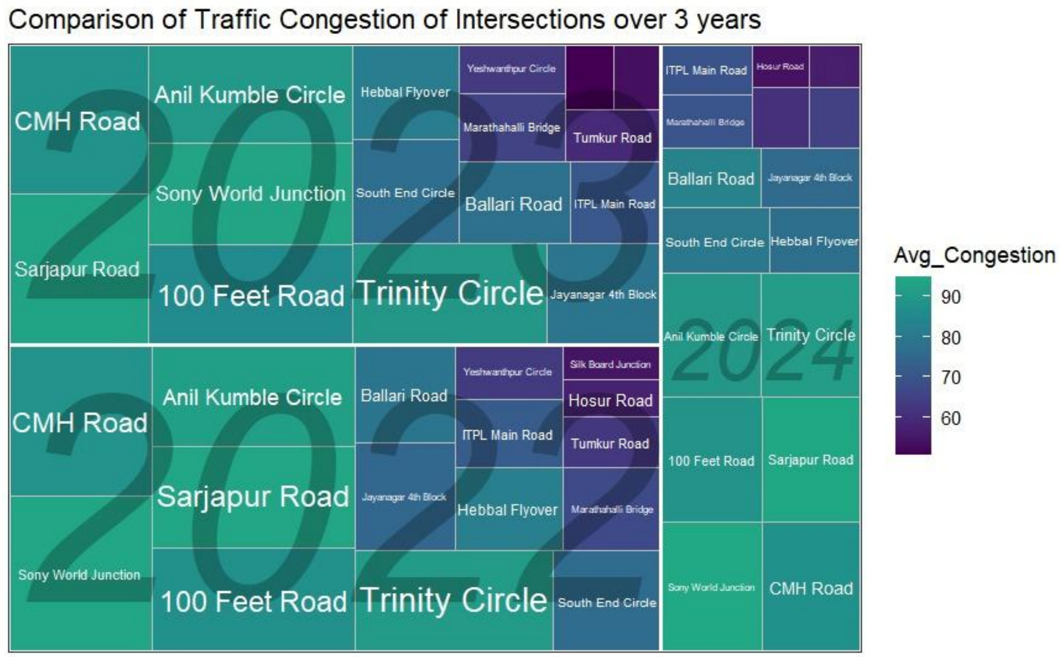
(Temporal)

1. Slopegraph Plot



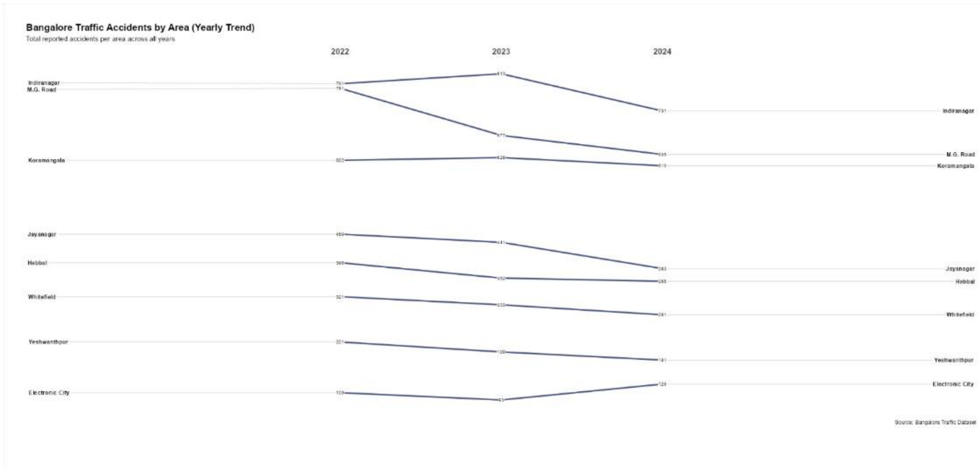
This slope chart illustrates the **yearly trend in pedestrian and cyclist counts** across key areas in Bangalore from **2022 to 2024**, revealing both general patterns and localized shifts in non-motorized mobility. **Indiranagar** consistently leads in pedestrian and cyclist activity, peaking in 2023 before a notable drop in 2024, which is a common pattern across most areas. **M.G. Road** also shows growth from 2022 to 2023, followed by a decline, possibly reflecting post-pandemic movement recovery and later stabilization or policy changes. **Hebbal** stands out with a clear increase in 2023—unlike the downward trends elsewhere—hinting at potential infrastructure improvements or increased foot/cyclist friendliness in that zone. Meanwhile, areas like **Whitefield**, **Jayanagar**, and **Koramangala** experience gradual declines year over year, suggesting a shift toward motorized transport or challenges in pedestrian access. Interestingly, **Electronic City**, despite being a major employment hub, maintains the lowest pedestrian and cyclist counts throughout, reinforcing the need for improved walkability and last-mile connectivity. Overall, the chart suggests a **peak in active mobility in 2023**, followed by a citywide dip, potentially tied to increased vehicle dependency or reduced support for non-motorized infrastructure in 2024.

2. Tree map



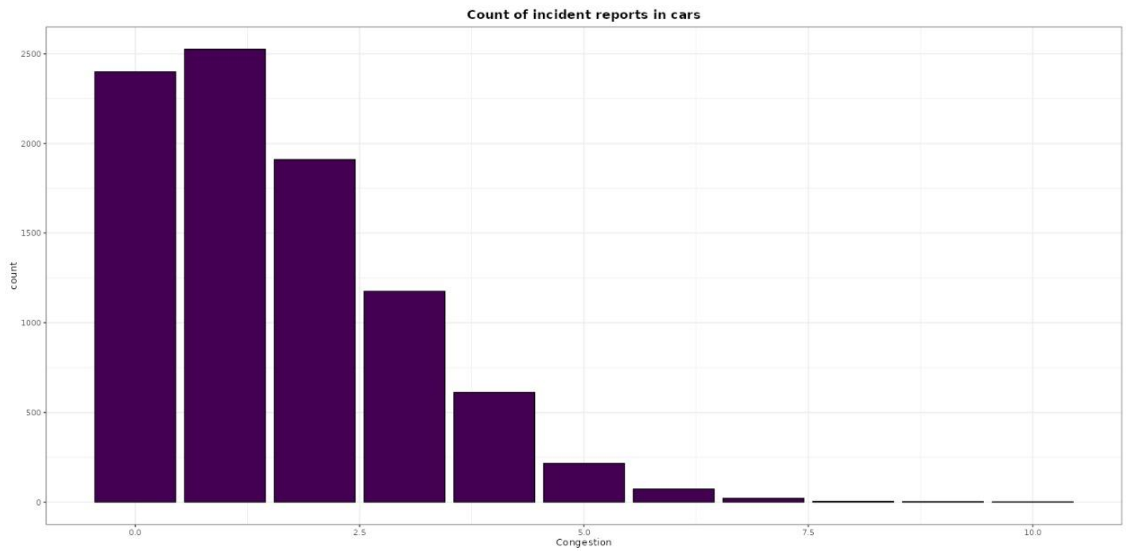
This treemap reveals persistent traffic congestion at key Bangalore intersections over three years, with **CMH Road**, **100 Feet Road**, and **Trinity Circle** consistently ranking among the most congested areas—indicating chronic bottlenecks that have seen little improvement. **Anil Kumble Circle** and **Sarjapur Road** also remain heavily congested across all years, suggesting systemic inefficiencies. In contrast, intersections like **Hosur Road**, **Silk Board Junction**, and **Yeshwanthpur Circle** show lighter shades in 2023 and 2024, pointing to potential success in congestion mitigation strategies. Interestingly, **Ballari Road** and **Hebbal Flyover** display noticeable year-to-year shifts in congestion, highlighting areas where traffic conditions are more volatile and possibly sensitive to seasonal or policy changes. Overall, the chart emphasizes a clear divide between **stubbornly congested zones** and **areas with dynamic or improving flow**, offering valuable direction for targeted traffic planning.

3. Slopegraph Plot



This plot tracks the number of reported traffic accidents in each area over three years and reveals that accident trends do not always correlate with pedestrian and cyclist activity. For instance, Indiranagar saw a drop in pedestrian traffic in 2024, yet accident counts remained nearly as high as they were in 2022. This suggests that accidents in such areas may not involve pedestrians at all, but instead stem from vehicle-to-vehicle incidents. Conversely, M.G. Road experienced a notable drop in accidents over the same period, aligning with its decrease in pedestrian volume. This could indicate improved traffic management, such as better signal control, stricter enforcement, or redesigned intersections. Peripheral areas like Hebbal and Yeshwanthpur also show steady decreases in both accidents and non-motorized activity. These regions likely benefited from infrastructure upgrades. Overall, this plot highlights that while pedestrian numbers may influence accident frequency in some areas, broader road design and vehicle regulation play an equally significant role.

4. Side by Side bars

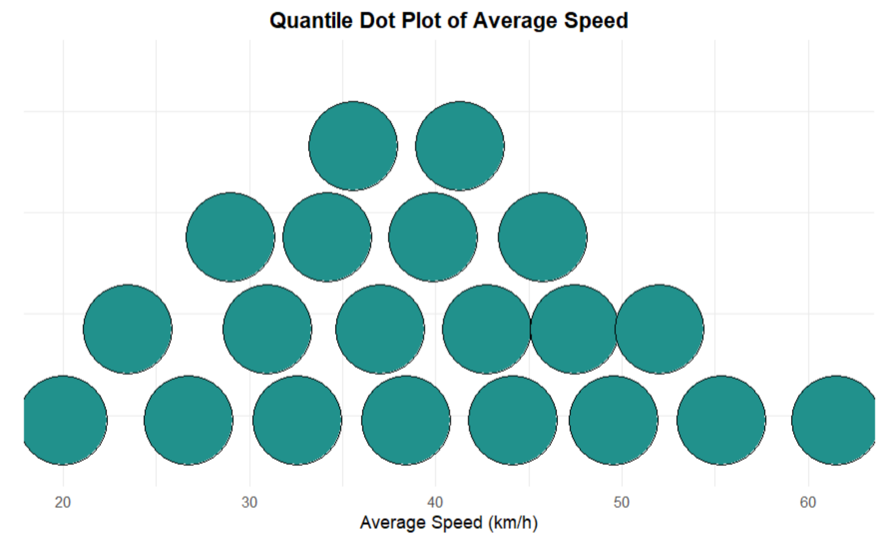


This plot takes a behavioral view by showing how incident frequency varies with congestion

level. Histogram shows that most incidents occur when congestion is low to moderate, specifcally between levels 0 and 3. When roads are relatively open, drivers tend to speed, switch lanes aggressively, or become distracted, which increases the likelihood of collisions. As congestion rises beyond level 4, incident counts drop steeply. Heavier traffic forces vehicles to slow down, reducing both the probability and severity of accidents. This trend shows low-speed environments are safer, though less efficient. This suggests that simply reducing congestion without addressing speed control and driver behavior may increase accident risk. Interventions such as speed calming measures, stricter enforcement in low-density zones, and real-time alerts during low-traffic periods could prove more effective than focusing solely on traffic volume as a safety metric.

(Deeper Dive)

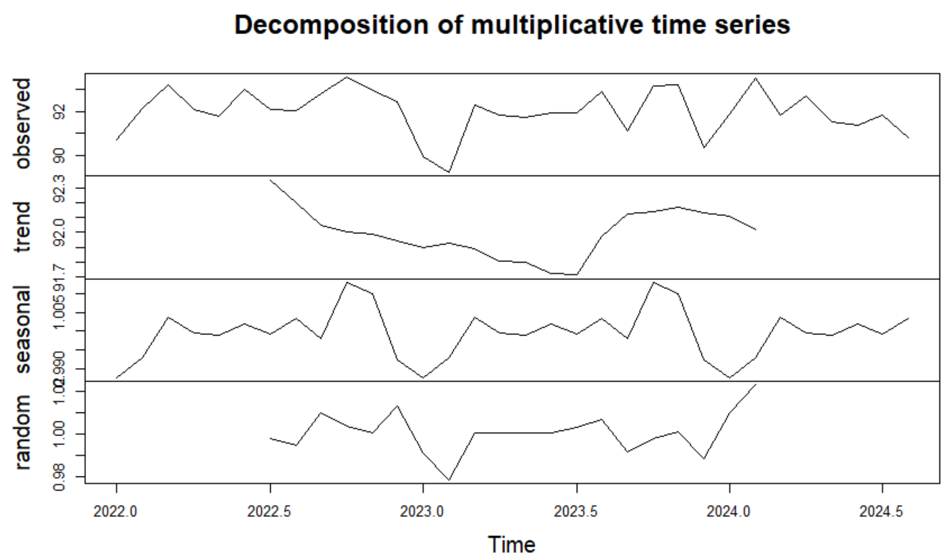
1.Quantile plot of Average speed:



The chart shows that the average vehicle speed in Bangalore ranges between 35 to 45 km/h, which is relatively low—especially for major roads and intersections such as CMH Road, Sarjapur Road, and Sony World Junction, where higher speeds and smoother traffic flow would normally be expected. This indicates that Bangalore is experiencing significant traffic congestion, which hampers vehicle movement and leads to generally slow travel across the city.

Bangalore is considered one of the most congested cities in the world, having topped global rankings for the worst traffic congestion. These low speeds reflect a deteriorating traffic situation, largely due to rapid and unplanned urban growth and the decline in infrastructure quality.

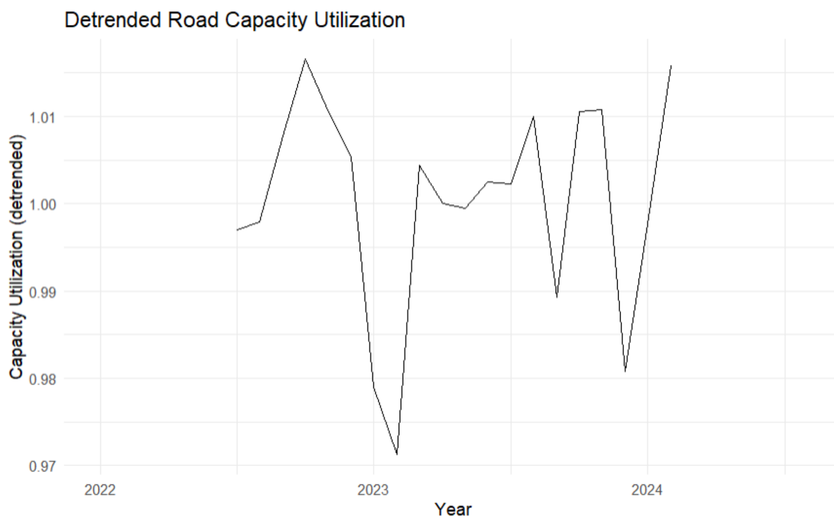
2.Decomposition:



From the trend plot, it is evident that the overall direction of the data was declining, but after May 2023, it started to rise. This change is likely due to the strong relationship between road capacity and traffic volume.
During the COVID-19 pandemic, traffic volume was significantly reduced, which in turn led to a drop in road capacity. Once the pandemic ended, traffic activity resumed on the roads, leading to a gradual increase in road capacity.

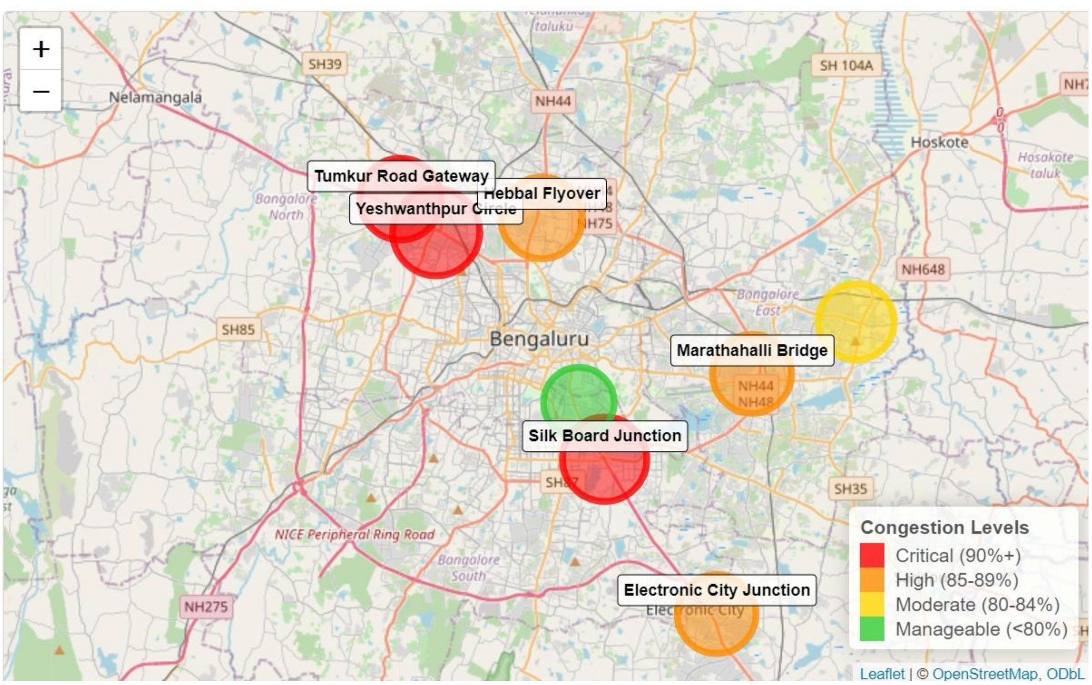
From the seasonal plot, we can observe a clear seasonal pattern in the data, with a similar shape repeating each year. The decline in road capacity during certain periods is likely due to weather conditions and the monsoon seasons, when traffic movement slows down.
In contrast, road capacity tends to increase during the spring and summer months, when the weather is more favorable and traffic movement improves.

3. Detrended Road Capacity Utilization



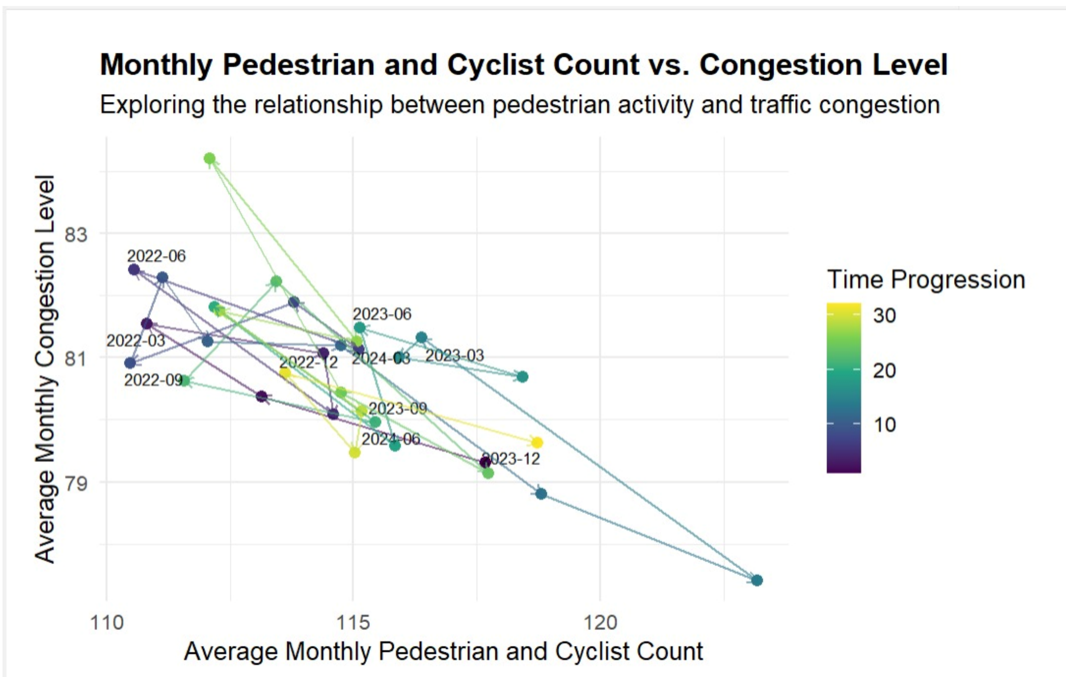
There are clear fluctuations in road capacity utilization over time without a long-term upward or downward trend. These changes are caused by seasonal factors such as weather conditions and tourist traffic, which affect traffic flow and consequently lead to variations in road capacity.

4. Geospatial congestion map



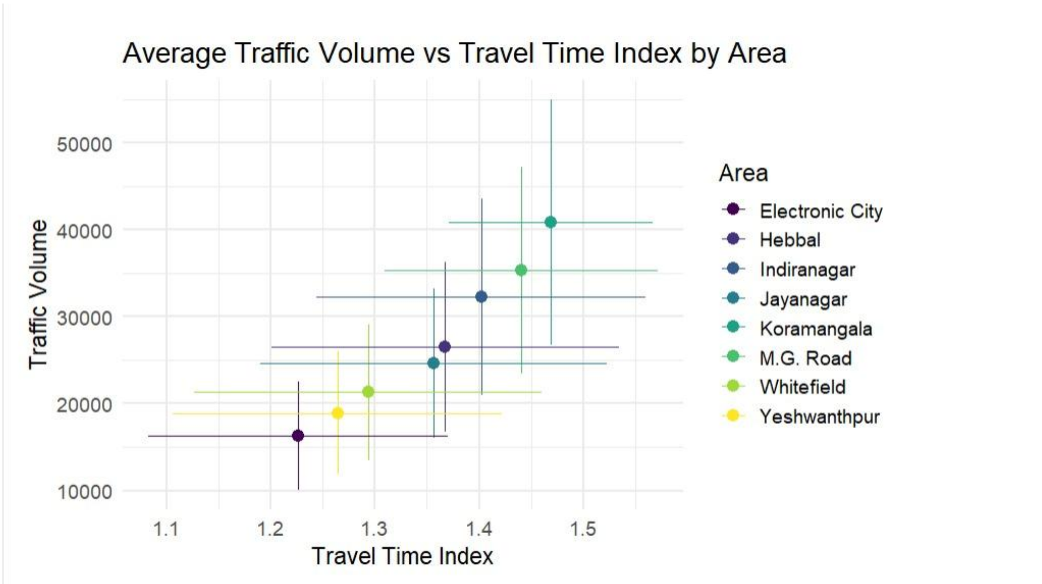
This geospatial map reveals that Bangalore's most critically congested intersections are concentrated around major transportation corridors, with Tumkur Road Gateway, Yeshwanthpur Circle, and Silk Board Junction marked in red, indicating congestion levels above 90%. High congestion zones (85–89%) such as Hebbal Flyover, Marathahalli Bridge, and Electronic City Junction align closely with key highways like NH44 and NH275, suggesting that arterial roadways bear the brunt of traffic load. In contrast, the area near Silk Board shows a rare pocket of manageable traffic, indicating localized infrastructure relief. Overall, the map highlights that congestion in Bangalore is strongly tied to highway-linked nodes and emphasizes the urgent need for targeted interventions at these critical bottlenecks.

5.Connected scatter plot



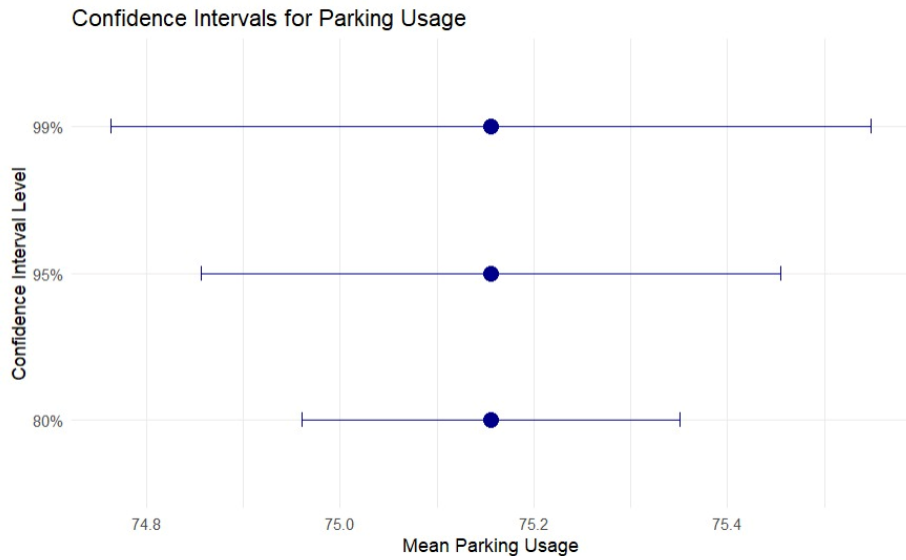
This connected scatter plot illustrates the monthly relationship between average pedestrian and cyclist activity and traffic congestion in Bangalore over time. A general downward trend can be observed: as pedestrian and cyclist counts increase, the average monthly congestion level tends to decrease. This suggests a potential inverse relationship—greater use of non-motorized transport modes may be associated with reduced vehicle congestion. Additionally, the time progression coloring reveals that recent months (e.g., 2023-12) correspond with both higher pedestrian counts and lower congestion, implying possible improvements in urban mobility infrastructure or a shift toward more sustainable transportation habits. Overall, the plot highlights how promoting pedestrian and cyclist activity could be an effective strategy in mitigating urban congestion.

6. Error bar in scatter plot



This plot reveals a clear positive relationship between average traffic volume and the Travel Time Index across Bangalore's key areas, indicating that zones with heavier traffic tend to experience slower movement. Koramangala and Jayanagar emerge as the most congested, with both high volume and elevated travel time indices, suggesting severe traffic delays. In contrast, Electronic City, despite its prominence, shows relatively low traffic volume and better travel efficiency, possibly due to distributed commuting or improved infrastructure. Indiranagar and Hebbal fall in the mid-range for both metrics, reflecting moderate congestion levels, while Whitefield and Yeshwanthpur exhibit lower travel times despite moderate volumes, hinting at effective flow management. Overall, the chart reinforces that traffic volume is a strong predictor of travel inefficiency, with some areas showing promising signs of balance between flow and capacity.

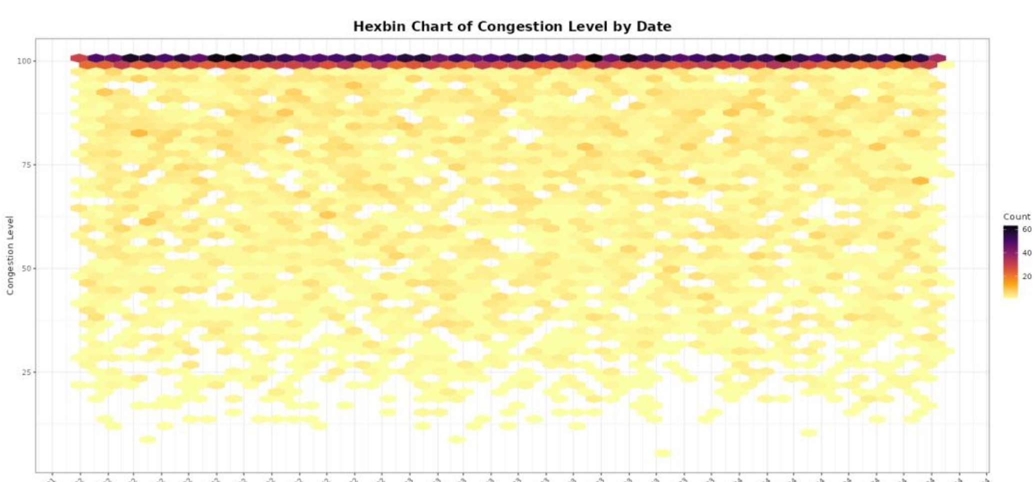
7. Error bar



This chart illustrates the confidence intervals for mean parking usage across Bangalore, with intervals calculated at 80%, 95%, and 99% confidence levels. The average parking usage is centered around 75.2%, and all intervals remain tightly clustered, indicating a low level of variability and a high degree of certainty around the estimate. Even at the most conservative 99% level, parking usage consistently falls within a narrow range, suggesting that the dataset reflects a stable and reliable parking pattern. With such a high mean utilization rate—indicating that three-quarters of parking capacity is regularly used—this insight points to sustained demand for parking infrastructure and highlights the potential need for improved management strategies, such as dynamic pricing or expanded facilities in high-traffic zones.

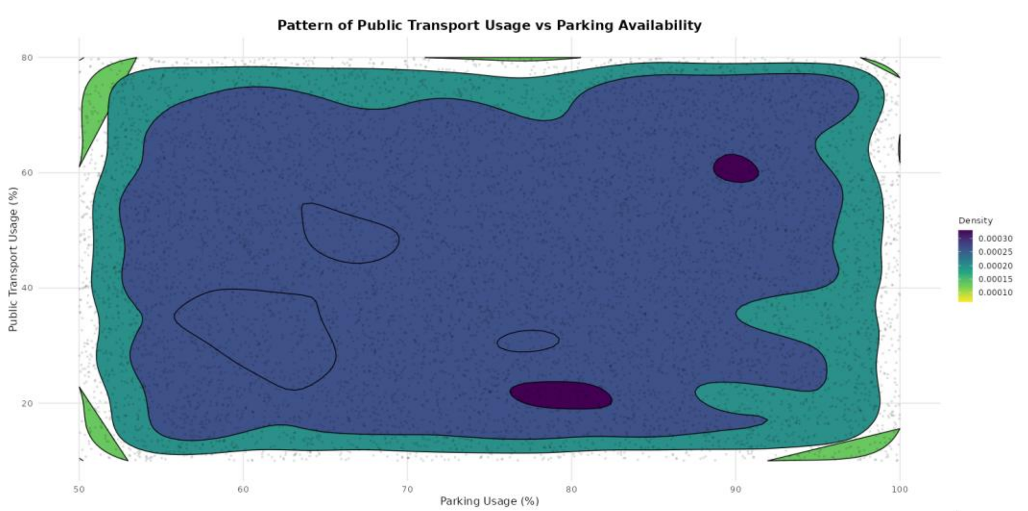
(Expanded Analysis)

1.2D Histogram



This plot visualizes congestion levels over time to show the density of data points across a multi-year period. Congestion levels consistently peak at 100 across the entire timeline, forming a dense horizontal band at the top of the chart. This suggests that maximum congestion is not only frequent but persistent throughout months and years, indicating a chronic traffic saturation issue in Bangalore. Below that, the spread of lighter density in mid-to-low congestion levels reflects more variability and occasional relief, but these are much less common. The darker hexes at the top, representing the highest counts, reinforce that gridlock conditions are the norm, not the exception. This could be attributed to factors such as rapid urban growth, under-capacity infrastructure, and peak-hour surges that consistently push the city's traffic systems to their limit. Interestingly, there is no significant temporal trend; no obvious improvement or deterioration over time, highlighting that congestion is a systemic, stable pressure point rather than one influenced by seasonal or policy shifts during this period.

2.Contour Line Plot



This density contour plot illustrates the relationship between public transport usage and actual parking usage, offering insight into how urban residents balance personal vehicle reliance with transit options. The densest regions of the plot fall between 60% to 90% parking usage and 20% to 60% public transport usage, indicating that areas with high parking usage also see moderate public transport activity. This suggests hybrid mobility behavior, where even in zones where public transit is available and somewhat utilized, private vehicle usage remains dominant. The fact that low parking usage rarely overlaps with high public transport usage indicates that true transit-first zones are rare, and most neighborhoods haven't shifted fully away from car dependence. Additionally, the concentration of density in this mid-range pairing may point to the absence of strong disincentives for driving, such as restricted parking or congestion tolls. Instead, parking remains widely used, possibly because it is still accessible, affordable, or expected in daily commuting behavior. Overall, this plot reveals that while public transport is present and used to a degree, it hasn't significantly replaced car usage, and parking infrastructure remains heavily relied upon, pointing to a lingering structural and behavioral preference for private mobility in Bangalore's urban environment.

5. Challenges and Future Work

Challenges:

- **Plot selection**: Ensuring each chart maximally explained its concept without redundancy and revealed hidden data pattern was a key challenge. We prioritized clarity and relevance in our visualizations.
- **Effective use of colour**: with 16 intersections, and many plots featuring small elements the selection of the color scheme was challenging. We aimed for a palette that is distinguishable for colour blind users, avoids confusion, and remains easy to read and interpret
- **Handling Mixed Data Types**: Balancing continuous and categorical variables required careful feature engineering and thoughtful visualization choices.
- **GUI navigation complexity**: Organizing over 30 plots in a logical flow demanded meticulous user experience planning to ensure intuitive navigation.

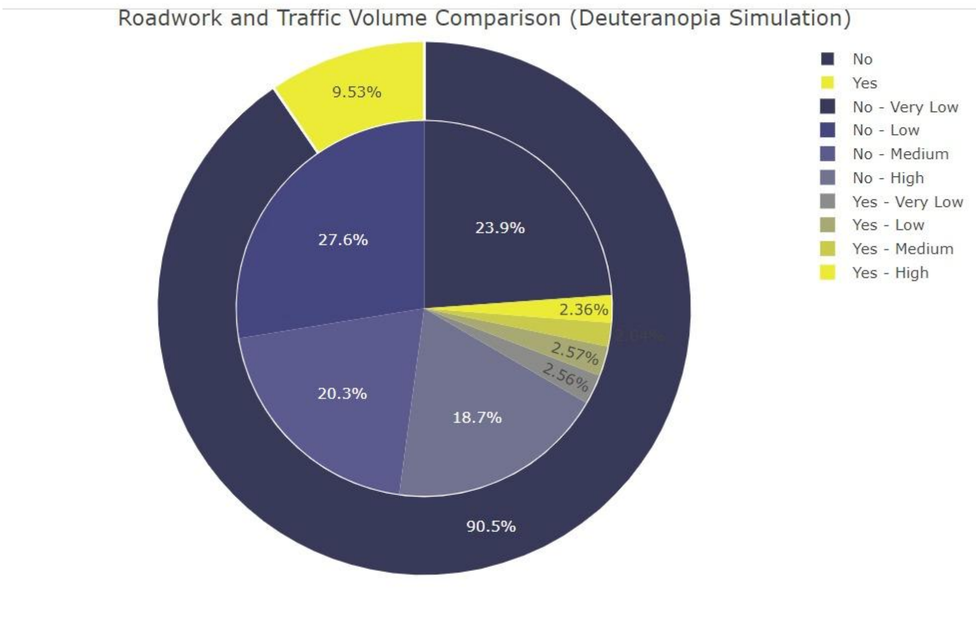
Future Work:

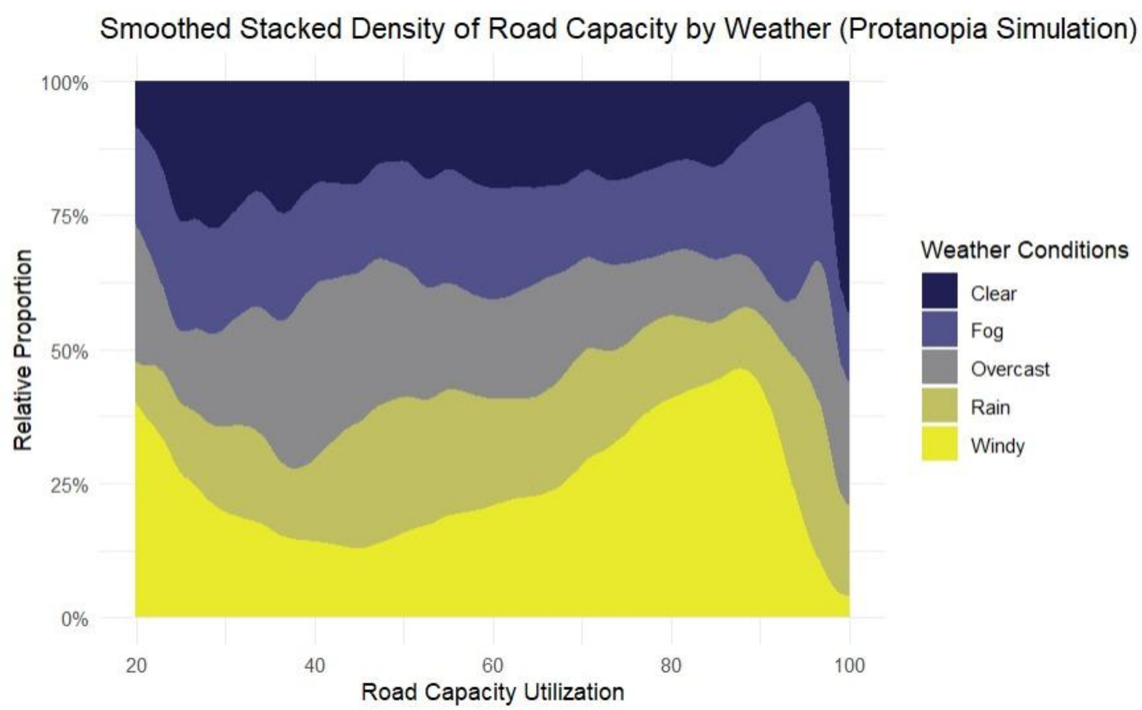
1. **Advanced Predictive Modeling:**

    - Use machine learning (e.g., time-series forecasting, regression models) to predict congestion levels based on historical trends, weather, and events.
    - Integrate model outputs into the app
2. **Enhanced Geospatial Visualizations:**
    - Add route optimization features to help users plan commutes based on current or predicted traffic.
3. **Comparative City Analysis:**
    - Expand the dataset to include traffic data from other cities (e.g., Mumbai, Delhi) to compare congestion patterns and identify transferable solutions.
4. **Causal Analysis:**
    - Investigate the root causes of congestion (e.g., road design, signal timing) by integrating additional datasets like infrastructure layouts, public transit schedules or hourly traffic and congestion data .

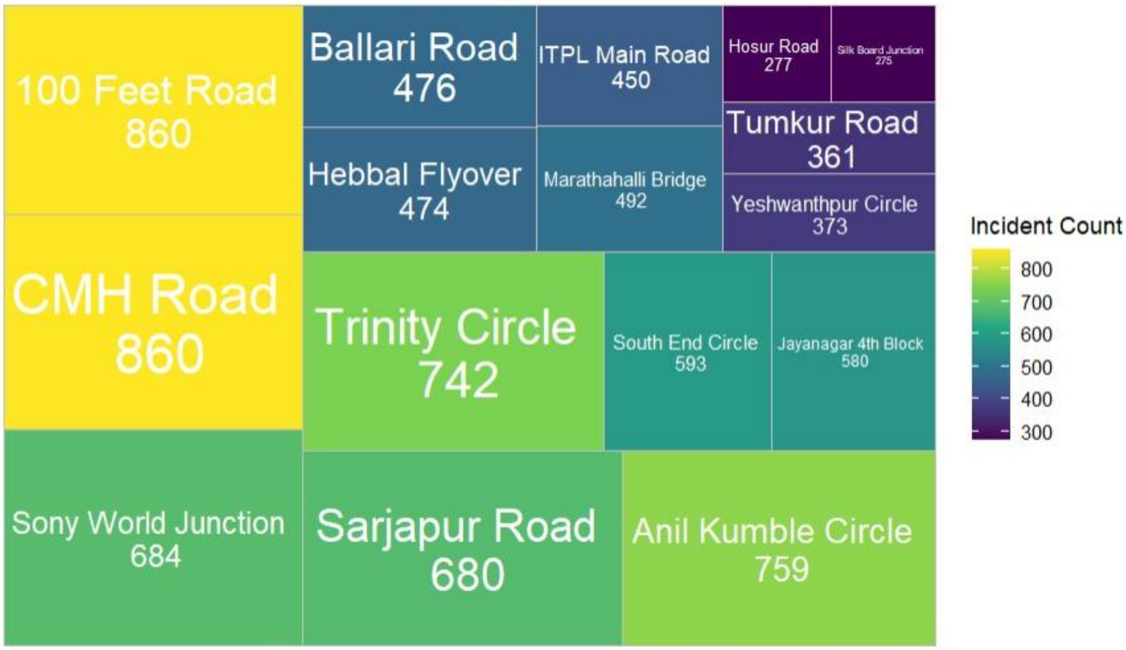
6. Enhancing Accessibility Through Inclusive Color Schemes

To make our Shiny app more inclusive and accessible, especially for users with visual color deficiencies (VCD), we plan to integrate a dedicated toggle button in future versions that allows switching between colorblind-friendly palettes (e.g., Deuteranopia, Protanopia, Tritanopia simulations) and standard color schemes. This feature will enhance usability and ensure that key visual insights remain distinguishable for all users, regardless of their color perception.

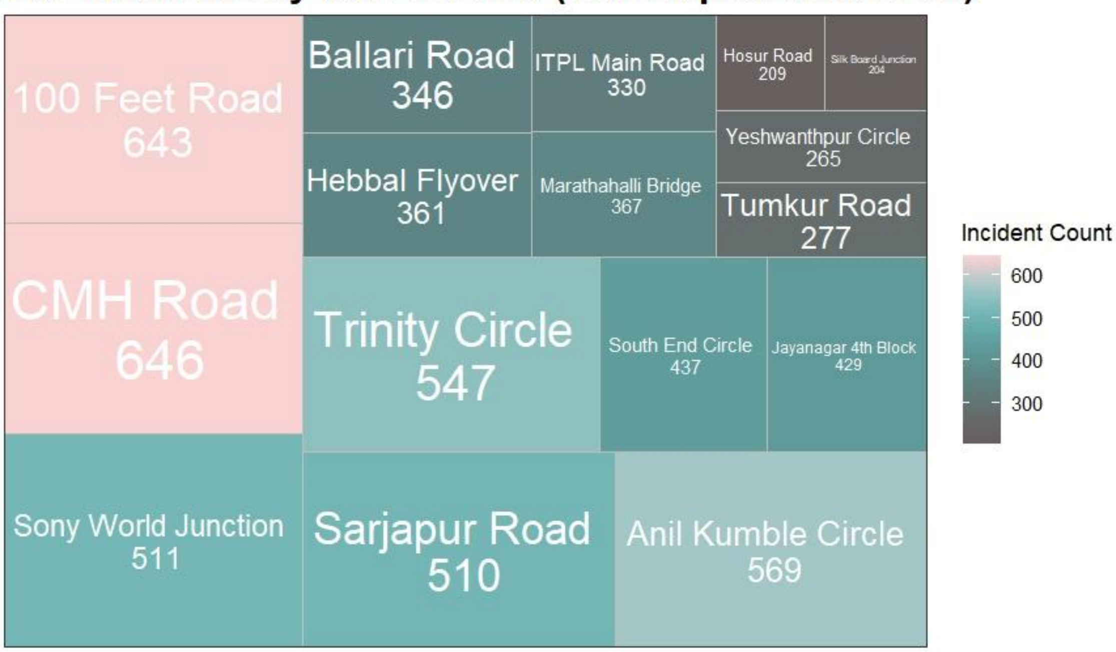

Roadwork and Traffic Volume Comparison (Deuteranopia Simulation)
9.53%
23.9%
27.6%
2.36%
2.57%
2.56%
20.3%
18.7%
90.5%
No
Yes
No - Very Low
No - Low
No - Medium
No - High
Yes - Very Low
Yes - Low
Yes - Medium
Yes - High


Smoothed Stacked Density of Road Capacity by Weather (Protanopia Simulation)
Relative Proportion
100%
75%
50%
25%
0%
20
40
60
80
100
Road Capacity Utilization
Weather Conditions
Clear
Fog
Overcast
Rain
Windy

Traffic Incident by Intersection



affic Incidents by Intersection (Tritanopia Simulation)



7. Conclusion

This project successfully leveraged visual analytics to uncover key traffic patterns in Bangalore, providing actionable insights for urban planners, policymakers, and residents. Through an interactive R Shiny app, we transformed complex traffic data into accessible visualizations, highlighting factors such as compliance, roadwork, weather, and long-term trends.

Our findings revealed chronic congestion across most locations, with roadwork and weather exacerbating but not independently causing traffic issues. Notably, pedestrian movement mirrored traffic volume patterns, and certain areas like MG Road showed unique congestion dynamics. The app's structured design—progressing from exploratory analysis to specific external factors—enables users to intuitively explore data and derive meaningful conclusions.

While challenges like plot selection and GUI navigation were addressed, future work could expand the app's capabilities with predictive modeling, and geospatial enhancements. By continuing to refine this tool, we aim to contribute to data-driven solutions for Bangalore's traffic crisis, fostering smarter urban mobility and improved quality of life for its residents.