Simulation of Traffic intersections in Rural, Urban and Metro areas using SUMO and OpenStreetMap

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Simulation & Modelling

BACKGROUND AND IMPORTANCE

The rapid growth of urbanization and vehicles has made managing traffic at intersections increasingly challenging. Rural, urban and metro areas each face unique issues: rural areas lack infrastructure, urban areas deal with high population density, and metro areas experience severe congestion. These challenges result in longer travel times, increased fuel consumption and higher emissions. Efficient traffic management is essential to reduce delays, improve traffic flow and ensure road safety. Analyzing traffic patterns across these different areas helps in identifying solutions to optimize intersection operations and address specific traffic needs.

OBJECTIVES

Analysis of traffic density and queue lengths for future optimization at intersections in rural, urban and metro areas using OpenStreetMap and SUMO.

1. **Extract Real-World Intersection Data:** Used OpenStreetMap to import intersection layouts from rural, urban, and metro areas into SUMO, ensuring accurate modeling based on actual road structures and traffic patterns.
2. **Simulate and Compare Traffic Density:** Examined traffic density levels at each intersection type, identifying patterns in vehicle flow and congestion specific to rural, urban and metro environments.
3. **Analyze Queue Lengths for Optimization Potential:** Assess queue length trends across intersections to highlight areas where adjustments to signal timing and traffic control strategies could reduce congestion and improve flow in future implementations.

LITERATURE REVIEW

Traffic Analysis and Optimization Needs

With rapid urbanization and the growing number of vehicles, managing traffic flow efficiently is becoming increasingly critical, particularly at busy intersections where congestion is most severe. Understanding traffic patterns is essential to minimize congestion, reduce fuel consumption and lower vehicle emissions. Effective traffic management can also reduce delays, improve safety and contribute to a more sustainable environment. Analysis of traffic density and queue lengths at intersections enables targeted optimization efforts, ensuring smoother traffic flow and better resource allocation, which is especially valuable for urban planners and policymakers.

Why Use SUMO and OpenStreetMap?

SUMO (Simulation of Urban Mobility) is a versatile and powerful tool for traffic simulation that enables the analysis of complex traffic systems in a controlled, virtual environment. It supports the study of various traffic parameters, allowing researchers and planners to simulate real-world scenarios, test different traffic control strategies, and evaluate potential outcomes without affecting live traffic. SUMO is particularly effective in handling real-time data, which makes it suitable for analysing dynamic traffic behaviours and optimizing intersections.

OpenStreetMap (OSM) complements SUMO by providing free, detailed geographic data, including accurate layouts of roads and intersections. This makes it easy to extract real-world intersection designs for use in simulations, ensuring that the simulated scenarios are realistic and relevant. Integrating SUMO with OpenStreetMap allows for precise modelling of real traffic conditions, helping planners assess and improve traffic control measures tailored to specific locations, such as rural, urban, and metro intersections.

METHODOLOGY

This section outlines the step-by-step process followed for traffic density and queue length analysis using SUMO (Simulation of Urban Mobility) in three different urban contexts: rural, urban, and metro intersections. The process involves data extraction from OpenStreetMap (OSM), the setup of the SUMO environment, and the execution of simulations for each intersection.

Selection of Study Areas:

To study traffic density and queue lengths in different urban contexts, three distinct intersection areas were selected:

- Rural Area: Court Square, Betnoti (representing a rural traffic scenario with lower traffic density).
- Urban Area: Murgabadi Circle, Baripada (representing a typical urban intersection with moderate traffic flow).
- Metro Area: Wellington Fountain, Kala Ghoda, Mumbai (representing a metro city intersection with high traffic density).

Data Extraction from OpenStreetMap

The first step was to extract real-world intersection data from OpenStreetMap (OSM) for each of the chosen areas. This involved the following steps:

1. **OpenStreetMap Access:**
    - Visit the website.
    - Select the region corresponding to the study areas (Court Square, Murgabadi Circle, and Wellington Fountain).
    - Use the export feature to download the selected areas in OSM XML format.
2. **Exporting the OSM Data:**
    - After selecting the desired region, export the OSM data by clicking on the "Export" button. This results in an OSM file for each area that will be used in the simulation.

SUMO Installation and Configuration

To simulate traffic scenarios, SUMO software was installed and configured as follows:

1. **SUMO Installation**:
    - Download and install the SUMO software suite from the official SUMO website.
    - Ensure that both the SUMO core software and the SUMO-GUI (Graphical User Interface) are installed for better visualization and interaction with the simulation.
2. **Setting up the Environment**:
    - Configure the SUMO environment by setting the necessary environment variables for easier access to SUMO tools.
    - Verify the correct installation by running basic SUMO commands through the terminal or command prompt.

Conversion to SUMO Configuration File (.sumocfg)

Once the OSM data was obtained, the next step was to convert it into a format suitable for use within the SUMO simulation environment. This was achieved by performing the following steps:

1. **Converting OSM Data to SUMO Network File:**

- Use the netconvert tool to convert the OSM data into a SUMO network file with the following command:
- netconvert --osm-files OSM_file_name.osm -o network_file_name.net.xml

2. **Importing Polygons and Additional Data:**
   - OpenStreetMap (OSM) data includes road networks as well as additional geographical elements like buildings, rivers, and other features. To incorporate these, the polyconvert tool was used to convert OSM data into polygons and create a poly.xml file
3. **Generating Random Routes for Simulation:**
   - To simulate traffic flow, a routes file (.rou.xml) was generated using the randomTrips tool, which creates random vehicle routes based on the network file:
4. **Creating the SUMO Configuration File:**
   - Finally, a SUMO configuration file (.sumocfg) was created to link all necessary components (network, routes, polygons) and define the simulation parameters. The configuration file was structured as follows:

```
<configuration>
  <input>
    <net-file value="network_file_name.net.xml"/>
    <route-files value="route_file_name.rou.xml"/>
    <additional-files value="poly_file_name.poly.xml"/>
  </input>
  <time>
    <begin value="0"/>
    <end value="1000"/>
    <step-length value="0.1"/>
  </time>
</configuration>
```

Simulation Execution in SUMO-GUI

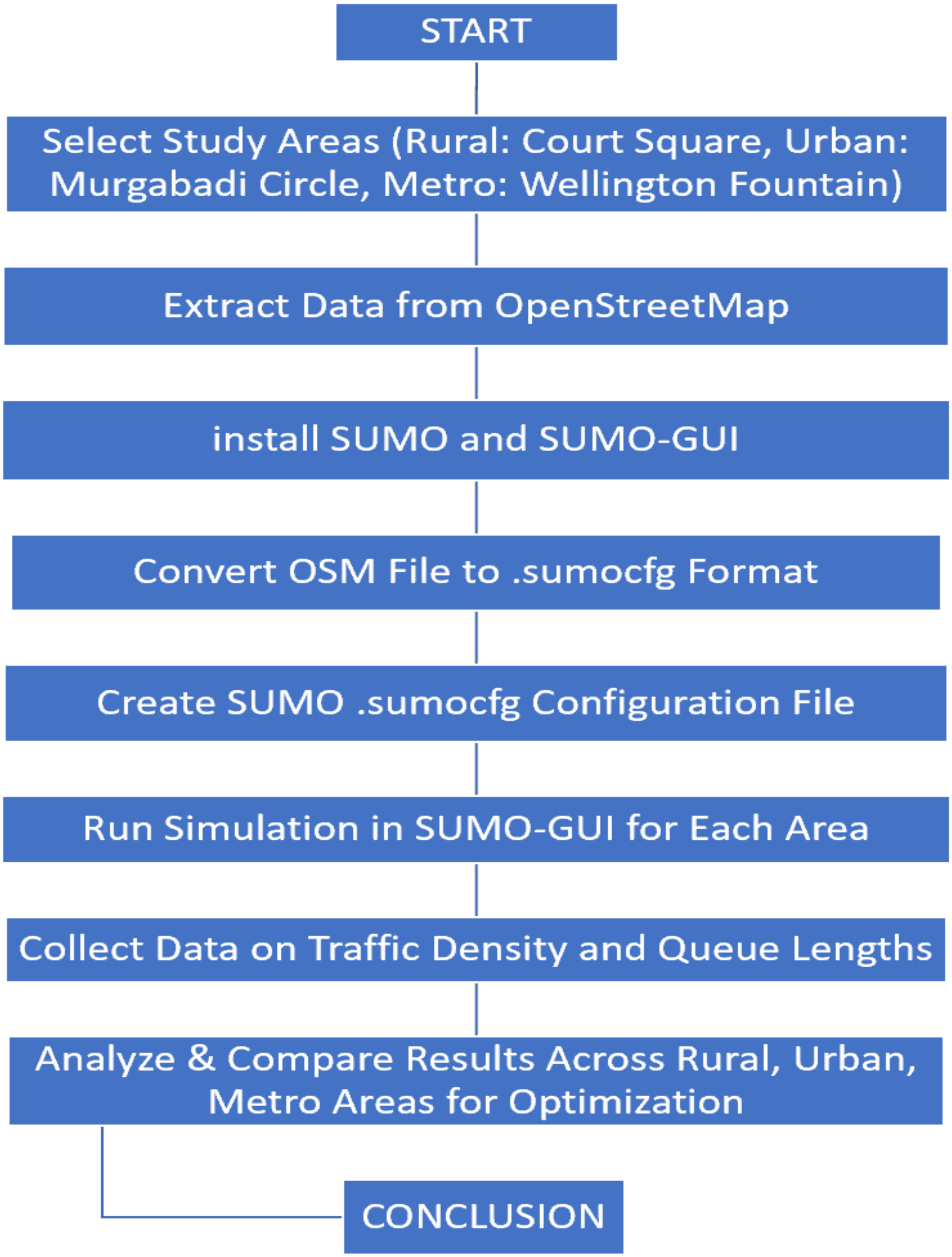
After configuring the SUMO environment and generating the necessary configuration files, the simulation was executed:

1. **Loading the SUMO Configuration File:**
   - Open the SUMO-GUI and load the generated .sumocfg file for each area (rural, urban, and metro).
2. **Running the Simulation**:
   - Execute the simulation using the following command

   sumo-gui config_file_name.sumocfg

   - Observe the simulation in real time, collecting data on traffic density, vehicle flow, and queue lengths at intersections.

FLOWCHART

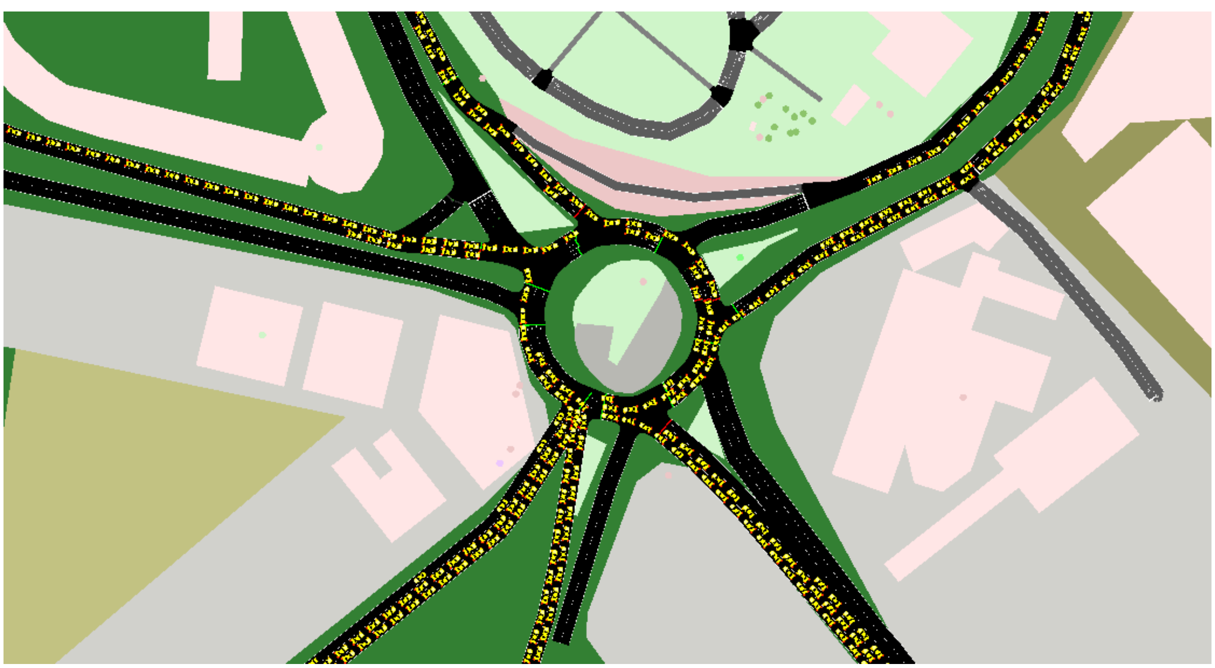

START
Select Study Areas (Rural: Court Square, Urban: Murgabadi Circle, Metro: Wellington Fountain)
Extract Data from OpenStreetMap
install SUMO and SUMO-GUI
Convert OSM File to .sumocfg Format
Create SUMO .sumocfg Configuration File
Run Simulation in SUMO-GUI for Each Area
Collect Data on Traffic Density and Queue Lengths
Analyze & Compare Results Across Rural, Urban, Metro Areas for Optimization
CONCLUSION

MAP AND SIMULATIONS

Metro Area:

Map [Wellington Fountain, Kalaghoda, Mumbai]

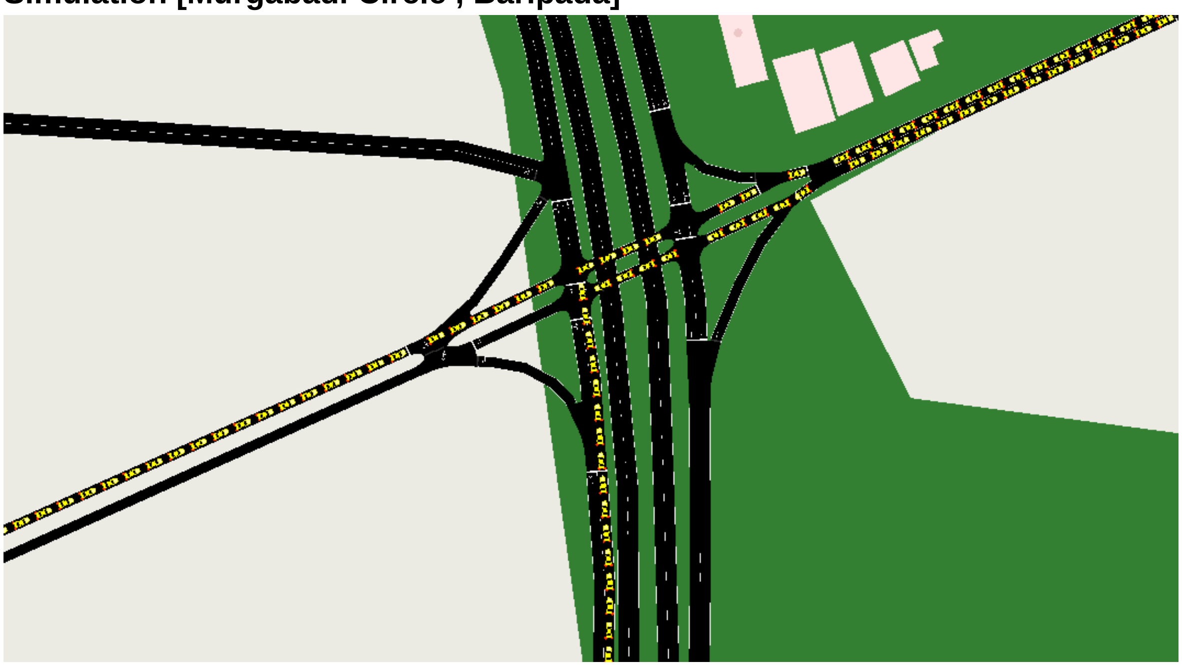
Simulation [Wellington Fountain, Kalaghoda, Mumbai]



Urban Area:

Map [Murgabadi Circle, Baripada]

Simulation [Murgabadi Circle , Baripada]



Rural Area:

Map [Court Square,Betnoti]

Simulation [Court Square,Betnoti]

COMPARISION AND CONCLUSION

Based on the simulations performed using SUMO for traffic analysis at three distinct areas—Rural (Court Square, Betnoti), Urban (Murgabadi Circle, Baripada), and Metro (Wellington Fountain, Kala Ghoda, Mumbai)—the following key observations were made:

1. Traffic Density and Queue Length: The metro area exhibited the highest traffic density and queue length compared to both urban and rural areas. This indicates a significant level of congestion in metro regions, with traffic jams more prevalent due to the high volume of vehicles.

2. Urban Areas: Traffic density and queue lengths in the urban area were moderate, reflecting typical city traffic conditions, though not as severe as the metro area. These areas experience moderate congestion, often during peak hours.

3. Rural Areas: As expected, the rural area showed the least traffic density and queue length, with smoother traffic flow and fewer delays.

4. Optimization Potential: The higher congestion in the metro area suggests a greater need for traffic optimization strategies, such as adaptive signal control or alternative routing to improve traffic flow and reduce delays. Urban areas may also benefit from such optimizations, albeit to a lesser extent.

These findings underscore the need for targeted traffic management solutions that account for the specific characteristics of each type of area-rural, urban, and metro to ensure efficient traffic flow and minimize congestion.