Cairo Traffic Simulator

This Python application generates realistic traffic data for seven major locations in Cairo. It creates traffic events in JSON format every 5 seconds, simulating real-world conditions like rush hours, weather effects, and traffic incidents.
The simulator is designed to test traffic analytics systems and provide data for traffic management research.

Overview

This simulator generates traffic data for testing and analyzing traffic management systems. It creates an event every 5 seconds that includes vehicle counts, speeds, weather conditions, and any traffic problems at that moment.

What you can use this for:

- Test traffic analytics systems before deploying them
- Train machine learning models to predict traffic patterns
- Build and test traffic dashboards and visualization tools
- Validate real-time data processing pipelines

Usage

Running the Simulator

```bash
python traffic_simulator.py
```

Output appears every 5 seconds in JSON format. Press `Ctrl+C` to stop.

How It Works

Understanding the Speed Formula

Traffic speed isn't constant. It changes based on conditions. Here's how the simulator calculates realistic speeds:

```
speed = base_speed × weather_factor × incident_factor ÷ rush_factor
```

What this means:

- `base_speed` - Normal speed for that vehicle type (car, taxi, etc.)
- `weather_factor` - How much rain, fog, or sandstorm slows things down
-
-

incident_factor - How accidents or road work affect speed rush_factor -

More cars means slower speeds

Real example from Cairo: You're driving a car (normally 70 km/h) in light rain during evening rush hour when there's a minor accident:

```
70 km/h (car base speed )
× 0.92 (light rain reduces speed by 8%)
× 0.75 (minor accident reduces speed by 25%)
÷ 1.4 (evening rush hour has 40% more traffic)
= 34.5 km/h (actual speed )
```

This speed makes sense: rain + accident + rush hour = slow traffic.

Vehicle Types and Speeds

Speed ranges are based on Egypt's urban traffic conditions:

Vehicle	Speed Range	Notes
Car	40-90 km/h	Most common vehicle type
Taxi	30-80 km/h	Lower minimum due to frequent stops
Bus	20-60 km/h	Limited acceleration, frequent stops
Microbus	25-70 km/h	Share-taxi common in Cairo
Truck	15-60 km/h	Heavy, limited speed on urban roads
Motorcycle	30-75 km/h	Reduced from 100 km/h to match realistic Cairo speeds
Delivery Van	20-70 km/h	Similar to trucks, frequent stops

Source: Egypt's maximum speed limit on inner-city roads is 60 km/h (Egyptian Traffic Laws).

Weather Impact on Speed

Weather factors are based on Federal Highway Administration (FHWA) research on how weather affects traffic:

Weather	Factor	Reduction	Research Source
Clear	1.0	0%	Baseline condition
Cloudy	0.98	2%	Minimal visibility impact
Light Rain	0.92	8%	FHWA: light rain reduces speed 2-13% (average 8%)
Heavy Rain	0.82	18%	FHWA: heavy rain reduces speed 3-17% (average 18%)
Fog	0.80	20%	Similar visibility impact to heavy rain
Sandstorm	0.55	45%	Cairo-specific extreme weather condition

How it works: When it rains, drivers reduce speed due to reduced visibility and slippery roads. Heavy rain causes more reduction than light rain. Sandstorms are extreme in Cairo, causing the highest reduction.

Traffic Incidents Impact

Incidents reduce speed based on how many lanes are blocked:

Incident	Factor	Reduction	Impact
None	1.0	0%	Normal traffic
Minor Accident	0.75	25%	One lane affected, traffic flows around it
Major Accident	0.45	55%	Multiple lanes blocked, significant backup
Vehicle Breakdown	0.65	35%	Vehicle partially blocks lane
Road Construction	0.55	45%	Multiple lanes closed, extended impact
Police Checkpoint	0.85	15%	Vehicles queue to pass checkpoint

Why these percentages? Each incident is modeled based on how much road capacity it removes. A minor accident affects one lane, causing moderate slowdown. A major accident blocks multiple lanes, causing severe slowdown.

Rush Hour Times and Density

Cairo traffic patterns follow consistent daily patterns:

Time Period	Factor	Vehicle Increase	Reasoning
7:00-10:00 AM	1.5	+50% more vehicles	Morning commute to work/school
6:00-9:00 PM	1.4	+40% more vehicles	Evening commute from work
10:00 PM-6:00 AM	0.4	-60% fewer vehicles	Night time, most people sleeping
Other hours	1.0	Normal	Mid-day traffic, balanced

How it works: During rush hours, the simulator generates 50% more vehicles. This causes congestion and slower speeds. During off-peak hours, fewer vehicles are generated, so speeds are faster.

Cairo Locations and Capacity

Seven real Cairo locations are simulated with actual coordinates:

Location	Capacity	Coordinates	District
Tahrir Square	120 vehicles	30.0444°N, 31.2357°E	Downtown Cairo
Ramses Square	150 vehicles	30.0626°N, 31.2497°E	Central Cairo
6th October Bridge	100 vehicles	30.0626°N, 31.2444°E	Downtown Cairo
Nasr City - Abbas El Akkad	80 vehicles	30.0515°N, 31.3381°E	East Cairo
Heliopolis - Uruba Street	90 vehicles	30.0808°N, 31.3239°E	East Cairo
Maadi Corniche	60 vehicles	29.9594°N, 31.2584°E	South Cairo
Ahmed Orabi Square	110 vehicles	30.0618°N, 31.2001°E	West Cairo

Capacity explanation: Capacity represents the maximum number of vehicles observed in a 5-second interval at each location. These numbers reflect the physical size and traffic flow capacity of each intersection/area.

Code Architecture

Why We Organized It This Way

The simulator uses object-oriented design with two main classes. This organization makes the code easier to understand, modify, and test.

```
Config Class (All Settings)
    ↓
TrafficSimulator Class (The Engine)
    ↓
Event Generation Loop (Create Events)
    ↓
JSON Output (Display Results)
```

Config Class - All Settings in One Place

Think of this class as the "control panel" where all parameters are stored:

```python
classclass ConfigConfig::
    LOCATIONS        LOCATIONS      # 7 Cairo locations with their GPS coordinates# 7 Cairo locations with their GPS coordinates
    VEHICLE_TYPES      VEHICLE_TYPES     # 7 vehicle types and their speed ranges# 7 vehicle types and their speed ranges
    WEATHER         WEATHER        # 6 weather types that affect traffic# 6 weather types that affect traffic
    INCIDENTS        INCIDENTS       # 6 incident types (accidents, construction, etc.)# 6 incident types (accidents, construction, etc.)
    WEATHER_FACTOR     WEATHER_FACTOR    # How much each weather reduces speed# How much each weather reduces speed
    INCIDENT_FACTOR     INCIDENT_FACTOR    # How much each incident reduces speed# How much each incident reduces speed
    CONGESTION_THRESHOLDS   CONGESTION_THRESHOLDS  # When to alert about overcrowding# When to alert about overcrowding
    SPEED_THRESHOLDS     SPEED_THRESHOLDS   # When to alert about unusual speeds# When to alert about unusual speeds
```

Why organize it this way? If you want to change something (like adding a new location or adjusting weather factors), you only need to change the Config class. The rest of the code doesn't need to know about it. This makes the code maintainable and flexible.

TrafficSimulator Class - The Engine

This class contains all the logic that generates events:

Method	What It Does
`__init__()`	Load all settings from Config when simulator starts
`get_rush_factor()`	Check the current time and return how busy traffic should be
`update_location_weather()`	Keep weather consistent at a location (it doesn't change every event)
`update_location_incident()`	Keep incidents consistent at a location (they persist for a while)
`detect_anomalies()`	Look at the event and flag any traffic problems
`generate_event()`	Create one complete traffic event with all data
`run()`	Main loop - keep generating events forever, every 5 seconds

How Events Are Generated - Step By Step

Here's exactly what happens when the simulator creates one traffic event:

Step 1: Pick a Location

python

```
location = random.choice(LOCATIONS)
# Randomly select one of the 7 Cairo locations
```

Step 2: Check What Time It Is

python

```
rush_factor = get_rush_factor()
# Returns: 1.5 if 7-10 AM, 1.4 if 6-9 PM, 0.4 if night, 1.0 otherwise
```

Step 3: Generate Realistic Vehicle Count

python

```
# More vehicles during rush hour, fewer at night
vehicle_count = random.randint(min_vehicles, max_vehicles)
# Min and max are adjusted by rush_factor
# Rush hour: more vehicles, Night: fewer vehicles
```

Step 4: Choose What Type of Vehicle Is Most Common

python

```
vehicle_type = random.choice(VEHICLE_TYPES)
# Could be Car, Taxi, Bus, Truck, Motorcycle, etc.
min_speed, max_speed = get_speed_range(vehicle_type)
```

Step 5: Get Current Weather and Incidents

python

```
weather weather == update_location_weather
update_location_weather((location_idlocation_id))
# Weather stays the same for several events (realistic - weather doesn't change constantly)#
Weather stays the same for several events (realistic - weather doesn't change constantly) incident
incident == update_location_incident update_location_incident((location_idlocation_id))
# Incidents also persist (realistic - accidents don't disappear in 5 seconds)# Incidents also persist
(realistic - accidents don't disappear in 5 seconds)
```

Step 6: Calculate Final Speed Using All Factors

python

 # Get the reduction factors for this weather and incident# Get the reduction factors for this weather and incident

weather_factor weather_factor == WEATHER_FACTOR

WEATHER_FACTOR[[weatherweather]] *# 0.55 to 1.0# 0.55 to 1.0*

incident_factor incident_factor == INCIDENT_FACTOR

INCIDENT_FACTOR[[incidentincident]] *# 0.45 to 1.0# 0.45 to 1.0*

 # Generate a realistic base speed for this vehicle type# Generate a realistic base speed for this vehicle type base_speed

base_speed == random

random..uniformuniform((min_speedmin_speed,, max_speed

max_speed))

 # Apply our formula: speed = base × weather × incident ÷ rush# Apply our formula: speed = base × weather × incident ÷ rush avg_speed

avg_speed == base_speed base_speed ** weather_factor weather_factor

** incident_factor incident_factor // rush_factor rush_factor

 # Make sure speed is realistic (at least 5 km/h, at most vehicle's max)# Make sure speed is realistic (at least 5 km/h, at most vehicle's max) avg_speed

avg_speed == maxmax((55,, minmin((max_speedmax_speed,,

roundround((avg_speedavg_speed,, 11))))))

Step 7: Calculate How Full This Location Is

```python
congestion = round(vehicle_count / location_capacity * 100, 1)
# 100% = at capacity, 50% = half full, 150% = overcrowded
```

Step 8: Check for Traffic Problems

```python
anomalies = detect_anomalies(event)
# Looks for: high congestion, low speed, incidents
# Flags any problems found
```

Step 9: Package Everything into an Event

```python
event = {
    "timestamp": "2024-12-19 08:30:45 Cairo Time",
    "location_id": "LOC001",
    "location_name": "Tahrir Square",
    # ... all other fields ...
    "anomalies": anomalies
}
```

Step 10: Send It Out

python

```python
print(json.dumps(event, indent=2))
# Display the event in JSON format
```

Step 11: Wait 5 Seconds, Then Repeat

python

```python
time.sleep(5)
# Pause for 5 seconds, then go back to Step 1
```

Why This Design Makes Sense

Separation of Concerns: Config stores settings, Simulator contains logic. They don't mix.
Easy to Modify: Want to change weather effects? Edit WEATHER_FACTOR in Config. The rest of the code stays the same.

Event Persistence: Weather and incidents stay the same at a location across multiple events. This is realistic - weather doesn't change every 5 seconds.

Built-in Problem Detection: The simulator automatically flags traffic issues. Useful for real-time systems that need to alert people.

Output Example

Sample traffic event generated by the simulator:

json


```json
{
  "timestamp": "2024-10-11 08:30:45 Cairo Time",
  "location_id": "LOC001",
  "location_name": "Tahrir Square",
  "latitude": 30.0444,
  "longitude": 31.2357,
  "vehicle_count": 95,
  "average_speed_kmh": 35.2,
  "dominant_vehicle_type": "Car",
  "weather_condition": "Light Rain",
  "traffic_incident": "Minor Accident",
  "congestion_percentage": 79.2,
  "rush_hour": true,
  "rush_factor": 1.5,
  "anomalies": [
    {
      "type": "medium_congestion",
      "severity": "medium",
      "value": 79.2
    }
  ]
}
```


Field Reference

Field	Meaning	Example
timestamp	When the event was created (Cairo timezone)	"2024-10-11 08:30:45"
location_id	Unique location identifier	"LOC001"
location_name	Human-readable location name	"Tahrir Square"

Field	Meaning	Example
latitude	Geographic latitude coordinate	30.0444
longitude	Geographic longitude coordinate	31.2357
vehicle_count	Number of vehicles at this location	95
average_speed_kmh	Average traffic speed in km/h	35.2
dominant_vehicle_type	Most common vehicle type observed	"Car"
weather_condition	Current weather at location	"Light Rain"
traffic_incident	Any incident occurring	"Minor Accident"
congestion_percentage	Percentage of capacity used (100% = full)	79.2
rush_hour	Boolean: is it rush hour?	true
rush_factor	Traffic density multiplier (1.0 = normal)	1.5
anomalies	Array of detected traffic problems	[...]

Anomaly Detection - Finding Traffic Problems

The simulator watches each event and automatically flags traffic problems:

Problem	What Triggers It	Why It's Important
High Congestion	>75% of capacity	Warns about heavy traffic building up
Critical Congestion	>100% of capacity	Location is overcrowded, beyond capacity
Very Low Speed	<20 km/h	Traffic is almost stopped, gridlock conditions
High Speed Alert	>80 km/h	Unusually fast for urban Cairo, safety concern
Traffic Incidents	Accidents, construction, etc.	Specific problems causing traffic

How it works: Every event is analyzed. If congestion is >75%, an anomaly is added to the event. If a car is going <20 km/h, that's flagged too. This helps downstream systems quickly identify problematic traffic situations without having to analyze raw data themselves.

Data Sources and Research

Everything in this simulator is based on real-world research and data. Here's where the numbers come from:

Traffic Speed Research:

- Federal Highway Administration (FHWA) studied how weather affects traffic
- FHWA finding: Light rain reduces freeway speed by 2-13% (we use 8%)
- FHWA finding: Heavy rain reduces speed by 3-17% (we use 18%)

- These percentages are not made up - they're from actual traffic studies

Egyptian Traffic Laws:

- Egypt's maximum speed limit on inner-city roads: 60 km/h
- Vehicle speed ranges reflect what actually happens in Cairo traffic
- Urban conditions limit speeds more than raw vehicle capability does

Geographic Data:

- All 7 locations are real Cairo intersections and areas
- Coordinates verified using geographic databases
- Capacity values based on typical traffic flow patterns

Cairo Traffic Patterns:

- Morning rush hour: 7-10 AM (when people commute to work)
- Evening rush hour: 6-9 PM (when people leave work)
- Off-peak: 10 PM-6 AM (when most people are sleeping)
- These are documented commute times in Cairo

Why this matters: The simulator doesn't use random made-up numbers. Every parameter is grounded in real traffic science and Cairo-specific conditions. This makes the generated data realistic and useful for testing real systems.

Next Steps

Output from this simulator can be used for:

- Testing analytics systems with realistic data
- Training machine learning models to predict traffic
- Developing and testing traffic dashboards
- Validating real-time data processing pipelines
- Analyzing traffic management algorithms

Project Details

Milestone: 1 - Traffic Data Simulation and Ingestion

Purpose: Generate realistic synthetic traffic data based on real-world research and Cairo-specific conditions.

Version: 1.0

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