Team 7

Computer Theoritical Project

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Algorithm Selected:

The chosen algorithm for analysis is the A* algorithm, implemented in the transportation optimization system to find the fastest emergency routes from any location to the nearest hospital. A* is a heuristic-based shortest path algorithm that balances efficiency and optimality, making it ideal for real-time navigation in dynamic environments like urban road networks.

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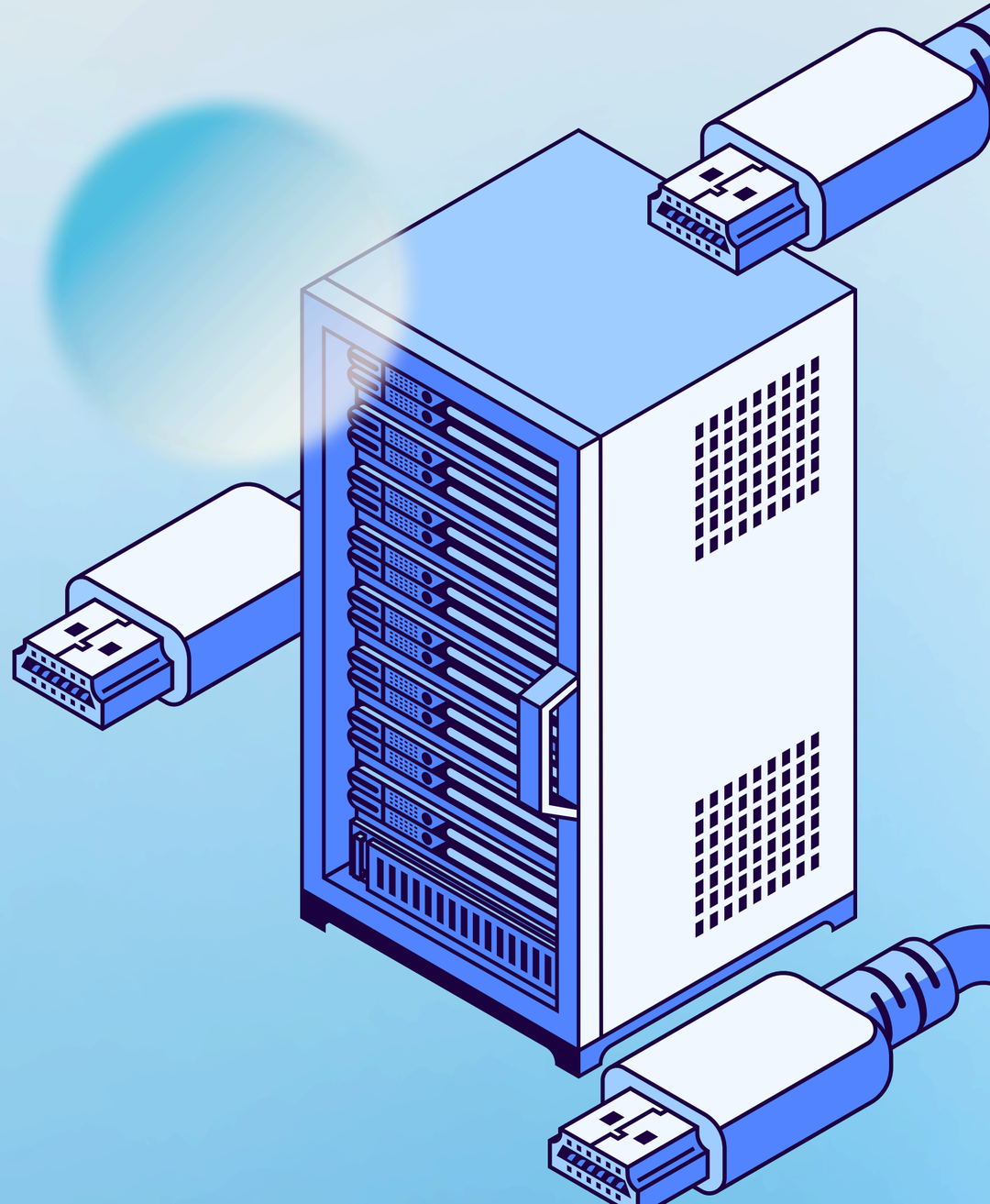
Introduction

Problem: Find fastest emergency routes in Cairo's traffic.

A*: Heuristic-based shortest path algorithm.
Why A*: Balances speed and optimality using heuristics.

Application: Finds fastest emergency routes to hospitals.



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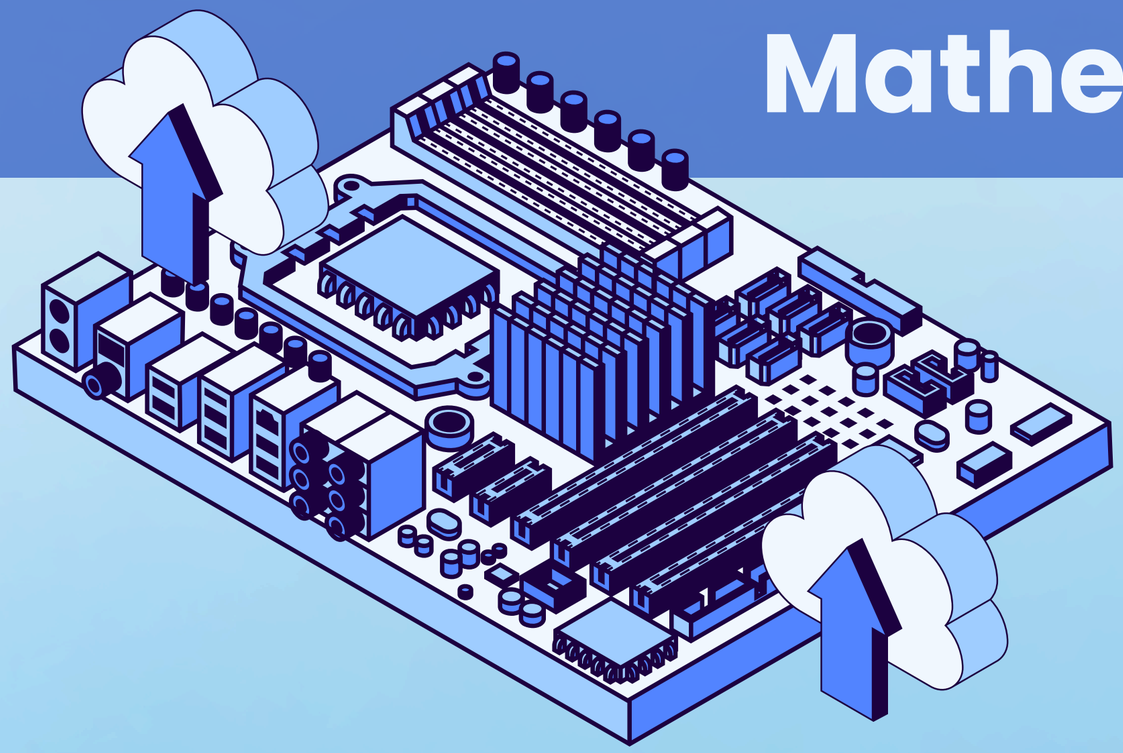
Mathematical Foundations :-



- **A* Formula: f(n) = g(n) + h(n)**

  g(n): Actual cost from start to node n. h(n): Heuristic estimate to goal (Euclidean distance in Cairo).

- **Heuristic: h(n,t) = ✓(Xn - Xt)2 + (Yn - Yt)2 (Euclidean).**

Admissible and consistent → optimal path.
Optimal Path :-

Admissible Heuristic : h(n) ≤ h*(n)
Euclidean distance ≤ road distance.

Consistent Heuristic: h(n) ≤ c(n,n') + h(n')
Satisfies triangle inequality.

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Complexity Analysis :-

- n: number of nodes,
- m : number of edges. Time Complexity (Worst Case): O(m + n log n) (binary minheap, priority queue).
- Space Complexity: O(n) (queue, dictionaries). for storing openSet, gScore, fScore, and cameFrom.

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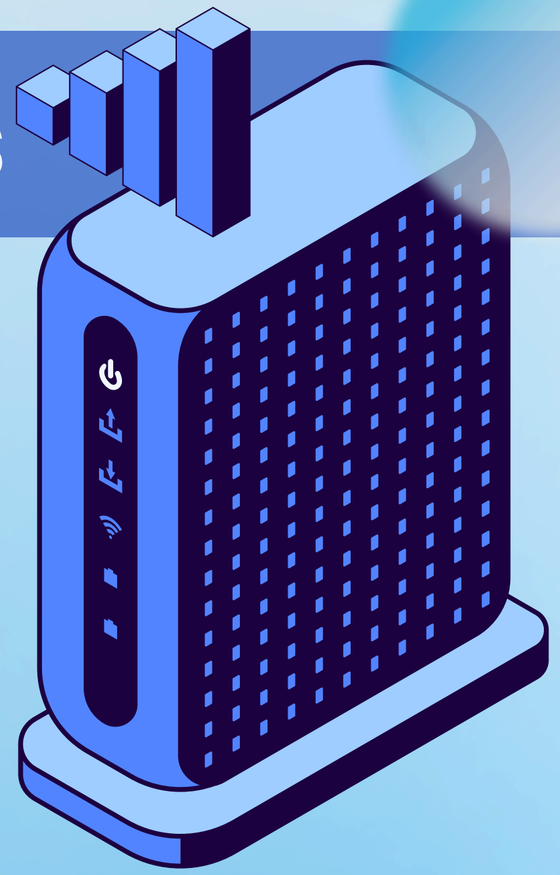
Implementation and Modifications

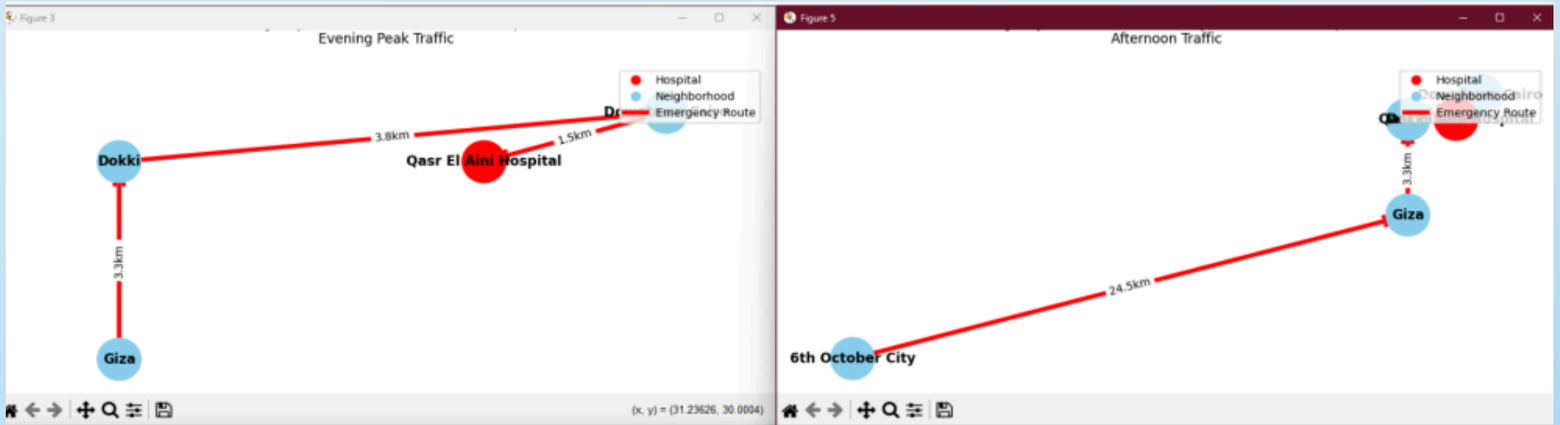


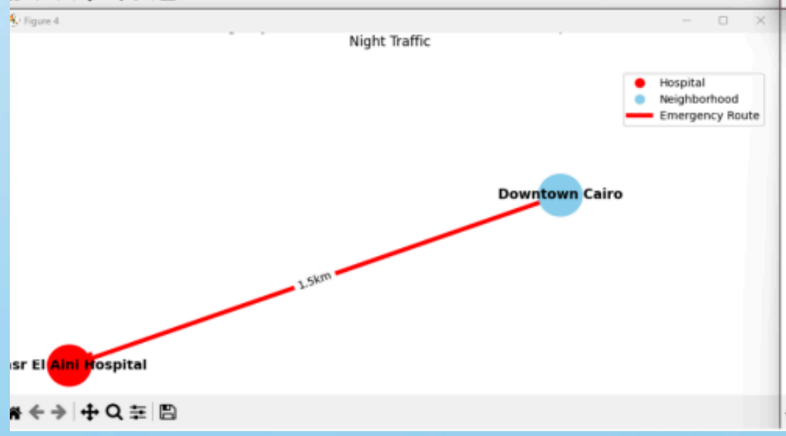
**we modified A*
as follows :-**

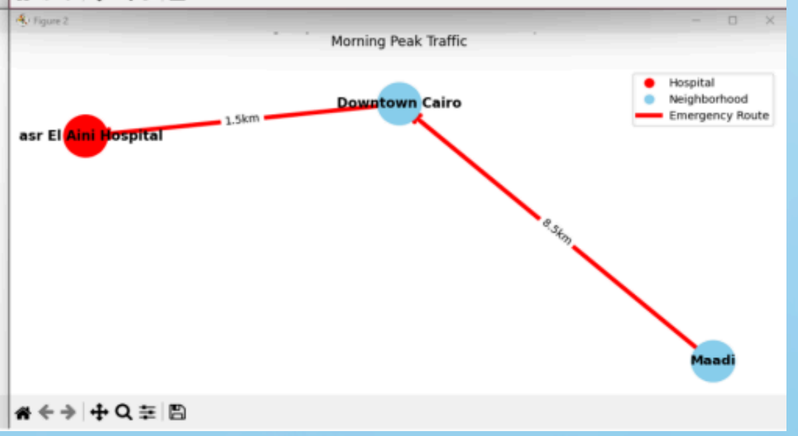
- Edge Weights were made time-dependent :
- Heuristic was Euclidean distance to nearest hospital:
- Graph Preprocessing ensured all roads are bidirectional, and road conditions and traffic levels are normalized.
- Traffic-Aware Modifications:
- Implementation of A*:

- def get_traffic_factor(time_of_day, capacity, flow): utilization = flow / capacity return 1.0 + (0.8 if time_of_day == 'morning_peak' else 0.3) * utilization
- function A_star(start, goal): openSet := {start} cameFrom := empty map gScore[start] := e fScore[start] := h(start, goal) while openSet is not empty: current := node in openSet with lowest fScore if current == goal: return reconstruct_path(cameFrom, current) remove current from openSet for each neighbor of current: tentative_gScore := gScore[current] + d(current, neighbor) if tentative_gScore < gScore[neighbor]: cameFrom[neighbor] := current gScore[neighbor] := tentative_gScore fScore[neighbor] := gScore[neighbor] + h(neighbor, goal)if neighbor not in openSet: add neighbor to openSet

Mathematical Foundations :-







We evaluated A* in different real-time traffic scenarios using our Greater Cairo graph dataset. These Test Cast Traffic Scenarios :-

Morning Traffic (bottom right) :

The route from Maadi to Qasr El Aini Hospital was dynamically chosen via Downtown Cairo, selected the least-cost path (10 km total).

Afternoon Traffic (top right):

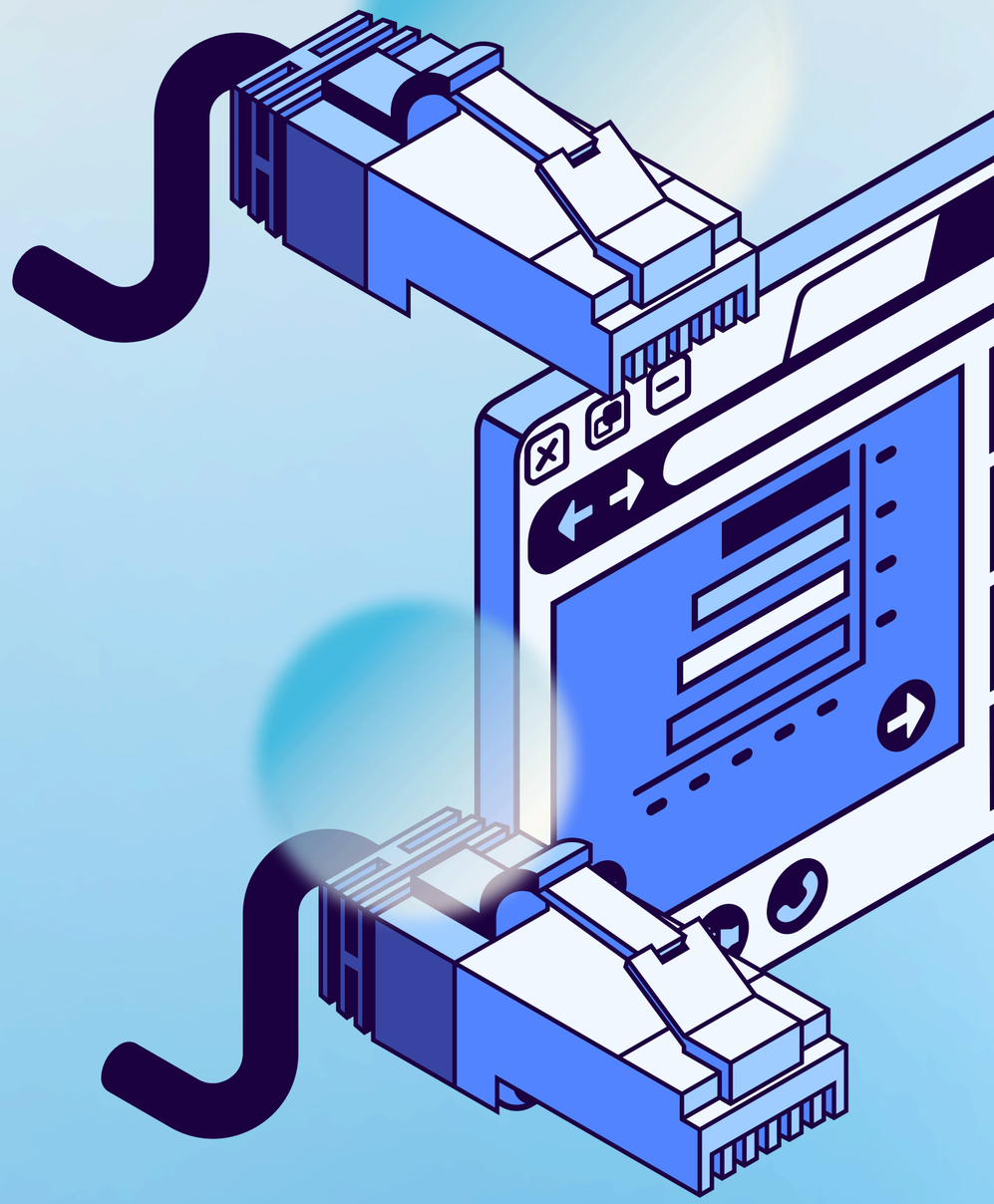
A longer emergency route of 24.5 km was computed from 6th October City to Giza, then to Qasr El Aini Hospital.

Evening Traffic (top left):

In a more central scenario, A* routed traffic from Giza to Dokkī (3.3 km) and then to the hospital (total 8.6 km).

Night Traffic (bottom left):

A direct and minimal-cost path from Downtown Cairo to the hospital (1.5 km) reflects the effectiveness of A* under low-traffic scenarios.



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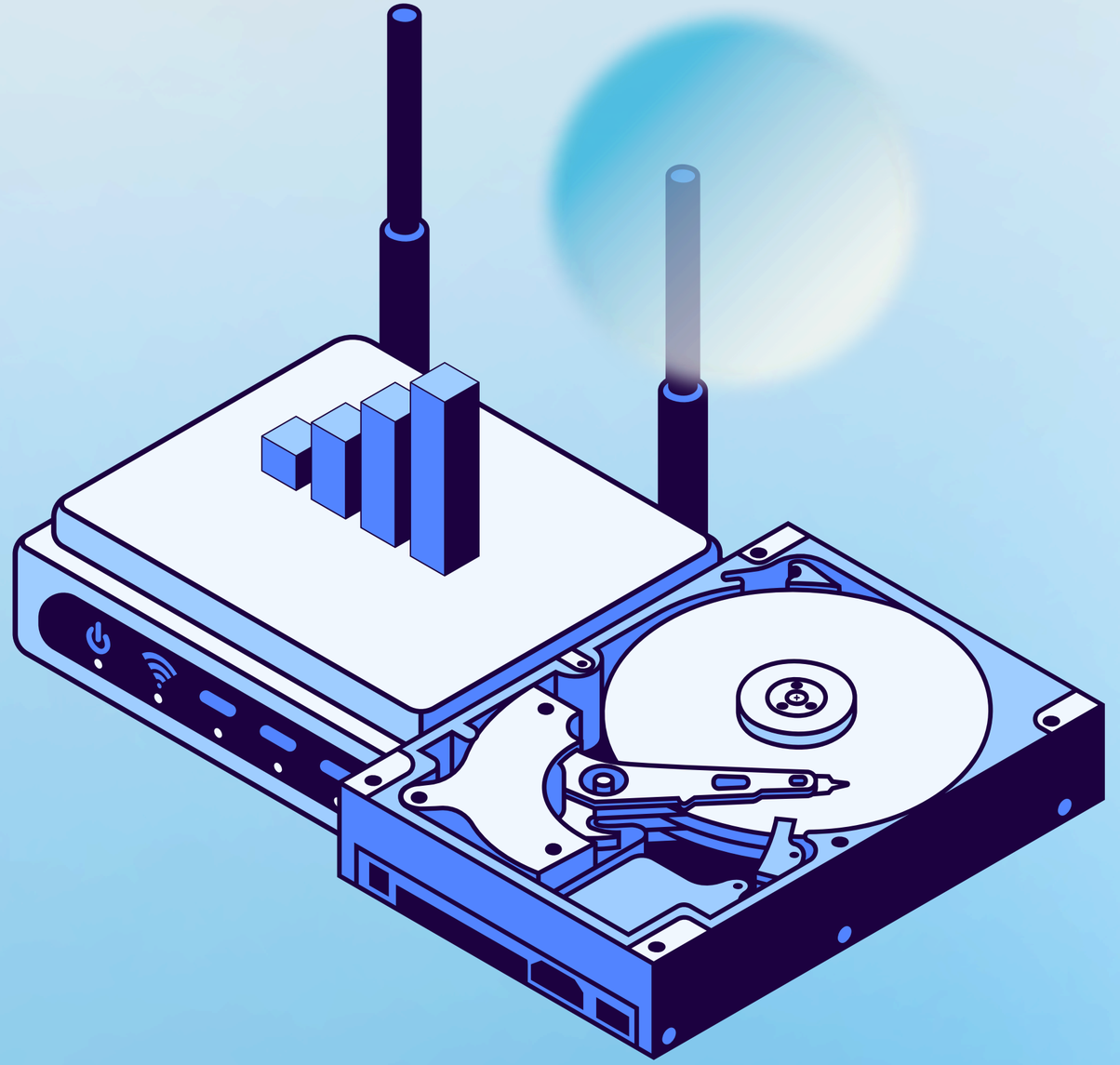
These Scenarios cases validate that A* effectively balances accuracy, optimality, and responsiveness :-

- The heuristic function (Euclidean distance) guided the search effectively.
- The algorithm scaled efficiently with the size of the network.
- It supported dynamic edge weights, enabling real-time adjustments based on traffic density and road conditions.



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Comparison with Alternatives

- **Dijkstra:**

  O(m log n), no heuristic, more nodes explored, it lacks heuristic guidance, it explores more nodes, increasing execution time in large city graphs.

- **Bellman-Ford:**

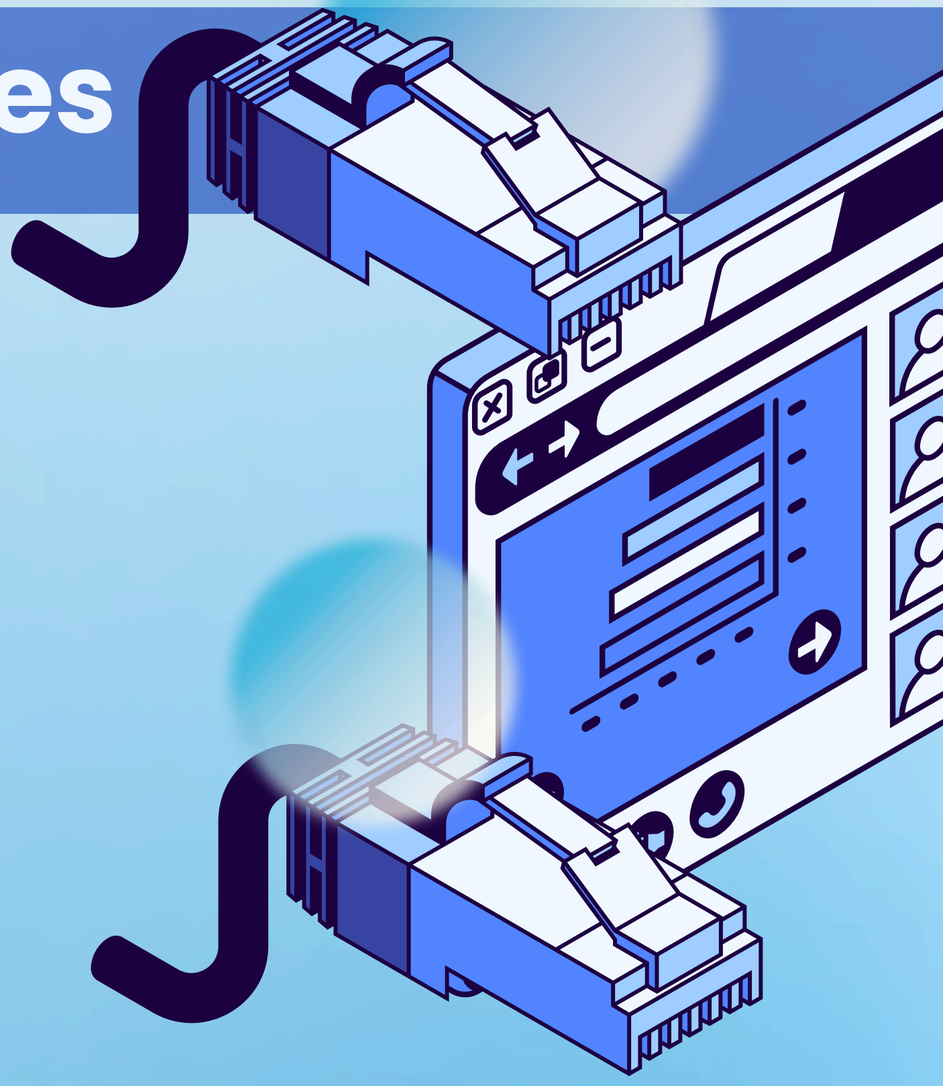
  O(n m), too slow, Handles negative weights and Impractical for large graphs and unnecessary here, as edge weights (distances) are positive.

- **Breadth-First Search:**

  O(n + m), unweighted graphs only, not suitable for real-world traffic systems where edge weights matter, It cannot adapt to variable traffic conditions.

- **A*:**

  O(m + n log n), optimal for weighted, goal-directed search, balance of optimality and efficiency, leveraging the Euclidean heuristic to reduce the search space.



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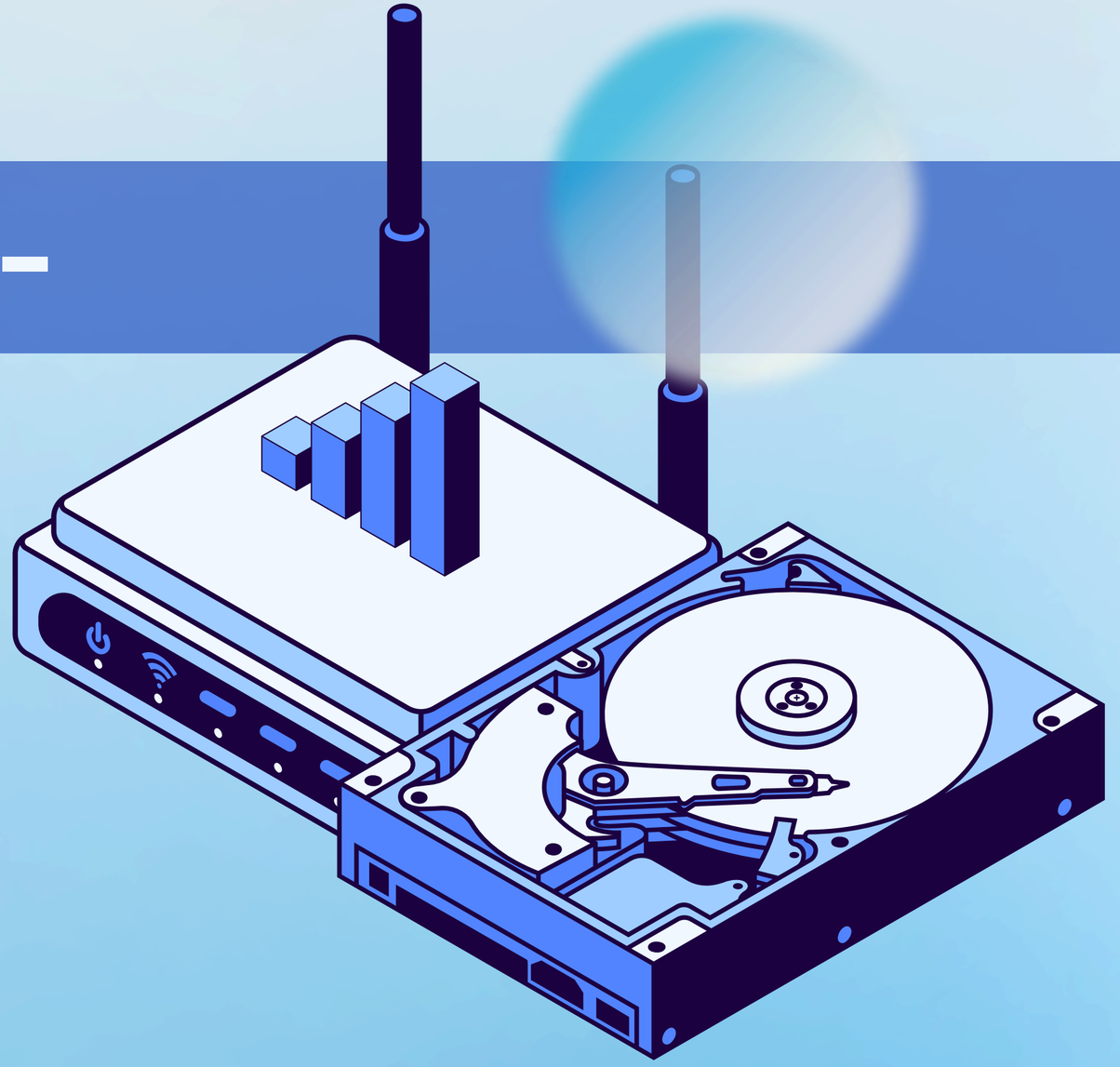
Lessons Learned :-

Given the need for fast, accurate, and adaptable routing in emergency situations within smart cities, A* offers the best balance. Its ability to incorporate traffic data through cost functions and heuristics makes it superior for real-time urban navigation, particularly in dense areas like Greater Cairo.



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Conclusion :-

A* outperforms alternatives like Dijkstra's and BFS in emergency routing due to its goal-directed approach and ability to integrate real-time traffic data through heuristics. This makes it faster and more suitable for dynamic, realworld urban environments like Greater Cairo.

Team 7

Thank You!

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