4. Why Your City Is a Network: The Role of Graph Theory in Earthquake Response

To a computer, a city is not a map of buildings and streets; it is a network. It is a vast, interconnected system of points and connections. The formal mathematical framework for modeling such systems is **Graph Theory**, a cornerstone of our simulation approach (D4.3, Section 3.2.2).

In our models, the urban environment is translated into a graph:

- **Nodes (or Vertices):** These are key locations. They can represent street intersections, hospitals, fire stations, or critical infrastructure points like bridges.
- **Edges:** These are the connections between the nodes. They represent roads, power lines, or pipelines. Each edge is assigned properties, or "weights," such as **length** (travel time) and **capacity** (how much traffic it can handle).

This graph-based representation is indispensable in a crisis like the **Earthquake Scenario (Section 3.4)**. When an earthquake strikes, this "graph" is dynamically damaged.

- **Nodes** may be destroyed and "removed" from the graph.
- **Edges** may be blocked by debris, and their "capacity" is reduced to zero.

The simulation's primary task is to instantly re-analyze this new, broken graph. The AI uses established graph algorithms to find new optimal routes. Key computations include:

- **Shortest Path:** Finding the new fastest route from a "start" node (like a fire station) to an "end" node (an incident location) on the damaged network. This is the new, optimized route for emergency responders.
- **Independent Paths:** Identifying multiple routes from A to B that do not share any common nodes (intersections). As seen in **Figure 9** of the deliverable, this is crucial for resilience. It ensures that if one evacuation route fails, the others remain viable, preventing a single point of failure.

By representing the city as a dynamic graph, we can instantly calculate new, safe, and efficient routes for both evacuation and emergency response the moment the infrastructure is compromised.