2. The Bottleneck Busters: Using "Queue Theory" to Manage Disaster-Stricken Urban Areas

In any large-scale disaster, one of the most immediate and dangerous problems is congestion. Mass evacuations or the dispatch of emergency vehicles can create critical bottlenecks at intersections, on bridges, and at hospital entrances. This congestion is not just an inconvenience; it can be fatal, preventing aid from reaching victims or stopping evacuees from getting to safety.

To address this, our research (D4.3, Section 3.2.3) employs a powerful mathematical tool: **Queue Theory**.

Queue Theory is the formal, mathematical study of waiting lines. It provides models—such as the M/M/c model used in our work—to analyze systems where "customers" (which can be cars, patients, or data packets) arrive for "service" (such as passing an intersection, being triaged, or being processed). This theory allows us to precisely calculate metrics like expected wait times and the probability of a queue becoming overloaded.

In our **Earthquake Scenario (Section 3.4)**, this theory is put into practice. When an earthquake damages roads, traffic is forcibly funneled onto fewer available routes.

- First, our simulation uses queue theory to *predict* the length of the resulting traffic jams (queues) at key intersections.
- Then, the self-adaptive system begins to solve the problem.

By referencing **Figure 10** in the deliverable, we can see the initial simulation, which shows massive, uncontrolled queue lengths at several nodes. This is the "before" picture.

After applying our adaptive AI (detailed in **Figure 11**), the "after" picture is dramatically different. The AI, using Reinforcement Learning, "learns" to reduce these queues by digitally testing new parameters. It might, for example, discover that by changing the traffic signal timings at three key intersections and re-allocating a specific road for emergency-only traffic, the queue lengths (and thus wait times) are reduced by over 60%.

By digitally modeling and solving these "queues," we can design and validate traffic management strategies to mitigate the worst bottlenecks *before* they paralyze a real-world emergency response.