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Rapid Urban Evacuation across Constrained Transport Networks

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BACKGROUND

Evacuations are necessary response in the event of disasters. However, traffic congestions due to the surge of demand and sub-optimal planning often limits the effectiveness of an evacuation. It is suggested that scheduling the departure time and assisting the destination and path choice of evacuees could optimise the evacuation process. A system-optimal dynamic traffic assignment problem is formulated.

FRAMEWORK

The problem is solved using a simulation based, metaheuristic approach. The proposed model has two levels, a decision-maker and a evaluator. The upper-level is a real-coded genetic algorithm **(RCGA) engine** while the lower-level is a **path based traffic simulator** by (Han, et al., 2012).

The model preprocesses the network to generate paths using Yen's algorithm (Yen, 1971). Each solution is evaluated and given a fitness score. Each individual is a 2D array. At decision intervals(a number of simulation timestep), the shortest paths are recalculated and the next values of departure rates assigned to them.

Table 1: An individual. Rows represent the decision timestep & columns represent the paths

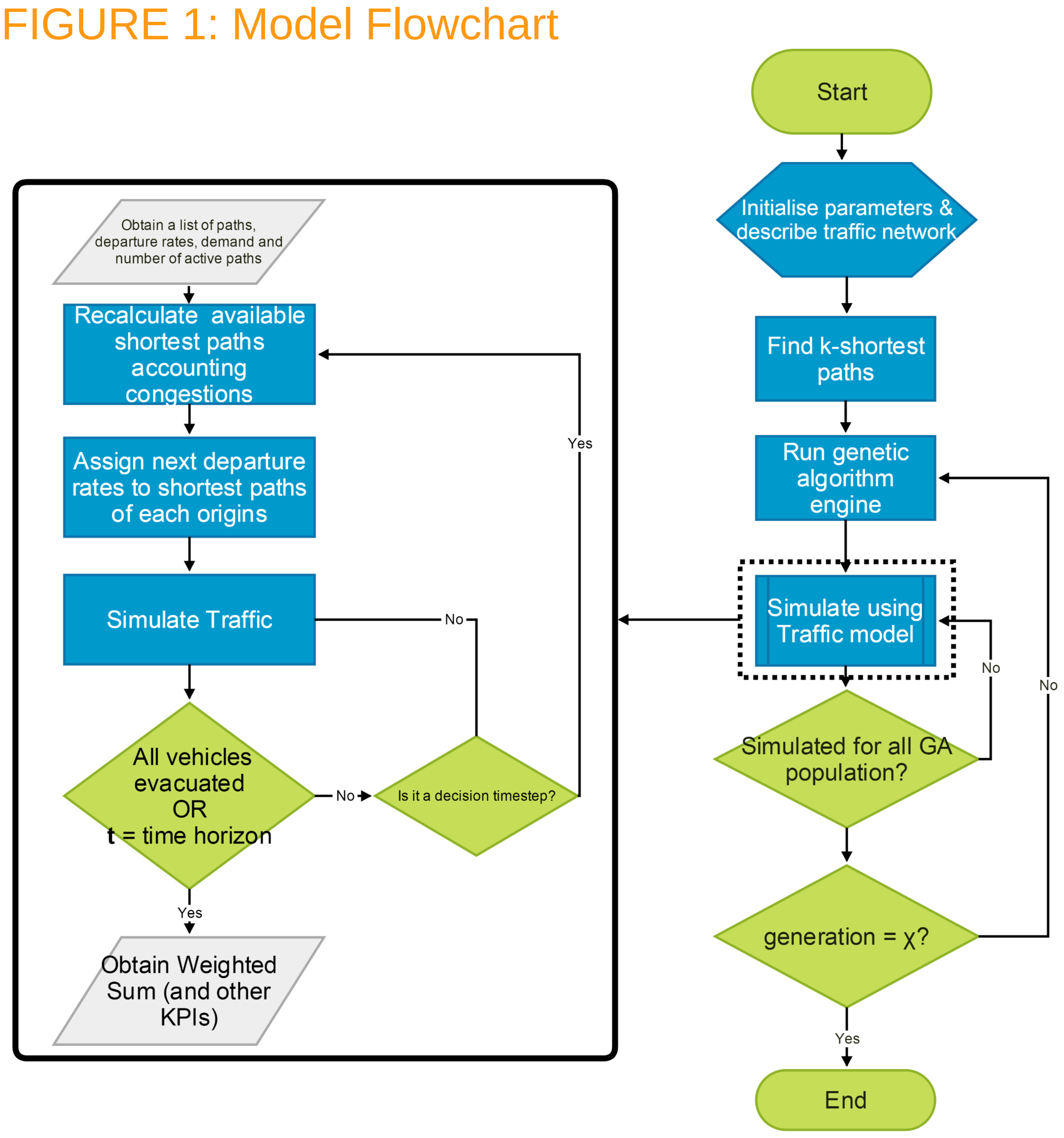
	path 1	path 2	path 3
t=0-10	2.1	1.5	3.1
t=10-20	1.7	1.6	2.4

OBJECTIVE FUNCTION

$$\text{maximise } Z = \sum_{j}\sum_{t}^{T}\frac{1}{t}\times V_{cum}^{t}$$

The objective function aims to maximise the weighted sum of the cumulative number of vehicles arriving at sink nodes. This promotes solutions which facilitate early vehicle network exits.

FIGURE 1: Model Flowchart



TRAFFIC SIMULATION

A state-of-the-art dynamic traffic assignment model, a continuous time link-based kinematic wave model (LKWM), by (Han, et al., 2012) deals with the disadvantages of macroscopic models. The model is based on the scalar conservation law model (LWR model). It models traffic as flows but is able to capture queues in traffic flow and perform the simulation dynamically.

GENETIC ALGORITHM

RCGA is used to optimise our problem as it is able to generate good-enough solutions and remain computationally efficient. The basic idea is to represent each variable as a chromosome, each solution as a candidate/individual. A population consist of many individuals.

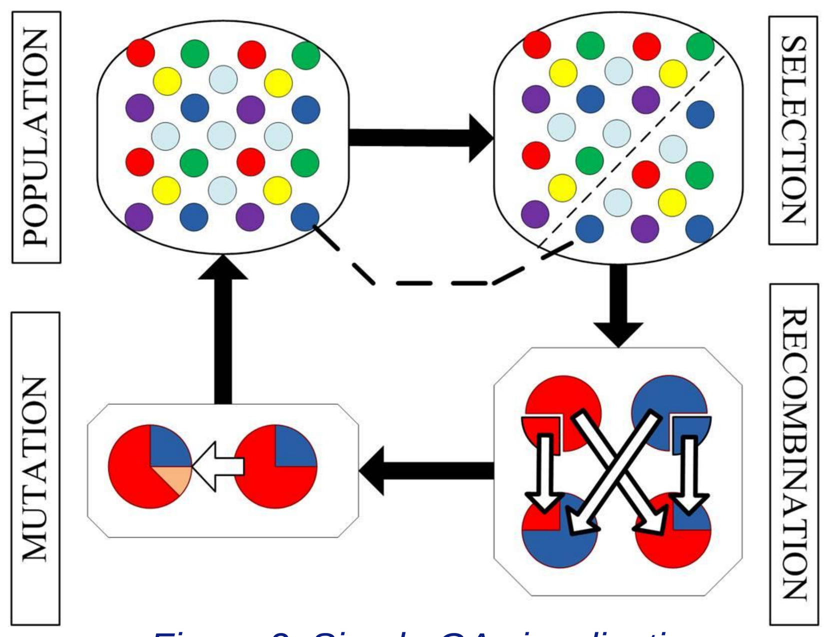


Figure 2: Simple GA visualisation

Based on the fitness score, individuals undergo selection to create a parent set. Offspring are generated from the parent set through crossover and mutation operators.

This procedure is iterated until it reaches the number of iterations specified and a optimal solution is output.

TABLE 2

GA Elements	Method
Encoding	Real Coded Integers
Initial Population	Random
Selection	Binary Tournament Selection
Crossover	BLX-alpha
Mutation	Non-uniform Mutation
Stopping Criterion	Reaching specified generation

RESULTS

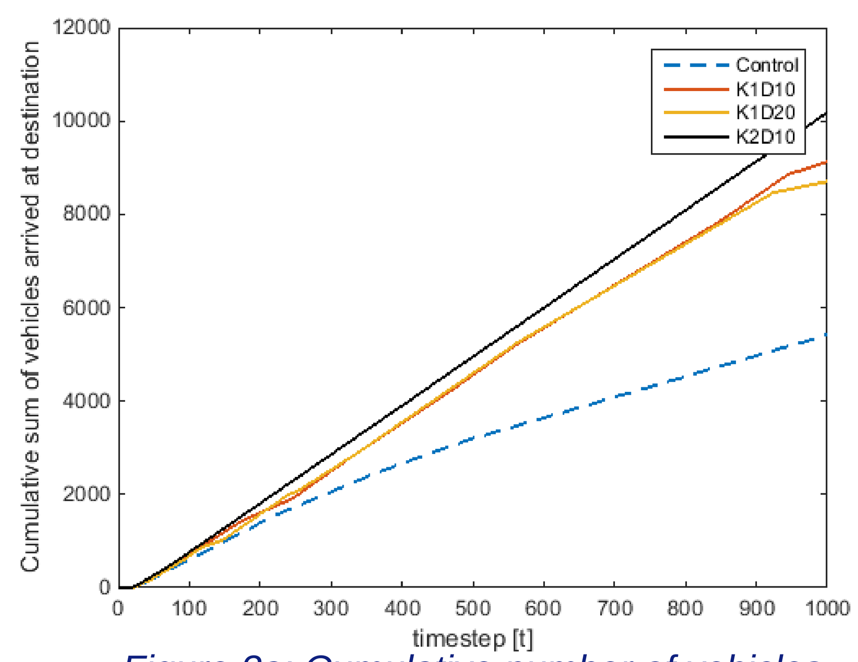


Figure 3a: Cumulative number of vehicles arriving at sinks

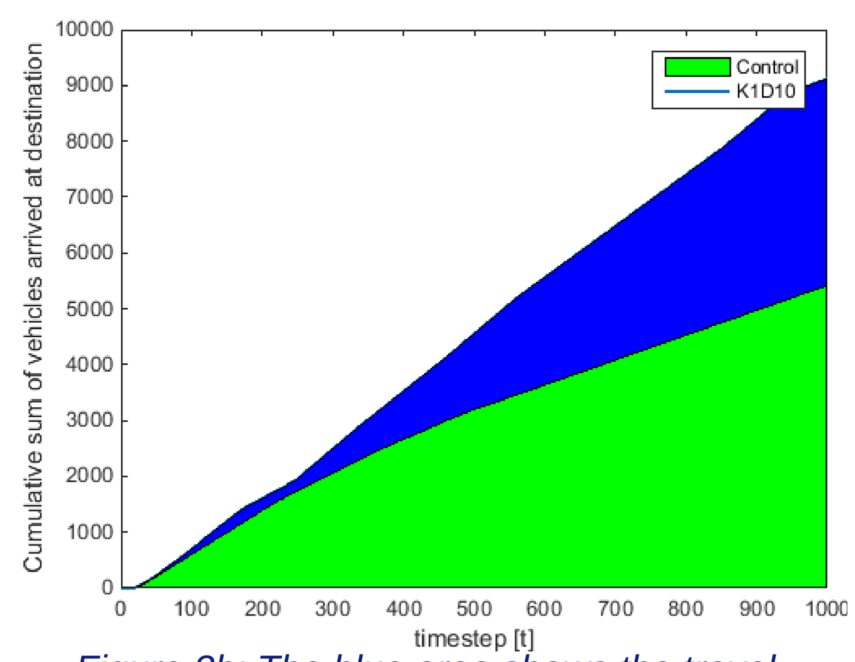


Figure 3b: The blue area shows the travel time saved

Three cases were compared against a benchmark case. The three cases have slightly differing parameters to test the sensitivity of the model. All three cases showed significant improvement over the benchmark case. The best case (K2D10) showed 66.3% reduction in total travel travel and twice the number of vehicles exiting the network at the end of the simulation.

All three scenarios converged to a solution by the end of the optimisation process. K2D10 can be seen visibly to be much better than the other two cases.

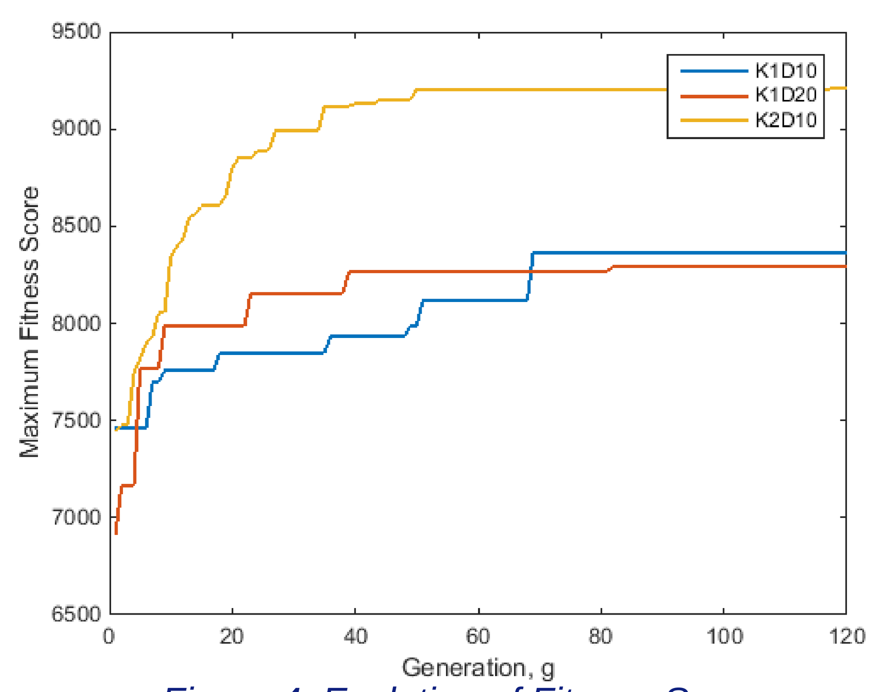


Figure 4: Evolution of Fitness Scores

CONCLUSION

The model generated very promising non-conservative solutions with improvement to all KPIs. The model has potential to improved by incorporating other evacuation strategies, optimizing the code, better parameterization, and increased parallelisation support.

REFERENCES

Han, K., Piccoli, B. & Szeto, W.Y. (2012) Continuous-Time Link-based Kinematic Wave Model : Formulation, Solution Existence and Well-Posedness. 1–34.

Yen, J.Y. (1971) Finding the K Shortest Loopless Paths in a Network. Management Science. [Online] 17 (11), 712–716. Available from: doi:10.1287/mnsc.17.11.712.

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