Medical Geography

EMS Resource Allocation

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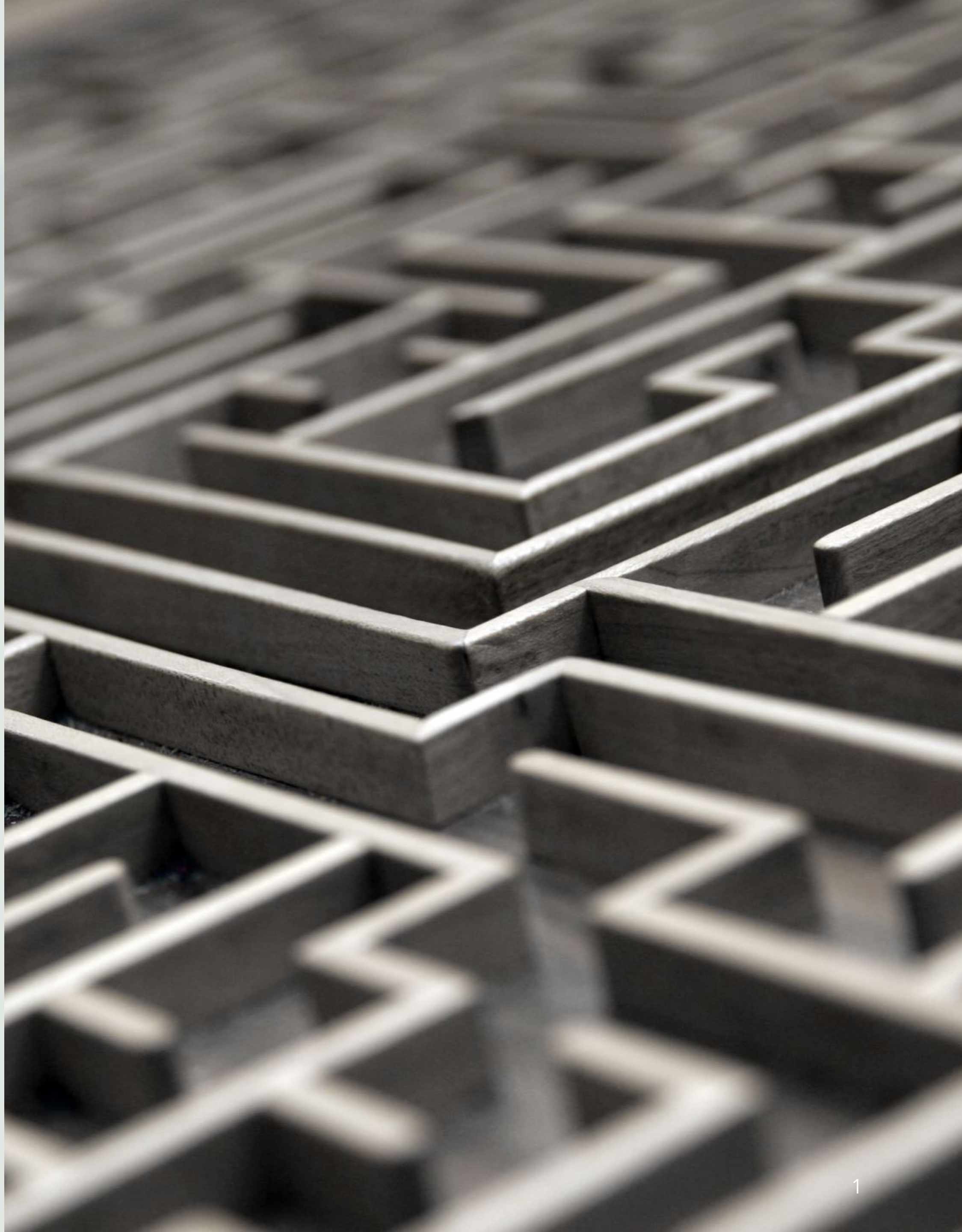
Outline

- EMS Dispatch Dilemma
- Medical Resource Allocation
- Ambulance Dispatch



EMS Publications

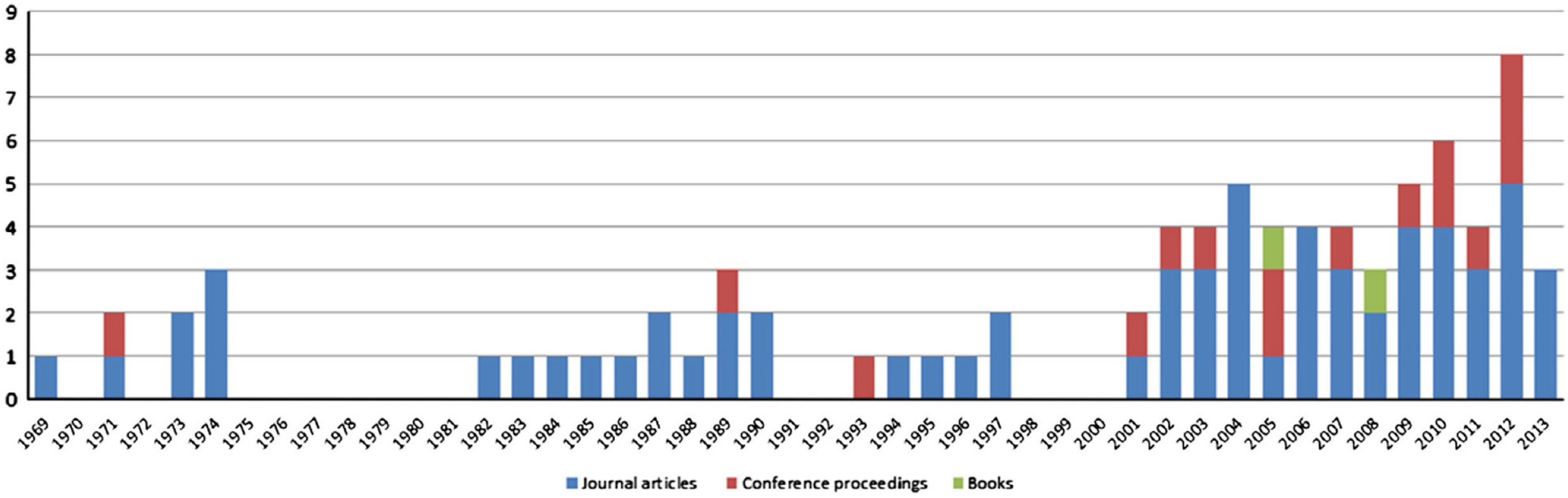


Fig. 1. Number of publications per year and per type.

Aboueljinane, L., Sahin, E., & Jemai, Z. (2013). A review on simulation models applied to emergency medical service operations. *Computers & Industrial Engineering*, *66*(4), 734-750.

Agent-based Model

- Agent-based modeling is a powerful simulation modeling technique that has seen a number of applications in the last few years, including applications to real-world business problems. After the basic principles of agent-based simulation are briefly introduced, its four areas of application are discussed by using real-world applications: flow simulation, organizational simulation, market simulation, and diffusion simulation. For each category, one or several business applications are described and analyzed.

Bonabeau, E. (2002). Agent-based modeling: Methods and techniques for simulating human systems. Proceedings of the national academy of sciences, 99(suppl_3), 7280-7287.

Agent-based Model

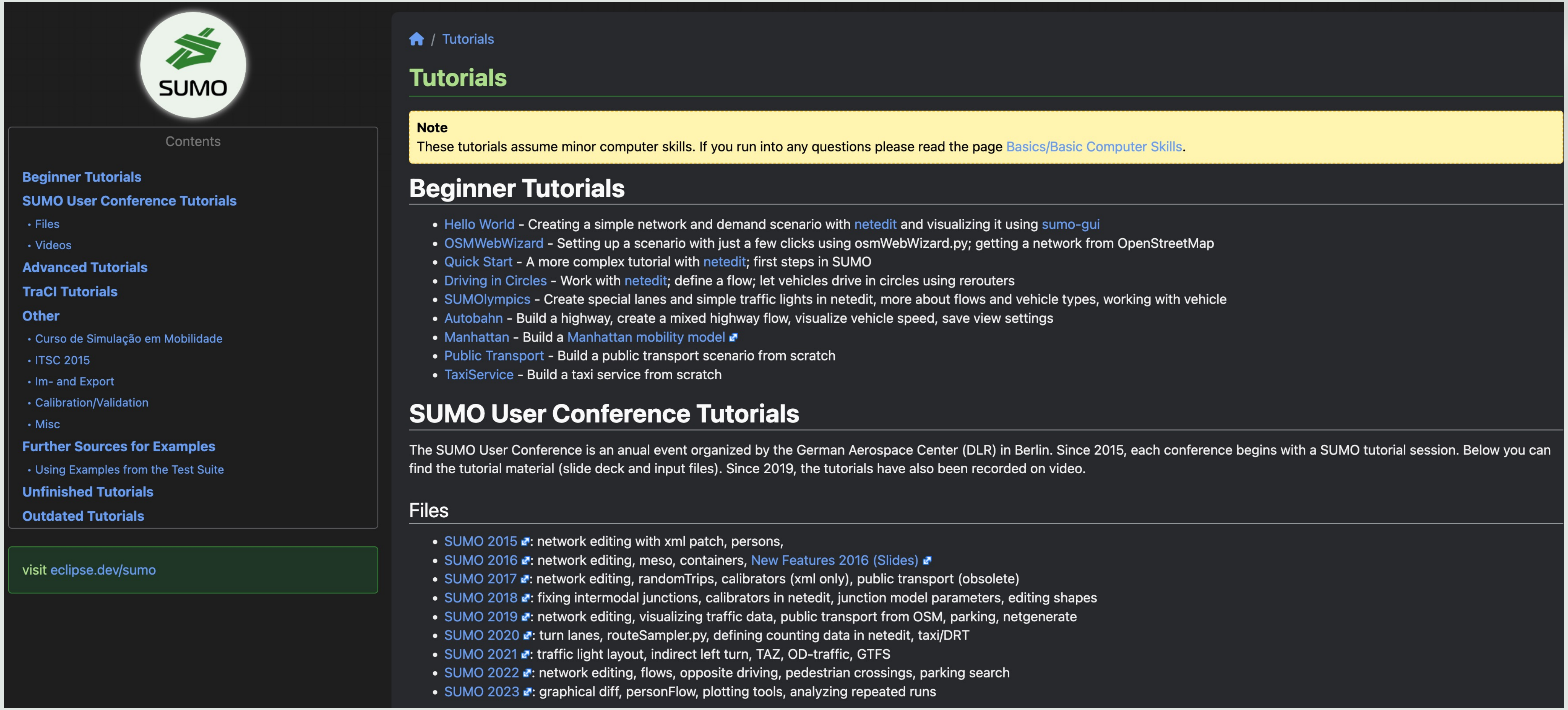
Bonabeau, E. (2002). Agent-based modeling: Methods and techniques for simulating human systems. *Proceedings of the national academy of sciences*, *99*(suppl_3), 7280-7287.

- One may want to use ABM when there is potential for emergent phenomena, i.e., when:
  - **Individual behavior** is **nonlinear** and can be characterized by **thresholds**, if-then rules, or nonlinear coupling. Describing discontinuity in individual behavior is difficult with differential equations.
  - **Individual behavior** exhibits memory, path-dependence, and hysteresis, non-markovian behavior, or temporal correlations, including learning and adaptation.
  - **Agent interactions are heterogeneous and can generate network effects.** Aggregate flow equations usually assume global homogeneous mixing, but the topology of the interaction network can lead to significant deviations from predicted aggregate behavior.
  - **Averages will not work.** Aggregate differential equations tend to smooth out fluctuations, not ABM, which is important because under certain conditions, fluctuations can be amplified: the system is linearly stable but unstable to larger perturbations.

Agent-based Model

- Examples of emergent phenomena abound in the social, political, and economic sciences. It has become progressively accepted that some phenomena can be difficult to predict and even counterintuitive. In a business context, situations of interest where emergent phenomena may arise can be classified into four areas:
  - **Flows:** evacuation, traffic, and customer flow management.
  - **Markets:** stock market, shopbots and software agents, and strategic simulation.
  - **Organizations:** operational risk and organizational design.
  - **Diffusion:** diffusion of innovation and adoption dynamics.
- The rest of the article is organized around these areas of application.

Traffic Simulation – SUMO



Contents

visit eclipse.dev/sumo

/ Tutorials

Tutorials

Note
These tutorials assume minor computer skills. If you run into any questions please read the page Basics/Basic Computer Skills.

Beginner Tutorials

- Hello World - Creating a simple network and demand scenario with netedit and visualizing it using sumo-gui
- OSMWebWizard - Setting up a scenario with just a few clicks using osmWebWizard.py; getting a network from OpenStreetMap
- Quick Start - A more complex tutorial with netedit; first steps in SUMO
- Driving in Circles - Work with netedit; define a flow; let vehicles drive in circles using rerouters
- SUMOlympics - Create special lanes and simple traffic lights in netedit, more about flows and vehicle types, working with vehicle
- Autobahn - Build a highway, create a mixed highway flow, visualize vehicle speed, save view settings
- Manhattan - Build a Manhattan mobility model
- Public Transport - Build a public transport scenario from scratch
- TaxiService - Build a taxi service from scratch

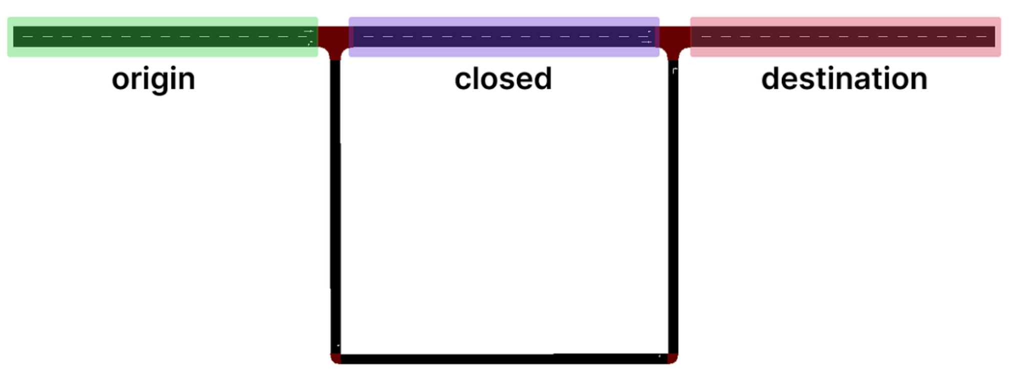
SUMO User Conference Tutorials

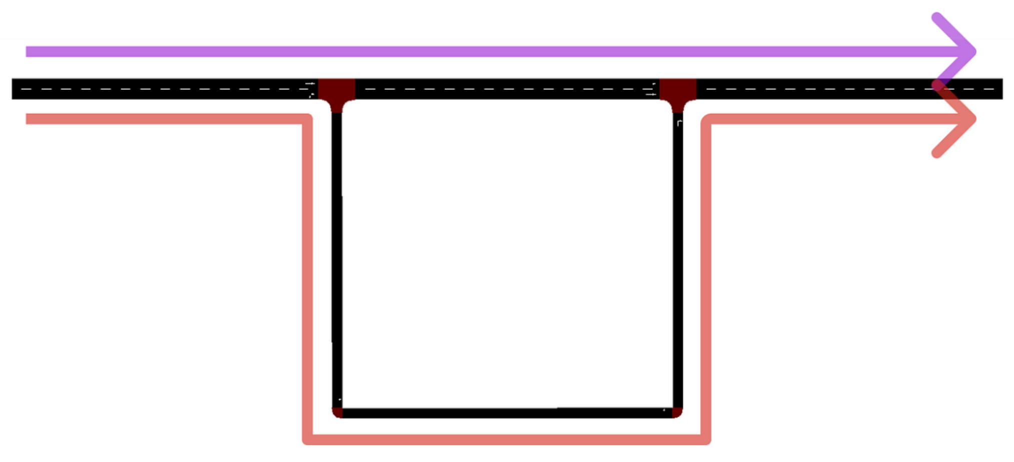
The SUMO User Conference is an anual event organized by the German Aerospace Center (DLR) in Berlin. Since 2015, each conference begins with a SUMO tutorial session. Below you can find the tutorial material (slide deck and input files). Since 2019, the tutorials have also been recorded on video.

Files

- SUMO 2015: network editing with xml patch, persons,
- SUMO 2016: network editing, meso, containers, New Features 2016 (Slides)
- SUMO 2017: network editing, randomTrips, calibrators (xml only), public transport (obsolete)
- SUMO 2018: fixing intermodal junctions, calibrators in netedit, junction model parameters, editing shapes
- SUMO 2019: network editing, visualizing traffic data, public transport from OSM, parking, netgenerate
- SUMO 2020: turn lanes, routeSampler.py, defining counting data in netedit, taxi/DRT
- SUMO 2021: traffic light layout, indirect left turn, TAZ, OD-traffic, GTFS
- SUMO 2022: network editing, flows, opposite driving, pedestrian crossings, parking search
- SUMO 2023: graphical diff, personFlow, plotting tools, analyzing repeated runs

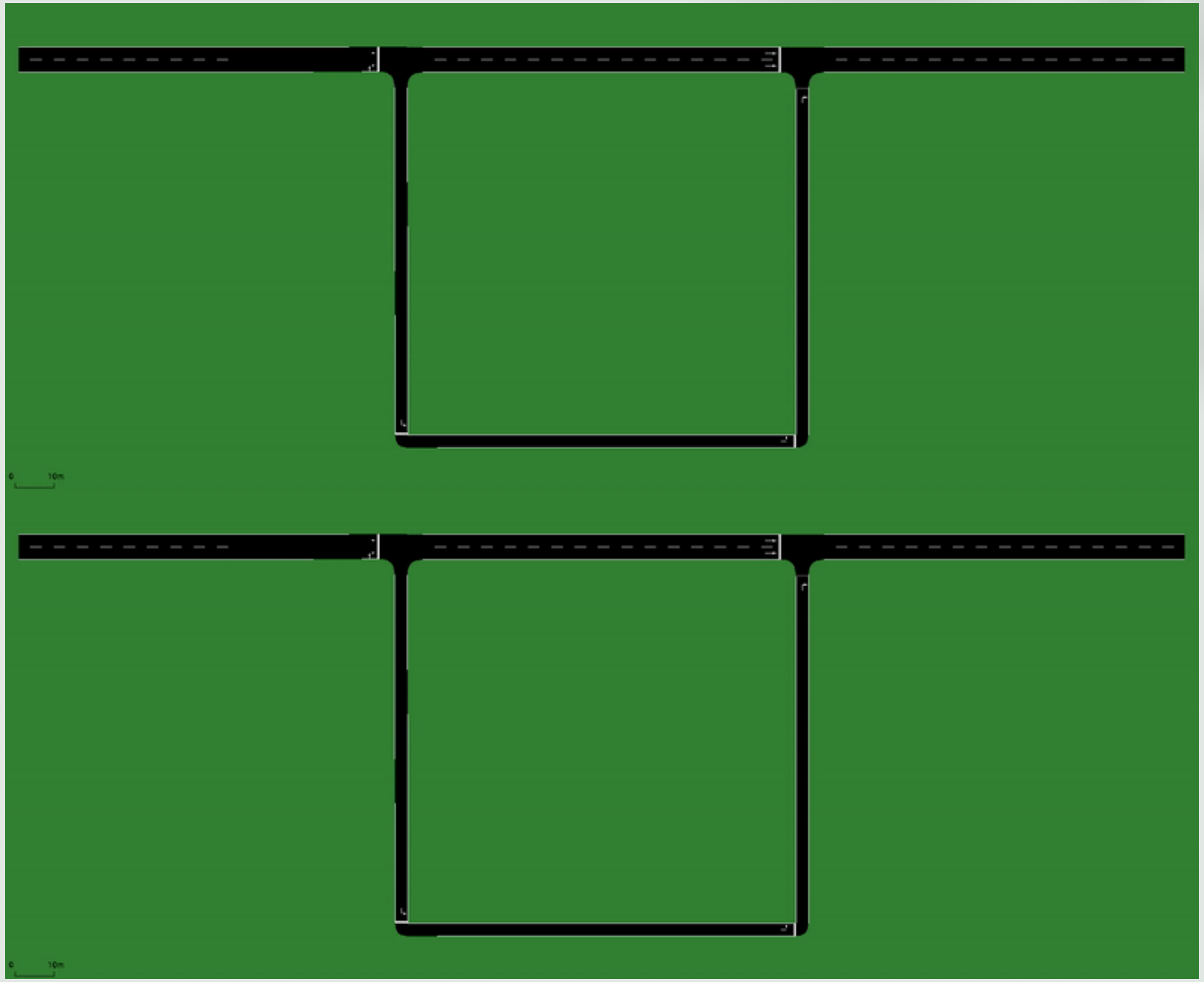
Traffic Simulation – SUMO



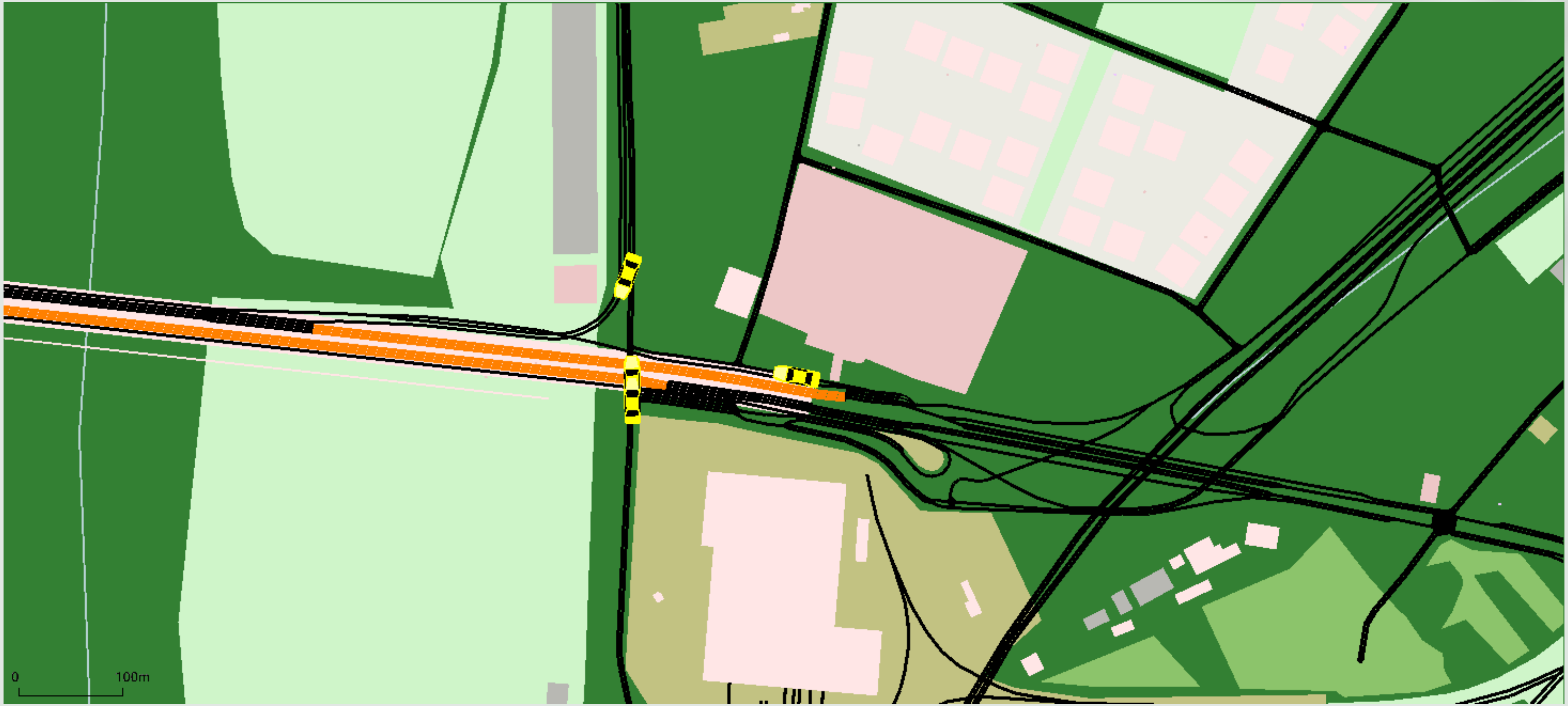


Possible vehicular route configurations on the example network.

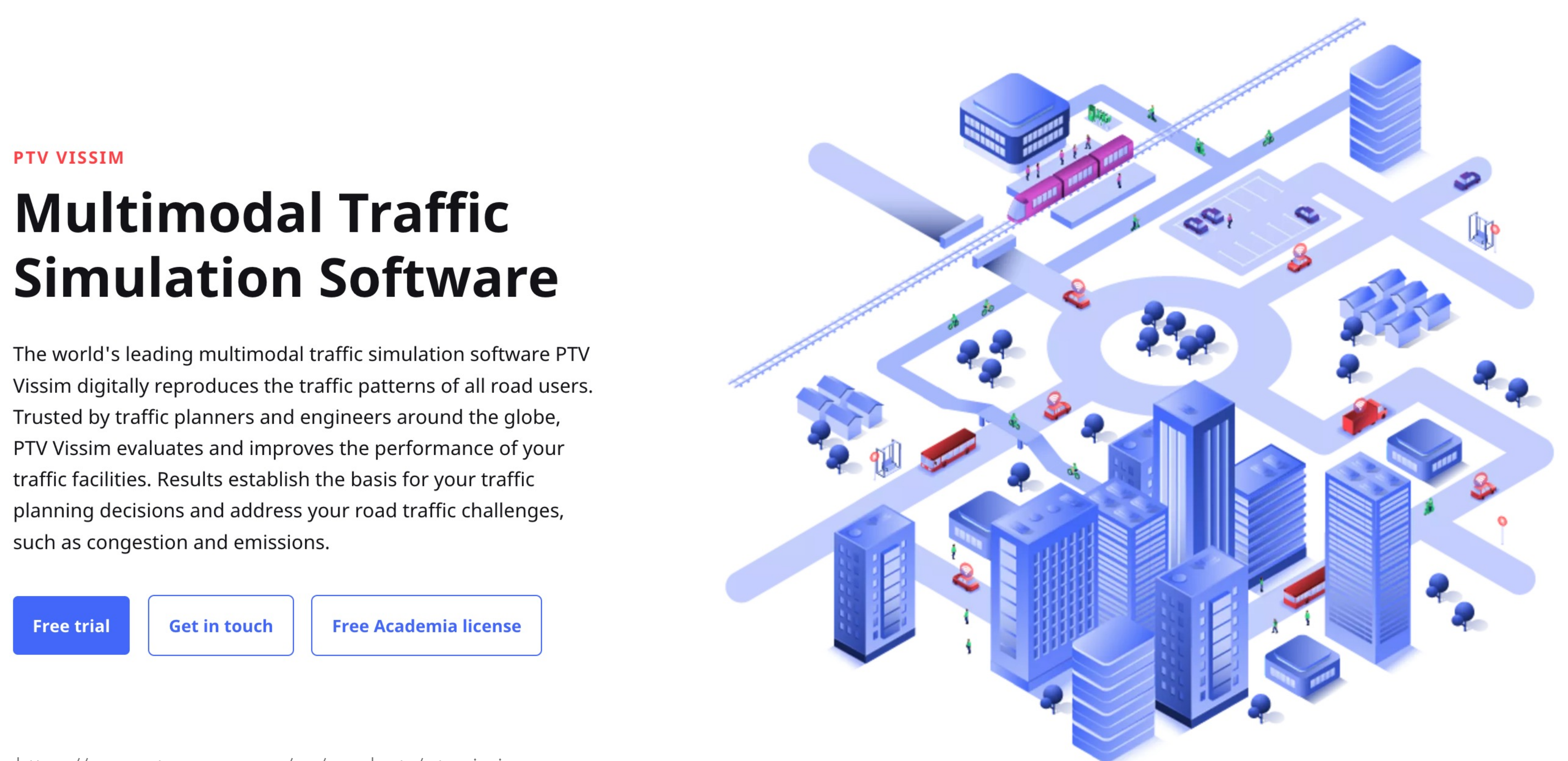
https://medium.com/@devonfazekas/simulating-dynamic-vehicular-detours-based-on-edge-travel-time-in-sumo-e57a50457dba



Traffic Simulation – Demo



Traffic Simulation – VISSIM



PTV VISSIM

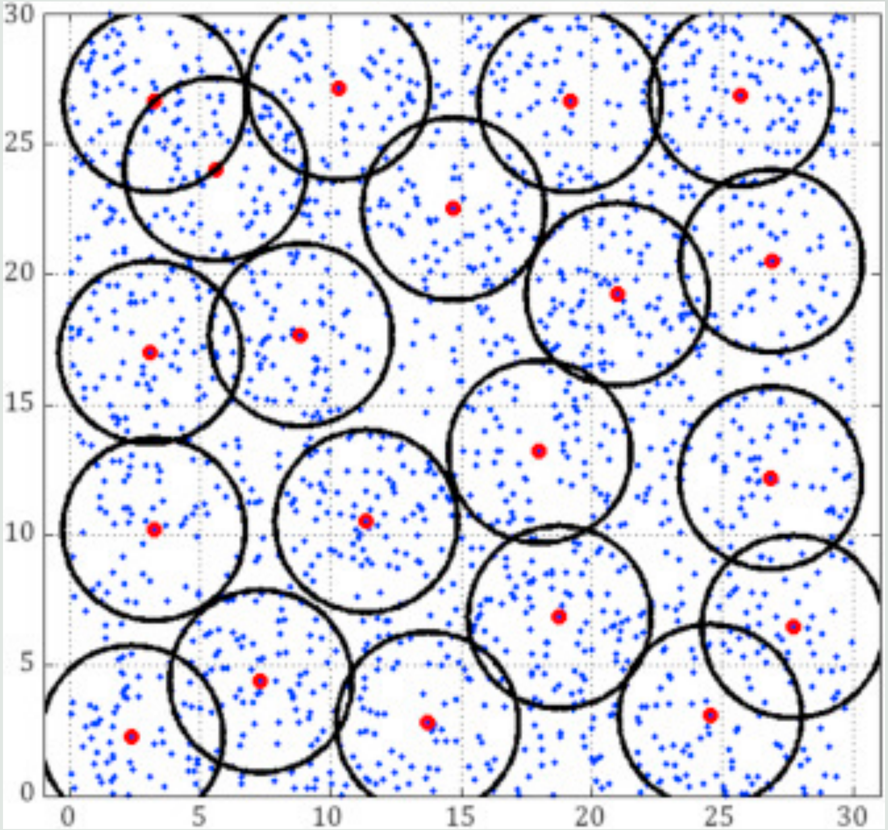
Multimodal Traffic Simulation Software

The world's leading multimodal traffic simulation software PTV Vissim digitally reproduces the traffic patterns of all road users. Trusted by traffic planners and engineers around the globe, PTV Vissim evaluates and improves the performance of your traffic facilities. Results establish the basis for your traffic planning decisions and address your road traffic challenges, such as congestion and emissions.

https://www.ptvgroup.com/en/products/ptv-vissim

Mathematical Modeling

- Some facilities have to be set in a location that could satisfy all users with a reasonable service range, for example, emergency facilities.
- We usually classify these problems into two types:
    - LSCP (location set covering problem)
    - MCLP (maximal covering location problem)



Zarandi, M. F., Davari, S., & Sisakht, S. H. (2011). The large scale maximal covering location problem. *Scientia Iranica*, *18*(6), 1564-1570.

Location Set Covering Problem (LSCP)

- Think about that your budget is infinite, … and all facilities have to offer service to all people within the service area under some conditions.

$$minimize \sum_{j} C_j X_j$$

$$subject\ to: \sum_{j \in N_i} X_j \geq 1, \forall i$$

$$X_j \in \{0,1\}, \forall j$$

$$where\ N_i = \{\, j \mid d_{ij} \leq S \}$$

Location Set Covering Problem (LSCP)

- Please find a suitable location for new hospital.

$$D = \left(d_{ij}\right) = \begin{array}{cc} \begin{matrix} A & B & C & D \end{matrix} & \\ \begin{bmatrix} 3 & 7 & 4 & 8 \\ 4 & 3 & 3 & 6 \\ 8 & 7 & 6 & 4 \\ 6 & 6 & 3 & 6 \\ 4 & 3 & 7 & 4 \end{bmatrix} & \begin{matrix} V \\ W \\ X \\ Y \\ Z \end{matrix} \end{array} = \begin{bmatrix} 1 & 0 & 1 & 0 \\ 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 1 & 1 & 0 & 1 \end{bmatrix}$$

>5min → 0

$$arcmin\ X_1 + X_2 + X_3 + X_4$$
$$subject\ to\ X_1 + X_3 \geq 1$$
$$X_1 + X_2 + X_3 \geq 1$$
$$X_4 \geq 1$$
$$X_3 \geq 1$$
$$X_1 + X_2 + X_4 \geq 1$$
$$X_1, X_2, X_3, X_4 \in \{0,1\}$$

Maximal Covering Location Problem (MCLP)

- Given a finite (limited) budget, maximize the service area of all facilities under some conditions.

$$maximize \sum_{i} h_i Z_i$$

$$subject\ to\ Z_i \le \sum_{j \in N_i} X_j\ , \forall i$$

$$\sum_{j} X_j \le P \ldots \Rightarrow maximal\ number\ of\ service\ stations \Rightarrow j$$

$$X_j \in \{0,1\}, \forall j$$

$$Z_i \in \{0,1\}, \forall i$$

$$where\ N_i = \left\{ j \mid d_{ij} \le S \right\}$$

Maximal Covering Location Problem (MCLP)

- Given the population of each district is as follows:

$$h_1 = 100; h_2 = 50; h_3 = 40; h_4 = 18; h_5 = 3$$

- Please find a suitable location for new hospital.

$$D = \left(d_{ij}\right) = \begin{array}{cc} \begin{matrix} \mathbf{A} & \mathbf{B} & \mathbf{C} & \mathbf{D} \end{matrix} & \\ \begin{bmatrix} 8 & 3 & 4 & 7 \\ 1 & 3 & 3 & 3 \\ 9 & 4 & 7 & 7 \\ 4 & 0 & 9 & 0 \\ 2 & 5 & 1 & 8 \end{bmatrix} & \begin{matrix} \mathbf{V} \\ \mathbf{W} \\ \mathbf{X} \\ \mathbf{Y} \\ \mathbf{Z} \end{matrix} \end{array} = \begin{bmatrix} 0 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 \\ 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 1 \\ 1 & 0 & 1 & 0 \end{bmatrix}$$

>5min ➔ 0

$$\begin{aligned} & arcmax\ 100Z_1 + 50Z_2 + 40Z_3 + 18Z_4 + 3Z_5 \\ & subject\ to\ Z_1 \leq X_B + X_C \\ & \qquad Z_2 \leq X_A + X_B + X_C + X_D \\ & \qquad Z_3 \leq X_B \\ & \qquad Z_4 \leq X_A + X_D \\ & \qquad Z_5 \leq X_A + X_C \\ & \qquad X_A + X_B + X_C + X_D \leq 1 \\ & \qquad X_A, X_B, X_c, X_D \in \{0,1\} \\ & \qquad Z_1, Z_2, Z_3, Z_5, Z_5 \in \{0,1\} \end{aligned}$$

EMS Dispatch Dilemma

- Dispatch EMS in Taiwan has several dilemmas:
    - Not enough EMTs in the numbers
    - Not enough EMTs in the levels (T1, T2, and TP)
    - EMT stations are located in the urban area
    - Each EMT service takes 2 hours
    - Hospital ERs are usually occupied

Ambulance Dispatch

Asgharizadeh et al. (2022) mentioned that an intelligent traffic management system has also been used to accelerate the movement of vehicles and reach the patient as quickly as possible:

1. Integrating the home healthcare planning and in- telligent traffic management
2. considering two-stage programming to manage the intelligent traffic system and home healthcare routing
3. considering uncertainty in demand parameters for home healthcare optimization and providing robust counterpart formulation to deal with such uncertainty.

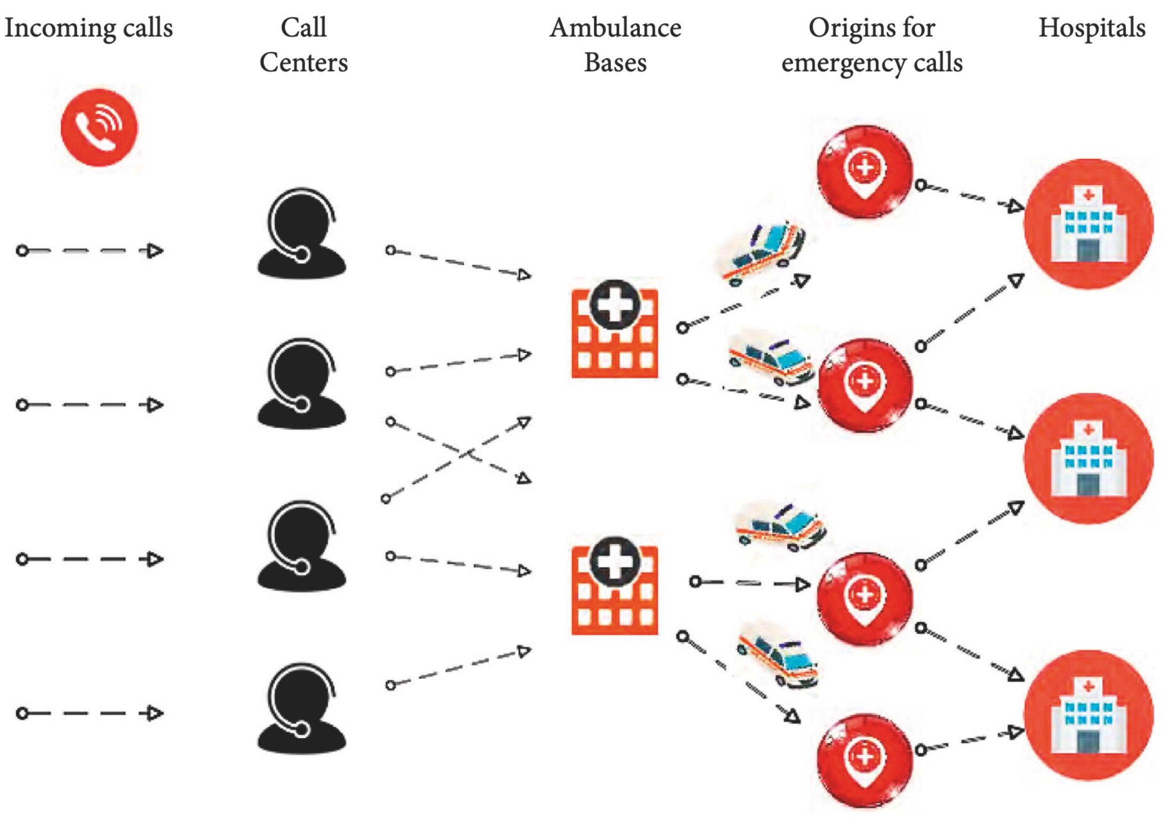
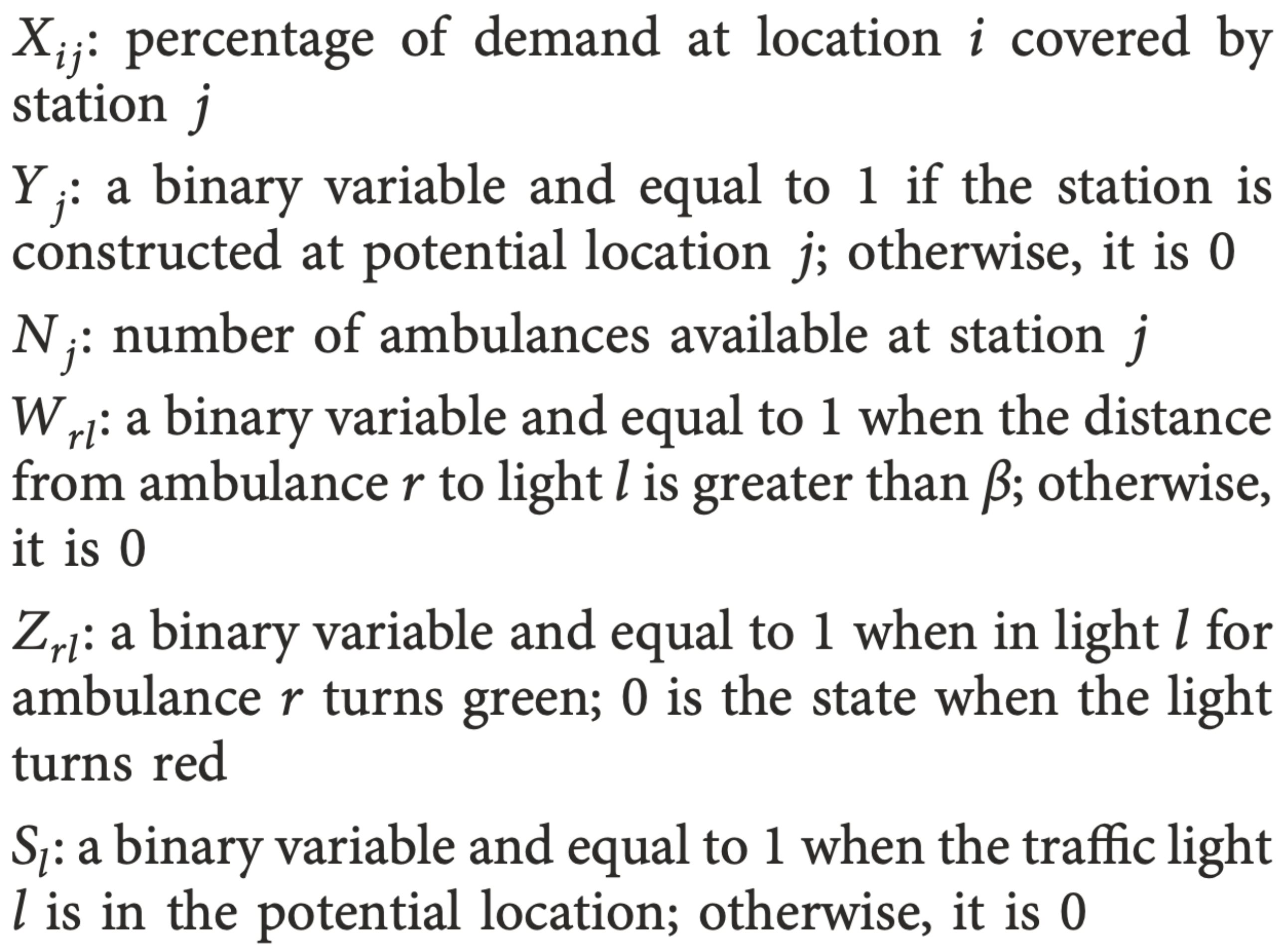


FIGURE 1: Overview of demand and allocation of ambulances to the demand place.

Asgharizadeh, E., Kadivar, M., Noroozi, M., Mottaghi, V., Mohammadi, H., & Chobar, A. P. (2022). The intelligent traffic management system for emergency medical service station location and allocation of ambulances. *Computational intelligence and neuroscience*, *2022*.

Parameters



X_{ij}: percentage of demand at location i covered by station j

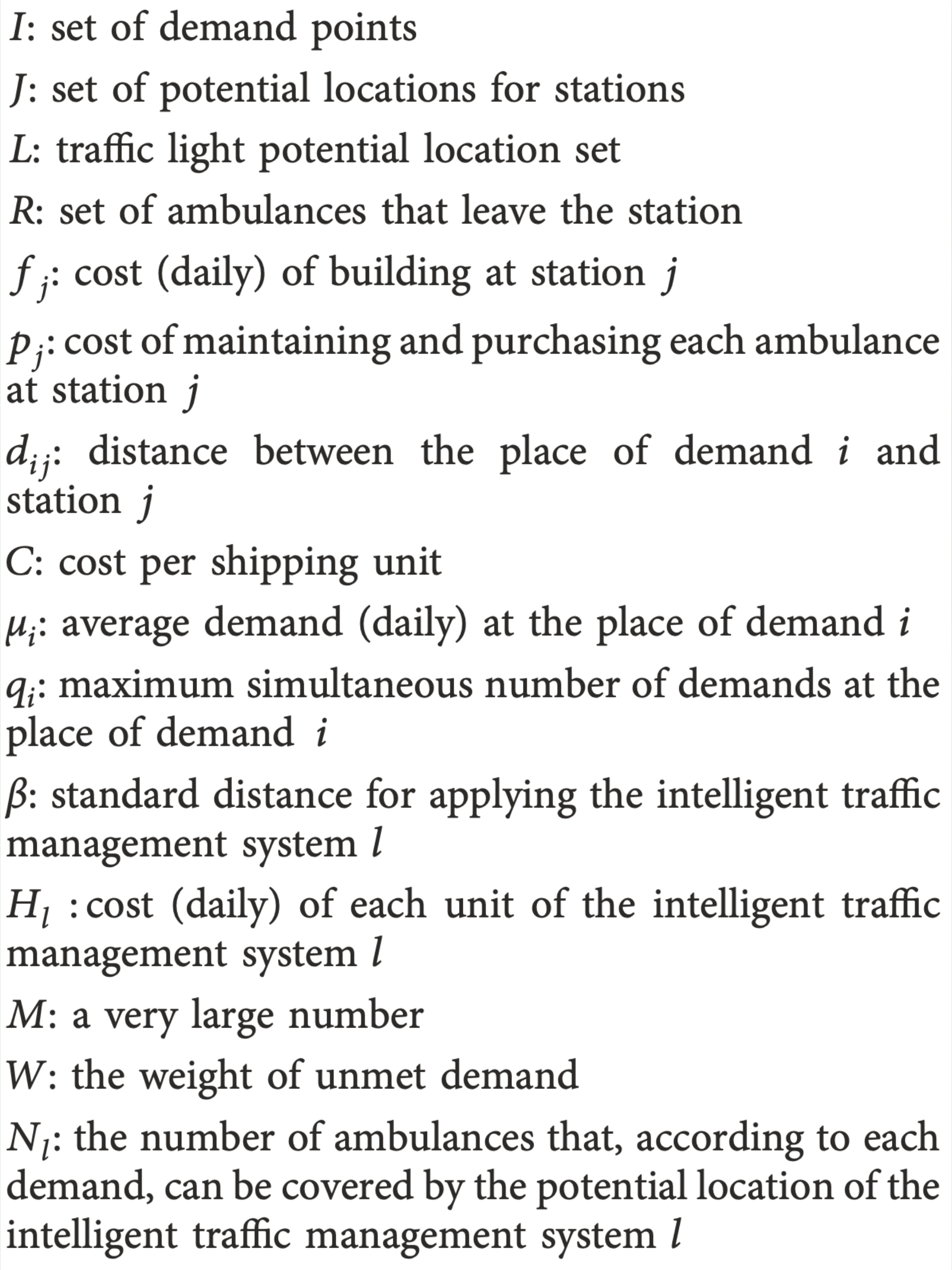
Y_j: a binary variable and equal to 1 if the station is constructed at potential location j; otherwise, it is 0

N_j: number of ambulances available at station j

W_{rl}: a binary variable and equal to 1 when the distance from ambulance r to light l is greater than β; otherwise, it is 0

Z_{rl}: a binary variable and equal to 1 when in light l for ambulance r turns green; 0 is the state when the light turns red

S_l: a binary variable and equal to 1 when the traffic light l is in the potential location; otherwise, it is 0



I: set of demand points

J: set of potential locations for stations

L: traffic light potential location set

R: set of ambulances that leave the station

f_j: cost (daily) of building at station j

p_j: cost of maintaining and purchasing each ambulance at station j

d_{ij}: distance between the place of demand i and station j

C: cost per shipping unit

μ_i: average demand (daily) at the place of demand i

q_i: maximum simultaneous number of demands at the place of demand i

β: standard distance for applying the intelligent traffic management system l

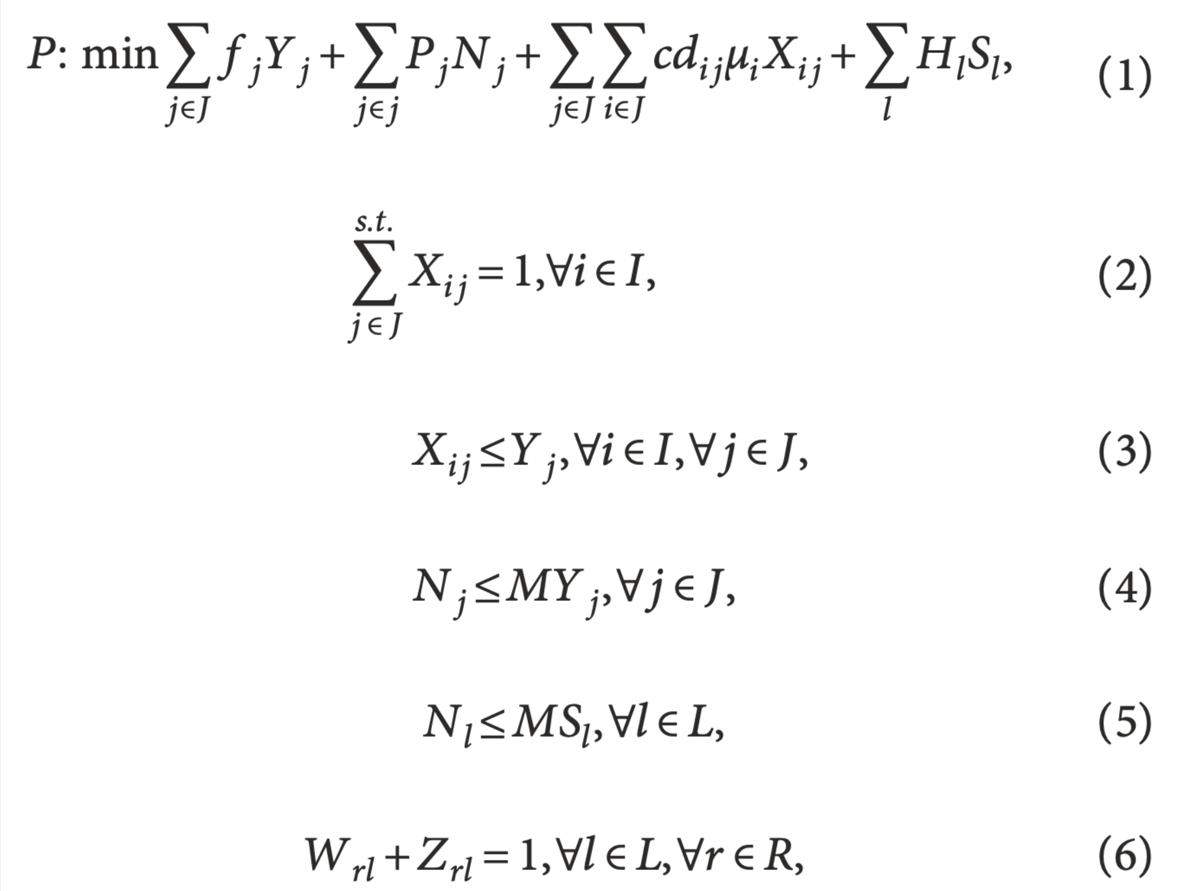
H_l : cost (daily) of each unit of the intelligent traffic management system l

M: a very large number

W: the weight of unmet demand

N_l: the number of ambulances that, according to each demand, can be covered by the potential location of the intelligent traffic management system l

Formulation



$$P\text{: } \min \sum_{j\in J} f_j Y_j + \sum_{j\in j} P_j N_j + \sum_{j\in J}\sum_{i\in J} c d_{ij} \mu_i X_{ij} + \sum_{l} H_l S_l, \tag{1}$$

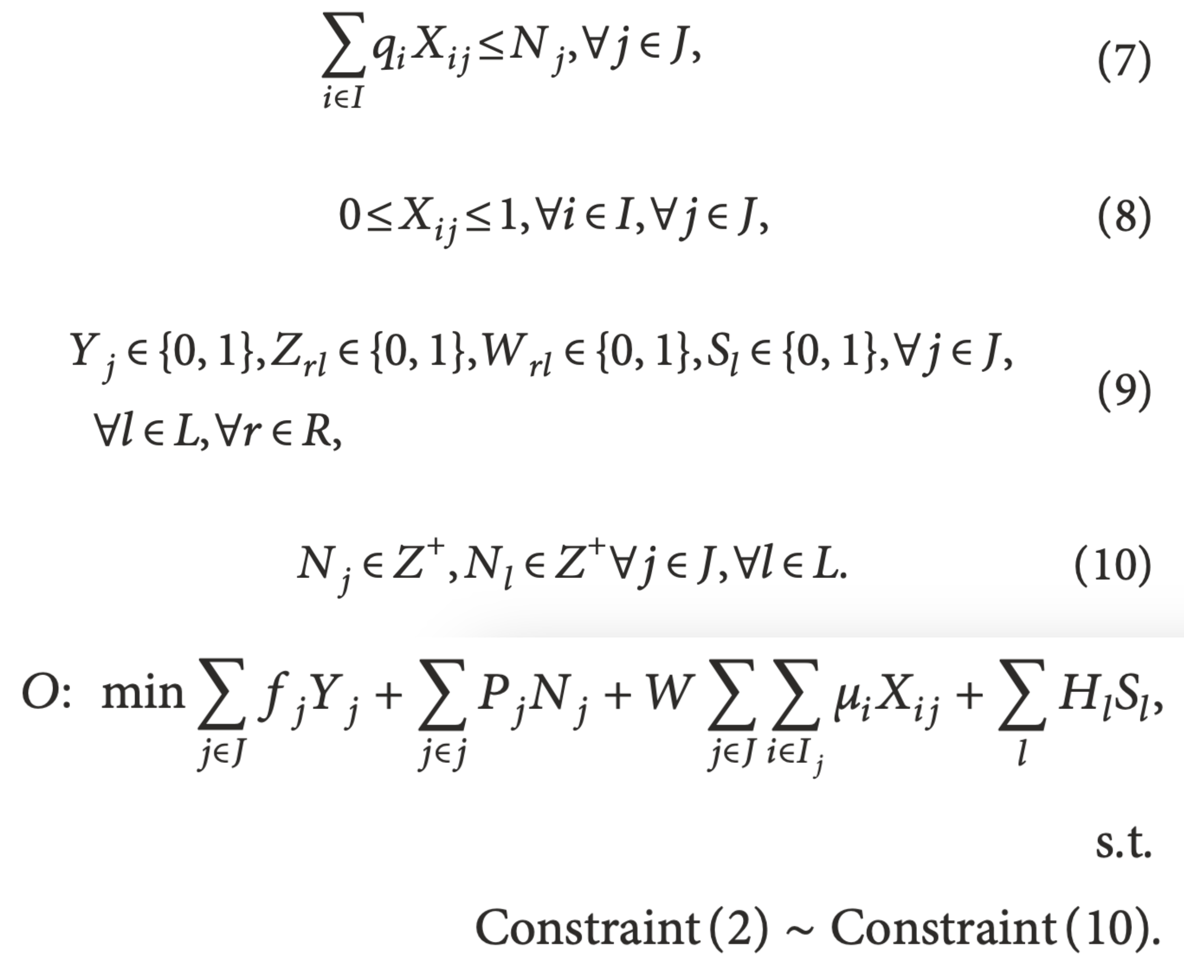
$$\overset{s.t.}{\sum_{j\in J}} X_{ij} = 1, \forall i \in I, \tag{2}$$

$$X_{ij} \leq Y_j, \forall i \in I, \forall j \in J, \tag{3}$$

$$N_j \leq M Y_j, \forall j \in J, \tag{4}$$

$$N_l \leq M S_l, \forall l \in L, \tag{5}$$

$$W_{rl} + Z_{rl} = 1, \forall l \in L, \forall r \in R, \tag{6}$$



$$\sum_{i\in I} q_i X_{ij} \leq N_j, \forall j \in J, \tag{7}$$

$$0 \leq X_{ij} \leq 1, \forall i \in I, \forall j \in J, \tag{8}$$

$$Y_j \in \{0, 1\}, Z_{rl} \in \{0, 1\}, W_{rl} \in \{0, 1\}, S_l \in \{0, 1\}, \forall j \in J, \forall l \in L, \forall r \in R, \tag{9}$$

$$N_j \in Z^+, N_l \in Z^+ \forall j \in J, \forall l \in L. \tag{10}$$

$$O\text{: } \min \sum_{j\in J} f_j Y_j + \sum_{j\in j} P_j N_j + W \sum_{j\in J}\sum_{i\in I_j} \mu_i X_{ij} + \sum_{l} H_l S_l,$$

s.t.

Constraint (2) ~ Constraint (10).

The End

Thank you for your attention!

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SCAN ME