Chapter 16

The Science of Safe Evacuation

Field of expertise: Transportation Planning, Simulation Computational Techniques

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Summary

There are many areas where it is difficult to evacuate safely due to traffic congestion if each person drives to the nearest shelter. After the Great East Japan Earthquake, research on safe evacuation planning has rapidly progressed based on simulation and optimization computing techniques. Based on the results of this research, we hope that the feasibility and reliability of evacuation plans will be improved in collaboration with residents.

Keywords: tsunami evacuation, automobile evacuation, traffic jam, simulation, optimization, route guidance

Introduction

The tsunami that followed the Great East Japan Earthquake demonstrated the existence of areas that require evacuation by car and the need for safe evacuation planning. Since then, research on detailed simulation technology and optimization computing technology has progressed, and it has become possible to understand where traffic problems are likely to occur and how to use the road network efficiently. In the future, we hope that the feasibility and reliability of evacuation plans will be improved in collaboration with residents, taking into account the detailed conditions of the road network and the characteristics of local people.

1: Problems Revealed by the Great East Japan Earthquake

What happened?

The Great East Japan Earthquake tsunami reached more than 4 kilometers inland from the coastline in the plain areas especially along rivers. In such areas, many people lost their lives when they were hit by the tsunami while evacuating on foot or while their cars were caught in heavy traffic jams in urban areas. For example, 73% of the 163,000 people in Ishinomaki City, Miyagi Prefecture, were living within the inundation area, and 3.1% of them, or 4,378 people, were killed. As a result of interviews with nearby residents, 62% of the victims died at home, 23% died during the evacuation, and we can see that the number of people killed while driving and on foot was almost equal (Mikami, 2014). During the Sanriku earthquake in December 2012 and the Fukushima earthquake in November 2016, coastal roads were immediately congested with cars after the tsunami warning was issued. It was confirmed that the current road network does not have enough capacity to evacuate many people by car.

2: Conventional Evacuation and Traffic Guidance Planning

Conventional wisdom

In Japan, the total number of cars surpassed the household counts in 1996, and cars became widespread among most households. However, until the Great East Japan Earthquake and Tsunami of 2011, there had been no disasters that required vehicle evacuation of large numbers of people in advance, and there was no expectation that people evacuating in vehicles would cause traffic congestion. For disasters such as tsunamis, river floods, landslides, and volcanic eruptions, all of which can be predicted in advance, one can take evacuation actions in advance. Aside from the restrictions on mountain entry for volcanic eruptions, the danger zones for all of these disasters are limited, and it has been thought that evacuation without automobiles is possible. In addition, since delayed evacuation has been a problem in many natural disasters, the key to successful evacuation is the start time of evacuation, and psychological research on the content and communication of evacuation information has been emphasized. However, there has been no research on safely guiding people and vehicles once they begin to evacuate.

On the other hand, research on how to alleviate severe traffic congestion during commuting hours has been conducted in traffic engineering. Singapore, Oslo, London, and other cities began to charge for vehicles entering the city center, and around 1995, research began on ways to reduce traffic congestion by adjusting departure times. The conclusion was that the essential cause of commuting congestion is the cars leaving their homes earlier than necessary. If the earlier departure is charged appropriately, congestion can be eliminated, and the total travel time of all vehicles can be minimized. This study assumes, however, that all drivers are familiar with urban traffic conditions and choose their routes and departure times based on calm calculations of travel times and fees.

3: New Technologies for Predicting and Planning Evacuation Traffic

During the tsunami evacuation, the situation will be different from daily life, as the road conditions ahead are unknown, traffic lights are not working, and pedestrians and cars are mixed. It is doubtful that people will behave rationally, like they do during regular commuting. In particular, when pedestrians and cars merge or intersect at an intersection with no traffic lights, the number of cars and pedestrians that can pass through at a particular time is an important number that determines the success or failure of an evacuation, but the actual value has not been well estimated.

Without actually conducting experiments with large numbers of people and vehicles, it has become possible to determine the location of traffic jams, changes of those in time, and the time required to pass through intersections, by calculating the movements of people and vehicles on a computer. In particular, the widespread use of parallel computers and general-purpose software that performs multi-agent simulations to quickly calculate the movements of thousands of people and vehicles, it becomes possible to track abnormalities and changes in the state of individual people and vehicles (Figure 16-1). The number of people who can safely reach the evacuation site can be calculated by combining this technique with the inundation depth and flow velocity at each location and time in the physical simulation of a tsunami.

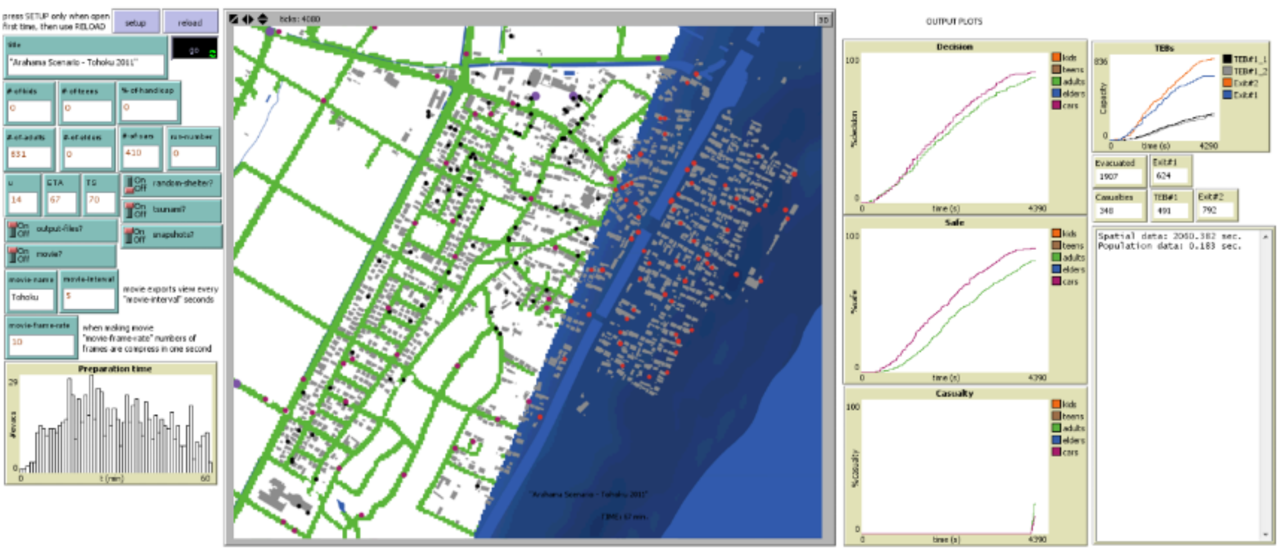

Figure 16-1. A screenshot of the Multi-agent Simulation calculation tool (Mas et al., 2012)

On the other hand, as an evacuation plan, it is necessary to appropriately determine the start time of evacuation, means of transportation, evacuation destination, and evacuation route for each area. Instead of the total travel time of all vehicles in the of commuting traffic optimization, a calculation method was developed to minimize the total risk of encountering tsunamis at home and on road during evacuation. As a result, we obtained a traffic pattern in which people do not wait for departure at their risky homes in the coastal area, but move parallel to the coastline while the risk is low, and then use many roads to go inland. Compared to where everyone concentrates on the shortest route, the total travel time can be reduced to 60% and the danger to 7%. Furthermore, we calculated the effect of the mixture of pedestrians and cars on travel speed and found that it is desirable to differentiate the rate of car use between the coastal and inland areas, and use the parallel roads separately for pedestrians and cars, as shown in Figure 16-2.

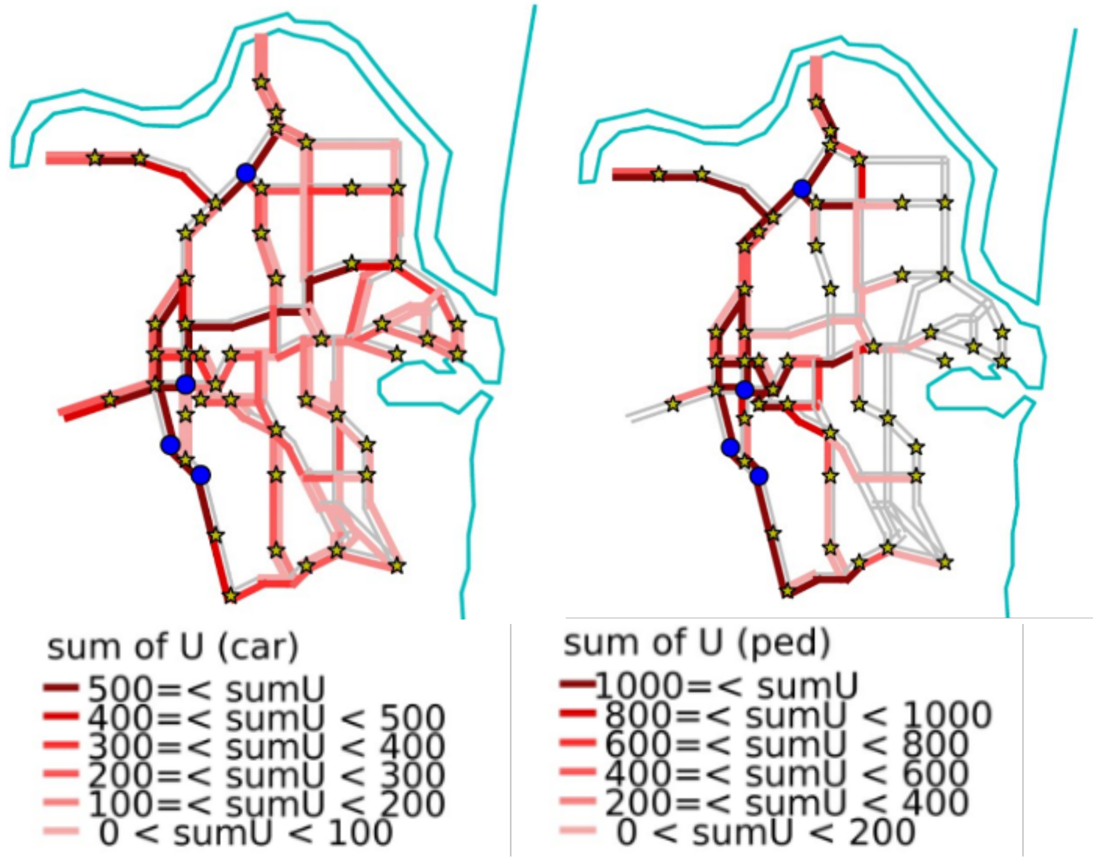

Figure 16-2. An example of the calculation of optimal tsunami evaluation traffic volume (automobile and pedestrian) in Watari, Miyagi Prefecture (Takei & Okumura, 2018)

4: Ensuring Safe Evacuation

In the future, we hope to combine the above two technologies. The simulation results should be reviewed with the residents to confirm and eliminate their concerns one by one, which will lead to a reliable evacuation. The optimal evacuation plan should be updated based on the detailed situation of the community and considering the possibility that the earthquake may have caused damage to roads. Simulation should be used to check for changes in safety, considering that some people may not act according to the optimal evacuation plan due to work, nursing care, or other reasons. The local speed reduction revealed from the simulation should be recalculated back into the optimization. If these steps are taken, people will be able to evacuate with peace of mind according to a plan that considers the detailed differences of each region’s conditions.

Conclusion - from the authors

Those who are able to drive should offer a lift to as many evacuees on foot as possible and move to higher elevations beyond the evacuation centers to reduce the danger to those who come after them. Using roads and automobiles efficiently, we hope to quickly realize a compassionate society where zero lives will be lost because of the tsunami.

References

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