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Spatial Analysis of Traffic and Routing Path Methods for Tsunami Evacuation

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Abstract. Tsunami disaster occurred relatively very fast. Thus, it has a very large-scale impact on both non-material and material aspects. Community evacuation caused mass panic, crowds, and traffic congestion. A further research in spatial based modelling, traffic engineering and splitting zone evacuation simulation is very crucial as an effort to reduce higher losses. This topic covers some information from the previous research. Complex parameters include route selection, destination selection, the spontaneous timing of both the departure of the source and the arrival time to destination and other aspects of the result parameter in various methods. The simulation process and its results, traffic modelling, and routing analysis emphasized discussion which is the closest to real conditions in the tsunami evacuation process. The method that we should highlight is Clearance Time Estimate based on Location Priority in which the computation result is superior to others despite many drawbacks. The study is expected to have input to improve and invent a new method that will be a part of decision support systems for disaster risk reduction of tsunamis disaster.

1. Introduction

The process to save people's lives and to survive from the natural disaster impact like the tsunami may require the right evacuation planning within several minutes. Especially to people who live in low-lying areas along the coast for local tsunami events and within hours for tsunamis that occurr very far from the earthquake or tsunami-triggering sources in the ocean basins. The conventional method used to assess is by calculating the capacity or number of people who are evacuated using demand and network modelling such as roads and tracks [1]. The newest and efficient evacuation modelling and simulation process can be good references for both the government and non-government organizations. Therefore, the evacuation process of tsunami disaster planning can hit the center of the target. Thus, reducing the number of casualties can be achieved. Roughly about 90% of the estimated populations who are exposured to tsunami disaster can save their lives by rapid evacuation to high places and high lands [1]. One of modelling and simulations of the evacuation process is to determine the route and estimate the traffic that occurr during the disaster [2]. The process to reduce the evacuation time is very important to minimize the potential hazards exposure. In adddition, reducing the computational time is very critical to improve the response to natural disasters. In this paper, we have already reviewed the spatial analysis techniques regarding the condition of road traffic or network traffic density and routes as tsunami evacuation routes [3]. The methods used vary from K-Shortest path, LSB optimization (location-based service) through web map service, analytical cluster model, to dynamic traffic network flow based on location priority.

IOP Conf. Series: Earth and Environmental Science **118** (2018) 012034 doi:10.1088/1755-1315/118/1/012034

2. State Of The Art Of Traffic and Routing Path Methods

2.1. K – Traffic Tolerance Path

Using multiple routes (k-paths) per "Source Destination" (SD) is based on the traffic density history data on the relatively same trajectory of human activities, for example: traffic density when office hours begin to be active, and the market spills [4]. Google maps use this application for routing. K-TTP is relatively a new algorithm for reducing route search time from existing algorithms (K-Shortest Path). The algorithm used in this method has NP-Hard complexity. SD route search is done by an expert which means that it is still manually to operate [4]. The computational cost of the vector computation rises dramatically as the M-dimension becomes larger than before. The method does not calculate aspect, slope, width of road constraints, vehicle average, and number of vehicles. Figure 1 shows the implementation of K-TTP.

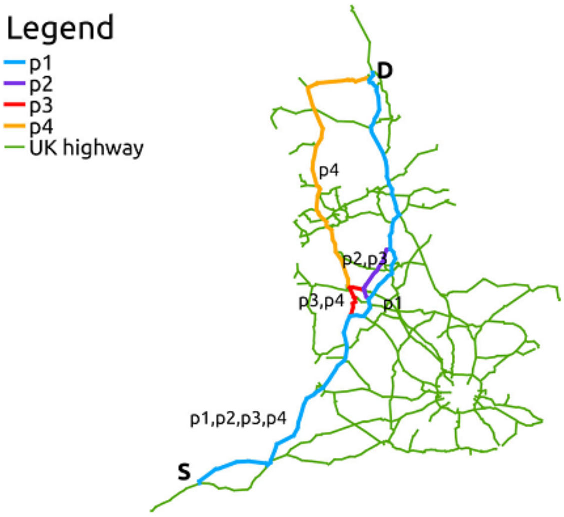

Figure 1. *Traffic Tolerance Path* implementation in UK Highway with k=4.

2.2. DPW-ND DPW-SA Based on WMS (Web Mapping Services)

DPW-ND and SA are techniques or methods of searching routes and traffic by optimizing direction sharing and optimizing parallel submissions and waypoints on Web Mapping Service such as Google Maps, Bing Maps, and Quest Maps. DPW is an extension of parallel requesting and waypoints [5]. DPW-SA or Sharing Ability uses the Dijkstra algorithm if there is no route history information data. There is a longer path when the request does not get the results and will be computed. DPW-SA aims to minimize route demand and response time.

$$SA(R(o_i \rightarrow d_i), Q) = |\{q_j = (o_j, d_j) \in Q \mid R(o_j \rightarrow d_j) \subset R(o_i \rightarrow d_i)\}| \quad (1)$$

$SA(R(o_i \rightarrow d_i), Q)$ is sharing ability from $R(o_i \rightarrow d_i)$ with reference Q, while Q is a set query of the user. R(oi → di) is the shortest path from origin oi to destination di. With qi = (oi, di) the most concise travel time request equation with query qi with the origin of oi and destination of d_i.

DPW - ND or Network Distance differs only in the selection of waypoints from DPW-SA. DPW-ND uses the distance between networks (network distance) rather than sharing ability in the range of waypoints. This method is beneficial for evacuation simulation process because it uses current traffic situation. However, the response time will be very long when demand increases; this can be seen in Figure 2. Regarding critical cases which need a fast response time, this method does not count some

IOP Conf. Series: Earth and Environmental Science **118** (2018) 012034 doi:10.1088/1755-1315/118/1/012034

obstacles such as road width, peak condition, and human behavior. Also, it requires an internet network connection to stay connected with WMS.

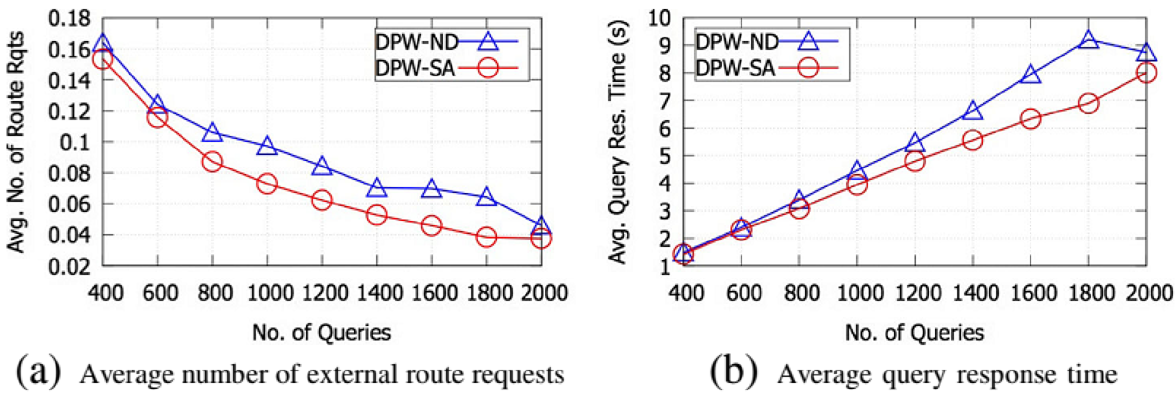

Figure 2. A graph, explaining the relationship between the number of requests and the response time as well as the mean of the outside route request.

2.3. Critical Cluster Model

The Critical Cluster Model (CCM) is a model that calculates the risk of evacuation on a neighborhood scale. The risk of static evacuation is based on the calculations that depend on the structure of the network (C) and the number of population (P) evacuated. Formulated as [6]:

$$CCM = P/C$$

The advantage of CCM is a minimum input parameter with computation time which is relatively short. The distance and direction of evacuation are not correlated to CCM, accident risk factors. On the contrary, this method is to emphasize staying away from the point of danger. The algorithm for route search and direction uses the Euclidean method based on single s - t (source, destination) per network node. Figure 3 shows the implementation of this method. The weakness of this method is the very minimal input, which excludes accident risk factors and has no input on buffer time for tsunami disaster reaching the point of the evacuees. The direction is to get people away from danger but not to the evacuation area. The absence of street width input and other accessibility factors is noticed. Data networks are considered homogeneous.

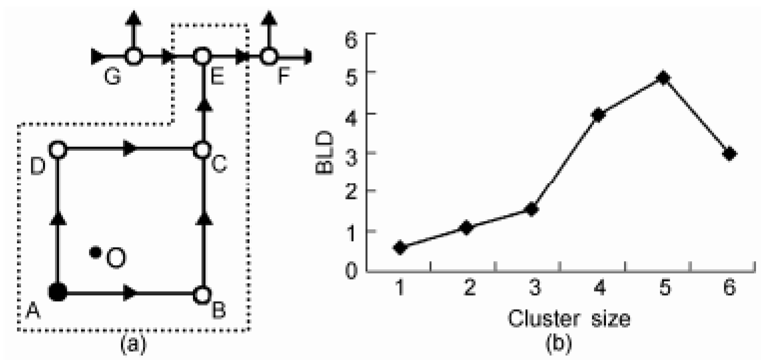

Figure 3. CCM with O as the center of hazard, as early evacuee point and evacuation route model (a) and the size of cluster (b).

2.4. Clearance Time Estimation (CTE) based on Priority Location

CTE based on priority location uses optimized Dynamic Network Flow Problem (DNFP) method. It is routing dynamically by processing the earliest evacuation request at the origin with the high priority location. High priority location means the closest location exposed to hazard. DNFP (Dynamic Network Flow Problem) in the evacuation process [7] are:

- Maximum flow; to send the possible maximum amount upon request from S to Q within a certain time Q;
- The fastest flow; to send some requests from S to T in the fastest time
- The earliest flow of dating; to send a certain number of requests from each S to T maximizing the number of arrivals in T in some time Ɵ, for all Ɵ∈ (0,Q)

The DNFP formulations were introduced by Ford and Fulkerson in Alipour and Mirnia (2017), as follows:

$$\text{dynamic network } N=(V,E,u,\tau,\{s,t\})$$

A set of node V, a set of directional edges E, with a non-negative value of integral function capacity along with transit time τ, a set of nodes S, a source or origin s, and destination t. The primary purpose of this method is to send as many streams or flows from origin to destination as given in T [8].

This routing methods, yet still using single origin - single destination (s-t DRP's or dynamic routing problem), is very contradictory to the reality. Evacuation areas, shelters and potential shelters that are widely available can be a reference of destination in the calculation of traffic. So, there is no optional route or multi T. Simulation of traffic uses DYNASMART-P by using a modification of Greenshields model to describe traffic propagation on each link. Figure 9 indicates that the use of more evacuation routes makes it possible to produce relatively small estimates of difference.

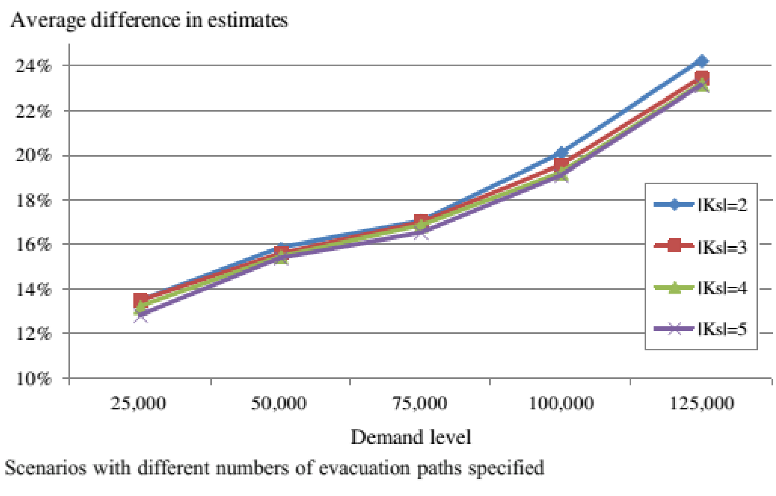

Figure 4. A scenario showed with a different number of specific evacuation paths.

3. Conclusion

Various methods on route searching and traffic engineering in evacuation process computation have their advantages and disadvantages, particularly on Clearance Time Estimation method that has a more excellent picture than any other method. It is because the method had taken into account clearance time as well as acknowledged the number of population or demand before the dangers of natural disasters strike the destination. Also, it employs the propagation of traffic. As a result, the simulation

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can explain traffic congestion. The shortcoming in all methods is the lack of information on human behavior that determines the route and the type of transportation they will choose spontaneously in the evacuation effort. Route or route change due to jamming has not been used. In addition, infrastructure conditions such as shelters, shelter potential, the width of the road body, lighting conditions also have not become input parameters. Weather and day or night conditions, peak season, religious, political and cultural situations significantly affect the speed of travel time. The magnitude of earthquakes and tsunami scale also become a very significant role. The relatively complete input parameters will give a simulation picture and a model that is close to the reality. The simulation of the evacuation process can further reduce the loss of the impact of the tsunami disaster.

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