A Brief Introduction to Critical Cluster Model

Part 1: Theory and Method

The critical cluster model (CCM), originally proposed by Cova and Church (1997), is a novel contribution to assessing the evacuation risk in a network-based city. The evacuation risk in the CCM is measured by an index called bulk lane demand (BLD), which is formulated as:

$$\mathrm{BLD} = \frac{\mathrm{P}}{\mathrm{C}}$$

The following statement about CCM is quoted from Chen et al. (2012).

In this simply equation, P represents the number of people within a specific region (called a cluster) and C, the overall capacity of exits (in terms of number of lanes) across the boundary of this region. By this definition, the ratio of P–C or BLD, can be considered the number of evacuees a lane can sustain. In a network, when this ratio reaches its maximum for a designated node, it represents the worst evacuation condition and the evacuation risk for that node. Thus, the risk depicted in the CCM stands for the worst case scenario for a possible evacuation.

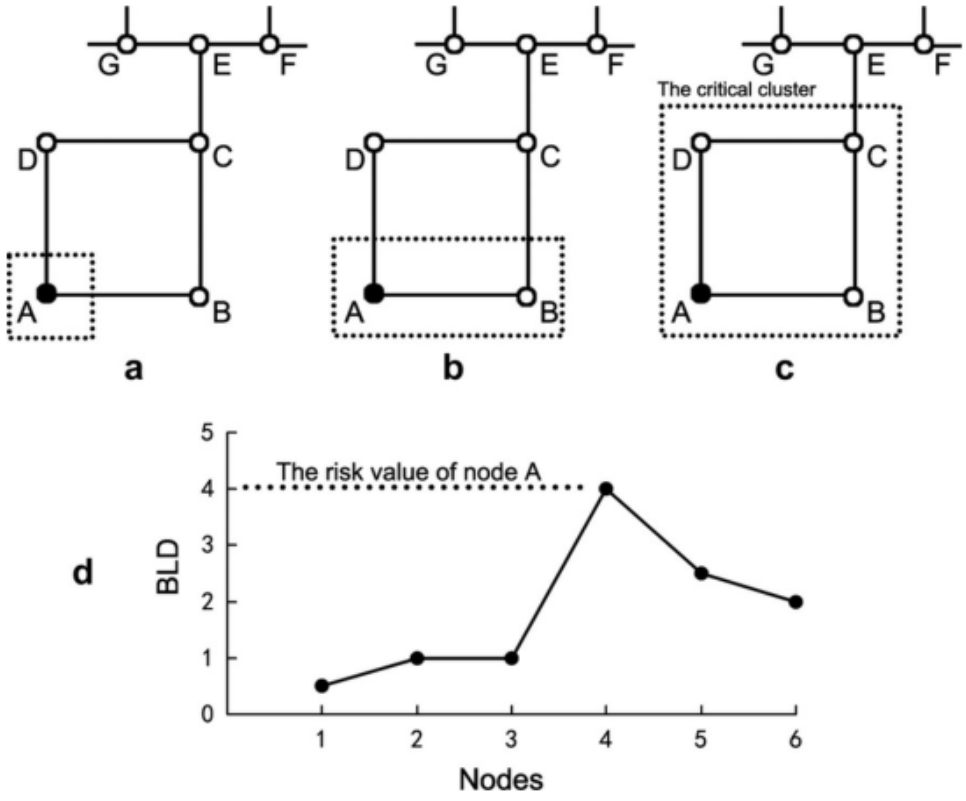

Fig 1. An example of searching for the evacuation risk for anchor node A. (a) Node A's cluster with one node; (b) node A's cluster with two nodes; (c) node A's cluster with four nodes which becomes its critical cluster; and (d) a plot of A's BLD value with changing cluster size.

For example, given a network shown in Fig. 1a, each node in the network has a population of one, while each edge represents a two-lane road, and the cluster size is limited to at most six nodes. The node of interest is called an anchor node, as illustrated by node A in Fig. 1a. The CCM first identifies a region called a cluster that includes only the anchor node (see the dotted-line in Fig. 1a). In this case, the BLD for the anchor node is two, which is the ratio of one unit of population to two exits for the cluster. After the cluster size has been expanded, as illustrated in Fig. 1b and c, the BLD changes and reaches its maximum in Fig. 1c. The maximum BLD, which is four, is the ratio of four units of population in the cluster to one outward exit. The corresponding cluster in Fig. 1c, called the critical cluster, represents the most difficult evacuation scenario for anchor node A. The BLD of the critical cluster is thus assigned as the evacuation risk for node A, as depicted in Fig. 1d.

Part 2: Program Manual

To implement this idea, a custom program is employed (CCM.exe). The original code written in C++ (CCM.cpp) is also provided. This program has a cluster size of 10 nodes (search limit). To illustrate the use of the program, an example in Fig.2 is used. In Fig.2, green nodes represent disaggregated population and roads are associated with number of lanes.

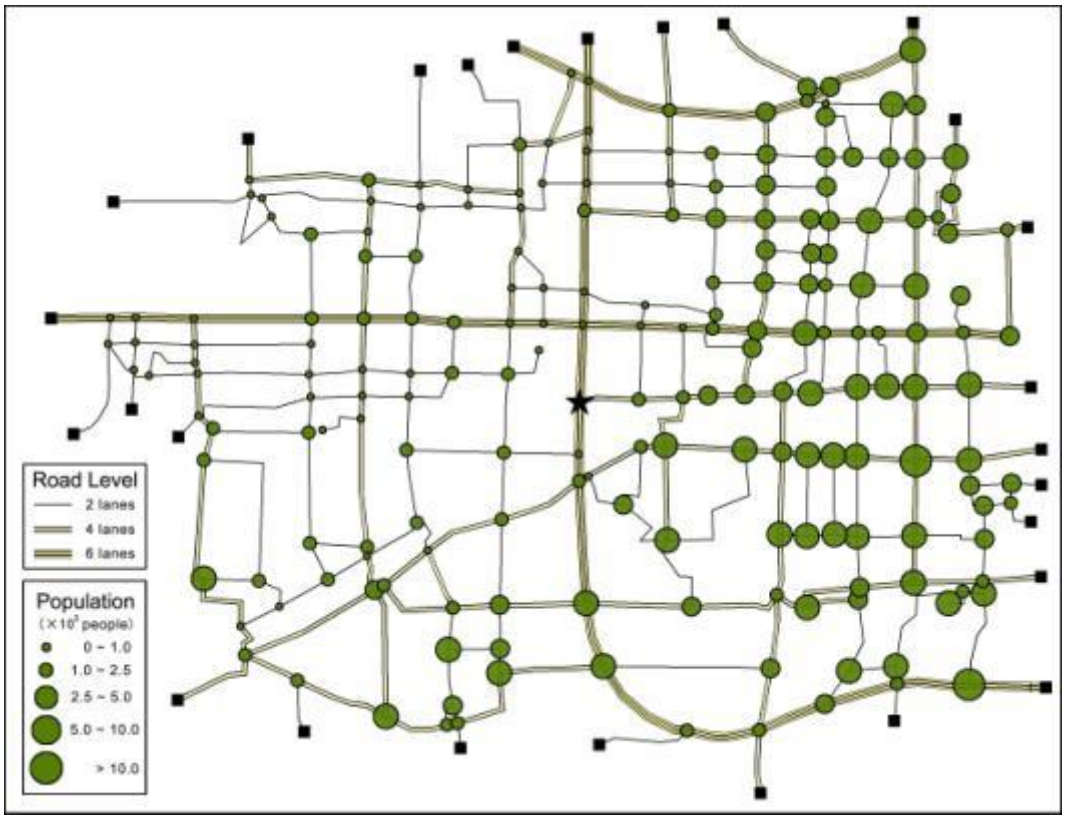

Fig 2. An example of CCM on the city scale

Output.txt is a text file generated in *ArcMap* that abstracts Fig 2. This process can be completed by any custom language such as VBA or Python (not provided here). Below explains the structure of the file.

Output.txt

```
227       (number of nodes)

 .0307325039579          (population on 1st node)
 .0749304553241          (population on 2nd node)
……
.122646842896            (population on 227th node)

 354       (number of roads)

 1   2   1 (1st road: from 1st node to 2nd node with 1 lane. Each road is counted only once)
 1   3   1 (2nd road: from 1st node to 3rd node with 1 lane)
……
79   75   .666666666667 (354th road: from 79th node to 75th node with 0.67 lanes. Here the number of lanes is normalized. You can also use the original numbers such as 1, 2, 3, etc.)
```

Then click on the CCM.exe. The result (result.txt) will be generated.

Resut.txt

```
227       (number of nodes)
0.257     (BLD of 1st node)
0.367     (BLD of 2nd node)
……
0.665     (BLD of 227th node)
354       (number of roads)
0.312     (BLD of 1st road. This is the average of the BLDs of the two end nodes)
0.241     (BLD of 2nd road)
……
0.386     (BLD of 354th road)
```

This result could be further imported to a GIS platform and visualized. The result is given in Fig 3.

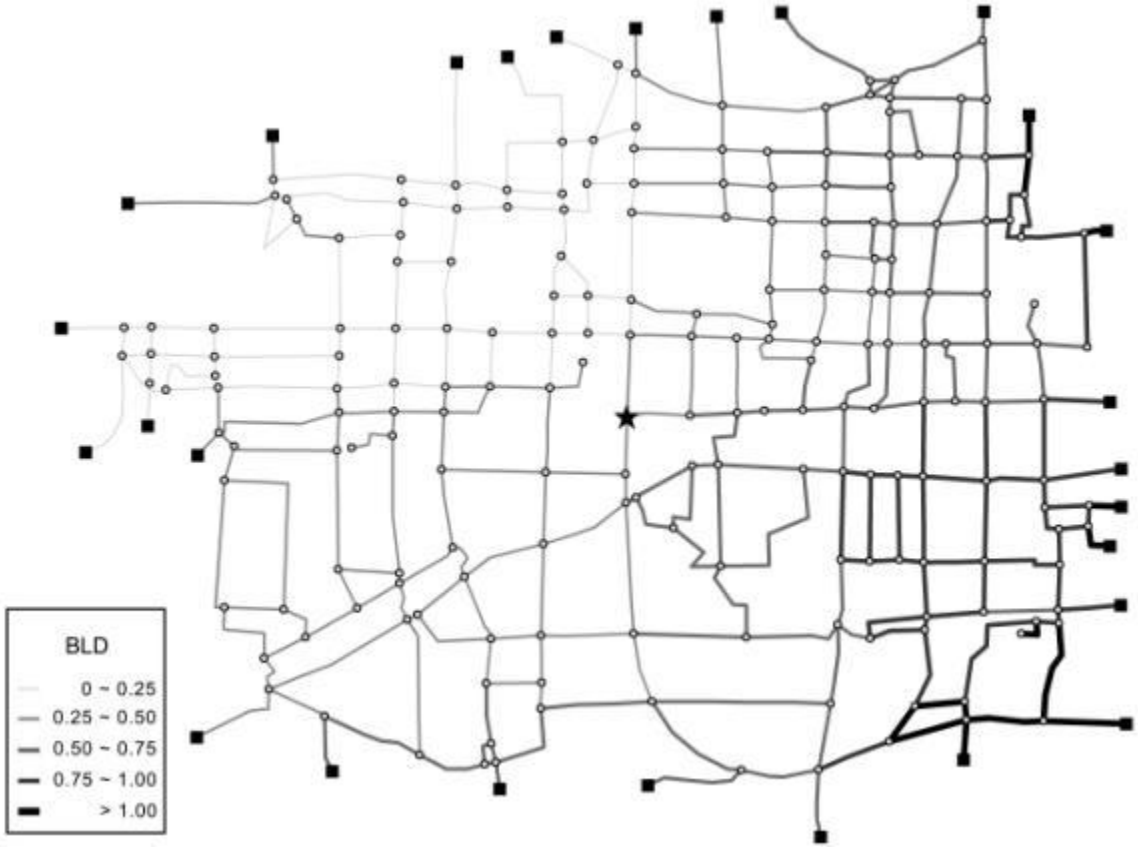

Fig 3. Visualization of evacuation risk in terms of BLD

References

When using or modifying the CCM program, please cite the following sources:

Chen, X., Kwan, M. P., Li, Q., & Chen, J. (2012). A model for evacuation risk assessment with consideration of pre-and post-disaster factors. *Computers, Environment and Urban Systems*, 36(3), 207-217.

Cova, T. J., & Church, R. L. (1997). Modelling community evacuation vulnerability using GIS. *International Journal of Geographical Information Science*, 11(8), 763-784.

Li, Q., Chen, X., Chen, J., & Tang, Q. (2010). An evacuation risk assessment model for emergency traffic with consideration of urban hazard installations. *Chinese Science Bulletin*, 55(10), 1000-1006.

Chinese References

陈翔，李强等. (2009). 临界簇模型及其在地面公交线网可达性评价中的应用. 地理学报 [J], 64(6).

李强，陈翔等. (2010). 考虑危险源的城市应急交通疏散风险评价模型. 科学通报 [J], 16.