How do pedestrian choose their routes?

Predict the pedestrian route choice pattern round Redline Central Station, Cambridge, MA

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Abstract:
The research investigates how pedestrians choose routes around a subway station during the evening peak hour and tries to find out what are the possible factors that affect the choice. An ArcGIS based model was built to predict the pedestrian walk pattern and was adjusted based on the field survey of actual pedestrian number. The adjusted prediction model indicates the pedestrians on the streets around the Central Station are mainly those employees in Cambridge, - who work within 1km walking distance from the station but live remotely. The pedestrian route choice is effected by the walking distance, and they are more likely to walk directly to the station without too many detours, especially when the weather is terrible. Combing analytical tools in ArcGIS platform and field survey calibration approach, the research reveals the movement of people at neighborhood scale, based on which urban planners could efficiently implement people-orient designs and planning policies.

Map Link:
https://www.dropbox.com/s/ln29swvndsycxve/How%20do%20pedestrian%20choose%20their%20routes.pdf?dl=0

1. Introduction

Influenced by various factors such as safety and comfort of the streets, pedestrian route choice is closely related with the vitality of street network in a city. Especially around the subway station during a certain time period of a day, the pedestrians tend to choose some specific routes rather than randomly walk around. In order to find out how pedestrians choose routes around a subway station during the evening peak hour, we look into the areas within one kilometer walking distance from the MBTA Central Station in Cambridge as a case study. By route choice modeling and field survey, we come up with a best fit prediction model to simulate the pedestrian flows around the Central Station during the evening peak hour.

2. Hypothesis

In our case study, there might be four possible directions of pedestrian flows around the Central Station during the evening peak hour, with different pairs of origin and destination. Firstly, those employees working around the Central Station often take the subway to go back home during the evening peak hour. Secondly, local Cambridge residents around central station who work remotely or possibly walk from the Central Station home in the evening peak hours.

In these two possible kinds of travelling routes, pedestrians might also wonder around for shopping, entertainment or some other activities on their way home. However, under some extreme circumstances, especially when the weather is cold and rainy for example, which was exactly the case of the day[1] when we carried out our survey, we might presume that during the evening peak hour, pedestrians on the roads around the Central Station, possibly directly walk from their workplace to the Central Station, or from the station to home without any intentional detours on the way.

However, between those two possible kinds of travelling routes, we also presume that pedestrians on the road around the Central Station during the evening peak hour, are mainly those local Cambridge residents who work remotely or possibly in other cities of Boston, and after work should take the subway home.

Therefore, it is those local Cambridge residents who take the subway to work that our prediction model focuses on.

3. Prediction Model

Our prediction model is used to predict the pedestrian flows on each street segment, considering mainly three parameters: 1) The types of pedestrian (employee or resident); 2) pedestrians' sensitivity to travelling distance ; 3) and the directness of the routes that pedestrians travel.

[1] We implemented our field survey from 6:30 pm to 8:00 pam on February 15, 2017. During that time period, the temperature was 37/34 °F with light rain and fog. Source: timeanddate .com

We use the *Close Facility Tool*[2] embedded in the ArcGIS based add-ons named UNA Toolbox[3] to choose the buildings within one-kilometer[4] actual walking distance centered on the Central Station, catching up a total of 3,434 buildings inhabited by residents, part of whom take up most of the amount of the total pedestrians on the roads to the Central Station during the evening peak hour.

Furthermore, in the prediction model, each of those selected buildings is given a Gravity Index[5]. Equivalently, the Gravity Index could also be interpreted as the percentage of pedestrians in a certain building, who are willing to walk to the destination. In the Gravity Index equation, the higher the βvalue and the longer distance between an origin and a destination, the less walkability of the destination, hence the fewer people are willing to walk to the destination. In the prediction model, we use 0.004 rather than the other two, given that pedestrians would be less willing to walk on that cold and rainy evening, and also because of which, we presume that pedestrians would be less likely to wander around in such bad weather during the evening peak hour. Therefore, we use low detour ratio[6] of 1.1 value. Although with the same βvalue, the respective Gravity Index of each of the selected 3,434 buildings might also vary, due to their different distance from the Central Station, as indicated in the Gravity Index equation. By using the Gravity Centrality Tool[7], we can get the Gravity Index of each building as an origin within the one-kilometer actual walking distance from the Central Station as a destination.

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[2] This tool helps find a closest destination facility to each origin along a given network, within a certain walking distance (Andres Sevtsuk, 2015).

[3] UNA Toolbox refers to the Urban Network Analysis, which provides a tool for the assessment of distances, accessibilities and encounters between people or places along spatial networks (Andres Sevtsuk, 2015).

[4] Generally, few people are likely to walk a distance beyond one kilometer.

[5] Gravity Index is a measurement of the accessibility of a destination, which is proportional to the attractiveness and inversely proportional to the distance from the origin to the destination (Hansen, 1959).

$$Gravity^{r}[i] = \sum_{j \in G-\{i\}; d[i,j] \leq r} \frac{W_j}{e^{\beta \cdot d[i,j]}}$$

r: search radius for destinations;

D [i, j]: distance between an origin i and a destination j;

β : exponent that controls the effect of distance decay;

W_j: destination weights;

[6] Detour Ratio indicates the directness of the routes that pedestrians travel. When pedestrians choose the shortest route, then the Detour Ration would be 1. But when pedestrians choose 10% longer of the shortest route, then the detour ratio of the route would be 1.1

[7] This tool analyzes how central each origin is with respect to given destinations (Andres Sevtsuk, 2015).

Based on the Gravity Value of each building and general percentage of population in Cambridge who usually take subway travelling back and forth between workplace and home[8], each building is weighted by

Weight=R*53%*19%*β

R: Residents in each building;
53%: There are 53% of the Cambridge residents who work;
19%: Among the Cambridge residents who work, there are 19% of them take the subway back and forth between workplace and home;
β: In this case we use 0.004 as discussed previously.

4. Field Survey

Using Betweenness Tool[9], we predict the pedestrian flows on all the street segments within one-kilometer distance from the Central Station, with a detour ratio of 1.1, given each building weighted by "R*53%*19%*β" respectively. Then we rank the street segments by the pedestrian numbers predicted in descending order; and pick out 8 street segments from top 5% of the busiest street segments, 4 street segments from top 5% to 20% less busy streets, and 4 from 20% to 45%, 4 from 45% to 60% and 4 from 60% to 75%. Finally we get a total of 24 street segments to count the actual number of pedestrian from 6:30 pm to 8:00pm on February 15th. Then we multiply the pedestrian flows of each selected street segment by its corresponding ratio[10] to achieve an hourly pedestrian flows of the segments.

5. Prediction Model Adjustment

Inputting different β values[11], detour ratios[12], and types of pedestrians on road, the prediction model was adjusted to achieve highest Raw Correlation and Spearman's Rank Correlation of the actual and predicted pedestrian flows on the chosen street segments. Based on the component pedestrian, there are three highly possible scenarios.

The first scenario assumes the local residents, who live within one - kilometer walking distance from the Central Station but work remotely, will take the subway. When the β value is 0.002, and detour ratio is 1.1, the actual and predicted pedestrian flows on the selected 24 street segments, have a Raw Correlation of 0.72 and Spearman's Rank Correlation of 0.78.

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[8] We obtained this data from American Fact Finder website. See: https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_15_5YR_B08301&prodType=table

[9] This tool calculates and visualizes the by-passing traffic or footfall at certain locations in a given spatial network (Andres Sevtsuk, 2015).

[10] According to the research by Mike Barry and Brian Card, we calculate different percentages of pedestrian flows in different time period during the evening peak hour. See: http://mbtaviz.github.io/

[11] We consider β=0.001, 0.002, 0.004.

[12] We consider detour ratio=1.0, 1.1, 1.2.

The second scenario only considers that the employees who work within one - kilometer walking distance from the Central Station but live remotely. It turns out that, if the β Value is 0.004, and the detour ratio is 1.0, the actual and predicted pedestrian flows on the selected 24 street segments, have a Raw Correlation of 0.90, along with Spearman's Rank Correlation of 0.86.

In the third scenario, we presume that above two types of commuters constitute the major amount of the pedestrians on roads around the Central Station within one - kilometer walking distance. It turns out that in this scenario when the β is 0.004, and the detour ratio is 1.1, the actual and predicted pedestrian flows on the selected 24 streets segments, have a Raw Correlation of 0.89 and Spearman's Rank Correlation of 0.83.

6. Conclusion

During the evening peak hour, the pedestrians on the roads around the Central Station are mainly the employees in Cambridge, who work within one-kilometer walking distance from the station but live remotely. After work, they walk to the Central Station to return home. They tend to be quite sensitive to the walking distance. And they are more likely to walk directly to the station without any intentional detours, especially when the weather is cold and rainy.

Reference

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