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Using Multi-Criteria Analysis to Estimate Retail Site Attractiveness for the Huff Model

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ABSTRACT

The Huff model is an advanced trade area delineation technique widely used in retail site selection. It is based on site attractiveness and distance, and models probabilities of customers patronizing specific retail locations. In this research, we examine the suitability of multi-criteria analysis (MCA) to estimate the attractiveness parameter in the Huff model. In a case study of shopping centres in Toronto, we illustrate that MCA provides a suitable framework for retail site attractiveness. However, variations in the MCA technique have noticeable impacts on the Huff model results.

1. Introduction

Retail geography, business geomatics, and location intelligence are some of the concepts that capture the idea that the location of private sector enterprises has significant implications on their success with respect to production, sales, and work force (e.g. Jones & Simmons 1993). In a political climate of accountability and efficiency in using tax revenues, government and not-for-profit organizations increasingly make use of the same operational and strategic decision support tools to determine service site locations and resources offered to their "clients".

The theoretical framework for retail geography includes rational choice theory – the assumption that consumers will make cost-effective choices with respect to their use of retail outlets and services (Swales 2008). Given similar product and service offerings in a transparent economy, location plays a crucial role in reducing costs through reducing travel distance. Geographic analysis techniques such as Thiessen polygons, the Huff model, and customer spotting were developed as normative representations of consumer behaviour (Swales 2008). In a business context, Thiessen (or Voronoi) polygons separate a region with supply points (such as retailers or social service centres) into catchment areas, in which each demand point is assigned to the closest facility. The Huff model allows for more complex gravity modeling of attractiveness of supply locations and competition between them by assigning demand to supply points on the basis of probability (Swales 2008). Finally, customer spotting draws on ever growing affinity program datasets to facilitate visualisation, analysis and location strategies related to patronage of facilities and services (Swales 2008).

The Huff model (Huff 1964, Huff & Black 1997) is widely used in the retail business sector. It combines principles of distance decay with site attractiveness. To model retail site attractiveness for potential customers most accurately, analysts often use composite metrics (e.g. Lin et al. 2016, Jia et al. 2017).

Multi-criteria analysis (MCA) is a normative modeling approach that integrates decision-maker preferences (e.g. criterion weights) in the evaluation of decision alternatives such as retail sites. To support site selection, each site is assessed by a composite score created from multiple criteria (site attributes).

In this research, we examine the conceptual and practical fit of MCA techniques with the creation of composite attractiveness metrics. We estimate site attractiveness for the Huff model using MCA and explore the impact of MCA parameters on the outcome.

2. Methods and Data

2.1 Techniques and Technology

One of the most commonly used MCA techniques is the weighted linear combination (WLC), a weighted sum of criterion values (Malczewski 2000). To transform the criteria into a common value range such as 0...1 for comparison and combination, a rescaling procedure is applied (Malczewski & Rinner 2015).

The normative aspect of MCA is most obvious in the use of importance weights. These are set by the decision-maker and may include an element of subjectivity along with expert knowledge. Weights are commonly defined as fractions or percentages that add up to 1.0 or 100%.

The Huff model calculates a quotient of the attractiveness of a destination site over the distance to a source point or area. Distances may be measured as straight lines or via a transportation network, and the distance decay effect can be modelled linearly or exponentially. In retail, the source locations often are residential areas representing potential customers. The destination sites are retail locations, the attractiveness of which is often characterized by a combination of size and quality indicators such as floor space and type of goods offered. The attractiveness-distance quotient is normalized by the sum of all quotients to represent the probability of customers from the source to shop at the destination over all other destinations. For each source, the sum of probabilities is 1.0.

We implemented the Huff model with MCA-based attractiveness estimation in a plugin for the open-source QGIS 3.2 package using Python 3.6 along with QT5 for the development of the user interface shown in Fig. 1. An earlier version of the underlying scripts is available at https://github.com/ryersongeo/qgis_location_analytics.

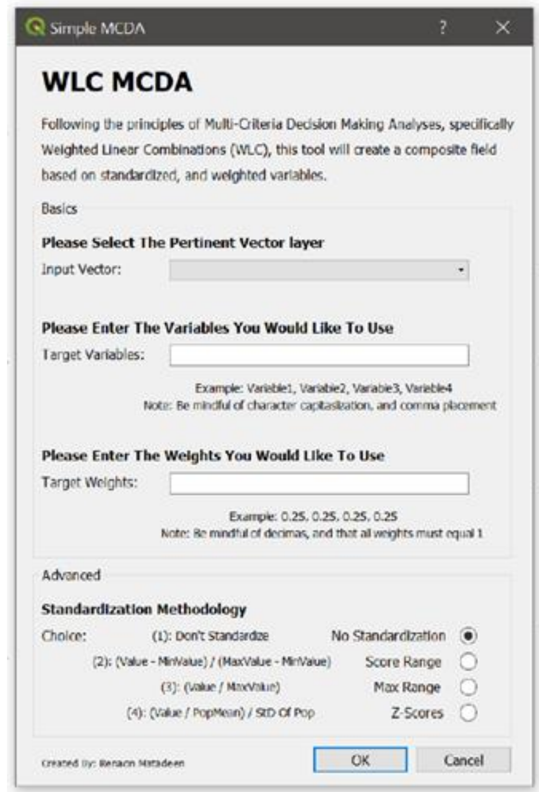

Fig.1: User interface of the MCA component of the Huff model plugin for QGIS

2.2 Case Study

In a case study for the 16 largest indoor shopping centres in the Toronto Census Metropolitan Area, we experimented with two common multi-criteria rescaling techniques: maximum-score and score-range transformation. For criteria that are to be maximized, maximum-score transformation divides each criterion value by the largest value. For minimization criteria, the quotient of the smallest value divided by the criterion value at hand is subtracted from 1.0 to form the rescaled criterion value. For maximization criteria, score-range transformation assigns the smallest value to 0.0, the largest to 1.0, and all other values in proportion. For minimization criteria, the assignment is reversed.

The data for the case study included a hexagonal tessellation of the Toronto Census Metropolitan Area to represent source areas (without further attributes) and a point shapefile of shopping centres

(Fig. 2) with a sample of nine attractiveness indicators sorted from most to least important:

- Average Google Places score
- Gross leasable area
- Number of anchor stores
- Number of fashion stores
- Number of technology stores
- Number of food stores
- Total number of stores
- Number of parking spaces
- Adjacent housing density

Weights between 25% and 2.5% were assigned manually for the purpose of the experiment. All criteria were considered as to be maximized, i.e. larger values represent greater utility for potential customers. Primary and secondary trade areas were defined by the commonly used probability thresholds of 60% and 30% (Jones & Simmons 1993; Swales 2008) and mapped for the 16 shopping centres.

Fig. 2: Hexagonal tessellation of Toronto Census Metropolitan Area and major shopping centre locations

3. Results

In comparing the results of maximum-score transformation (Fig. 3) and score-range transformation (Fig. 4), some differences are visually noticeable. In particular, some of the larger trade areas grow further while some of the smaller trade areas all but disappear under the score-range procedure. Since distances do not change, the composite attractiveness metrics change under the score-range procedure.

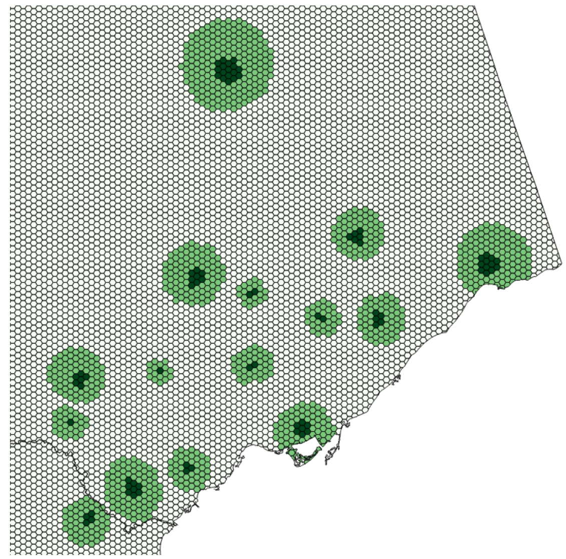

Fig. 3: Trade areas after maximum-score transformation of attractiveness criteria

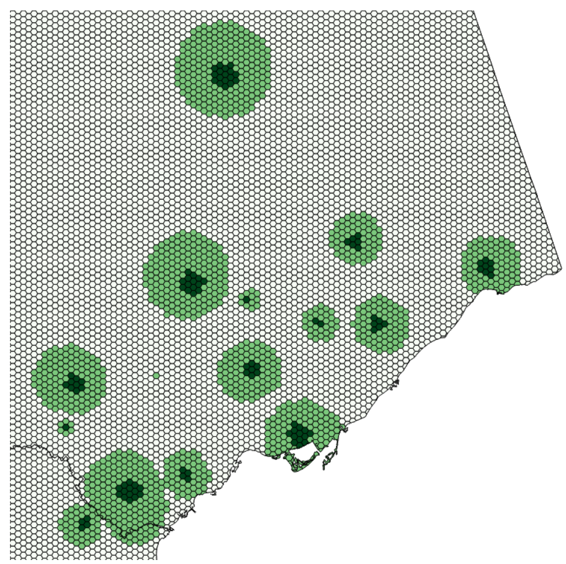

Fig. 4: Trade areas after score-range transformation of attractiveness criteria

This can be explained by the fact that the maximum-score method is “anchored” at the maximum value, which is transformed to 1.0, while the minimum value only gets down to 0.0 if the original indicator value also was 0.0; other minimum values are transformed to rescaled values between 0.0 and 1.0, thus larger minima than under the score-range procedure, which always uses the full value range (Young et al. 2010). The score-range procedure therefore results in more extreme probabilities and trade areas, while the maximum-score transformation produces more equally distributed probabilities (see also Fig. 5).

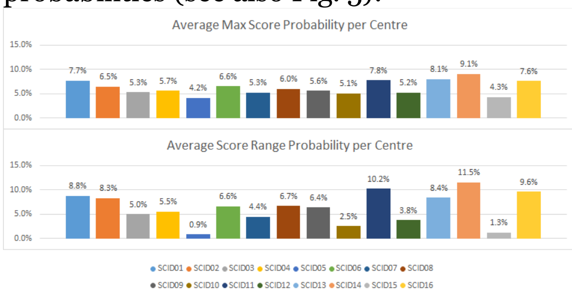

Fig. 5: Average probabilities per centre under maximum-score (top) and score-range (bottom) transformations

4. Conclusion

In summary, MCA methods were shown to be applicable to the estimation of site attractiveness for the Huff model in retail geography. MCA provides a structured, framework for the combination of multiple, commensurate criteria. This approach integrates decision-maker preferences in a way that may be considered normative or subjective.

We are in the process of expanding the existing QGIS plugin with additional retail geography functionality, including other trade area delineation techniques and alternative distance calculation. Our goal is to create a location analytics toolkit that makes market research accessible to smaller companies, non-profits, academic researchers, and the general public.

It would also be of interest to examine the normative modeling framework of MCA in conjunction with crowdsourcing and volunteered geographic information, which include elements of subjectivity. In addition, the methods described could benefit from integrating open data and using geospatial Web technology in an online modeling and decision support framework.

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