Huff Model for Shopping Centre Assessment using Aggregated Mobile Phone Data

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Abstract: There are several models of gravity, one of which is Huff model. It calculates customer gravity probabilities for existing locations of trade objects. In this study, aggregated mobile data-based approach using Huff model to determine the market share of trading objects is developed. The mobile activity data is used to give a more precise understanding of available number of potential customers in a certain territory of Latvia. By using the mobile phone base station unique number of users per day in 2016 within an area of each shopping centre, it is possible to determine the unique user share and ratio between shopping centres. The use of mobile data, as well as other statistics and real estate appraisal data, provides the opportunity to create universal criteria for location and shopping centre standardization to compare prices for similar real estates in a specific region. The research results have shown that the mobile activity data could be applied in gravity-based Huff model for estimation of retail attractiveness and market share.

1 INTRODUCTION

Market analysts have used four theoretical approaches to analyze the potential and location of a retail area: analogy models, regression models, central location theory and retail gravity theory (Aboolian, et al, 2007). Analog models use existing data and growth models from similar retailers or leasable areas. Regression models determine potential sales based on such factors such as population, income and number of households in the region (De Beule, et al, 2014).

Central location theory states that customers are willing to travel longer distances to shopping centres with a relatively wide selection of goods. Gravity models determine that customer groups are redirected to specific locations due to such factors as the distance to a shopping centre, the distance between shopping centres, customers of a retail area, the size of a shopping centre, location of competitors, etc. (Friske & Choi, 2013).

There are several models of gravity (Anderson, 2011), one of them is Huff model, which calculates customer gravity probabilities to existing locations of trade objects. From these probabilities, sales potential can be estimated for each location using income, population or other factors.

Huff model depends on distance calculation using the traditional Euclidean distance or travel time in the street network. Other factors, such as sales volume, product variety, and retail space, should be considered when determining the attractiveness of a trade area. Huff model is used to:

- Display probability-based locations for trade objects,
- Model economic impact of new competitive store locations;
- Predict high and low potential trade areas resulting from the development of a new trade object (Fernández & Hendrix, 2013).

Huff's gravity model predicts that as the size of a shopping centre increases, the probability that the customer will prefer the location of the shopping

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centre increases. Similarly, as distance increases, the probability that customers will visit a retail facility decreases (1):

$$P_{ij} = \frac{\frac{S_j}{T_{ij}^{\lambda}}}{\sum_j^n \frac{S_j}{T_{ij}^{\lambda}}} \quad (1)$$

where:

- P_{ij} is the probability that the customer will go from the location *i* to the shopping centre location *j*;
- S_j is the size of the shopping centre in location *j*;
- T_{ij} is the travel time (or distance) from the customer location *i* to the shopping centre location *j*;
- λ is a parameter that needs to be empirically evaluated to reflect the impact of different types of shopping travel time.

Other studies have developed gravity models using Geographic Information System (GIS) technologies for the train station catchment area determining (Lin, et al, 2016), healthcare services spatial access analysis and planning (Luo, 2014), evaluation of new university site locations (Bruno & Improta, 2008) and others.

To prove that the new technical solutions and in this particular case mobile data availability allow developing applications of mobile data in multiple fields, the cooperation with the largest mobile operator in Latvia from 2016 to 2018 implemented a cooperation project for updatable Latvian regional business index development (Arhipova, et al, 2019).

This research has generated substantial knowledge and data to work on multiple business user cases in real estate, retail related and utility business sectors where the mobile telecommunication data can be used as a tool to optimize business decisions and test assumptions for long-term strategic investment decisions. Researchers at the University of Latvia, in collaboration with leading real estate experts, have developed a user case for shopping centers attractiveness evaluation.

According to the latest data, shopping center stock in Riga, the capital city of Latvia, significantly changed during 2018 and 2019. During the last two years, the expansion of several existing shopping centers and new projects was finished. *IKEA* opened its first shopping center near Riga with the total area of 34 500 m^2. A year later, in 2019, one shopping center was opened – *Akropole Riga* (adding more than 60 000 m^2 of new leasable retail space) and *Alfa* expansion (adding 18 300 m^2 and providing a total gross leasable area of 66 000 m^2) was commissioned. There is also *Origo* expansion that could be finished in 2020, thus increasing the leasable retail stock by additional 16 500 m^2 (CBRE Baltics, 2018).

Riga as capital of Latvia had 649 000 m^2 of total leasable space in shopping centers by the end of 2018. The vacancy rate of shopping centers in Riga was around 4%. Economic growth, salary grows by 6 to 7 percent in recent years, and subsequentially consumption increase activity on the retail market in 2018. At the same year two large shopping center sale transactions took place in Riga. The 24 300 m^2 *Galleria Riga* shopping center was purchased by the East Capital Baltic Property Fund and the 18 000 m^2 *Dole* shopping center by the Premier Estates Ltd. Details of the transactions have not been disclosed (Realia Group, 2019).

The challenge of existing models is source data reliability that largely depends on the quality of statistics gathered or obtained from statistics variety of statistical sources. The study explores the use of alternative data sources for shopping centres attractiveness statistics based on mobile-data obtained from mobile network providers.

The purpose of the study is developing and testing a new aggregated mobile data-based approach to estimate the market share for selected shopping centers based on the Huff model. The new mobile data-based modes will provide a more reliable source for customer number probability estimates than existing models.

2 HUFF MODEL DEVELOPMENT, USING MOBILE PHONE DATA STATISTICS

Huff's gravity model could be used with different metrics to calculate gravity-based probabilities of customers to each location using income, population or other variables. It is very important that accurate data about economic or social activity available for specific territories. However, statistical data of people living in a certain territory is not accurate and at same time does not represent real number of people available in this territory.

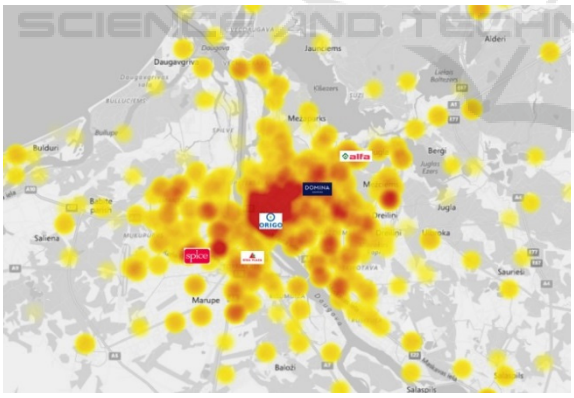
Therefore, for this research a mobile activity data is used which gives a more precise understanding of available number of potential customers in a certain territory. Mobile activity data used from 297 mobile base stations placed in capital of Latvia - Riga city territory is used (Fig. 1).

Base stations are used as a geographic reference instead of dividing territory in quadrants. Daily average unique mobile users are calculated for each mobile base station for year 2016. Unique mobile users represent unique devices (mobile users) connected to mobile station in 15 minutes interval. To avoid overlapping of potential and existing customers all unique mobile users in 1 km radius from shopping centre were excluded from further calculations.

Figure 1: Mobile phone base stations in Riga.

Huff's gravity model assumes that attractiveness is based on the size and distance to shopping centres, therefore the following two datasets were selected for the analysis (Fig. 2):

- Locations and size of 5 shopping centres (j = 1,..,5)
- Mobile network base stations (i = 1, .., 297).



The lowest mobile phone activity

The highest mobile phone activity

Figure 2: Shopping centres and mobile phone base stations.

To evaluate the probabilities of a customer preference of shopping centre location, there are 3 steps:

- Determine the distance from 5 shopping centres to mobile phone base stations;
- Determine the attractiveness of 5 shopping centres, which are directly proportional to the leasable area S_j (m^2) and inversely proportional to the square of the distance T_{ij}^2 (2):

$$Attractiveness = \frac{S_j}{T_{ij}^2} \tag{2}$$

where j=1,…5; i=1,…,297.

- Calculate the probabilities when customers from each mobile phone base station's area i are most likely to go to each shopping centre j (3):

$$P_{ij} = \frac{\frac{S_j}{T_{ij}^2}}{\sum_j^5 \frac{S_j}{T_{ij}^2}} \tag{3}$$

where j=1,…,5; i=1,…297.

The Euclidean distance was used to determine the distance (km) from 5 shopping centres to the mobile network 297 base stations in Riga city area. For example, the distance from # 100102 base station to *Riga Plaza* shopping centre equals 4.49 km, but to *Origo* shopping centre equals 2.02 km (Tab. 1).

Table 1: Example of the distances (km) from shopping centres to base stations.

Base station #	Shopping centre				
	Riga Plaza	***Domina***	***Alfa***	***Spice***	***Origo***
100102	4.49	1.67	4.64	7.09	2.02
100103	4.20	1.70	4.74	7.01	1.75
100105	3.93	2.37	5.35	6.39	1.48
100409	0.97	6.44	9.34	4.35	3.32

2.1 Shopping Centre Attractiveness Determination

Mobile phone base stations within a 1 km radius of the shopping centre are excluded from further analysis, because the actual mobile phone users are already connected to the base stations as customers with the probability tends to 1.

The attractiveness from all 297 base stations in Riga territory and the total attractiveness are calculated for 5 shopping centres. The overall attractiveness from the base station area is calculated as the sum of the attractiveness of all 5 shopping centres. For example, the total attractiveness from # 100102 base station equals 27064.4, but from # 100409 base station equals 58549.9 (Tab. 2).

Table 2: Example of shopping centre attractiveness.

Shopping centre	Base station #			
	100102	**100103**	**100105**	**100409**
Riga Plaza	2484.1	2830.3	3235.4	52947.5
Domina	16766.7	16112.6	8340.8	1129.3
Alfa	2227.3	2138.5	1676.2	550.4
Spice	814.5	834.5	1004.8	2162.5
Origo	4771.9	6292.9	8818.1	1760.3
Total	**27064.4**	**28208.8**	**23075.3**	**58549.9**

The overall attractiveness of shopping centres is identified on the map from the mobile phone base stations within 30 km surrounding area of Riga in Figure 3.

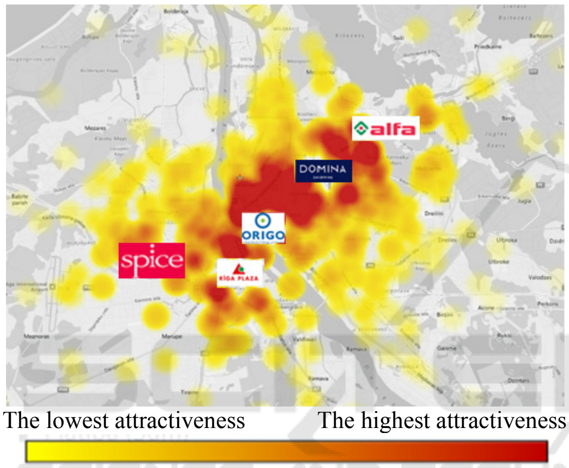


Figure 3: Shopping centres attractiveness.

It can be concluded, that the *Origo* shopping centre is the most attractive compared to other shopping centres.

2.2 Shopping Centre Market Share Probability Estimation

Using formula (3) the probabilities when customers from each mobile phone base station area i are most likely to go to the shopping centre j is calculated (Tab. 3).

Table 3: Example of shopping centre market share probability estimation.

Base station #	Shopping centre				
	Riga Plaza	***Domina***	***Alfa***	***Spice***	***Origo***
100102	9.2%	62.0%	8.2%	3.0%	17.6%
100103	10.0%	57.1%	7.6%	3.0%	22.3%
100105	14.0%	36.1%	7.3%	4.4%	38.2%
100409	90.4%	1.9%	0.9%	3.7%	3.0%

For example, probability that customers will go to *Riga Plaza* from # 100102 base station equals (4):

$$P_{11} = \frac{\frac{S_1}{T_{11}^2}}{\sum_j^5 \frac{S_j}{T_{1j}^2}} = \frac{2484.1}{27064.4} = 9.2\ \% \qquad (4)$$

In its turn, probability that customers will go to *Riga Plaza* from # 100103 base station equals (5):

$$P_{21} = \frac{\frac{S_1}{T_{21}^2}}{\sum_j^5 \frac{S_j}{T_{2j}^2}} = \frac{2830.3}{28208.8} = 10.0\ \% \qquad (5)$$

As a customer approaches a shopping centre, it gains a higher market share, resulting in higher red values (Fig. 4a - 4e).

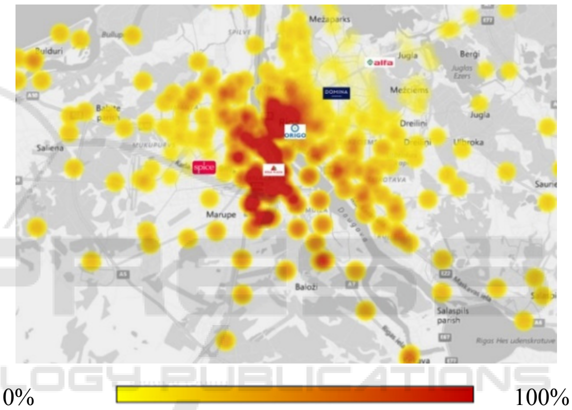


Figure 4a: *Riga Plaza* shopping centre market share probability estimation.

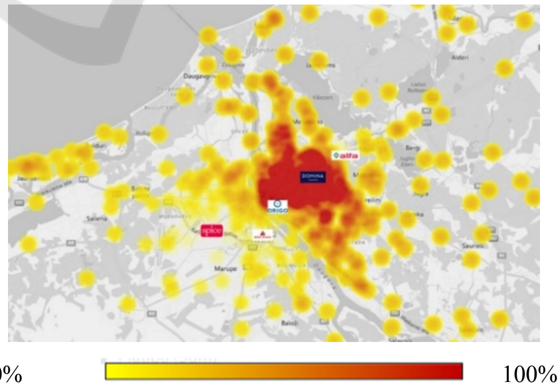


Figure 4b: *Domina* shopping centre market share probability estimation.

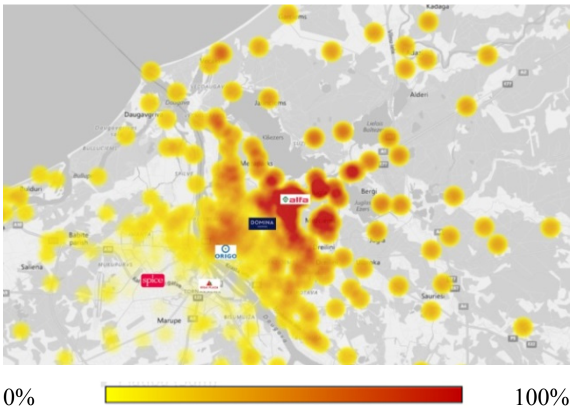


Figure 4c: *Alfa* shopping centre market share probability estimation.

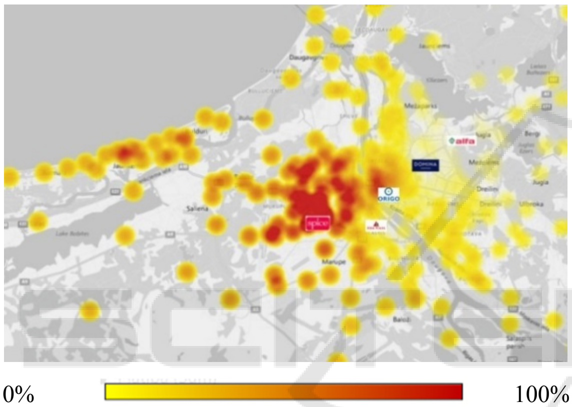


Figure 4d: *Spice* shopping centre market share probability estimation.

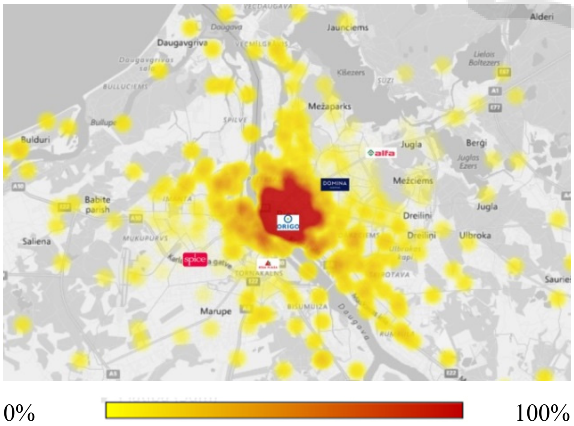


Figure 4e: *Origo* shopping centre market share probability estimation.

3 MARKET SHARE ESTIMATION OF SHOPPING CENTRE

To determine the number of potential customers C_j for a particular shopping centre j (average daily, monthly, yearly), it is necessary to multiply the unique mobile phone users N_i (average daily, monthly, yearly) in each base station area i with the probability P_{ij} that customers are likely to go to shopping centre j and count them together (6):

$$C_j = \sum_{i=1}^{297} N_i \cdot P_{ij} \quad (6)$$

Accordingly, the share of potential customers in each shopping centre equals (7):

$$MC_j = \frac{C_j}{\sum_{j=1}^{5} C_j} \quad (7)$$

It is possible to compare potential and actual share of customers in each shopping centres. By using a mobile phone base station unique number of users per day in 2016 within a 1 km radius of each shopping centre, it is possible to determine the unique user share and ratio among shopping centres by selecting *Riga Plaza* as 100%. Therefore, the market share of potential customers within a radius of 1 km is the highest for *Origo* – 58 %, and the lowest for *Alfa* – only 7 %. (Tab. 4).

Table 4: Mobile phone unique users and potential customers share within a 1 km radius of shopping centre.

#	Shopping centre	Base station unique users and potential customers		
		number per day	share	ratio
1	*Riga Plaza*	24 719	10 %	100 %
2	*Domina*	28 653	12 %	116 %
3	*Alfa*	17 583	7 %	71 %
4	*Spice*	31 042	13 %	126 %
5	*Origo*	143 800	58 %	582 %

By using Huff's model, it is possible to determine potential number of customers within a 10 km radius of each shopping centre (5), the potential customers share (6) and ratio between shopping centres by selecting *Riga Plaza* as 100% (Tab. 5).

Comparing the obtained potential customer ratio (Tab. 5) and actual ratio of customers in shopping centres, it has concluded that the relationship between shopping centres differed significantly from previous results within a 1 km radius. This can be explained by the fact that only 2 factors are used in the model: the leasable area and the distance to the shopping centres from mobile phone base stations, without taking into account other relevant factors, for example, the presence of a train station in the case of *Origo*. Therefore, it is necessary to add to the model other factors or to multiply the number of potential customers by a coefficient based on the ratios within a 1 km radius.

Table 5: Potential customers within a 10 km radius of shopping centre.

#	Shopping centre	Potential customers		
		number per day	share	ratio
1	*Riga Plaza*	415 925	21 %	100%
2	*Domina*	524 305	27 %	126%
3	*Alfa*	322 640	17 %	78%
4	*Spice*	296 272	15 %	71%
5	*Origo*	392 442	20 %	94%

Valuation of shopping centres in illiquid markets, such as the capitals of the Baltic States, is the subject to subjective fluctuations in valuation due to the lack of comparable deals and the absence of analogous or similar objects in the largest and unique facilities in the Baltic region. There is an objective difficulty in comparing shopping centres across a broader geography because the information about different markets is aggregated in different, incomparable formats and the data is affected by many local factors. There is a lack of standardized reference points for comparing locations and retails objects. Using mobile data, as well as other statistics and real estate appraisal data, provides the opportunity to create universal criteria for location and shopping centre standardization to compare prices for similar real estate in a specific region.

Huff model-based approach for shopping center assessment has been validated using real data, including shopping centre total leasable area S_j (thsd. m^2), share of the customers (%), value per purchase (EUR) and the turnover (EUR/m^2). The research results show that the model with two distance and leasable area factors is not sufficient for the practical purposes and should be expanded by the other factors for model usability increasing, such as sales volume, turnover, customer service level, etc.

4 CONCLUSIONS

In this research, the new type of source data for measuring customer retail potential and market share analysis using mobile activity data has been proposed. The results have shown that mobile activity data could be used as alternative source data for the gravity-based Huff model to estimate retail attractiveness, market share, and potential customer. Mobile activity data gives more precise and realistic information about several potential customers in a specific territory, therefore mobile activity data could be used in the Huff model.

The finding also indicated the specific requirements for conditions to obtain high-reliability source data for the Huff model. Results indicate that mobile base stations could be used as a reference to customer location in urban territories with a large number and density of mobile base stations. Mobile station density should be evenly distributed across the territory to avoid overfitting problems. The granularity of available mobile activity data allows the use of the Huff model for different periods not losing accuracy.

The advantage of mobile data use for shopping center market share estimates is the possibility to constantly track market share fluctuations and seasonal changes. The model provides reliable data sources for potential customer estimates. The method is relatively low cost compared with traditional methods used.

There are several opportunities for future studies of the gravity-based approach using mobile activity data. It is possible to use more frequent information on a weekly level that requires data from retail stores on weekly basis such as turnover, gross profit, number of purchases and putting it together with mobile activity on weekly bases that could increase prediction accuracy and explain the impact of seasonal sales, special sales events, etc.

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REFERENCES

Aboolian, R., Berman, O., Krass, D., 2007. Competitive facility location and design problem. *European Journal of Operational Research,* 182(1), pp.40–62.

Anderson, J., 2011. The Gravity Model. *Annual Review of Economics*, 3(1), pp.133-160.

Arhipova, I., Berzins, G., Brekis, E., Opmanis, M., Binde, J., Steinbuka, I., Kravcova, J., 2019. Pattern Identification by Factor Analysis for Regions with Similar Economic Activity Based on Mobile Communication Data. *Advances in Intelligent Systems and Computing*, 886, pp.561–569.

Bruno, G., Improta, G., 2008. Using gravity models for the evaluation of new university site locations: A case study. *Computers & Operations Research*, *35*(*2*), pp.436-444.

De Beule, M., Van den Poel, D., Van de Weghe, N., 2014. An extended Huff-model for robustly benchmarking and predicting retail network performance. *Applied Geography,* 46, pp.80-89.

Fernández, J., Hendrix, E.M.T., 2013. Recent insights in Huff-like competitive facility location and design. *European Journal of Operational Research*, 227, pp.581–584.

Friske, W., Choi, S., 2013. Another look at retail gravitation theory: History, Analysis, and Future Considerations. *Academy of Business Disciplines Journal*, 5(1), pp.88-106.

Lin, T., Xia, J., Robinson, T. P., Olaru, D., Smith, B., Taplin, J., Cao, B., 2016. Enhanced Huff model for estimating Park and Ride (PnR) catchment areas in Perth, WA. *Journal of Transport Geography*, 54, pp.336–348.

Luo, J., 2014. Integrating the Huff Model and Floating Catchment Area Methods to Analyze Spatial Access to Healthcare Services. *Transactions in GIS*, 18(3), pp.436-438.

Real estate market report. Baltic States Capitals Vilnius, Riga, Tallinn, 2019, Realia Group, https://www.ober-haus.lt/wp-content/uploads/Ober-Haus-Market-Report-Baltic-States-2019.pdf#page=62

The Baltics anticipating new stock increases in the capitals. Baltics Retail, H2 2017/Q1 2018, CBRE Baltics, www.cbre.com/researchgateway