

# Using location-based Social Networks for optimal placement of tourist facilities: Zagreb case study

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Đokić, Kristian; Štavlić, Katarina; Potnik Galić, Katarina

Source / Izvornik: **Međunarodni znanstveni simpozij Gospodarstvo istočne Hrvatske - jučer, danas, sutra, 2020, 167 - 181**

Conference paper / Rad u zborniku

Publication status / Verzija rada: **Published version / Objavljena verzija rada (izdavačev PDF)**

Permanent link / Trajna poveznica: <https://urn.nsk.hr/urn:nbn:hr:112:263371>

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Download date / Datum preuzimanja: **2025-02-06**



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9<sup>th</sup>  
**INTERNATIONAL SCIENTIFIC SYMPOSIUM  
REGION, ENTREPRENEURSHIP, DEVELOPMENT**

Under the auspices of:

**REPUBLIC OF CROATIA  
MINISTRY OF SCIENCE AND EDUCATION**

Osijek, June 2020

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### ***Print***

Studio HS internet d.o.o., Osijek

ISSN 1848 – 9559

Previous editions of the Proceedings published under the title  
Economy of eastern Croatia – Vision and Growth

Proceedings indexed in:



**9<sup>th</sup> INTERNATIONAL SCIENTIFIC SYMPOSIUM  
REGION, ENTREPRENEURSHIP, DEVELOPMENT**

**Content**

<b>Foreword.....</b>	<b>15</b>
<b>Topics.....</b>	<b>16</b>
<b>1. Region.....</b>	<b>17</b>
Romina Alkier, Ervin Mihelj, Vedran Milojica: <b>INFLUENCE AND SIGNIFICANCE OF WOMEN FOR DEVELOPMENT OF CROATIAN TOURISM .....</b>	<b>19</b>
Martina Basarac Sertić, Marija Beg, Martina Harc: <b>THE IMPACT OF CHINA ON EUROPEAN UNION INDUSTRY .....</b>	<b>34</b>
Heri Bezić, Tomislav Galović, Davorin Balaž: <b>THE COMPETITIVENESS AND ATTRACTIVENESS OF INVESTMENT ENVIRONMENT IN CROATIA AND EX- COMMUNIST COUNTRIES .....</b>	<b>49</b>
Vlatka Bilas: <b>CHALLENGES OF BUILDING EFFICIENT REGIONAL INNOVATION SYSTEMS .....</b>	<b>62</b>
Draženka Birkić, Silvija Podoljak, Paula Grgić: <b>THE BRANDING OF POŽEGA-SLAVONIA COUNTRY BY MEANS OF INTEGRAL QUALITY MANAGEMENT OF A TOURIST DESTINATION .....</b>	<b>74</b>
Berislav Bolfek, Elzbieta Wrońska-Bukalska, Jurica Bosna: <b>GARCH ESTIMATION OF CEE FINANCIAL INTEGRATION AS COMPARED WITH GERMANY .....</b>	<b>90</b>
Alaudin Brkić, Jasmina Džafić, Alem Merdić: <b>POSSIBILITIES AND LIMITATIONS OF IMPROVING FACTORING IN BOSNIA AND HERZEGOVINA: LEGAL AND ECONOMIC ASPECTS.....</b>	<b>104</b>
Mihaela Bronić: <b>ECONOMIC AND FINANCIAL CRISIS AND LOCAL GOVERNMENT UNITS' BUDGETS IN CROATIA.....</b>	<b>116</b>
Iva Buljubašić, Josipa Mijoč, Ivana Jobst: <b>THE EFFECTIVENESS OF UNCONVENTIONAL MARKETING IN THEATRES: TOP MANAGEMENT THEATRE PERSPECTIVE.....</b>	<b>130</b>
Dražen Ćučić, Ivona Srnec, Dominik Paparić: <b>POTENTIALS OF ACTIVE TOURISM IN THE AREA OF SLAVONIA AND BARANJA.....</b>	<b>143</b>

Lena Duspara:

**THE INFLUENCE OF TRADITION AND NUMBER OF EMPLOYEES ON THE COMPETITIVENESS AND PROFITABILITY OF ENTERPRISES IN THE METAL PROCESSING INDUSTRY**155

Kristian Đokić, Katarina Štavlić, Katarina Potnik Galić:

**USING LOCATION-BASED SOCIAL NETWORKS FOR OPTIMAL PLACEMENT OF TOURIST FACILITIES: ZAGREB CASE STUDY**.....167

Tvrtko Galić, Zvonimir Tomac, Dražen Maleš:

**DIGITAL TRANSFORMATION OF ACADEMIC SPORTS IN THE ROLE OF RAISING THE QUALITY OF UNIVERSITY EDUCATION – CASE STUDY OF FACULTY OF EDUCATION OSIJEK 2014–2019** .....182

Tomislav Galović, Petar Mišević, Heri Bezić:

**THE INTERNATIONAL COMPETITIVENESS OF THE EU AUTOMOTIVE INDUSTRY**.....192

Maja Haršanji, Ivana Bestvina-Bukvić, Marija Šain:

**BUDGET FUNDING AND ECONOMIC IMPORTANCE OF CULTURAL AND CREATIVE SECTORS IN CROATIA**.....208

Jelena Kasap, Višnja Lachner:

**COLLECTION OF TESTAMENTARY NOTES AS AN INDICATOR OF THE ECONOMIC SITUATION OF THE INHABITANTS OF THE CITY OF OSIJEK IN THE PERIOD THE SECOND HALF OF THE 19TH CENTURY** .....224

Ivan Kelić, Davorin Turkalj, Antun Biloš:

**DESTINATION BRANDING: MEASURING TOURIST PERCEPTION OF DESTINATION BILJE, EASTERN SLAVONIA** .....240

Anna Kubjatková, Anna Krizanová, Jana Kliestiková:

**MARKETING MOBILE COMMUNICATION OF COMMERCIAL BANKS IN THE SLOVAK REPUBLIC**.....253

Jelena Lakuš, Ines Horvat, Melita Aleksa Varga:

**BOOK ADVERTISING IN NOVINE HORVATZKE, THE FIRST NEWSPAPER IN CROATIAN LANGUAGE**.....263

Jelena Legčević, Marija Prejac:

**IMPACT OF PUBLIC DEBT ON THE ECONOMIC GROWTH OF THE REPUBLIC OF CROATIA**.....280

Biljana Lončarić:

**NEW LAW ON TOURIST BOARDS AND PROMOTION OF CROATIAN TOURISM IN FUNCTION OF TOURISM DEVELOPMENT OF THE SLAVONIAN POSAVINA**.....291

Antun Marinac, Mirela Mezak Matijević, Karolina Štefanac: <b>ROLE AND POSITION OF EUROPEAN REGIONS - ECONOMIC, POLITICAL AND LEGAL ASPECT.....</b>	<b>304</b>
Mirela Mezak Matijević, Antun Marinac: <b>ENVIRONMENTAL LAW TECHNIQUES – EASTERN CROATIA VERSUS GLOBAL STANDARDS.....</b>	<b>319</b>
Zoran Mihanović, Tonka Smoljanović, Ana Marija Sanader: <b>HISTORICAL REGION AS A BASE FOR BRANDING A DESTINATION – THE CASE STUDY OF THE REPUBLIC OF POLJICA.....</b>	<b>330</b>
Ljubica Milanović Glavan, Lucija Ivančić: <b>EXPLORING THE RELATIONSHIP BETWEEN INFORMATION TECHNOLOGY AND PROCESS ORIENTATION: CASE OF CROATIAN COMPANIES.....</b>	<b>349</b>
Ljubica Mišković, Zvezdana Hendija: <b>STRATEGIC PLANS AND TOURISM DEVELOPMENT IN HALF CENTURY PERIOD: THE CASE OF DUBROVNIK-NERETVA COUNTY .....</b>	<b>360</b>
Mario Pečarić, Tino Kusanović, Ante Tolj: <b>FOREIGN DIRECT INVESTMENT INFLOWS AND ECONOMIC GROWTH IN CENTRAL AND EASTERN EUROPEAN COUNTRIES – HETERODOX APPROACH .....</b>	<b>376</b>
Tunjica Petrašević, Tomislav Dagen, Marijana Majnarić: <b>THE LEGAL EFFECTS OF THE Lex Agrokor ACT AND ITS SIGNIFICANCE IN REGIONAL AND SECURITY CONTEXT .....</b>	<b>388</b>
Damir Piplica: <b>ECONOMIC CONSEQUENCES OF CORRUPTION IN CROATIA.....</b>	<b>405</b>
Irena Raguž Krištić, Marko Družić, Marija Logarušić: <b>DETERMINANTS OF FIRM PROFITABILITY IN EASTERN CROATIA.....</b>	<b>421</b>
Melita Šrpak, Silvija Zeman: <b>EXPLORATION AND EXPLOITATION OF MINERAL RESOURCES IN ENVIRONMENTAL PROTECTION .....</b>	<b>443</b>
Branko Stanić, Simona Prijaković, Mihaela Bronić: <b>WOMEN’S POLITICAL REPRESENTATION AND BUDGET TRANSPARENCY IN CITIES AND MUNICIPALITIES OF EASTERN CROATIA.....</b>	<b>454</b>
Slavko Šodan, Ivana Perica, Maja Vojvoda: <b>AGGREGATE LEVEL OF FINANCIAL REPORTING MANIPULATIONS IN COUNTRIES OF SOUTH-EAST EUROPE .....</b>	<b>469</b>



Branka Tuškan Sjauš, Maja Mihelja Žaja: <b>CROATIAN BANKING AND INSURANCE INDUSTRY: OVERVIEW OF COST EFFICIENCY PERFORMANCE AFTER ACCESSION TO THE EUROPEAN UNION .....</b>	<b>480</b>
Ivana Varičak, Silvija Vitner Marković, Mihovil Žokvić: <b>TOURIST EVALUATION OF THE EVENTS OF TOWN OF KARLOVAC ACCORDING TO VISITORS' EXPERIENCES.....</b>	<b>498</b>
Antonio Vlahov, Danijela Ferjanić Hodak: <b>IMPORTANCE OF GASTRONOMY HERITAGE FOR TOURISM DEVELOPMENT – THE CASE OF MEDITERRANEAN DIET IN CROATIA.....</b>	<b>508</b>
Ivona Vrdoljak Raguž, Aleksandra Krajnović: <b>DEMARKETING AS A STRATEGIC TOOL FOR SUSTAINABLE DEVELOPMENT OF TOURISM – THE CASE OF THE CITY OF DUBROVNIK.....</b>	<b>520</b>
Anna Zielińska-Chmielewska, Almir Alihodžić, Luboš Smutka: <b>THE MEASUREMENT OF TECHNICAL EFFICIENCY BY non- radial NR-DEA model IN FOOD PROCESSING SECTOR .....</b>	<b>539</b>
Mira Zovko, Vatroslav Zovko: <b>EXPLORING THE CONCEPT OF CIRCULAR ECONOMY AND ECOINNOVATIONS IN THE CONTEXT OF THE REGIONAL DEVELOPMENT .....</b>	<b>553</b>
<b>2. Entrepreneurship.....</b>	<b>569</b>
Željana Aljinović Barać, Marijana Ćurak: <b>INSIGHTS INTO VOLUNTARY DISCLOSURE OF CASH FLOWS INFORMATION IN CROATIA .....</b>	<b>570</b>
Filip Bartoluci, Iva Sundji, Dino Bartoluci: <b>AN ENTREPRENEURIAL APPROACH TO SUSTAINABLE DEVELOPMENT OF SPECIFIC TYPES OF TOURISM IN THE EASTERN CROATIA .....</b>	<b>580</b>
Igor Cvečić, Marko Tomljanović, Samanta Botički: <b>GLOBALIZATION AND DEVELOPMENT OF THE SMALL AND MEDIUM ENTERPRISES IN THE EU.....</b>	<b>588</b>
Teresa Dieguez, Paula Loureiro, Isabel Ferreira: <b>POSSIBLE GUIDELINES FOR ENHANCE ENTREPRENEURIAL ECOSYSTEM .....</b>	<b>601</b>

Marija Dragičević Ćurković: <b>IMPLEMENTATION OF VIRTUAL TECHNOLOGY IN MUSEUMS AND ART GALLERIES.....</b>	<b>316</b>
Lidija Gruber: <b>MAPPING LITERATURE REVIEW ON THE ROLE OF CONSCIOUSNESS IN ENTREPRENEURSHIP COMPETENCE DEVELOPMENT .....</b>	<b>622</b>
Lidija Gruber: <b>THE ROLE OF CONSCIOUSNESS IN THE ENTREPRENEURSHIP COMPETENCES DEVELOPMENT — TOWARDS EMPIRICAL RESEARCH DESIGN .....</b>	<b>637</b>
Domagoj Hruška, Damir Piplica, Tihomir Luković: <b>DRIVING FORCES OF ENTREPRENEURIAL DECLINE OF MAIN URBAN AREAS IN EASTERN CROATIA: HISTORICAL PERSPECTIVE .....</b>	<b>652</b>
Veronika Jurickova, Elena Gregova: <b>INFLUENCE OF CROWDFUNDING'S INVESTMENT ON COMPANY'S EARNINGS .....</b>	<b>669</b>
Paula Loureiro, Isabel Ferreira, Teresa Dieguez: <b>SOCIAL ENTREPRENEURSHIP AS METHODOLOGY FOR SKILLS IMPROVEMENT ON HIGHER EDUCATION STUDENTS .....</b>	<b>678</b>
Radojko Lukić, Blaženka Hadrović Zekić, Dominika Crnjac Milić: <b>FINANCIAL PERFORMANCE EVALUATION OF TRADING COMPANIES IN SERBIA USING THE INTEGRATED FUZZY AHPTOPSIS APPROACH .....</b>	<b>690</b>
Ljiljana Najev Čačija: <b>IMPACT OF MARKETING ACTIVITIES ON FUNDRAISING SUCCESS THROUGH DONOR'S MOTIVATION .....</b>	<b>704</b>
Ivana Plazibat, Stipe Marunica: <b>THE INFLUENCE OF GENDER IN M-RETAIL PURCHASING PATTERNS .....</b>	<b>719</b>
Nada Rajić, Mato Bartoluci, Alen Jerkunica: <b>ENTREPRENEURIAL ECOSYSTEM OF THE CITY OF ZAGREB AND OPPORTUNITIES FOR IMPROVEMENT .....</b>	<b>728</b>
Nataša Rupčić: <b>REINFORCEMENT AND CRITICAL SUCCESS FACTORS OF ERP IMPLEMENTATION: DOES THE SCOPE OF THE PROJECT PLAY A ROLE?.....</b>	<b>741</b>

Lenka Strakova, Pavol Durana:

**APPRAISAL OF DETECTION APTITUDES OF EARNINGS  
MANAGEMENT MODELS IN ENTERPRISES IN THE CZECH REPUBLIC .....754**

Eleni R. Theochari:

**THE ROLE OF AFFECT AND COGNITION IN THE  
ENTREPRENEURIAL THINKING AND ACTION .....768**

Eleni R. Theochari:

**THE ROLE OF ENTREPRENEURSHIP EDUCATION IN THE  
FORMATION OF ENTREPRENEURIAL MINDSET: ITS IMPACT  
ON DECISION MAKING .....781**

### **3. Development ..... 797**

Marko Akmačić, Andreja Rudančić:

**CAUSALITY OF THE DETERMINANTS OF GDP GROWTH RATE  
TRENDS AND THE LABOUR MARKET SITUATION IN THE  
REPUBLIC OF CROATIA.....798**

Filip Barić:

**PATIENTS' RELATIONSHIP MANAGEMENT PERFORMANCE  
INDICATORS SUCCESS IN HEALTHCARE INSTITUTIONS .....812**

Filip Barić:

**BUILDING CONFIDENCE IN PATIENTS UNDER THE  
RATIONALIZATION OF HEALTH EXPENDITURE .....828**

Ivana Barković Bojanić, Vesna Vučemilović:

**BUSINESS ENTITY RELATIONSHIP WITH THE LOCAL  
COMMUNITY AS PART OF CORPORATE SOCIAL RESPONSIBILITY .....843**

Ivana Bekić, Nerma Saračević, Katica Križanović:

**COMPETITIVENESS AS A DETERMINANT OF MARKET SUCCESS.....855**

Ivana Bestvina Bukvić:

**SIGNIFICANCE OF THE NATIONAL AND EU FUNDING IN  
FINANCING A LONG-TERM INVESTMENTS OF THE ICT SECTOR.....872**

Mateja Brozović, Sanja Sever Mališ, Lajoš Žager:

**FINANCIAL POSITION AND PERFORMANCE - TWO OPPOSING  
CRITERIA?.....886**

Verica Budimir, Vesna Vašiček, Svjetlana Letinić:

**WHO HAS MORE DEVELOPED PERFORMANCE  
MEASUREMENT IN CROATIA? PUBLIC HOSPITALS OR  
HIGHER EDUCATION INSTITUTIONS .....902**

Domagoja Buljan Barbača, Gina Lugović, Ivana Beljo: <b>FINANCIAL BEHAVIOUR AND WELL-BEING ATTITUDES.....</b>	<b>917</b>
Jan Chutka, Ladislav Vagner: <b>EFFICIENCY OF USING TECHNICAL INDICATORS AS A TOOL FOR PREDICTING FUTURE PRICE MOVEMENTS.....</b>	<b>932</b>
Lorena Dadić: <b>NON-PROFIT ORGANIZATIONS AS A STAKEHOLDER IN TOURISM DEVELOPMENT.....</b>	<b>939</b>
Žarko Dobrić: <b>CREATING AND TESTING NEW SERVPERF QUESTIONNAIRE ADJUSTED FOR ELEMENTARY SCHOOLS IN CROATIA.....</b>	<b>955</b>
Martina Dragija Kostić, Davor Vašiček, Sanja Broz Tominac: <b>ACCOUNTING INFORMATION IN THE FUNCTION OF COST MANAGEMENT AT HIGHER EDUCATION INSTITUTIONS.....</b>	<b>967</b>
Gordana Dukić, Darko Dukić, Goran Kozina: <b>ONLINE ADVERTISING: EFFECTIVENESS, INFORMATION CONTENT AND ETHICAL ISSUES.....</b>	<b>976</b>
Jelena Đurkin Badurina, Daniela Soldić Frleta, Ljiljana Kaliterna Lipovčan: <b>INDICATORS FOR MEASURING TOURISM IMPACTS ON LOCAL LEVEL: THEORY AND PRACTICE.....</b>	<b>990</b>
Sanja Gutić Martinčić: <b>THE ROLE OF ORGANIZATIONAL FACTORS IN THE TRANSFER OF KNOWLEDGE.....</b>	<b>1004</b>
Jasna Horvat, Ivana Jobst, Ana Zrnić: <b>MEASURING VOLUNTEER MOTIVATION IN THE CREATIVE INDUSTRY POPULARIZATION PROJECT.....</b>	<b>1017</b>
Ivana Jadrić, Jasmina Dlačić, Bruno Grbac: <b>ANALYSING INFLUENCES ON SERVICE QUALITY IN HIGHER EDUCATIONAL INSTITUTIONS: ROLE OF STUDENTS' INTRINSIC AND EXTRINSIC MOTIVATORS.....</b>	<b>1032</b>
Mirjana Jeleč Raguž, Nikola Raguž, Karolina Štefanac: <b>THE ROLE OF QUALITY ASSURANCE SYSTEM IN INCREASING THE QUALITY OF HIGHER EDUCATION IN THE REPUBLIC OF CROATIA.....</b>	<b>1047</b>
Sanja Knežević: <b>THE IMPACT OF ECONOMIC MOTIVES ON THE TREND OF EMIGRATION FROM THE REPUBLIC OF CROATIA.....</b>	<b>1063</b>

Vanja Krajinović: <b>RETHINKING CONTEMPORARY ROLE OF CARRYING CAPACITY IN DEVELOPMENT OF TOURISM DESTINATIONS.....</b>	<b>1073</b>
Nataša Lucić, Katarina Marošević: <b>PROTECTION OF CHILD’S RIGHT TO A HEALTHY ENVIRONMENT IN CONTEXT OF LOCAL DEVELOPMENT .....</b>	<b>1088</b>
Ivana Mamić Sačer, Ivana Pavić, Mateja Brozović: <b>THE IMPORTANCE OF ANNUAL REPORTS IN EVALUATING THE PERFORMANCE OF LISTED ACCOMMODATION COMPANIES IN CROATIA.....</b>	<b>1103</b>
Ivo Mijoč: <b>BUSINESS COMBINATIONS OF COMPANIES UNDER COMMON CONTROL.....</b>	<b>1119</b>
Alka Obadić, Hatidža Jahić: <b>IS GOOD GOVERNANCE IMPORTANT PREDICTOR OF EDUCATION QUALITY?.....</b>	<b>1134</b>
Martina Ostojić: <b>THE IMPACT OF MARKETING COMMUNICATION STRATEGY ON BUILDING BRAND PERSONALITY OF A PRIVATE HIGHER EDUCATION INSTITUTION.....</b>	<b>1149</b>
Ana Pap, Ana Živković, Jelena Franjković: <b>DEVELOPING DEMOCRACY WITH POLITICAL MARKETING – THE ROLE OF PERCEIVED POLITICAL KNOWLEDGE .....</b>	<b>1159</b>
Anita Papić, Katarina Knol Radoja, Igor Arežina: <b>LEGAL PERSPECTIVES ON POST-GDPR DEVELOPMENTS AMONG LAW STUDENTS AND INFORMATION SCIENCE STUDENTS AT UNIVERSITY OF OSIJEK .....</b>	<b>1174</b>
Veronika Paurova, Darina Chlebkova, Elena Gregova: <b>PRICE ADJUSTMENT STRATEGIES AS PART OF MARKETING STRATEGIES .....</b>	<b>1185</b>
Anita Pavković, Roman Šubić, Dario Hlupić Radić: <b>CLOSE COOPERATION AS PATH TO THE SINGLE SUPERVISORY MECHANISM.....</b>	<b>1194</b>
Dubravka Pekanov Starčević: <b>TOWARDS A LOW-CARBON ECONOMY AND GROWTH .....</b>	<b>1211</b>

Hrvoje Perčević:

**HAS THE IMPLEMENTATION OF EXPECTED CREDIT LOSS MODEL AFFECTED ON FINANCIAL POSITION AND PERFORMANCE OF BANKING SECTOR IN CROATIA? .....1222**

Martina Pezer:

**COUPLES, GENDER AND INEQUALITY: THE CASE OF CROATIA.....1237**

Barbara Pisker, Mirjana Radman-Funarić, Hareesh N Ramanathan:

**GLOBAL ISSUES IN GENDER INEQUALITY: A COMPARATIVE STUDY.....1246**

Monika Poradova, Boris Kollar:

**CREATIVE ACCOUNTING AS A POSSIBLE SOURCE OF FRAUDULENT BEHAVIOUR IN COMMERCIAL CORPORATIONS .....1261**

Barbara Puh:

**DESTINATION IMAGE: DIFFERENCES BETWEEN VARIOUS TOURISTS SEGMENTS .....1272**

Aleksandar Racz, Dora Smolčić Jurdana, Jasmina Gržinić:

**HOTEL MANAGERS' BELIEFS ON THE RELATION BETWEEN TOURISM AND CLIMATE CHANGE.....1286**

Aleksandar Racz, Dora Smolčić Jurdana, Zvonimira Šverko Grdić:

**ECOLOGICAL AWARENESS OF MANAGERS IN TOURISM ACCOMMODATION INDUSTRY RELATED TO CLIMATE CHANGE ISSUES .....1300**

Lucija Rogić Dumančić:

**SUSTAINABILITY OF THE TRADE BALANCE OF GOODS IN THE REPUBLIC OF CROATIA.....1315**

Lucija Rogić Dumančić:

**REWRITING THE EXPORT FUNCTION: THE ROLE OF NON-PRICE COMPETITIVENESS FACTORS IN BOOSTING EXPORTS IN THE REPUBLIC OF CROATIA .....1326**

Danijela Rogina, Ivana Šandrk Nukić:

**GREEN ROOFS AND SUSTAINABILITY OF URBANISATION .....1338**

Zuzana Rosnerova, Dagmar Hraskova:

**PRINCIPLES OF FINANCING OF NON-PROFIT ORGANIZATIONS IN SLOVAK REPUBLIC .....1353**

Andreja Rudančić, Marko Akmačić, Petar Mišević:

**ANALYSIS OF TREND DYNAMICS IN RISK ASSESSMENT OF MULTINATIONAL COMPANIES IN THE RENEWABLE ENERGY SECTOR .....1365**

Vesna Škare Ožbolt, Igor Bojanić, Ivana Nobilo: <b>THE IMPORTANCE OF THE COMMUNICATION FOR THE EFFICIENT COURT MANAGEMENT .....</b>	<b>1377</b>
Ivo Tokić, Ksenija Tokić, Lidija Šajatović, Miroslav Katić: <b>THE CONTRIBUTION OF PUBLIC LIBRARIES TO THE ECONOMIC DEVELOPMENT .....</b>	<b>1389</b>
Daniel Tomić, Saša Stjepanović, Dean Učkar: <b>FROM GREEN GDP TO GREEN GROWTH – STYLIZED MACROECONOMIC MODELLING.....</b>	<b>1403</b>
Maja Vretenar Cobović: <b>FINANCIAL EDUCATION OF THE POPULATION - A KEY FACTOR FOR SUCCESSFUL PERSONAL FINANCE MANAGEMENT .....</b>	<b>1418</b>
Katarina Žager, Nikolina Dečman, Ana Rep: <b>THE IMPACT OF ARTIFICIAL INTELLIGENCE ON THE ACCOUNTING PROCESS .....</b>	<b>1430</b>
Daria Župan Tadijanov, Jurica Lovrinčević, Dražen Rastovski: <b>LIFE SATISFACTION OF STUDENTS OF DIFFERENT STUDY PROGRAMMES AT THE FACULTY OF EDUCATION AS A POTENTIAL FACTOR OF DEVELOPMENT .....</b>	<b>1445</b>
<b>Gratitude to sponsors .....</b>	<b>1456</b>

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## USING LOCATION-BASED SOCIAL NETWORKS FOR OPTIMAL PLACEMENT OF TOURIST FACILITIES: ZAGREB CASE STUDY

### ABSTRACT

*In the last decade, the advance of services and social networks that can store location coordinates and ratings by visitors has had a significant impact on how potential visitors choose their visit destination. The destination can be a landmark, a city, a restaurant, a hotel, etc., and people visiting the destination can be tourists or locals. Also, the data from these services can be used to analyse the location before potential investment in the tourist facility by an investor. Clustering unsupervised machine learning algorithms can be used for that analysis, combining individual municipalities of a city into clusters that have similar properties, making potential investors informed about municipality's properties.*

*In this paper, the main goal is to propose an optimal placement model based on the available information. A prerequisite for this is the analysis of location-based service that can be used to make decisions about the location of a restaurant or bar, and the amount of information available at these service for the city of Zagreb. The proposed model is based on a k-means algorithm that belongs to unsupervised machine learning algorithms.*

*The result of the analysis is the list of municipalities in the city of Zagreb divided into clusters with similar properties. The municipalities are divided into six clusters and that division brings objective knowledge to the potential investor. These results can be used as a basis for decision-making or as a test of expert recommendation. The proposed model can be used for other purposes, depending on the area of interest and the amount of data available on the service.*

**Key words:** *big data, tourist facility, LBSN, foursquare.*

### 1. Introduction

In 2010, about 300 million smartphones were sold. Since 2015, sales have stopped growing, amounting to about one billion and a half smartphones a year (Holst, 2019). One of the essential components of smartphones is the satellite navigation module. This module uses satellites to provide geospatial positioning and make this information available to a smartphone (longitude, latitude, and altitude). Precision can be from a few centimetres to meters. The most popular and the oldest navigation satellite system is the Global Positioning System (GPS) made and



operated by the United States of America. Its development started in the 1970s and the system was fully operational in 1990s. The Global'naya Navigatsionnaya Sputnikova Sistema (GLONASS) is developed by Russian Federation and it can be used today, as well as the European global navigation satellite system Galileo (Teunissen & Montenbruck, 2017, VII). Chinese global navigation system BeiDou is still in the development phase (Yang, et al., 2019, 7).

Smartphones use one or more satellite navigation systems, which gives them a whole new set of functionality. With the use of data communication with the Internet, satellite navigation can serve to accurately locate users at any time. This capability has enabled the development of a range of services, and among other things have emerged social networks that use users locations. The first ideas about this service came out at the beginning of the century, and the authors recognized the huge potential of social networking and satellite navigation. Goel proposed in 2001 that real-time interactivity between wireless networks and Global Position System have big potential. The author proposed the tool with three-layer structure and these layers are: Personal Filtering, Information Layering and Social Networking (Goel, 2001). Three years later Melinger et al. proposed the first mobile social network called Socialight. It was in the development stage and included the location-based messaging system and other social network features (Melinger, et al., 2004, 1). By the end of the first decade of this century, location-based social networks became widespread. Long et al. published a paper about a first globally popular location-based social network called *Foursquare* and they analysed the reasons for its popularity (Long, et al., 2013, 3362).

In this paper data from location-based social networks will be used for Zagreb municipalities clustering for selection optimal placement of tourist facility. Zagreb is the capital city of Croatia, an European Union country. In the second section of the paper, location-based social networks will be explained. In the third section, unsupervised machine learning algorithms that will be used for clustering will be explained. The fourth section includes data, methodology and results. Finally, discussion and conclusion are in the fifth and sixth section.

## 2. Location-based social networks

Gordon and Silva defined Location-Based Social Networks (LBSN) as social network sites that include location information into shared contents (Gordon & Silva, 2011, 11). The first Location-Based Social Network was Dodgeball that allows members to send their location with SMS but it has been acquired and discontinued by Google (Krishnamurthy & Pelechris, 2013, 132). Location-Based Social Networks usually have two types of location information:

- a) continuous trajectory,
- b) discrete locations.

When LBSN records user continuous trajectory then members of a social network who are allowed can access the location of a user any time. The approach that uses discrete locations is usually controlled by users. When a user decides, he or she can check-in on some interesting location and share this location with other members. Both types of location recording approach have advantages and disadvantages. Discrete location approach has more contextual information but continuous trajectories have more information about the movement. Generally, the check-in concept is used more often than continuous trajectory concept and the check-in concept produces more valuable information (Krishnamurthy & Pelechris, 2013, 130).

As mentioned in the Introduction, growth in Location-Based Social Networks usage has been fuelled by the growth of smartphone with a satellite navigation module purchases. LBSN service is most commonly used by users as an app on a smartphone.

Krishnamurthy & Pelechrinis proposed four categories of Location-Based Social Networks:

- a) Location Sharing Services
- b) Location Guides
- c) Business-Oriented LBSNs
- d) Gaming-Oriented LBSNs (Krishnamurthy & Pelechrinis, 2013, 132).

Location Sharing Services category is the simplest and these services came first because of their simplicity. The primary objective of these services is to allow other users to know the real-time location of an active user who shares his/her location. The earliest LBSN belonged to that category.

Location guides category services are more advanced than Location Sharing Services and its primary purpose is to store and share interesting locations. An example from that category is Gowalla, LBSN that was able to provide interest places based on the opinions of other members. Gowalla was acquired by Facebook in 2011 after four years of existence but it has been shut down.

We can say that Business-Oriented LBSNs category is different because their founders had a viable business model from the beginning. LBSNs from that category used the opportunity to exploit collected information about venues to enhancing commerce at such venues. There are lots of such LBSNs and some of them are Foursquare, Yelp and Shopkick. Research in this paper is based on Foursquare LBSN so it will be described in detail. In China there are different LBSNs from Business-Oriented category and of them is Jiebang that is called “Chinese Foursquare” (Chiang, 2012).

The last category that was proposed by Krishnamurthy & Pelechrinis was Gaming-Oriented LBSNs. The authors state that services from that category usually provide smartphone application that is a platform for gaming, location sharing and advertising. Frith analysed games implemented in the Foursquare platform and concluded that some users render locations as digital objects that have to be collected (Krishnamurthy & Pelechrinis, 2013, 133) (Frith, 2013, 249).

## **2.1. Foursquare**

Foursquare Labs Inc. is an American company with headquarter in New York City. It was launched in 2009 but it takes almost a decade for them to start making a profit (Miller, 2017). Co-founders are Dennis Crowley and Naveen Selvadurai. Crowley built the experience on a similar LBSN called Dodgeball that has been sold to Google in 2005 (Gonsalves, 2005).

Their LBSN services can be accessed with different applications and tools. They started with the concept of real-time location sharing and primary store discrete locations with data that users collected on these locations. Their first application for a smartphone was named simply *Foursquare* and it enabled users to share their locations complemented with comments and pictures, with friends. Users could do this on the web or SMS service but the main idea is to do it with a smartphone.

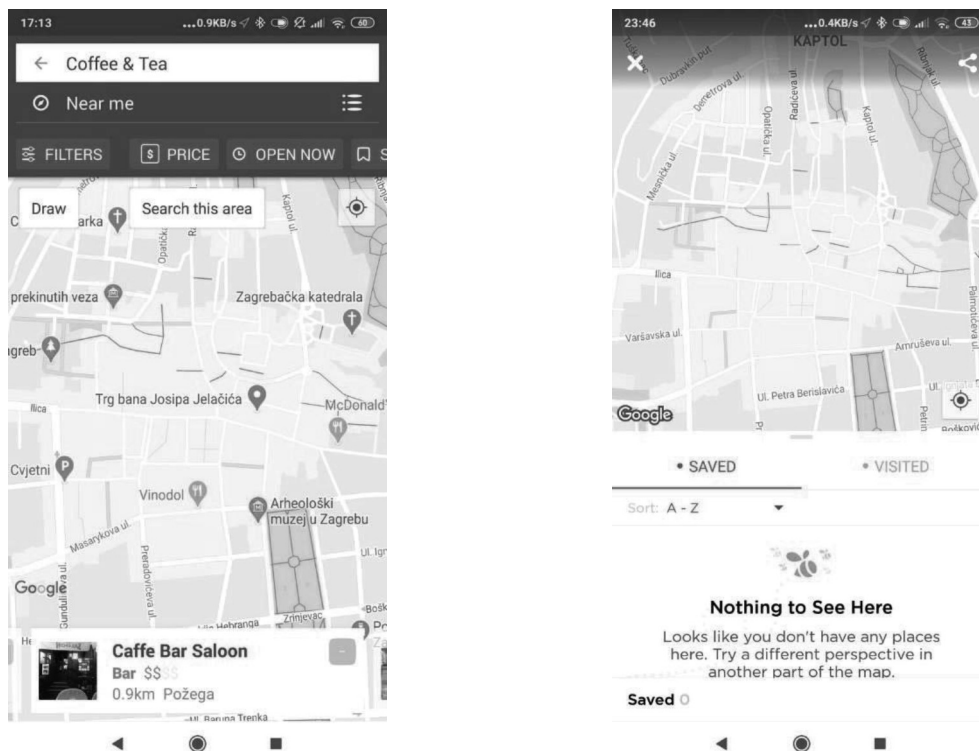
In 2014 Foursquare Labs Inc. launched another application called *Swarm* that included location sharing and social networking. The same year they upgraded main application *Foursquare*, changed its name to *Foursquare City Guide* and removed location sharing and social networking from it. The screens of both can be seen in figure 1 (Summers, 2014).

One of the main features that are available from Foursquare services is the *Places API*. It is a service primarily intended for developers and analysts that can be queried about any place using an HTTP request. It can be used for free but for larger query volumes users have to pay this service. Key features are:

- “real-time access to over 105 million places available across 190 countries,
- use custom API endpoints to power geo-tagging, venue search and recommendations,
- leverage 70+ venue attributes and 900+ categories and
- create location experiences with access to user-generated tips, tastes & photos.”

It has been used for research in this paper (Foursquare Labs Inc., n.d.).

**Figure 1:** Foursquare City Guide and Swarm screens on the Android platform



Source: authors

### 3. Unsupervised machine learning algorithms

Unsupervised machine learning deals with problems where the data is not labelled. Algorithms from that machine learning category simply find similar data points in multi-dimensional space and put them in clusters. Mohammed et al. consider that most important unsupervised machine learning algorithms are:

- K-means
- Hidden Markov model
- Principal component analysis

## d) Gaussian mixture model (Mohammed, et al., 2016, 140)

In this paper, the K-means algorithm is used.

K-means algorithm is a well known unsupervised machine learning algorithm proposed by Steinhaus in 1956. (Steinhaus, 1956). The main principle of that algorithm is the principle of least squares. It can be simply explained as grouping data on a finite number of groups with the goal that the sum of the squared deviation of group members from the centre of the group is minimized. It can be defined as:

$$WCSS = \sum_{c_i \in C} \sum_{j=1 \dots d} \sum_{x, y \in c_i} (x_{ij} - y_{ij})^2$$

where WCSS is the abbreviation for a within-cluster sum of squares and the main goal is to minimize it (Kriegel, et al., 2017, 12). This method is an iterative method and it starts with random positions of cluster centres. In each iteration, the central point is updated and it depends on cluster members. Because of a random selection of initial k-means, after every optimisation, we can get different clusters (Mohammed, et al., 2016, 129).

K-means algorithm is often used in scientific papers that deal with data from Location-Based Social Networks. Yang et al. used the k-means algorithm to cluster LBSN users and they propose a cultural mapping approach based on the data from LBSNs (Yang, et al., 2016). Modsching et al. used k-means algorithm to discover tourists activity areas and they found that twenty clusters are the optimal number in their research in the city of Gornitz in Germany (Modsching, et al., 2008). Claypo and Jaiyen used k-means algorithm for clustering of customer opinions for Thain restaurants into positive and negative groups. They used about one thousand text reviews from website th.tripadvisor.com (Claypo & Jaiyen, 2015). Isanan used k-means algorithm to retrieve restaurant category data on the Philippines and he used data from Foursquare and Google services (Isanan, 2019). In this paper, k-means algorithm implementation from the scikit-learn library is used (Scikit-Learn community, 2020).

## 4. Zagreb case study

### 4.1. Data and methodology

Zagreb is the capital city of Republic Croatia and official 2011 census counted almost 800000 residents. In 2011, the city of Zagreb has about 600 000 tourist arrivals but only six years later this number was more than doubled. In 2017 tourist arrivals number was more than 1,3 million (Kesar, et al., 2018, 192). This is recognised by global and regional restaurant and fast food corporations, like Subway and Lars&Sven, and they have opened or announced the opening of their restaurants and fast food outlets (teen385.com, 2019) (Punkufer.hr, 2019).

**Table 1:** Zagreb municipalities with the area and population data

	Municipalities	Area (km <sup>2</sup> )	Population (2011)	Population (2001)	Population density (2001)
1.	Donji Grad	3.01	37,123	45,108	14,956.2
2.	Gornji Grad – Medveščak	10.12	31,279	36,384	3,593.5
3.	Trnje	7.37	42,126	45,267	6,146.2

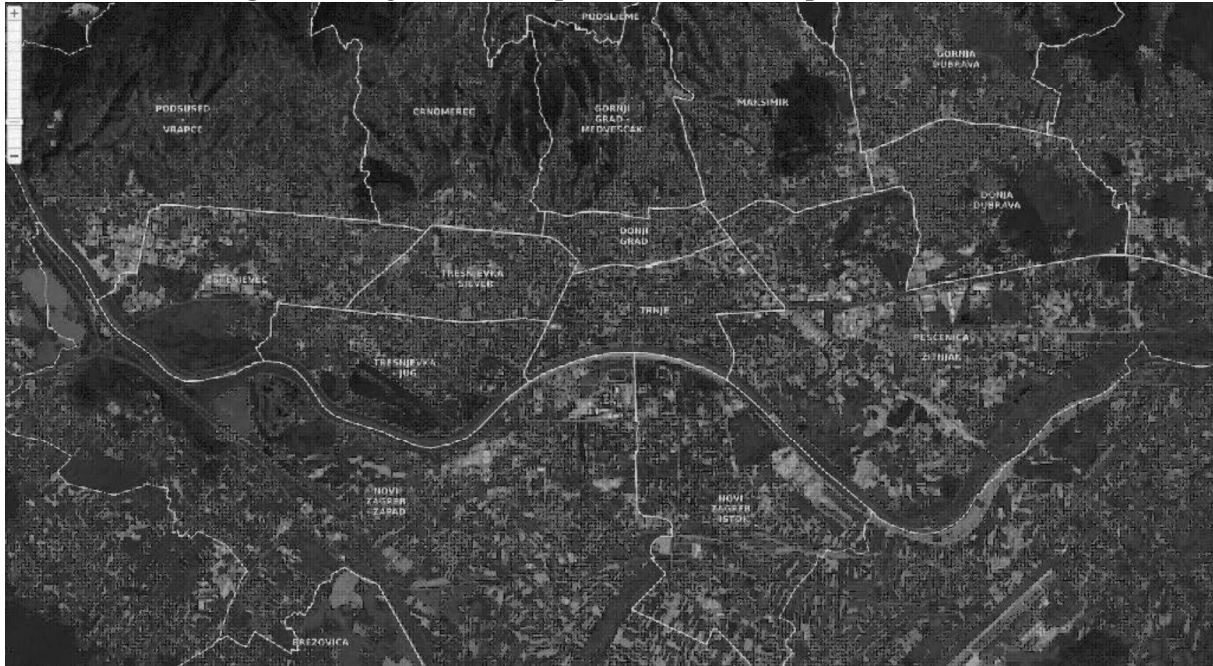
	Municipalities	Area (km <sup>2</sup> )	Population (2011)	Population (2001)	Population density (2001)
4.	Maksimir	14.35	49,448	49,750	3,467.1
5.	Peščenica – Žitnjak	35.30	56,446	58,283	1,651.3
6.	Novi Zagreb – istok	16.54	59,227	65,301	3,947.1
7.	Novi Zagreb – zapad	62.59	58,025	48,981	782.5
8.	Trešnjevka – sjever	5.83	55,342	55,358	9,498.6
9.	Trešnjevka – jug	9.84	66,595	67,162	6,828.1
10.	Črnomerec	24.33	39,040	38,762	1,593.4
11.	Gornja Dubrava	40.28	62,221	61,388	1,524.1
12.	Donja Dubrava	10.82	36,461	35,944	3,321.1
13.	Stenjevec	12.18	51,849	41,257	3,387.3
14.	Podsused – Vrapče	36.05	45,771	42,360	1,175.1
15.	Podsljeme	60.11	19,249	17,744	295.2
16.	Sesvete	165.26	70,633	59,212	358.3
17.	Brezovica	127.45	12,040	10,884	85.4
	<b>TOTAL</b>	641.43	792,875	779,145	1,214.9

*Source: Croatian Bureau of Statistics, 2011; Croatian Bureau of Statistics, 2001*

One of the most important factors for the success of fast food outlets or restaurant is its location. The main goal of this paper is to provide a method for municipalities clustering in Zagreb that is based on available data on Foursquare LBSN and k-means algorithm. This method is well-known before tourist facility location selection but Zagreb's special feature is the low availability of quantitative data on which decision can be made. Some cities have much more quantitative data available on the government web sites and the good example is Hong Kong with their annually Population and Household Statistics Analysed by District (The Government of the Hong Kong Special Administrative Region, 2019).

The city of Zagreb is divided into seventeen municipalities and they are listed in the table number one. On figure 2, there is a satellite picture with municipalities borders and it can be seen that there are many differences between municipalities in size, position etc.

**Figure 2:** Zagreb satellite picture with municipalities borders



Source: authors

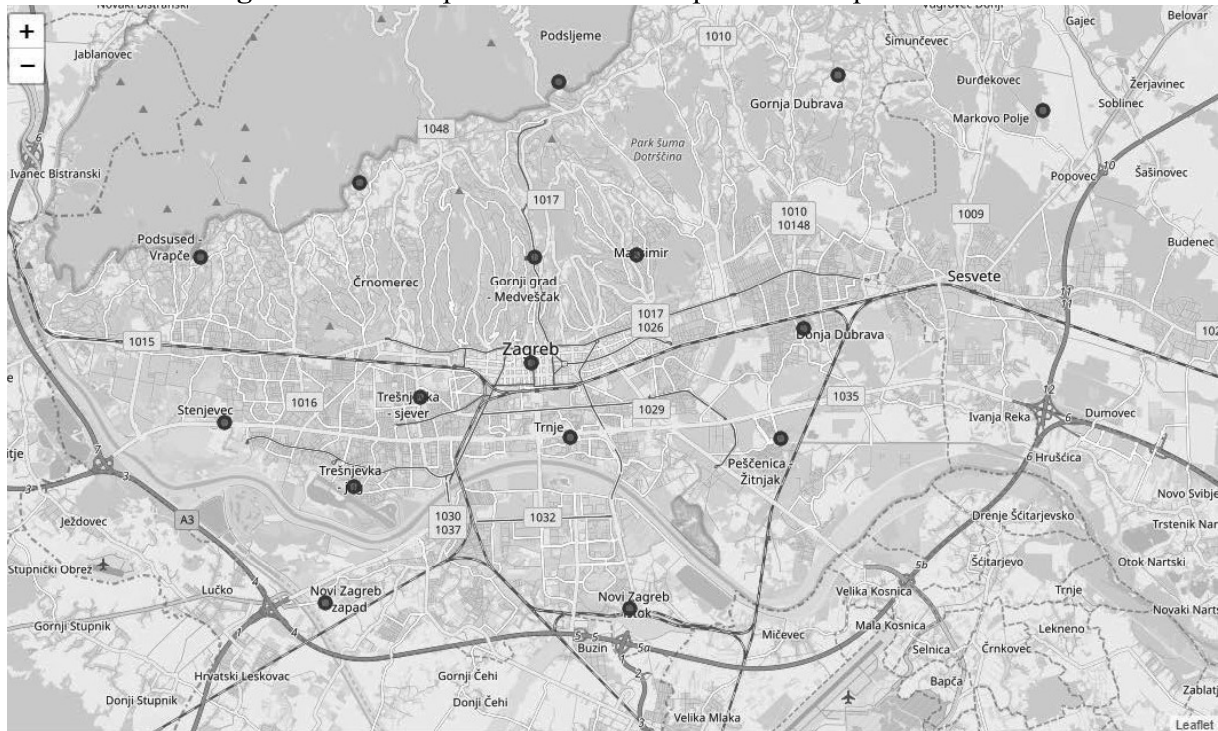
To analyse municipalities in Zagreb, Foursquare API is used (Foursquare Inc., n.d.). Their API enables search for locations based on longitude, latitude, and radius. Due to incomplete information entered into the Foursquare database, the municipality of a particular location is not known. This problem is solved in such a way that each municipality is defined as a polynomial and the polynomial points are stored in files. After that central point of every municipality has been found and this information was used for Foursquare queries. On figure 3, an example of one municipality polygon definition can be seen.

**Figure 3:** Municipality polygon example

1	LAT, LONG
2	15.999311, 45.811528
3	16.017087, 45.796825
4	16.000323, 45.795839
5	16.002607, 45.783964
6	16.053774, 45.757968
7	16.104917, 45.790154
8	16.124535, 45.787782
9	16.124879, 45.801496
10	16.046467, 45.799993
11	16.046321, 45.817971
12	

Source: authors

Central points of all municipalities except Brezovica can be seen in figure 4. Brezovica is a big municipality on southwest that cannot be seen without zoom out. This municipality can be seen along the bottom edge of figure 2.

**Figure 4:** Central points of all municipalities except Brezovica

Source: authors

1084 venues were obtained after the data was withdrawn for all 17 municipalities. After withdrawing, the data were prepared for the k-means algorithm but one of the common questions when using the k-means algorithm is how many clusters we want. There are many methods for that decision available in the literature but we tried with all values between 2 and 10 clusters. Results can be seen in table number 2.

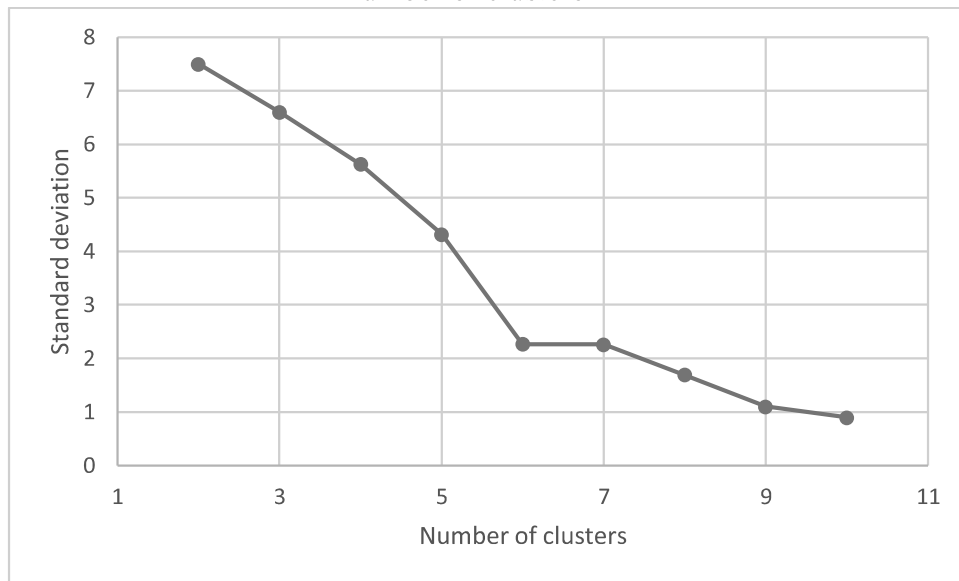
**Table 2:** Number of municipalities in one cluster

Number of clusters	Number of municipalities in one cluster									
1	17									
2	16	1								
3	15	1	1							
4	14	1	1	1						
5	12	2	1	1	1					
6	6	6	2	1	1	1				
7	6	6	1	1	1	1	1			
8	5	5	2	1	1	1	1	1		
9	4	3	3	2	1	1	1	1	1	
10	4	2	2	2	2	1	1	1	1	1

Source: authors

When this data is presented graphically in a way to calculate the standard deviation of the municipality number, we get the graph in figure 5.

**Figure 5:** The standard deviation of the number of municipalities in a cluster depends on the number of clusters



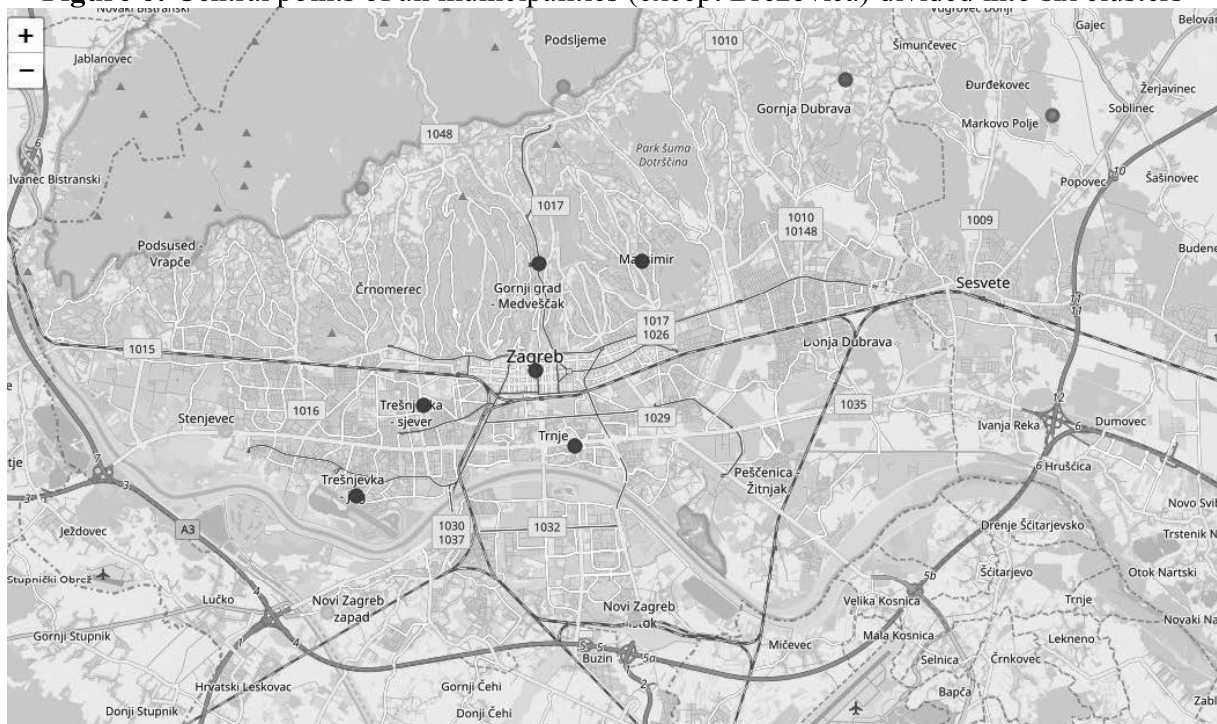
Source: authors

It is interesting that with six clusters there is a sharp drop in standard deviation so six clusters have been chosen. The whole program in Python can be seen on the Github: [https://github.com/kristian1971/RED2020\\_Zagrebstory](https://github.com/kristian1971/RED2020_Zagrebstory).

#### 4.2. Results

On figure 6, sixteen central points of six clusters can be seen but in different colours depends on cluster affiliation of the municipality.

**Figure 6:** Central points of all municipalities (except Brezovica) divided into six clusters



Source: authors



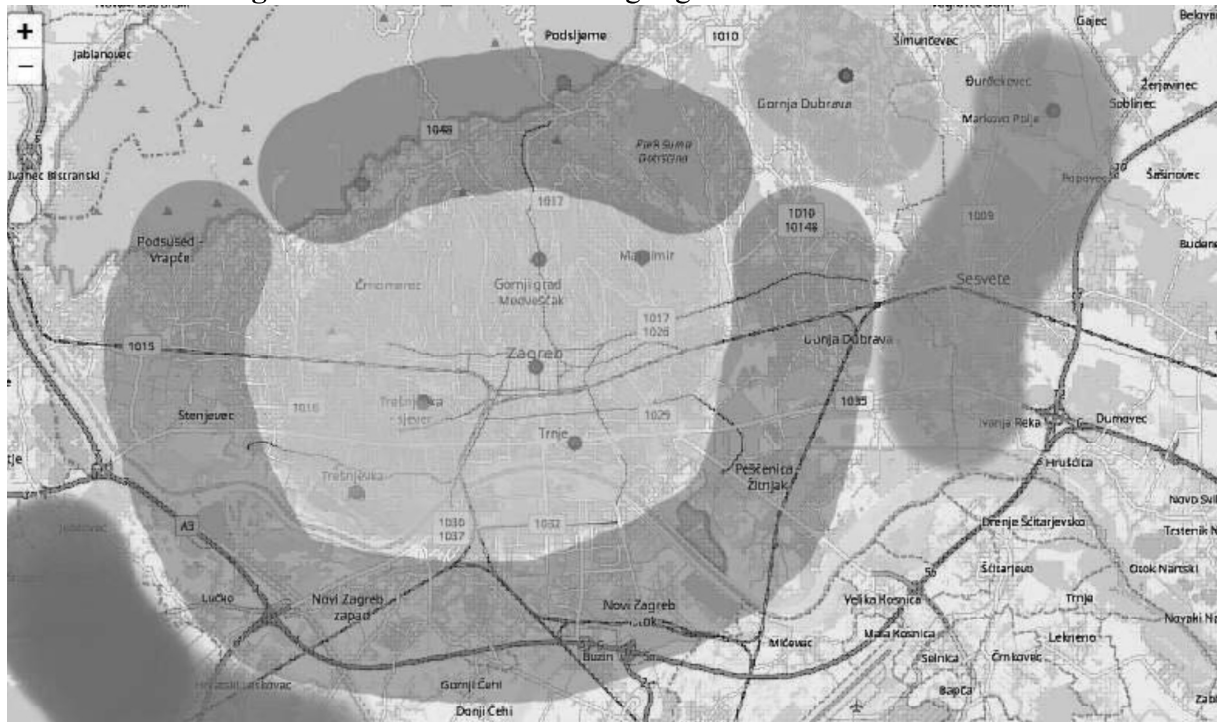
In table number 3 cluster affiliation of all municipalities can be seen, as well as ten the most common venues in a particular municipality.

**Table 3:** Ten most common venues for all municipalities

	Municipality	Cluster	1st MCV	2nd MCV	3rd MCV	4th MCV	5th MCV	6th MCV	7th MCV	8th MCV	9th MCV	10th MCV
10	Gornja Dubrava	0	Pizza Place	Grocery Store	Forest	Park	Middle Eastern Rest	Diner	Dessert Shop	Dog Run	Drugstore	Food
0	Donji grad	1	Café	Plaza	Restaurant	Bar	Dessert Shop	Hostel	Theatre	Historic Site	Coffee Shop	Burger Joint
1	Gornji grad	1	Café	Dessert Shop	Bar	Plaza	Mediterranean Rest	Park	Pub	Theatre	Hostel	Bistro
2	Trnje	1	Café	Bar	Restaurant	Plaza	Hotel	Pizza Place	BBQ Joint	Coffee Shop	Eastern European Rest	Dessert Shop
3	Maksimir	1	Café	Bar	Dessert Shop	BBQ Joint	Pizza Place	Theatre	Park	Restaurant	Wine Bar	Bakery
7	Tresnjevka - sjever	1	Café	Bar	BBQ Joint	Plaza	Restaurant	Mediterranean Rest	Dessert Shop	Burger Joint	Gym	Park
8	Tresnjevka - jug	1	Bar	Café	BBQ Joint	Pizza Place	Gym	Dessert Shop	Eastern European Rest	Supermarket	Pub	Restaurant
15	Sesvete	2	Restaurant	Café	Wine Bar	Farm	Flea Market	Fish Market	Field	Fast Food Rest	Farmers Market	Electronics Store
16	Brezovica	3	Playground	Farmers Market	Toll Booth	Farm	Wine Bar	Electronics Store	Flea Market	Fish Market	Field	Fast Food Restaurant
4	Pescenica	4	Supermarket	Furniture / Home Store	Restaurant	Café	Bar	Bakery	Grocery Store	Bus Station	Plaza	Chinese Restaurant
5	Novi Zagreb - Istok	4	Café	Supermarket	Bar	Grocery Store	Pet Store	Pizza Place	Restaurant	Wine Bar	Shopping Mall	Coffee Shop
6	Novi Zagreb - Zapad	4	Café	Supermarket	Bar	Pizza Place	Restaurant	Nightclub	Shopping Mall	Beach	BBQ Joint	Dessert Shop
11	Donja Dubrava	4	Café	Supermarket	Bar	Pizza Place	Grocery Store	Clothing Store	BBQ Joint	Restaurant	Shopping Mall	Furniture / Home Store
12	Stenjevec	4	Café	BBQ Joint	Bar	Pizza Place	Grocery Store	Fast Food Rest	Eastern European Rest	Supermarket	Electronics Store	Pub
13	Podsused	4	Café	Bar	Grocery Store	Supermarket	Trail	BBQ Joint	Restaurant	Mediterranean Restaurant	Pizza Place	Bus Station
9	Crnomerec	5	Trail	Food	BBQ Joint	Park	Sculpture Garden	Bistro	Café	Restaurant	Castle	Mountain
14	Podsljeme	5	Trail	Café	Grocery Store	Pizza Place	Eastern European Rest	Pub	Bakery	Seafood Rest	Light Rail Station	Restaurant

Source: authors

On figure 7 individual clusters highlighted in different colours can be seen.

**Figure 7:** Individual clusters highlighted in different colours

Source: authors

## 5. Discussion

Many authors used k-means or another clustering algorithm for urban municipalities analyse. Assem et al. used it to discover spatiotemporal functional regions in one New York City district (Assem, et al., 2016). Sun et al. proposed method for the city centres detection with the LGOG cluster method using LBNS data (Sun, et al., 2016). Hong and Jung proposed analytical method of cluster analysis for Foursquare data. They conclude that a qualitative approach for fully interpreting and analysing is important. Objects of their analyse were coffee shops in Seattle (Hong & Jung, 2017).

Our approach was a little bit different because we have started with municipalities and defined central points of every municipality. After that Foursquare service was queried and k-means cluster analyse has been performed on that data. Similar municipalities have been put in the same clusters and we have performed analyse with a different number of clusters.

In the literature three main methods for determining the optimal number of clusters have been suggested: silhouette, elbow and gap statistic methods (Krishna, et al., 2018, 301) (Kassambara, 2018). In this paper, we used the simplified method based on standard deviation values of cluster size and propose this method for such simple examples but this method has to be thoroughly compared with other methods.

Final results with six clusters can be seen in figure 7 and table number 3. The information in the table complements the figure and helps with interpretation. Figure 7 points the municipalities that are primarily intended for residential use and they belong to cluster number 4. Cluster number 1 shows that this is a downtown area dominated by café's, bars and restaurants. There are no supermarkets in that cluster between ten the most common venues in the municipality (only in one case). Other clusters are specific and are mostly municipalities on the outskirts of the city.

Finally, these results can be used by the potential investor because cluster division brings objective knowledge to a potential investor. These results can be used as a basis for decision-making or as a test of expert recommendation. The suggested approach is not new but the main contribution of the paper is in the proposed method that can be used on the occasions when we have low availability of quantitative data.

The proposed model can be compared with other models but it is not easy to compare our results with other papers because we couldn't find any published analyse that deals with Zagreb municipalities and clustering. Some organisations like Croatian Bureau of Statistics have quantitative data and they combined data from different sources but they do did not make these data publicly available. Before two years they merged administratively with spatial data from the Register of Business Entities with the Spatial Statistical Register ( Croatian Bureau of Statistics, 2018). Posloncec-Petric et al. also published a paper in which they presented the project "GIS database of census districts according to the 2001 population census". This project includes a database with Registry of business units and spatial information. That database is primarily made for the Zagreb City Office for Strategic Planning and Development and it is not publicly available (Poslončec-Petrić, et al., 2011).

## 6. Conclusion

The paper indicates that it is possible to use just location-based social network data for basic clustering of city municipalities. The city of Zagreb is not as digitized as it could be by the city government but using the available data from the Foursquare service we can obtain usable objective knowledge. With such basic information, potential investors have a more accurate view of the characteristics and similarities of individual municipalities of the Zagreb city. It is very important for foreign investors that are not familiar with the specifics and structure of individual municipalities.

The presented approach can be improved in several aspects. More information from different sources can be included before clustering, like population density or average population income by municipalities. Another possibility of improvement is to include data from other location-aware services like Google Maps, Yelp or Instagram. Croatian Bureau of Statistics has much more accurate data divided by one square kilometre areas so that data can be also used to improve the model.

Finally, our government must recognize that it is in the general interest to make information about business entities and their density available on public services. The availability of this information may make our country more interesting to potential investors and enable our entrepreneurs to develop business based on new technologies.

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