“Comparison and Evaluation of Spatial Statistical Methods for Forecasting Reported Crimes in the City of Wels, Austria”

by

Christian Mathias Pleschberger

2nd Bachelor Thesis

Submitted in partial fulfillment of the requirement of the degree
Bachelor of Science in Engineering

Carinthia University of Applied Sciences
School of Geoinformation

Supervisor: Dr. Michael Leitner

Department of Geography and Anthropology, Louisiana State University,

Baton Rouge, USA

Baton Rouge, June 2015

Science Pledge

By my signature below, I certify that my thesis is entirely the result of my own work. I have cited all sources I have used in my theses and I have always indicated their origin.

Villach, 15.06.2015

Christian Mathias Pleschberger

Acknowledgments

I would like to express my gratitude to all those who gave me the possibility to complete this thesis.

This thesis would not have been possible without the continuous support and understanding of my family and my closest friends.

I express thanks to my external supervisor Dr. Michael Leitner, Department of Geography and Anthropology, Louisiana State University, Baton Rouge, United States of America, who gave me the opportunity to do my internship at the Louisiana State University. I also thank him for his assistance and constructive comments in special affairs during the preparation of this thesis.

Furthermore I would like to show my great appreciation to the Austrian Marshall Plan Foundation and the Carinthian University of Applied Sciences for their financial support, which enabled me to undertake my research for my Bachelor Thesis at the Louisiana State University.

Without the help of all these persons and institutions, it would have never been possible to realize this bachelor thesis and to complete my internship in the United States. Finally also my interest in crime analysis and prediction increased and possibly showed me my future path in doing my next research projects or professional development.

Zusammenfassung

Das Ziel dieser wissenschaftlichen Forschungsarbeit ist es, die drei wichtigsten Vorhersage Analysemethoden in der Kriminalanalyse miteinander zu vergleichen, und daraus resultierend, die geeignetste Methode herauszufinden. In den Vereinigten Staaten werden hierzu verschiedene Vorhersage Analysemethoden angewandt. Um möglichst genaue Ereignisvorhersagen treffen zu können, werden unterschiedliche Analysemethoden angewandt und miteinander verglichen. In dieser Arbeit kommen insgesamt drei Methoden zur Anwendung. Als erste Methode werden die Deliktdaten mit „Crime Density Mapping", „Crime Cluster" und „Hot Spot Mapping" untersucht. Als zweite Methode wird die „Near-Repeat Analyse" untersucht. Mit dem „Risk Terrain Modeling" (RTM) Ansatz findet die dritte Methode ihre Anwendung. Anhand dieser drei Analysemethoden werden die Kriminalitätsdaten der Stadt Wels miteinander verglichen und daraus Rückschlüsse gezogen, welche der drei Methoden für zukünftige Analysen die genauesten Vorhersagen liefert. Das Ziel der Untersuchung ist es, die Methoden zu vergleichen, deren praktische Anwendung zu testen und die Vor- und Nachteile der einzelnen Methoden aufzuzeigen. Für diese wissenschaftliche Arbeit wird die Stadt Wels als Untersuchungsgebiet herangezogen. Die Kriminalitätsdaten werden vom Österreichischen Bundeskriminalamt zur Verfügung gestellt. Die Daten stammen hauptsächlich aus der Sicherheitsmonitor (SIMO) – Datenbank. Dies ist eine Datenbank, in welcher tagesaktuell, alle Kriminalfälle in allen Gebieten Österreichs aufgezeichnet werden. Um diese Analysen miteinander vergleichen zu können, werden verschiedene Software-Tools verwendet. Zur Identifizierung von Hot Spots werden CrimeStat, der Near Repeat Calculator, ArcGIS und die Erweiterung Spatial Analyst-Modul von ArcGIS verwendet. Die Ergebnisse der räumlichen Clustermethoden werden mittels Prediction Accuracy Index (PAI) und Hit Rate evaluiert und interpretiert. Zusätzlich wird auch eine visuelle Interpretation der Ergebnisse durchgeführt.

Abstract

The aim of this scientific research paper is to compare and evaluate three main important groups of forecasting crime analysis methods in order to identify the method that makes the most accurate predictions. In the United States different predictive analytical methods have already been applied by the police for several years. Until today, the following three important groups of predictive analytics methods have been developed: First, "crime density mapping", "crime cluster" or "hot spot mapping"; second, "near-repeat analysis" and third, the "Risk Terrain Modeling" (RTM) approach. These three methods are compared with each other using reported crime data for the City of Wels in Upper Austria. The aim of this study is to test the practical application of these three groups of methods and to identify the advantages and disadvantages of each of these groups. The crime data is provided by the Austrian Federal Criminal Police Office. The indicators are from the SIMO - database. This is a database in which all criminal cases are recorded in all regions of Austria on a daily basis. In order to compare these analyses with each other, different software tools are used. In order to identify hot spots CrimeStat, Near Repeat Calculator, ArcGIS and the extension uses Spatial Analyst module of ArcGIS were used. The results of spatial cluster methods were evaluated and interpreted by Prediction Accuracy Index (PAI) and hit rate, followed by a visual interpretation of the results. Furthermore, this work should provide future projects in crime predictions to support decision-making and appropriate preventive measures to reduce crime in the City of Wels.

Table of Contents

List of Abbreviations

ASCII	*American Standard Code for Information Interchange*
BIC	Bayesian Information Criteria
BKA	*Austrian Federal Criminal Police Office*
CUAS	*Carinthia University of Applied Sciences*
ESRI	*Environmental Systems Research Institute*
GIS	*Geoinformation System*
IfmPt	*Institute of pattern based forecasting technique*
KDE	*Kernel Density Estimation*
PAI	*Prediction Accuracy Index*
Precobs	*Pre Crime Observation System*
PredPol	*Predictive Policing*
PhiCAMS	*Philadelphia Crime Analysis and Mapping System*
RTM	*Risk Terrain Modeling*
RTMDx	*Risk Terrain Modeling Diagnostics Utility*
SIMO	*Security Monitor*
STGB	*Criminal Code*
UI	*User Interface*
USA	*United States of America*
URL	*Uniform Resource Locator*

1. Introduction

This scientific paper deals with the comparison of different crime forecasting analysis methods. The goal is to find out which analytical methods exist to identify their advantages and disadvantages, and to select the most appropriate method for forecasting crime in the study area Wels. Chapter one describes the motivation, discusses the statement of the project, and how to approach answering the research questions.

1.1. Motivation

The aim and motivation of this research work is to compare the three most important crime forecasting methods with each other and to test their practical applicability. Furthermore, the advantages and disadvantages of each method are also discussed in this work. The overall goal is to identify the most appropriate method to be applied. Furthermore, this work should help with future projects to support decision-making and appropriate preventive measures to possibly reduce crime in Austrian cities.

1.2. Problem Definition

According to a report from the year 2014 by the Austrian Federal Criminal Police Office the crime total in Austria has declined by 0.3% from 2012 to 2013. In the year 2012, 548.027 and in 2013, 546.396 crime incidents were reported to police authorities. The reason for this decrease in reported crimes is the increased presence and commitment of the Austrian law enforcement officers. Similarly, the crime clearance rate increased by 0.5 % during the same time-frame. Starting with a clearance rate of 38.1 % in 2004, the rate has been continuously rising to 42.6% in 2012 and 43.1% in 2013. According to the Austrian crime statistics in 2013, Vienna is the Austrian Province with the most reported cases (212,503), followed by the province of Lower Austria (76,264), and the province of Upper Austria (66,654).

In Austria, geospatial technology has been used to support crime analysis by the Federal Police since 2004. Since then, reported criminal offences are collected by the Federal Criminal Police Office in a database (SIMO), visualized, and processed with the help of analytical methods. The results are used for operational planning, prosecutions, measures for prevention, and resource planning.

The aim and motivation of this research paper is to compare and evaluate the three most important groups of crime analysis methods with each other and to test their practical applicability for the Austrian police. Furthermore, the advantages and disadvantages of each method will be addressed.

At the end, the most appropriate and accurate method will be identified and discussed with Austrian police. Moreover, this work should also provide support for future, similar projects to identify suitable decision making and preventive measures for reducing crime in Austrian cities. Results of this research will show, if this approach is beneficial for the Austrian police. Dr. Michael Leitner, professor of the Louisiana State University (LSU) in the USA is an expert in spatial crime analysis, in general, and in criminal predictive analytics, in particular. He has been collaborating with various law enforcement agencies in the USA and entertains a close working relationship with the federal, state, and local police forces in Austria. He has already collected the reported crime data from the SIMO for the city of Wels, which will be analyzed, modelled, and visualized in this research paper. Because of Dr. Leitner's expertise and connections, the particular study area (City of Wels) and research topic (criminal predictive analytics) have been selected to be researched at LSU during spring semester 2015.

1.3. Methods of Solutions

The first step in this scientific work is a review of important literature to get an overview over different forecasting methods, including hotspot analysis, the near repeat calculator, and the RTM method. Subsequently, the data are being processed and made readable for each software program. The next step is to implement the various methods of analysis using CrimeStat, the near repeat calculator, and the RTM Diagnostics Utility software (RTMDx). The individual results are visualized by using ArcGIS and followed by a comparison and evaluation with tools like the hit rate and the prediction accuracy index (PAI) throughout this thesis, the hit rate should always be discussed before the prediction accuracy index, including in the Table of

Contents. This analysis is used to compare individual methods with each other and to identify the best method for the prediction of crime events in Wels.

1.4. Expected results

The expected results of this scientific research paper are to identify the most appropriate method of crime predictive analysis for the city of Wels, Austria, to discover the main advantages and disadvantages of the different predictive analysis methods and to assess the practical applicability of these different methods.

1.5. Structure of the Thesis

This thesis is divided into six chapters. Chapter one gives a brief overview of the motivation, problem statement and solution approach. In addition, this chapter provides information on expected results. Chapter two focuses on the theoretical background and provides examples from various fields related to crime analysis. The third chapter deals with the methods that were used to answer the research question. It also describes what type of data was used for this scientific work and the study area. Subsequently, this chapter discusses the implementation and execution of the work. Each method is described and applied. The fourth chapter discusses and interprets the results obtained. Chapter five provides a critical reflection of the results. The last chapter summarizes the results and describes future applications.

2. Theoretical background

This chapter describes the relevant theoretical background concerning crime forecasting analysis methods. It provides examples from various fields related to crime analysis and gives best practice examples.

2.1. Theories and crime prediction methods

Crime has an inherent geographical quality. When crime occurs, it happens at a place with a geographical location. For someone to have committed a crime, that person, must have also come from a place (Chainey et al, 2005). Crime mapping and analysis have evolved significantly over the past 40 years. In the beginning, many agencies utilized city and precinct maps with colored pins to visualize crime events and crime plagued areas. Today, with the rapid advancement of geospatial technology, computer based techniques for exploring, visualizing and explaining the occurrences of criminal activity have quickly developed. One of the most influential tools of the spatial distribution of crime has been GIS (Grubesic et al, 2001). Since the 1960s GIS has emerged as a discipline in its own right. GIS developed from its origins in land use applications to an all-pervasive technology. The early use of GIS for mapping crime was often held back by organizational and management problems, issues with sharing information, technical problems and geocoding problems. Crime mapping now can play an important role in the policing and crime process, from the first stage of data collection through to the monitoring of any targeted response (Chainey et al, 2005).

2.2. Hot Spot Analysis

A crime hot spot is an area with a higher concentration of crime than what would be expected by chance. Hot spots can be street addresses, blocks, neighborhoods, or towns and cities. In the hot spot analysis it is determined whether spatial patterns are statistically significant and if a clustering in the data occurs. Also random patterns display a certain clustering, but those clusters would not be classified as being statistically significant. In other words, when interpreting crime hot spots, it is often difficult to say whether the results have been caused by spatial processes or purely by coincidence. One of the most often applied hot spot method is the Kernel Density Estimation (KDE) (Smith et al, 2008). This and alternative cluster methods will be applied in this research. Using cluster methods for crime prediction is based on the assumption that future crimes will also be located in past crime hot spots. Whether or not this is true for the city of Wels will be one of the main research questions to be answered in this project. There are some different theories why hot spots exist and these will be mentioned next. Place Theories explain why crime events occur at specific locations. They deal with crimes that occur at the finest level of analysis. These theories involve looking at specific incidents. Crime phenomena at this level occur as points. The appropriate units of analysis are addresses, street corners and other very small places, which are represented on maps as dots. Street Theories deal with crimes that occur at a slightly higher (coarser) level than specific places, such as streets or blocks. The appropriate units of analysis can be street segments, paths, and sections of highways, which are represented on maps as straight, bent, or curved lines. At a higher level (coarser resolution) than place or street, neighborhood theories deal with large areas. The appropriate units of analysis are quite varied and can include square blocks, communities, and census tracts. There are also other theories attempting to explain differences in crime patterns at much higher levels of aggregation. For example theories of crime differ among cities and among regions (Eck et al, 2005).

2.2.1. Spatial Fuzzy Mode

In this analysis method, a circle is drawn around each crime location in the study area. The radius of the circle is determined by using the nearest neighbor analysis. Thereafter, the number of crime locations falling in each circle are counted. The circle with the most "neighborhood points" is called a spatial fuzzy mode (Levine, 2015).

2.2.2. Nearest Neighbor Hierarchical Cluster Analysis

Hierarchical cluster analysis is based on a similarity matrix, in which the similarities between different elements are described. The Nearest Neighbor Hierarchical Cluster (NNHC) Analysis describes groups of events, which are located spatially close. This method follows a repetition process of groupings until all smaller clusters are aggregated into one large cluster, or the repetition process is no longer carried out due to the user-entered parameters. In the application, the value of different parameters can be chosen by the user. The number of points belonging to a cluster should be between 1% and 3% of the total point pattern. The more points are defined per cluster, the lower the number of cluster will be. Another parameter in this analysis is the level of significance. It ranges from 0.1 (10% of the shortest distances between all possible pairs of point in the point pattern), to 0.05 (5% of the shortest distance), to 0.01 (1% of the shortest distances). The basis for this hierarchical method is the nearest neighbor analysis. Different orders of clusters can be distinguished, are mostly dependent on the size of the study area (Levine, 2014, Anders, 2004).

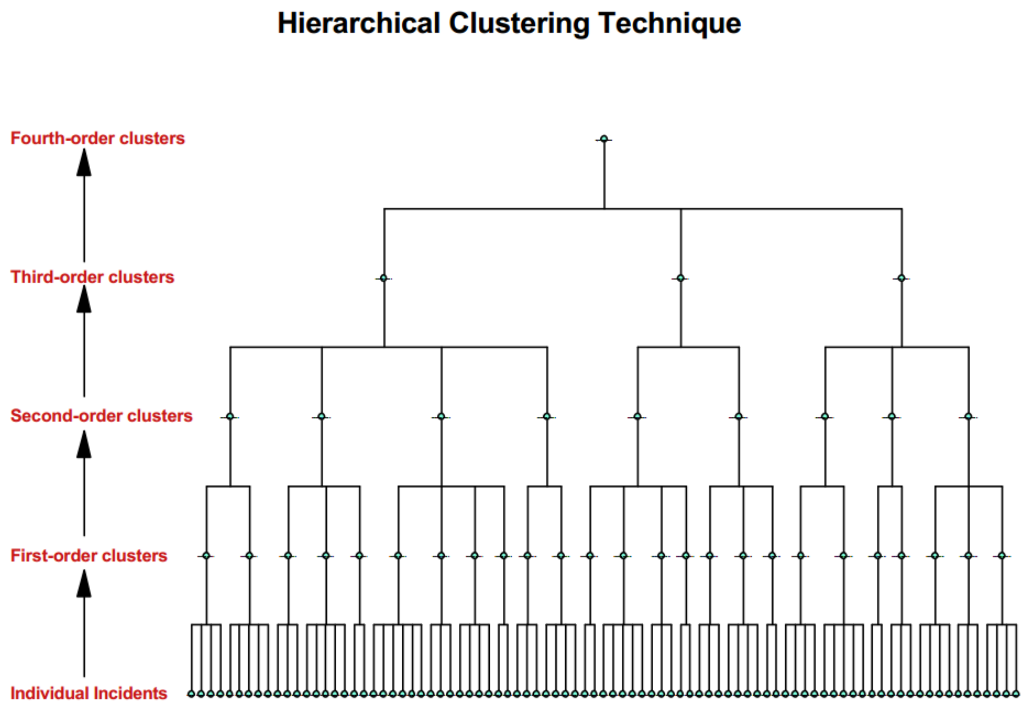

Figure 1 - Schematic view of a dendrogram representing the Nearest Neighbor Hierarchical Cluster method (taken from figure 7.1. in chapter 7, Levine & Associates 2015)

2.2.3. Kernel Density Estimation

The Kernel Density Estimation is a statistical method to estimate the probability distribution of interpolated spatial point patterns. There are five different types of kernel density functions, which include the triangular, quartic, uniform, normal, and negative exponential. Each of the individual functions describes the shape of the curves, i.e. the distance of influence of each point. Another important parameter relates to the bandwidth of each kernel function. The bandwidth can be either fixed or adaptive (recommended). Depending on the size of the dot pattern, the size of the output cell is defined (Levine, 2014).

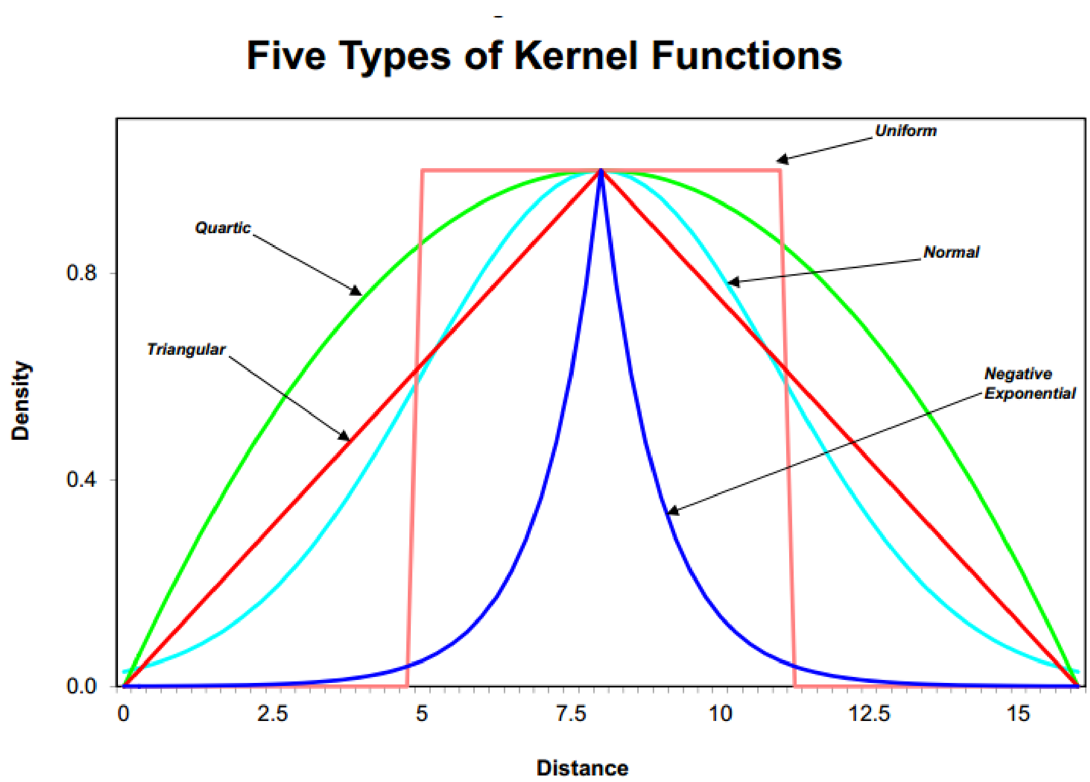

Figure 2 - Types of kernel functions for the Kernel Density Estimation method (taken from Figure 10.5. in Chapter 10, Levine & Associates 2015)

2.3. Near Repeat Analysis

The near repeat analysis is based on the assumption that within a certain neighborhood of a city, where previously a crime has occurred, the probability of a future crime to occur is increased. This is known as the near-repeat phenomenon and it has already been proven for various types of crime in US urban areas, especially for burglaries. This approach also considers the temporal component between the crimes (Ratcliffe, 2008), (Wilson, 2013).

2.4. Risk Terrain Modeling (RTM)

Risk Terrain Modeling (RTM) is a method to conduct and visualize a risk surface, where crimes are more or less likely to occur. The RTM technique was developed by Joel M. Caplan and Leslie W. Kennedy at Rutgers University School of Criminal Justice, USA, and has been tested and implemented with success several times (Caplan & Kennedy, 2010). While hotspot mapping is a widely available method which is also used in the Federal Criminal Police Offices (BKA) in Austria (Kampitsch et al., 2008), RTM is a more recent approach and has not yet been tested in Austria. Criminal predictive analytics is still in its infancy in Austria. However, the Austrian police is very keen in the RTM and other predictive crime modeling approaches and would like to implement those approaches into their proactive decision-making process. RTM-derived surfaces are created by combining different weighted criminogenic factors in a GIS. RTM is based on so called criminogenic factors, or risk factors, that correlate with crime events. The RTM compendium lists the criminogenic factors for 17 different crime events. These factors do not produce the crime, but influence the environment and can point out locations which are at a higher risk that a crime event will take place because the conditions are more attracting for offenders (Caplan & Kennedy, 2011). RTM supports the strategic planning process for police departments. Decisions can be made where crimes are likely to occur in the future and what measures must be taken to minimize their occurrence. Crime analysts can use these approaches to develop strategic models and to make predictions, where crime may be an issue. The objective of Risk Terrain Modeling is to represent criminal risk by the spatial influences of certain risk factors. The manual method of Risk Terrain Modeling involves the following steps (Caplan et al., 2011):

1. Select an outcome event
2. Choose a study area
3. Choose a time period
4. Obtain base maps
5. Identify all possible risk factors
6. Select model factors

7. Map spatial influence
8. Weight risk map layers
9. Combine risk map layers
10. Finalize maps to communicate information

2.5. Existing software packages for the forecasting of crime

In the United States there are many software packages for the prediction of crime. Always being improved by knowledge of the past years, these packages form the basis of the statistical prediction programs and mathematical algorithms, which are implemented in a Geographic Information System (GIS).

2.5.1. PhiCAMS

One practical example is the Philadelphia Police Department, which uses a Web-based application from the company Azavea, called the Philadelphia Crime Analysis and Mapping System (PhiCAMS). This system forms the basis of crimes to investigate, track, and analyze. The system is designed to be used primarily for non-GIS experts. PhiCAMS is often used by police officers from all departments. The analysis is based on complex queries over offenses relating to firearms custom maps and graphics. Since its founding, there were some improvements, such as the development of a private firearms analysis system and dispatch data of firearms, which is based on the feedback from law enforcement officials. PhiCAMS allows detailed analysis of criminal activities, leading to an improvement of the entire police system in Philadelphia with the officials being able to tackle crime effectively and safety (Azavea, 2015).

2.5.2. PredPol (Predictive Policing)

Another practical example is PredPol. PredPol analyzes historical data of burglaries and car thefts. The analysis is performed over a longer period. The software requires three types of point data, Arte of the crime scene of the crime and the time of the crime this sentence is incomplete. Based on the criminal pattern, PredPol applies a unique, mathematical algorithm and identifies places in the study area, where crimes could occur. These places are shown in a map with squares in the amount of 150 by 150 meters. The software is founded by the mathematician Dr. George Mohler from the Santa Clara University, California. The system incorporates geological techniques, which are used to predict earthquake aftershocks. The software was being tested first in Santa Cruz and in Los Angeles. During the first year of its use (2011-2012) burglaries decreased by 11% and robberies decreased by 27% (Predpol, 2015).

2.5.3. Precobs (Pre Crime Observation System)

Precobs is a software developed by the “Institute of patternbased forecasting technique” (IfmPt) in Germany. Precobs has developed an automated reporting and forecasting system, which are provided in apartments, daily assessments and forecasts in the range of dips. With findings from the fields of social sciences, criminology, and computer science Precobs form the basis of the concepts and methods of a forecasting software, with the goal to market it worldwide. The software is based on the principle of near repeats. Not sure what you want to say in these sentences? The areas where a recurrence of crime occurs (i.e., near-repeat) are recognized as near repeat affine and form the basis for the prediction of recidivism. Precobs generates forecasts, which can be used for operational and preventative policing (IfmPt, 2015).

2.6. Evaluation of crime forecasting methods

An evaluation is necessary to judge and compare the results of the forecasting methods. The aim is to find the most useful and accurate method to forecast crime in the study area. Again, make sure that you have longer paragraphs. Evaluation is an important task for testing the predictive validity of the produced results. A predictive model is implemented and it is tested how many crimes indeed happened in the predicted areas (Chainey et al., 2008). It is also possible to find out, which time period or which risk factors are most suitable for the prediction. In order to evaluate the model, additional data of the outcome events in the form of time-stamps are required (Caplan & Kennedy, 2010).

A widely used evaluation approach is the so called hit rate method. It is calculated by how many crimes happened in the predicted areas. The disadvantage of this method is that the size of the past hot spot areas is not considered, although it plays an important role. In this research project, the evaluation of the different forecasting methods is accomplished with using the Hit Rate and Prediction Accuracy Index (PAI). One measure to evaluate the forecasting quality is the hit rate that is the percentage of currently happened crime within previously predicted hot spot areas. One disadvantage is that the hit rate does not include the size of previously predicted areas and is therefore not as accurate as other prediction methods (Chainey et al. 2008, p. 10). Equation 1 shows the calculation form for the Hit Rate.

Equation 1 – formula to calculate the Hit Rate

$$\text{Hit Rate} = \frac{n}{N} * 100$$

The "n" shows the number of crime events that happened in the predicted areas, the "N" is the total number of crime events in the whole study area.

The Prediction Accuracy Index (PAI) considers the hit rate but takes the previously predicted areas and the study area size also into account. The PAI is calculated as the hit rate divided by the proportion of the study area that consists of the previously predicted hot spot areas (Chainey et al. 2008, pp. 10). The higher the prediction accuracy index the better the hot spot prediction of the method is. Through the PAI the size of the whole study area is included as well as the size of the previously predicted areas with a high risk of future crime events. The PAI was invented in order to "(…) consider the hit rate against the areas where crimes are predicted to occur with respect to the size of the study area" (Chainey et al., 2008, p.12). To calculate the Prediction Accuracy Index, the hit rate is divided by the percentage of the previously predicted areas in relationship to the whole study area. The hit rate is defined as the number of crime events which reside in the predicted areas divided by the whole number of crime events. Equation 2 shows the formula to calculate the PAI:

Equation 2 – formula to calculate the PAI

$$PAI = \frac{Hit\ Rate\ \%}{Proportion\ of\ hot\ spot\ areas\ to\ the\ entire\ study\ area\ (in\ \%)}$$

The advantage of the PAI is that it is not difficult to calculate and it can be used for study areas of any size and for any crime events and techniques (Chainey et al., 2008).

3. Methodology

This chapter describes the methodological progress of this research project. The explanation of the problem and the approach to tackle the problem are discussed. Furthermore, the study area and the data are described in detail.

3.1. Problem definition

The overall task of this research project is to find out how accurately future crimes can be predicted from previous crime data. Crime could be prevented by using crime prediction methods. Therefore, an overview of existing statistical methods to predict crime is discussed.

3.2. Methods of solutions

First, an overview over existing methods (hot spot methods, near-repeat analysis, and risk terrain modelling) is provided. For the hot spots methods the spatial fuzzy mode and the nearest neighbor hierarchical cluster analysis are used as two representatives. These methods are used because they are very simple to use and their results easy to interpret. The most appropriate parameters for the methods must be found. Then, the results are displayed and edited in ArcGIS and evaluated with the hit rate and the prediction accuracy index (PAI).

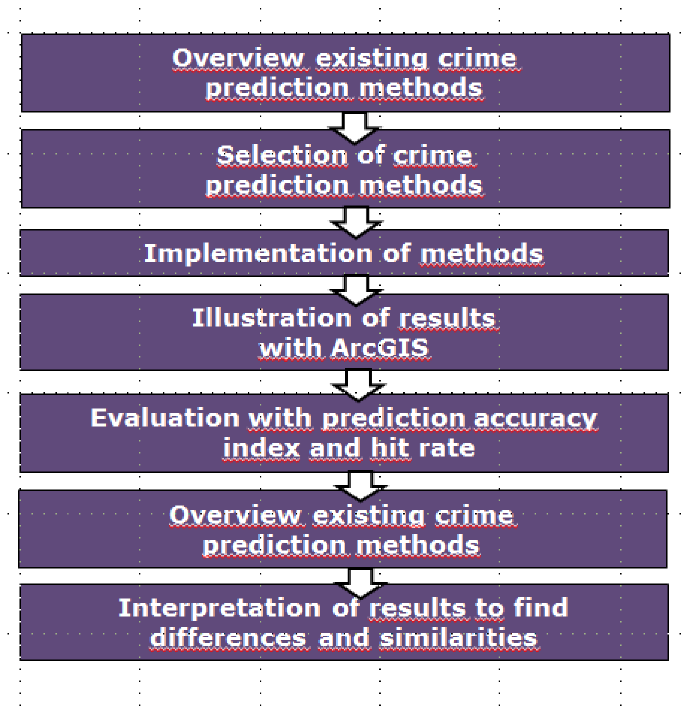

Figure 3: Conceptual model of project steps

3.3. Project or study area

With 59.339 inhabitants and an area of 45.88 square kilometers (Statistik Austria, 2015, Stand: 1.1.2014) Wels is, after the capital city Linz, the second largest town in Upper Austria. Wels is at an elevation of 317 m. From north to south, it extends over 9.5 km, from west to east over 9.6 km. 3.4% of the area is covered with forest, 23.5% is used for agriculture (Wels 2015, April 22, in Wikipedia).

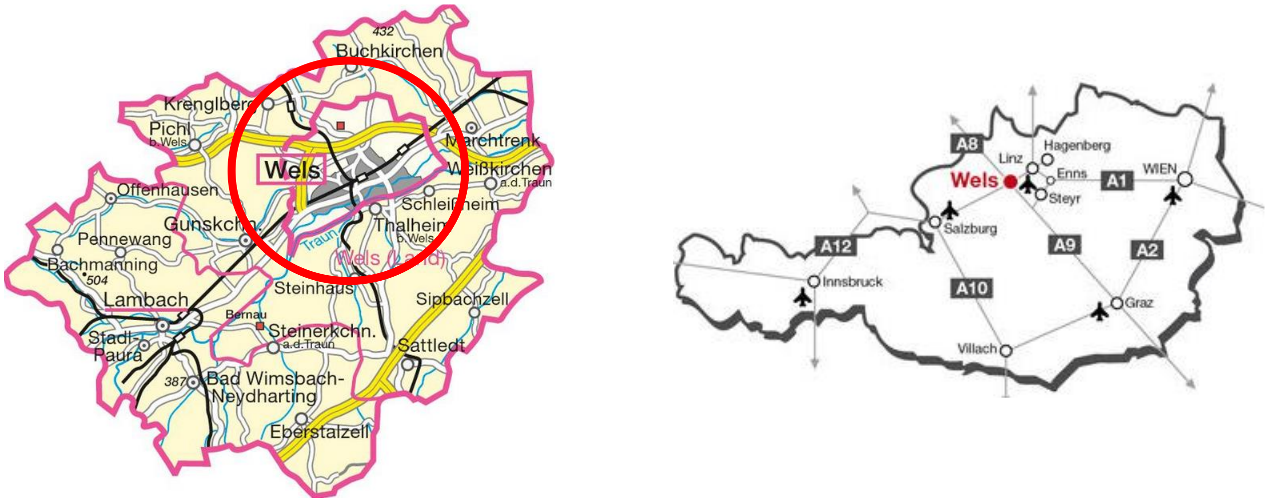

Figure 4 - The study area City of Wels is highlighted in red; on the right site there is the map of Austria

The goal is to issue which analytical methods are the most suitable and appropriate method for crime analysis for the study area City of Wels.

3.4. Geodata

Since 2004, the Austrian Federal Criminal Police Office (Österreichisches Bundeskriminalamt) collects and stores every reported crime in a database, the so-called Security Monitor (SIMO). On top of the SIMO "sits" a Geographic Information System (GIS) for the analysis, modeling, and visualization of these reported crimes. On the basis of these cases, different types of analyses are applied and further actions are planned. The SIMO is used for preventing, tracking, and predicting criminal activities. Subsequently, preventive measures can be taken and emergency plans are prepared.

3.4.1. Crime Data for Wels, Austria

Reported crime types for the city of Wels are provided by the Austrian Federal Criminal Police Office (Österreichisches Bundeskriminalamt) and are in the form of address-level crime locations. The data are from the SIMO which includes all crimes reported in Austria. For the analysis in this thesis, pickpocketing, criminal property damage, and burglary of business, houses and apartments are used (Table 1).

Table 1 – Selected attributes of reported crime types from Wels analyzed in this thesis

Data Name	File Format	Extention	Year	Data Format	Data Source
Pickpocketing	Comma Separeted Value	.csv	2009 - 2014	Vectror Point	BKA
Property damagae	Comma Separeted Value	.csv	2009 - 2014	Vectror Point	BKA
Burglary businesses	Comma Separeted Value	.csv	2009 - 2014	Vectror Point	BKA
Burglary houses/apartments	Comma Separeted Value	.csv	2009 - 2014	Vectror Point	BKA

3.4.2. Definition of the chosen crime events

In the following section definitions from the criminal code of Austria are provided first in German and then in translated in English for the different crime events that are being analyzed in this thesis. The selected crime data or types are pickpocketing, property damage and burglary of business, houses and apartments.

Definition of Pickpocketing | Diebstahl, Criminal Code Austria

§ 127 StGB Diebstahl

„Wer eine fremde bewegliche Sache einem anderen mit dem Vorsatz wegnimmt, sich oder einen Dritten durch deren Zueignung unrechtmäßig zu bereichern, ist mit Freiheitsstrafe bis zu sechs Monaten oder mit Geldstrafe bis zu 360 Tagessätzen zu bestrafen.” (Jusline, 2015)

Pickpocketing is translated as follows:

"Whoever is taking away an object intentionally and illegally from a third person, is punishable by up to six months imprisonment or a monetary penalty of up to 360 daily rates."

Definition of Criminal Property Damage | Sachbeschädigung und schwere Sachbeschädigung, Criminal Code Austria

§ 125 StGB Sachbeschädigung

„Wer eine fremde Sache zerstört, beschädigt, verunstaltet oder unbrauchbar macht, ist mit Freiheitsstrafe bis zu sechs Monaten oder mit Geldstrafe bis zu 360 Tagessätzen zu bestrafen."

Property damage is defined as follows:

„Whoever destroys somebody else's object, damages, defaces, or makes it unusably, is punishable by up to six months imprisonment or a monetary penalty of up to 360 daily rates."

§ 126. (1) Schwere Sachbeschädigung

„Mit Freiheitsstrafe bis zu zwei Jahren oder mit Geldstrafe bis zu 360 Tagessätzen ist zu bestrafen, wer eine Sachbeschädigung begeht

i. an einer Sache, die dem Gottesdienst oder der Verehrung durch eine im Inland bestehende Kirche oder Religionsgesellschaft gewidmet ist,

ii. an einem Grab, einer anderen Beisetzungsstätte, einem Grabmal oder an einer Totengedenkstätte, die sich in einem Friedhof oder einem der Religionsübung dienenden Raum befindet, *iii. an einem öffentlichen Denkmal oder an einem Gegenstand, der unter Denkmalschutz steht, iv. an einer Sache von allgemein anerkanntem wissenschaftlichem, volkskundlichem, künstlerischem oder geschichtlichem Wert, die sich in einer allgemein zugänglichen Sammlung oder sonst an einem solchen Ort oder in einem öffentlichen Gebäude befindet,*

v. an einer Einrichtung, Anlage oder anderen Sache, die der öffentlichen Sicherheit, der Verhütung oder Bekämpfung von Katastrophen, dem öffentlichen Gesundheitsdienst, der öffentlichen Versorgung mit Wasser, Licht, Wärme oder Kraft oder dem öffentlichen Verkehr dient, oder an einer für diesen Verkehr oder sonst für öffentliche Zwecke bestimmten Fernmeldeanlage,

vi. an einem Wehrmittel oder an einer Einrichtung oder Anlage, die ausschließlich oder vorwiegend der Landesverteidigung oder dem Schutz der Zivilbevölkerung gegen Kriegsgefahren dient, und dadurch die Landesverteidigung oder die Einsatzbereitschaft des Bundesheeres gefährdet, einen den Zweck eines Einsatzes gefährdenden Mangel an Menschen oder Material herbeiführt oder den Schutz der Zivilbevölkerung gefährdet, oder

vii. durch die der Täter an der Sache einen 3.000,00 Euro übersteigenden Schaden herbeiführt.

(2) Wer durch die Tat an der Sache einen 50 000 Euro übersteigenden Schaden herbeiführt, ist mit Freiheitsstrafe von sechs Monaten bis zu fünf Jahren zu bestrafen.

(1) "Whoever commits a criminal damage shall be punished by an imprisonment of up to two years or a monetary penalty of up to 360 daily rates if the following actions occur

i. damage to an item that is dedicated to worship

ii. damage at a grave or other memorial

iii. damage to a public monument

iv. damage to an item of recognized scientific, ethnographic, artistic, or historical value

v. damage to a facility, installation, or other thing that serves public safety

vi. damage to military installations which are used exclusively or mainly for the national defense or the protection of civilian populations against the dangers of war.
vii. all criminal damages above 3,000 EUR

(2) Whoever commits a damage worth over EUR 50,000 shall be punished with imprisonment from six months to five years.

Burglary of businesses, houses and apartements | Diebstahl durch Einbruch oder mit Waffen

§ 129 StGB Diebstahl durch Einbruch oder mit Waffen
Mit Freiheitsstrafe von sechs Monaten bis zu fünf Jahren ist zu bestrafen, wer einen Diebstahl begeht (…)
Burglary is defined as follows:
„With imprisonment from six months to five years is to punish, who commits theft in following cases:
1. by breaking in to closed spaces (buildings, means of transport) or using illegally acquired keys, 2. by breaking a container or using illegally acquired keys, 3. by otherwise breaking up a blocking device, 4. in which he or someone else carries a weapon to overcome the resistance of a person or to prevent."

3.4.3. Base map data

For the analysis with RTM different base data are used. The data are important for the visualization purpose. Information can be presented and interpreted easier. The base map data are the boundaries for the city of Wels, the street network and railways. All base map data are summarized in Table 3.

Table 2 – Base map data

Data Name	File Format	Extention	Year	Data Format	Data Source
City of Wels	Shapefile	.shp	n/a	Vector Polyline	Data.gv.at
Street Network	Shapefile	.shp	n/a	Vector Polyline	Open Street Map
Railways	Shapefile	.shp	n/a	Vector Polyline	Open Street Map

3.4.4. Risk factor data

For the RTM analysis risk factors are necessary. For this analysis eight risk factor datasets were provided. For this analysis eight risk factor datasets were self-captured and are included in Table 2. In the description of the RTMDx program it is mentioned that for each crime event risk factors are recommended. But for this thesis the risk factor data were caught at its own discretion by the autor.

Table 3 – Risk factor data

Data Name	File Format	Extention	Year	Data Format	Data Source
Banks	Shapefile	.shp	n/a	Vector Point	Self-captured
Buildings	Shapefile	.shp	n/a	Vector Polygon	Open Street Map
Cash Points	Shapefile	.shp	n/a	Vector Point	Self-captured
Clubs & Discos	Shapefile	.shp	n/a	Vector Point	Self-captured
Nightclubs	Shapefile	.shp	n/a	Vector Point	Self-captured
Police Departments	Shapefile	.shp	n/a	Vector Point	Self-captured
Post Offices	Shapefile	.shp	n/a	Vector Point	Self-captured
Schools	Shapefile	.shp	n/a	Vector Point	Self-captured

3.5. Implementation of the different analysis methods

This chapter deals with the procedure of the implementation of the different forecasting methods. It is divided into data processing, geocoding, compatible to the analysis and visualization in ArcGIS. Figure 5 describes the different steps of this scientific work, beginning with the crime event data, base maps and catching data for the risk factors. The next parts of the Figure 5 show the software is used and finally the visualized results.

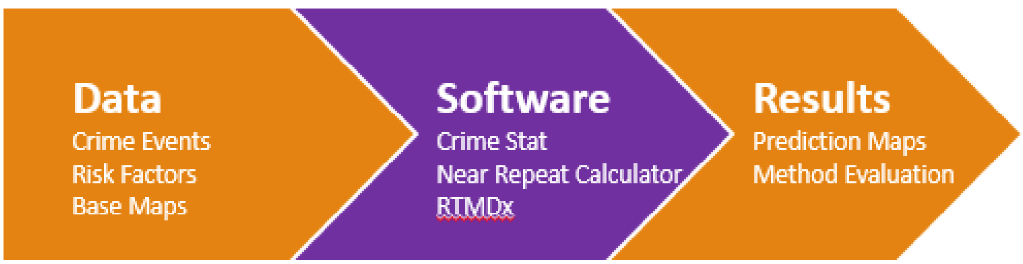

Figure 5 – Main implementation steps

3.5.1. Software used for forecasting crime analysis

The comparison and evaluation of three groups of criminal predictive analysis methods will be carried out with different software tools, including CrimeStat, Near Repeat Calculator, RTM software, and the ArcGIS extension Spatial Analyst (Eck et al. 2005) module of ArcGIS. CrimeStat is free of charge; the Near Repeat Calculator is an open-source software. There exist two kinds of RTMDx version, one for commercial use and the student's version, which is for free. The prediction results are presented in tables and graphs, but they will also be visualized in form of maps using ArcGIS by using the commercial version. The student's version does not produce final maps; they have to be created by the user. In the following, a short description of all software packages for the forecasting analysis is described in more detail.

Crime Stat IV

Crime Stat is a spatial statistics program and is used for crime analysis. This software tool is provided for free at the website of National Institute of Justice (http://www.nij.gov/topics/technology/maps/pages/crimestat-downloads.aspx#program). This program was developed by Ned Levin & Associates in Houston, TX starting in the 1990s. Initially it was used for the analysis of car accidents. Crime Stat works based on Windows and provides interfaces for different geo programs. On the basis of various statistical analyses it provides useful results for the prediction, such as crime incidents. It comprises of more than 100 statistical functions which can be used for the analysis of spatial patterns. Spherical and projected coordinates are supported (Levine, 2015).

ArcGIS 10.3

ArcGIS is a commercial geographic information system software program from Environmental System Research Institute (ESRI). The latest version which was also used for this research is 10.3. ArcGIS uses the concept of a Geographic Information System (GIS), to create maps. Each spatial feature is a separate layer. Different analyses as well as maps were made with the spatial analyst extension in ArcGIS. ArcGIS has hundreds of different analytical tools for solving a wide variety of problems. One example of its use is it to geocode tables that contain address data (Duke University, 2015).

Near Repeat Calculator

The Near Repeat Calculator was developed by Jerry H. Ratcliffe, Department of Criminal Justice at Temple University in Philadelphia PA (Ratcliffe 2008, p. 4) and is provided for free (http://www.cla.temple.edu/cj/misc/nr/download.htm). The software compares the actual pattern of spatio-temporal relationships between all points with the pattern one would expect if there were no near repeat processes taking place. For this process this random reallocation has to be performed many times. The standard minimum threshold for statistical significance is $p = 0.05$. This can be achieved with about 20 reallocations. The best statistical significance level the program can achieve is $p = 0.001$, which is reached with 1000 reallocations. The greater the number of reallocations is, the more reliable the results are. If you load data files, the program will ask for distance units. Therefore, you have to improve the quality of the output by labelling the tables. There are two distance settings available, including the Manhattan distance and the Euclidean distance. The

Manhattan distance is the sum of the difference between two x- and two y-coordinates. The Euclidean distance uses the Pythagorean equation to measure the direct (shortest) distance between two points (Ratcliffe 2008, p. 8). The Manhattan and Euclidean distances are shown in Figure 6.

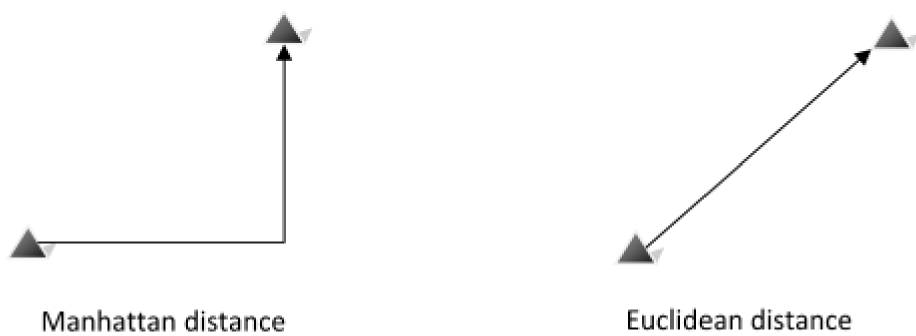

Figure 6 – Difference between Manhattan and Euclidean distance

The results of the near repeat calculator are two files, including a summary in htm format and a comma-separated-value file, which contains the frequency and the significance level of a crime event. The results of the analysis are more likely significant, the closer the events are in space and time (Ratcliffe 2008, p. 9). In order to determine the original and the near repeat event another function called "other function" is used. The user can choose the spatial and temporal frame. The output is a comma separated values file (csv). This file shows how many times an event was the originator and how many times it was the near repeat event. It is possible to identify hotspot events (Ratcliffe 2008, p. 12).

Risk Terrain Modeling Diagnostics (RTMDx)

This software tool is provided at the website of RUTGERS Center on Public Security. There exist two kinds of RTMDx version, one for commercial use and the student's version, which is for free. (http://rutgerscps.weebly.com/software.html). The RTMDx is a special software application for risk modelling and for diagnosing spatial crime vulnerabilities. It helps to identify and communicate environmental attractors of crime incidents. Information products can be used to anticipate places that will be most suitable for illegal behavior. RMTDx automates most steps of risk terrain modelling. The algorithm empirically tests a variety of spatial influences. Then, it empirically selects only the most appropriate risk factors to produce a "best" risk terrain model. The final model articulates the vulnerability for a specific crime type with relative risk values at every place throughout the research area. In some cases the run time could be several hours (Caplan & Kennedy, 2011).

3.5.2. Data preparation

The data material, which is provided by BKA in different formats (mainly csv data) had to be prepared for the usage in ArcGIS and for the use with the different software programs to calculate the results. To implement the raw data material into ArcGIS it was necessary to create a new data base. Data are including dates, time, criminal offense and the coordinates. Also data correction was included. For example, points that were lying outside of Wels were deleted to improve the data quality. For some reason, a few points were located in Graz and other cities of Austria. The incorrect data sets were deleted and only data sets which are located in Wels remained. To use the data with the CrimeStat software they needed to be in dbf format. The shape files include dbf files too, so a shape file can be used for data input. To do the analysis in CrimeStat there are only x and y coordinates used. To use the data with the Near Repeat Calculator they needed to be in csv format. The software only needs the x, y coordinates and time.

3.5.3. Data overview

The following reported crime records for the city of Wels are showed in Table 4.

Table 4 –Incidents for each crime event divided in the years 2009 – 2014.

Crime incidents						
Data Name	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Pickpocketing	75	103	95	69	101	234
Property damage	743	698	815	752	750	668
Burglary in houses	18	21	37	39	30	64
Burglary in apartments	23	25	23	13	7	39
Burglary in business	268	184	203	180	141	152

3.5.4. Data capture and geocoding for the RTM analysis

For the whole RTM analysis some of the data (risk factors) are very important. Therefore data were self-captured and geocoded. Overall, seven different risk factors were captured, which are presented in Table 5. Data source name, Uniform Resource Locator (URL) of the data source and number of features are listed.

Table 5 - Data capture for the risk factors

Data name	Data source name	Data source URL	Number of features
Banks	Herold	http://www.herold.at/gelbe-seiten/wels-stadt-land-und-umgebung-eferding/was_banken/	32
Cash Machines	Bankomaten	http://www.meinkauf.at/filialen/wels/bankomaten	49
Post Offices	Austrian Post	www.post.at	19
Nightclubs, Bars	Firmen ABC	http://www.firmenabc.at/firmen/wels-stadt_Hn/nachtclub-nightclub_CKE	57
Shops	Wels Info	http://www.wels-info.at/Wels/Einkaufen/	99
Police stations	Austrian Police	http://www.polizei.gv.at/ooe/lpd/dst/dienststellen.aspx?org=43732B5378702F632F50733D	5
Schools	Schulen Wels	http://www.schule.at/schulfuehrer/oberoesterreich/wels-stadt.html	38

For this analysis the name of the feature, address, street, house number, zip code and city were researched and recorded. Data were set up in an excel file which is necessary for the geocoding process. To do the geocoding process an ArcGIS online 30-day trial account is required. After that it is possible to use this service in

ArcMap. For the geocoding of addresses of the excel workbook the "World Geocode Service (ArcGIS Online)" is selected. The following figures illustrate these steps. The individual columns in the Excel table must be linked for successful geocoding with the correct column in ArcMap.

- Address - Address (example: country road 2)
- City - District (example: Wels City)
- Postal - code (example: 4060)
- Country - State (example: Austria)

When the process of geocoding was completed successfully, the user can access information about the found points. As seen in Figure 7 the update process for geocoding is shown.

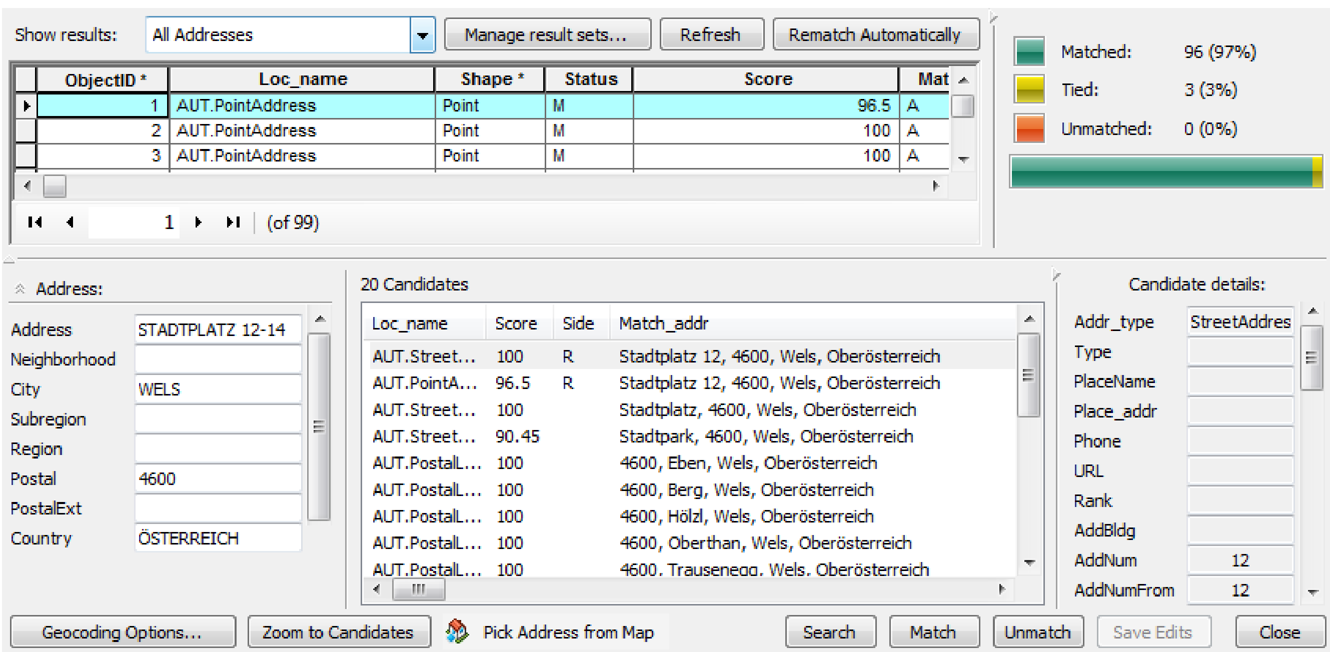

Figure 7 – Geocoding with ArcGIS 2015

3.5.5. Kernel Density Estimation

To calculate the Kernel Density Estimation CrimeStat is used. For the interpolation method normal and for the bandwidth adaptive was chosen. The points of the area units are measured per square meters and the units of the output are absolute densities. Also a fixed bandwidth was used but the best results were delivered by the above described parameters. To calculate the Kernel Density Estimation a reference file is required. With the reference file a rectangular grid has been created over the data points. The result is a shape file, which can be visualized in ArcGIS (Anselin, 2003). The Table 6 shows the used parameters for the Kernel Destiny Estimation.

Table 6 – Kernel Density Estimation parameters

Crimes	total	Minimum Points	Method	Bandwith	Output with
Pickpocketing	1120	33	normal	adaptive	squaremeters
Property damage	3673	120	normal	adaptive	squaremeters
Burglary shops, companies	986	30	normal	adaptive	squaremeters
Burglary houses	339	10	normal	adaptive	squaremeters
Burglary apartments	244	7	normal	adaptive	squaremeters

3.5.6. Nearest Neighbor Hierarchical Cluster

Another type of cluster analysis is the Nearest Neighbor Hierarchical Cluster Method (NHHC). CrimeStat includes a special algorithm which is used for the NNHC method. It is a risk-bases technique but involves elements of clumping. It identifies groups of incidents that are locally close. It clusters points together on the basis of criteria. Then the clustering is repeated until all points are grouped into a single cluster. The NNHC defines a threshold distance and compares them to all pairs of points. Only points that are closer should be selected for the clustering. For this analysis different parameters were fixed. For the minimum number of points 1 to 3 percent of the total number of data sets should be a good value. For the type of search radius default settings are used. That means that there is no distance but a probability level of 0.05 is chosen. In the program the fifth position from left of the scale bar is chosen. The results can be created as standard division ellipses or convex hulls. The advantage of convex hulls is that they have a great accuracy and they have a higher density. For this analysis a convex hulls are used (Levine, 2015). The Table 7 shows the used parameters for the Nearest Neighbor Hierarchical Cluster Analysis.

Table 7 – Nearest Neighbor Hierarchical Cluster parameters

Crimes	total	Minimum Points	Percantage	Output with
Pickpocketing	1120	33	0.05	meter
Property damage	3673	40	0.05	meter
Burglary shops, companies	986	30	0.05	meter
Burglary houses	339	10	0.05	meter
Burglary apartments	244	7	0.05	meter

3.5.7. Spatial Fuzzy Mode

The spatial fuzzy mode is a simple analysis method but very useful. It is calculated in CrimeStat and for this analysis only a dbf. or shp. files were used. For the spatial fuzzy mode it is necessary to search out a radius. The radius for the fuzzy mode is shown in Table 8. For the distance of radius it is important to do the distance analysis called nearest neighbor analysis which is also available in CrimeStat.

Table 8 – Radius Spatial Fuzzy Mode Parameters

Crimes	Radius F-Mode
Pickpocketing	20 m
Property damage	13 m
Burglary shops, companies	31 m
Burglary houses	95 m
Burglary apartments	88 m

3.5.8. Near Repeat Calculator

The Near Repeat Calculator requires some parameter settings (shown in Figure 8 and 9): the spatial bandwidth, the number of bands, the temporal bandwidth, the number of bands and the level of significance. In the distance settings can be selected between Manhattan distance and the Euclidean distance. The Near Repeat Calculator uses exclusively csv files. The data is processed so that in one row should be the date on which the event had happened and the respective X and Y coordinates. It does not matter which projection and which length (meters or feet) the data have. Latitude and longitude coordinates cannot be processed by the program (Ratcliffe 2008, pp. 5). The spatial bandwidth and the number of bands have to be selected. To find the correct settings, different values should be chosen. In the description of the program is proposed as a starting value ten for the spatial bandwidth (Ratcliffe 2008, pp. 6). It is recommended to use a temporal bandwidth of a week (7 days) or a month (28 or 30 days) (Ratcliffe 2008, pp. 7). The near repeat calculator requires only three information bases of the crime: the x-coordinate, y-coordinate and the date in the form of DD / MM / YY. However, since the data contains much more information, they must be adapted and processed. The projection of the points is not important, just cannot contain decimal places data. It is also important, which is the data format a csv file. The data are processed in excel listed in one column. In the end, the data is still being checked with Notepad ++ and the separator of ";" in "," changed. The analysis was carried out for the period "2009 - 2013". For the first step of calculation single data for crime events were loaded in the Near Repeat Calculator. In the next step the parameters for the analysis were chosen. For the spatial bandwidth 140 meters were fixed. As in the instruction described a number of bandwidth within ten spatial bands were approached. For the temporal bandwidth 30 days were fixed and the temporal bands were defined with twelve bands. The significance level was defined with p= 0.001.

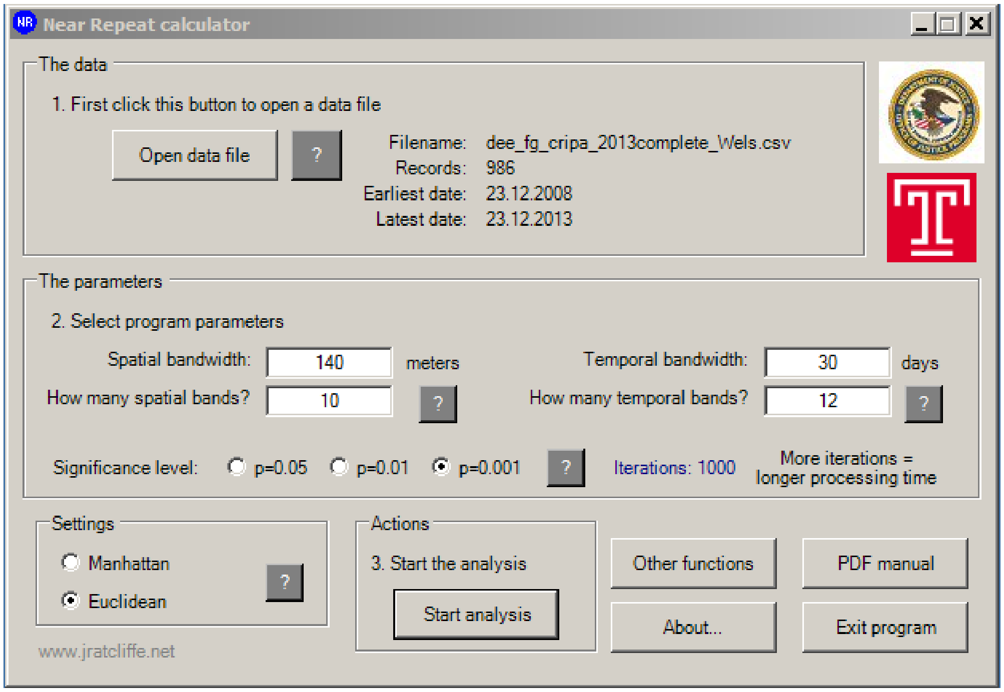

Figure 8 – User Interface (UI) of the Near Repeat Calculator

As distance the Euclidean distance was chosen, in fact of the best suitable calculation for the city of Wels. The Manhattan distance was not suitable. To find out the number of originator and near repeat points the button "other function" was pushed. For the other settings of parameters the instruction model was used.

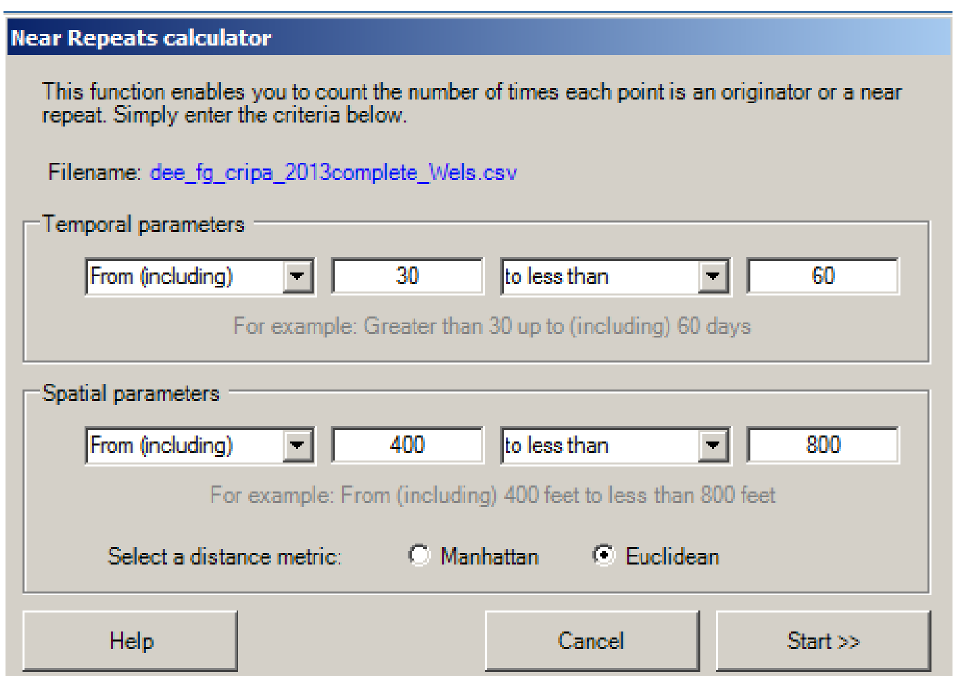

Figure 9 – UI counting originator or near repeat points

The near repeat calculator does not visualize the results in form of maps. This should be done by the user. The results are htm files with described tables. The results for the originator and repeat counter are csv files, which can be displayed in ArcGIS. The csv files were imported to ArcGIS and with right click on the csv file and push x, y, data, the data can be displayed as a point shape file. After displaying the originator and near repeat points for the originator a buffer with 140 meters (spatial bandwidth) was calculated. The final results are maps with the originator points, the near repeat points and the buffers.

3.5.9. RTMDx

As characterized in chapter 2.4. the defined workflow is used for the implementation of the risk terrain models. As already described, the steps one to five are the first steps to implement the risk terrain modelling analysis. After these steps a model for each crime event is calculated by using the RTMDx Utility Software. The study area, block length, cell size, model type, outcome event data and the output location have to be defined. The next step is to add the risk factors into the RTMDx. The operationalization type, the spatial influence and the analysis increments can be defined. But for this analysis the default values are used. The results of the analysis are combined in form of a report. The report includes the best model, lists the risk factors, the spatial influence and the weight. Also the report gives the formula to combine all the separate risk map layers. To convert the report results ArcGIS is used. The operationalization and combination are based on the best presented model, which is calculated by the RTM Software. For the operationalization the crime factors with the type proximity first a buffer was created with a distance which represents the spatial influence. The distance value is listed in the report. The next step was to join the created buffer with an empty vector grid which was produced with a function in ArcGIS. This tool is included in the toolbox "Risk Terrain Tools" and is provided for free at the website of RTM (http://rutgerscps.weebly.com/rtm.html). After that the features are converted to a raster file and reclassified the values by using the raster calculator. The reclassification is based on the count of overlapping buffer features. If the value is greater than one the reclassified value is one, otherwise they got the value zero. To operationalize a risk factor with the type density in the first step a kernel density is calculated. The radius for the calculation is also the spatial influence which is listed in the report. After that the values were reclassified based on the result of the kernel density and the property that the value should be greater than two standard deviations. All values of a cell are greater they got a new value "one" otherwise the cell got the number "zero".

As described above after these steps the separate risk map layers have to be combined. For this step the "raster calculator" is used and based on the formular in the report.

3.6. Summary

The chapter methodology described the problem definition and the method of solution in more detail. The project area Wels in Upper Austria is explained with the used geodata that included crime types. Pickpocketing, Criminal Property Damage and Burglary of businesses, houses and apartments are the three crime types being selected and analyzed. In the implementation subchapter the used software is described and how the data had to be prepared for the analyses. For example, data for the RTM Analysis had to be geocoded. It is then explained why the specific methods were chosen and which parameters were chosen for each method. The selected spatial cluster methods are the Kernel Density Estimation Density Estimation density estimation, nearest neighbor hierarchical clustering, the mode and the spatial fuzzy mode. For the near repeat analysis the near repeat calculator and for the RTM the RTMDx was used and the chosen settings are also described.

4. Results and Interpretation

4.1. Results of three different hot spot analysis methods

In this chapter the results of the three groups of forecasting analysis methods are discussed together with a short overview and interpretation of the results. The first subsection discusses the results of the spatial fuzzy mode. The second subsection discusses the results of the Kernel Destiny Estimation and the third subsection discusses the results of the Nearest Neighbor Hierarchical Cluster method.

4.1.1. Results of the spatial fuzzy mode

In Figure 10 the result of the spatial fuzzy mode analysis is shown. The spatial fuzzy mode is the value, which includes most criminal offenses within a defined perimeter. To Determines the choice of the circle radius the nearest neighbor analysis was used (Table 8). The blue points represent the number of points of crime events. The results show that the crime happening is more in the south of study area. The locations with the highest crime count (rank) are shown in Table 9 and the locations of the crime events are shown in Figure 10.

Table 9 – Results for the spatial fuzzy mode

Crimes	x coordinates	y coordinates	Rank
Pickpocketing	453036	473766	55
Property damage	451630	473375	68
Burglary shops, companies	450277	473925	17
Burglary houses	451337	475769	10
Burglary apartments	449524	471931	13

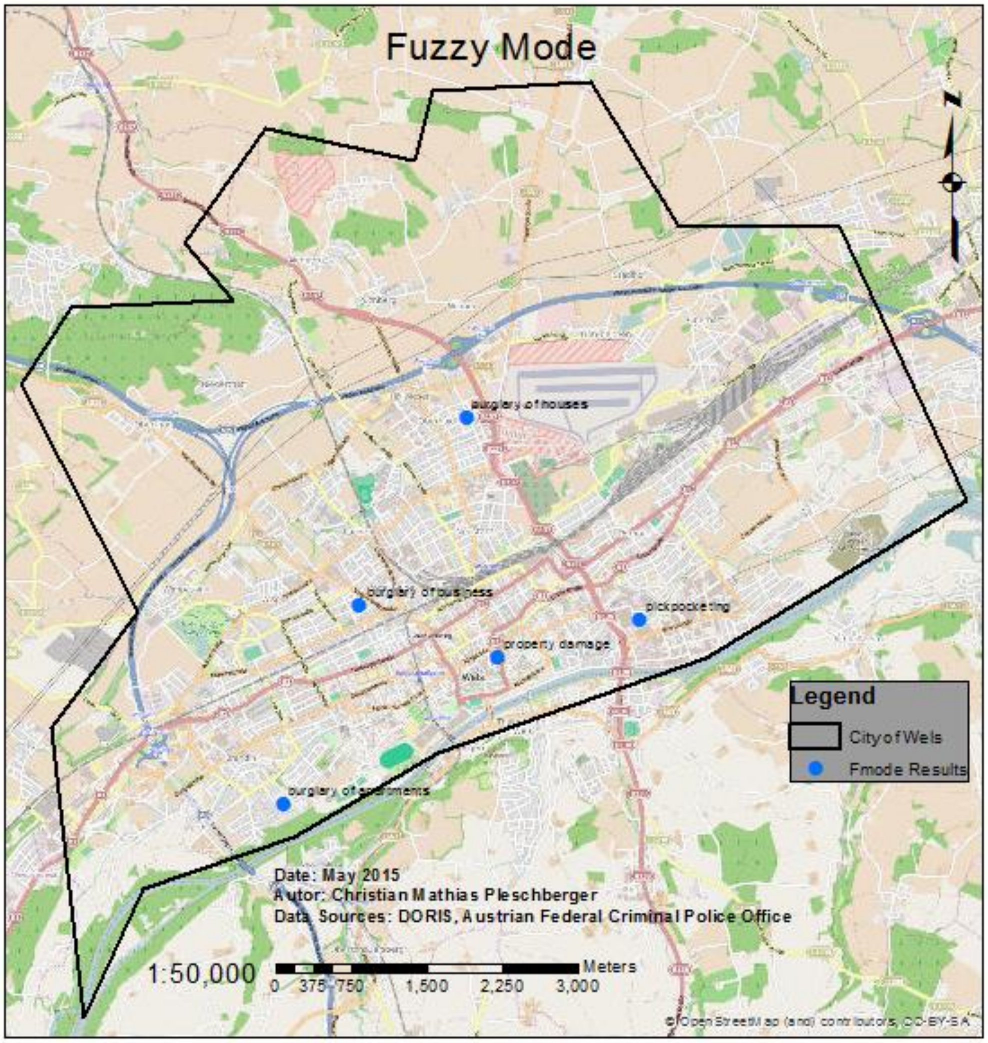

Figure 10 – Result of the spatial fuzzy mode analysis

4.1.2. Kernel Density Estimation

In order to better understand the results of the Kernel Density Estimation density estimation, the resulting density values (i.e., "z" values) have been classified in the map displays in five different classes, ranging from "low" to "high". It is easier to interpret the results with these five different classes, because it is difficult to explain the meaning of the Z-scores (Smith et al., 2011). The points of the area units are measured per square meters and the units of the output are absolute densities. Absolute densities are chosen because it is good to use for comparisons between different crime types (Levine 2013d, p. 22). The results were clustered in five categories and the lowest and highest are figured with “low” and “high”.

The results of Kernel Density Estimation are shown in Figures 11 - 15. The crime data are used from year 2009 to 2013.

Figure 11 shows the results of Kernel Density Estimation pickpocketing:

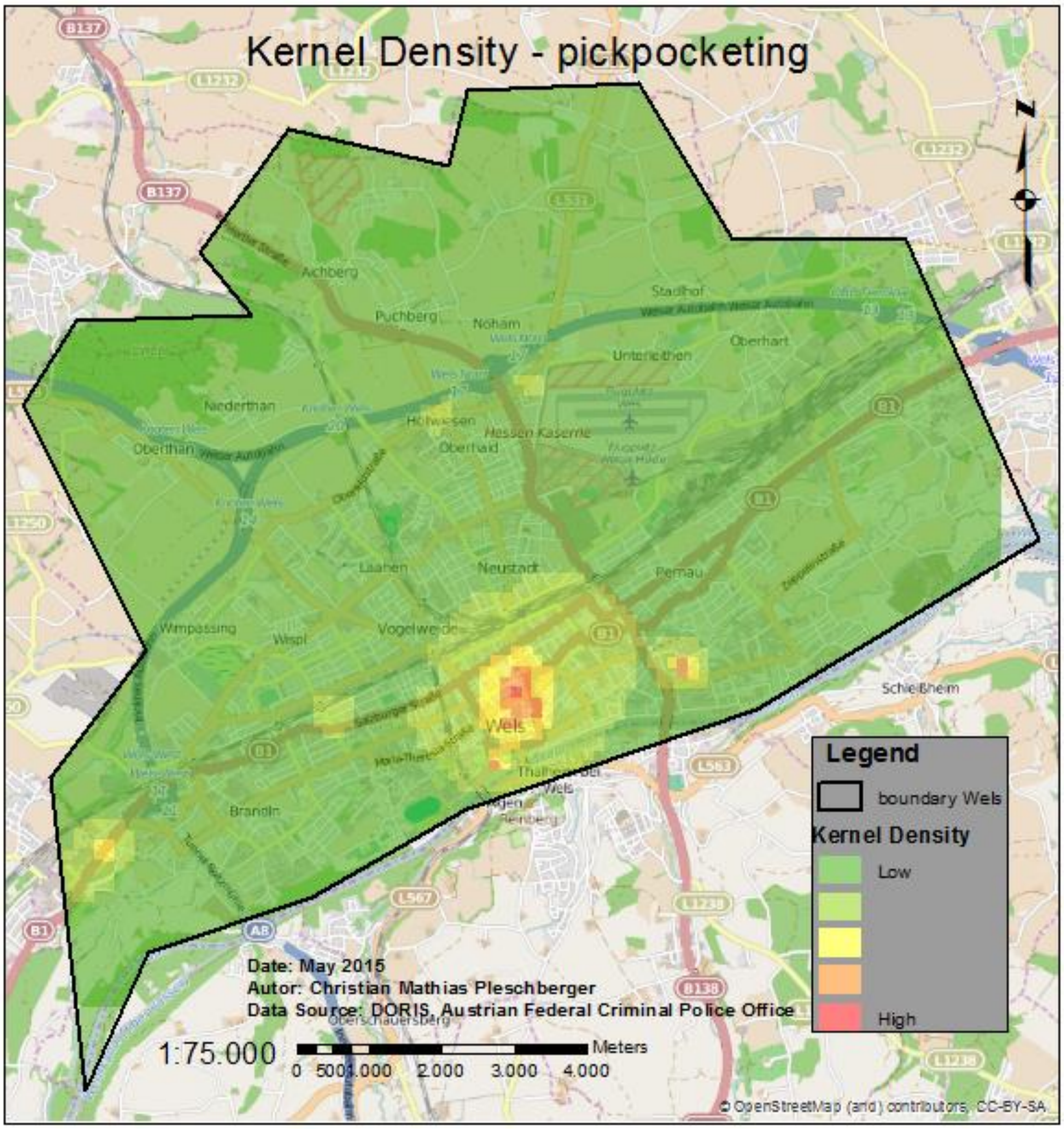

Figure 11 – Results of Kernel Density Estimation (pickpocketing)

As seen in Figure 11 a small hot spot area is located in the south of city of Wels. The forecasting crime event for pickpocketing is very high in the red area.

Figure 12 shows the results of Kernel Density Estimation for property damage:

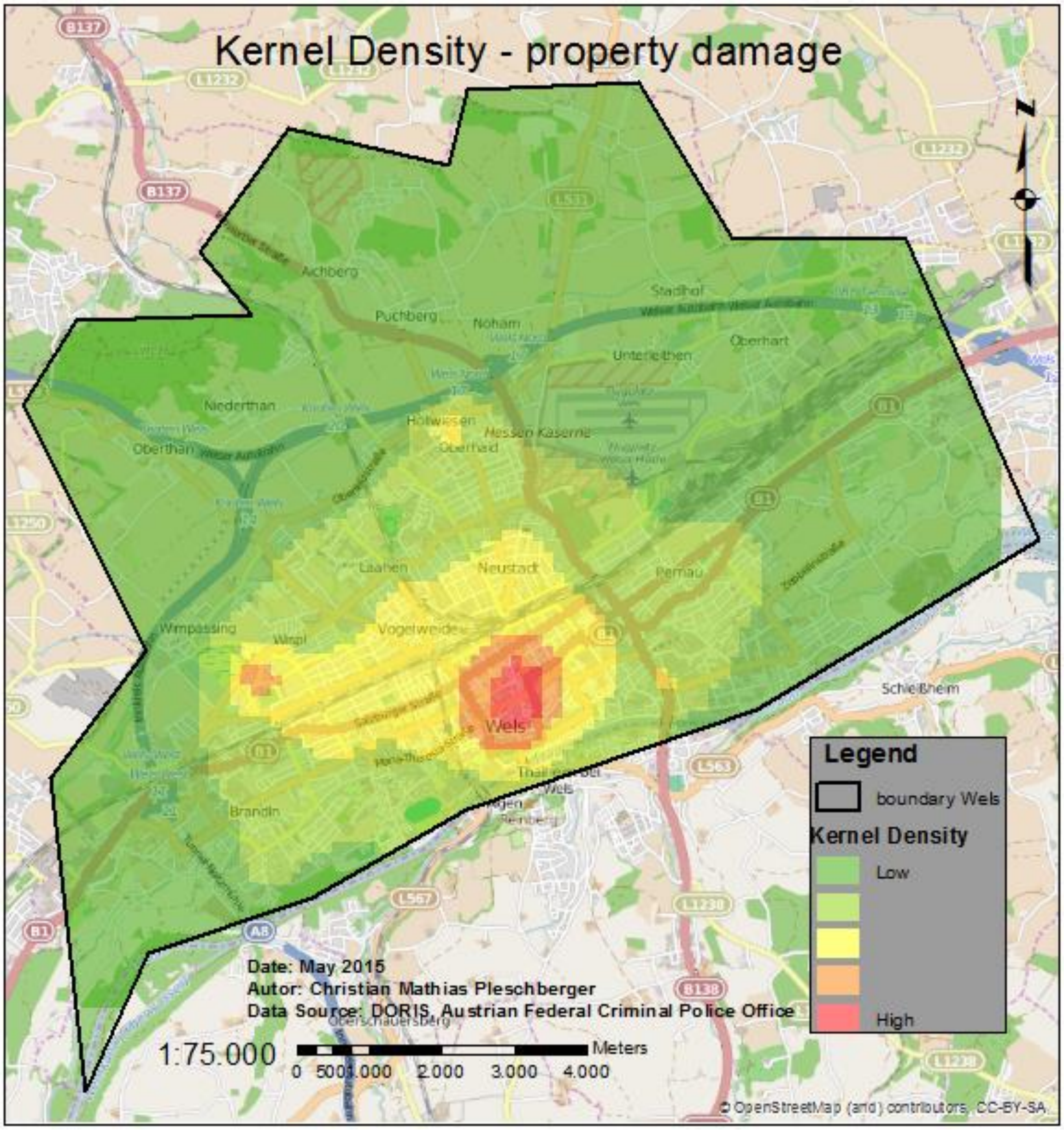

Figure 12 – Results of Kernel Density Estimation (property damage)

As seen in Figure 12 the hot spot area is located in the south of city of Wels. The forecasting crime event for property damage is very high in the red area shown in the map.

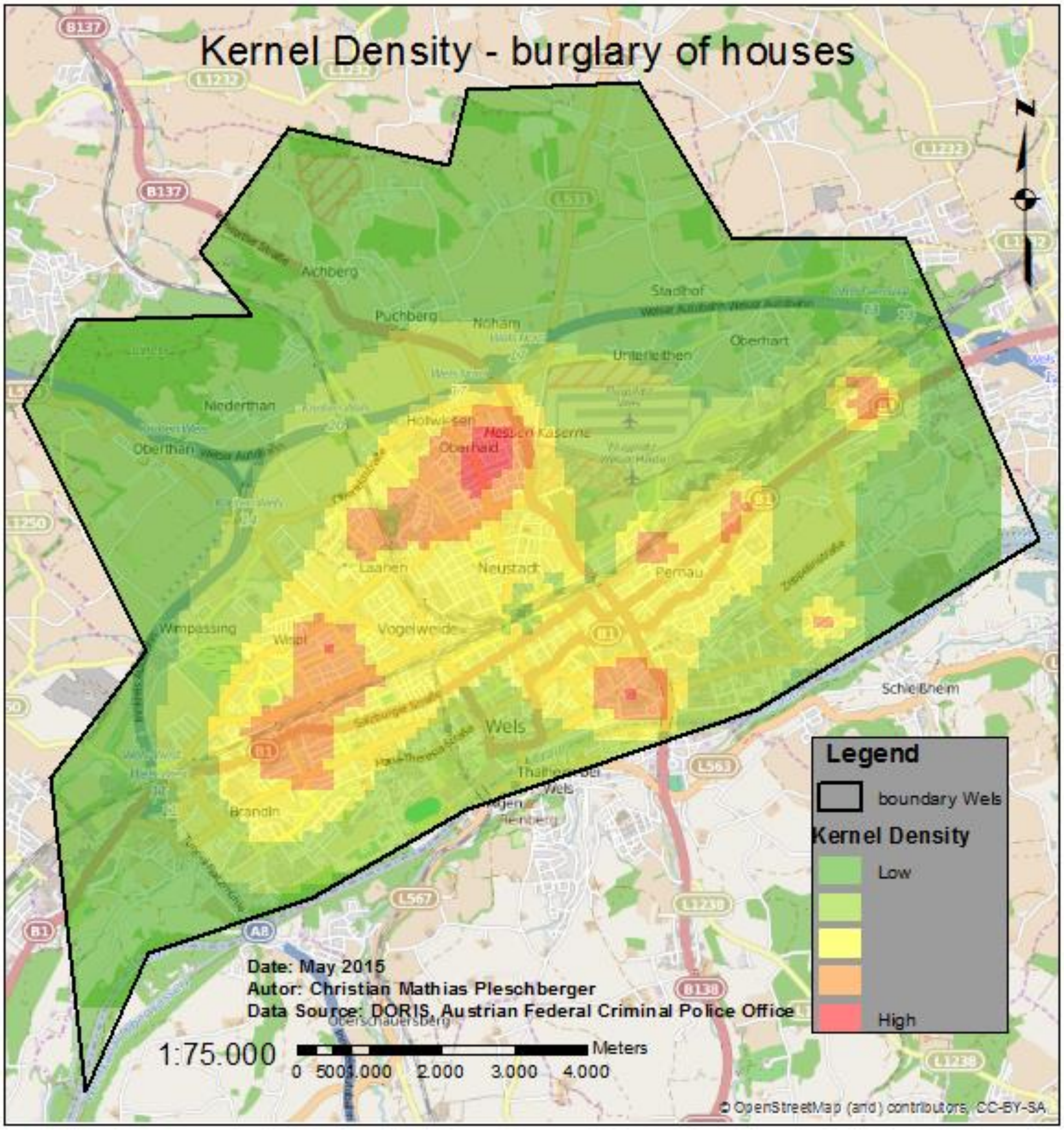

Figure 13 - Results of Kernel Density Estimation (burglary of houses)

As seen in Figure 13 the hot spot area is more divided. The red area shows a high risk of the crime event burglary in houses.

Figure 13 shows the results of Kernel Density Estimation for burglary of apartments:

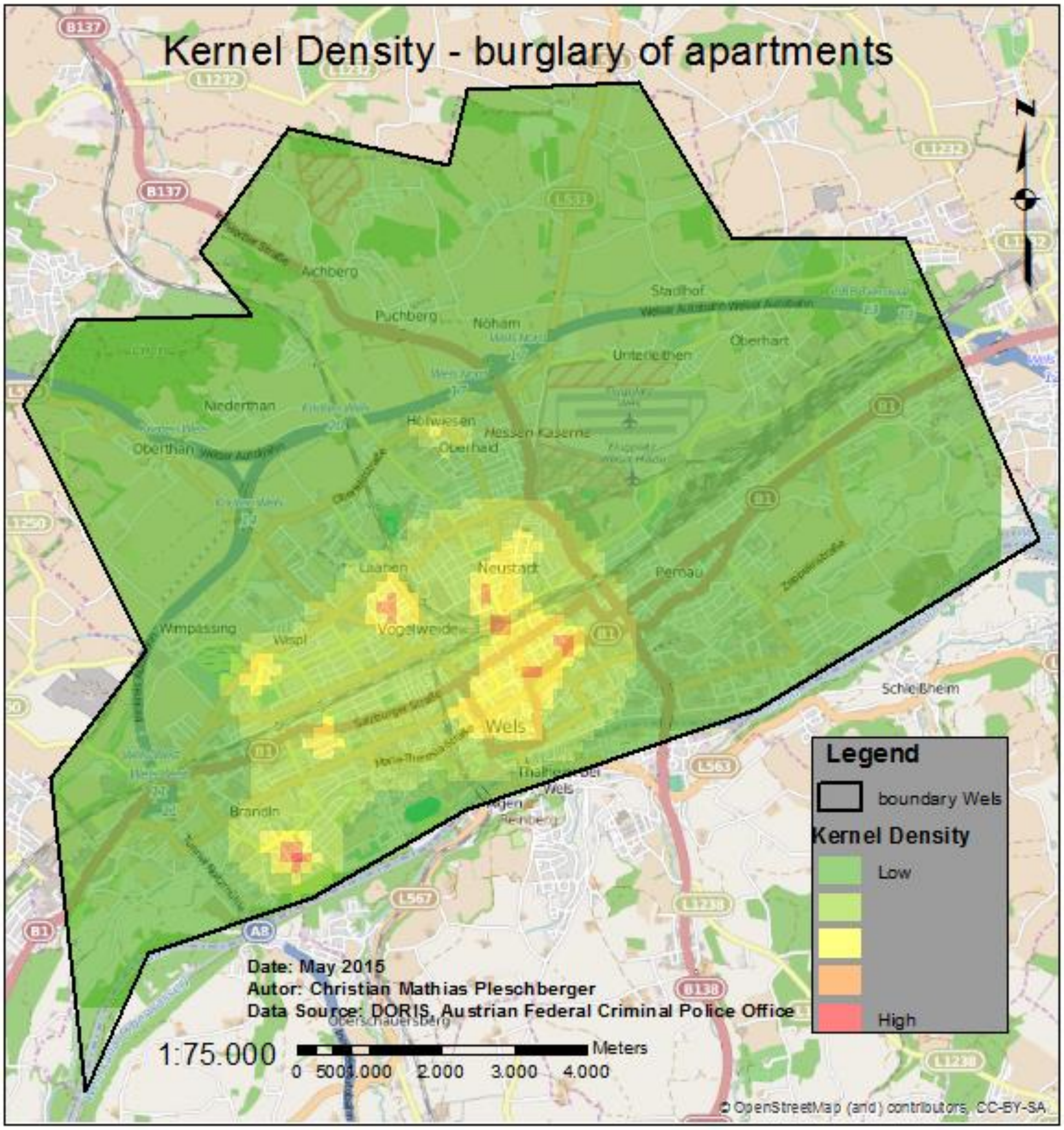

Figure 14 – Results of Kernel Density Estimation (burglary of apartments)

As seen in Figure 14 the hot spot areas are more divided and the red areas of high risk crime events are only a few.

Figure 15 shows the results of Kernel Density Estimation for burglary of business:

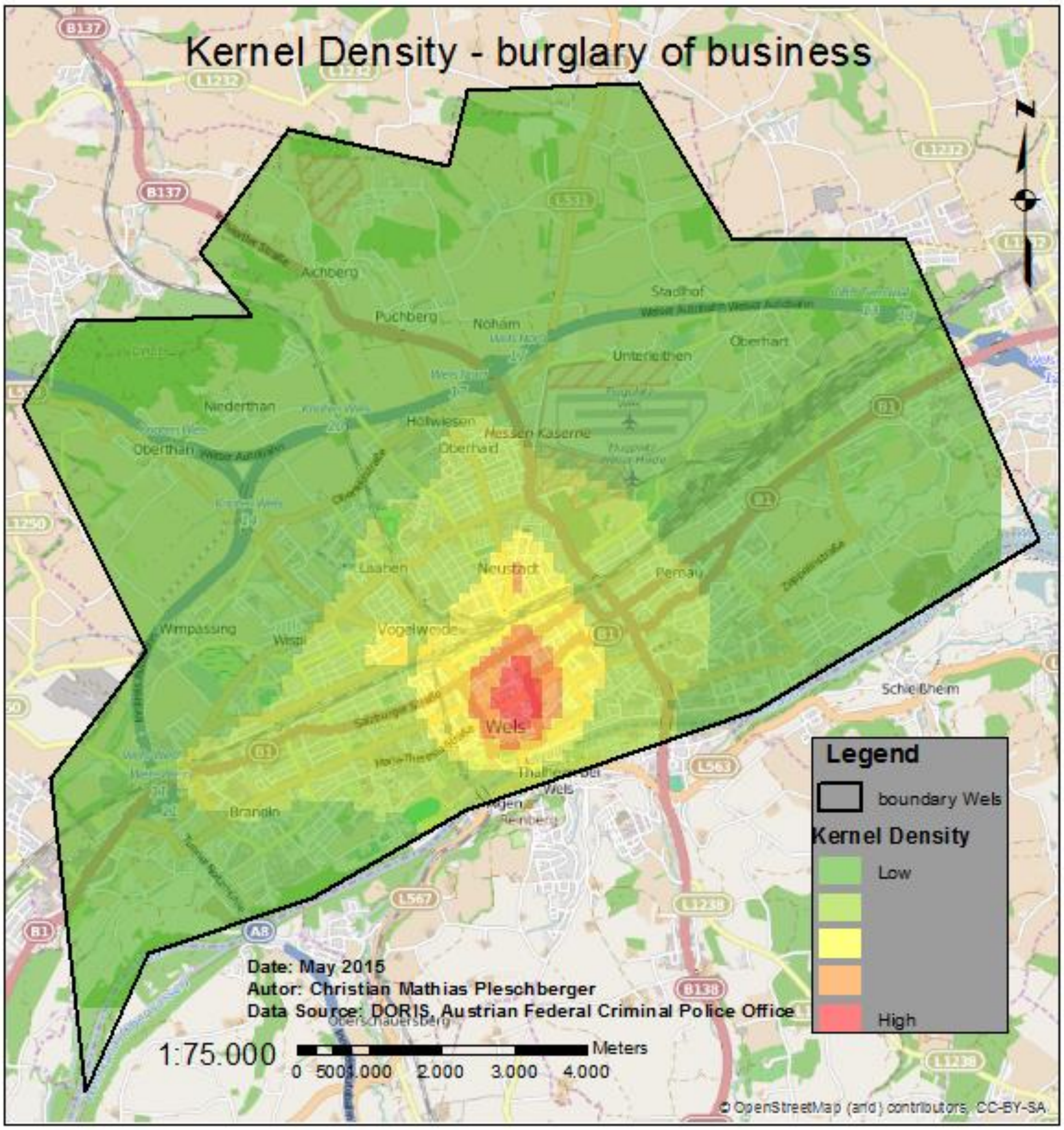

Figure 15 – Results of Kernel Density Estimation (burglary of business)

As seen in Figure 15 the hot spot area is located in the center of City Wels. The risk of the crime event of burglary in business is quite high in the red areas.

The red areas are called hotspots, i.e., those surfaces with the highest concentration of incidents. For the presentation of the Z-scores were divided into five classes. In other words, the red areas are the highest 20 % of the Z-values, displayed as hot spots.

4.1.3. Nearest Neighbor Hierarchical Cluster

The results of the NNHC Analysis are shown in the Figures 16 – 20. The small polygons (first and second order) are hot spots, that means all shown polygons represents the highest concentration of incidents.

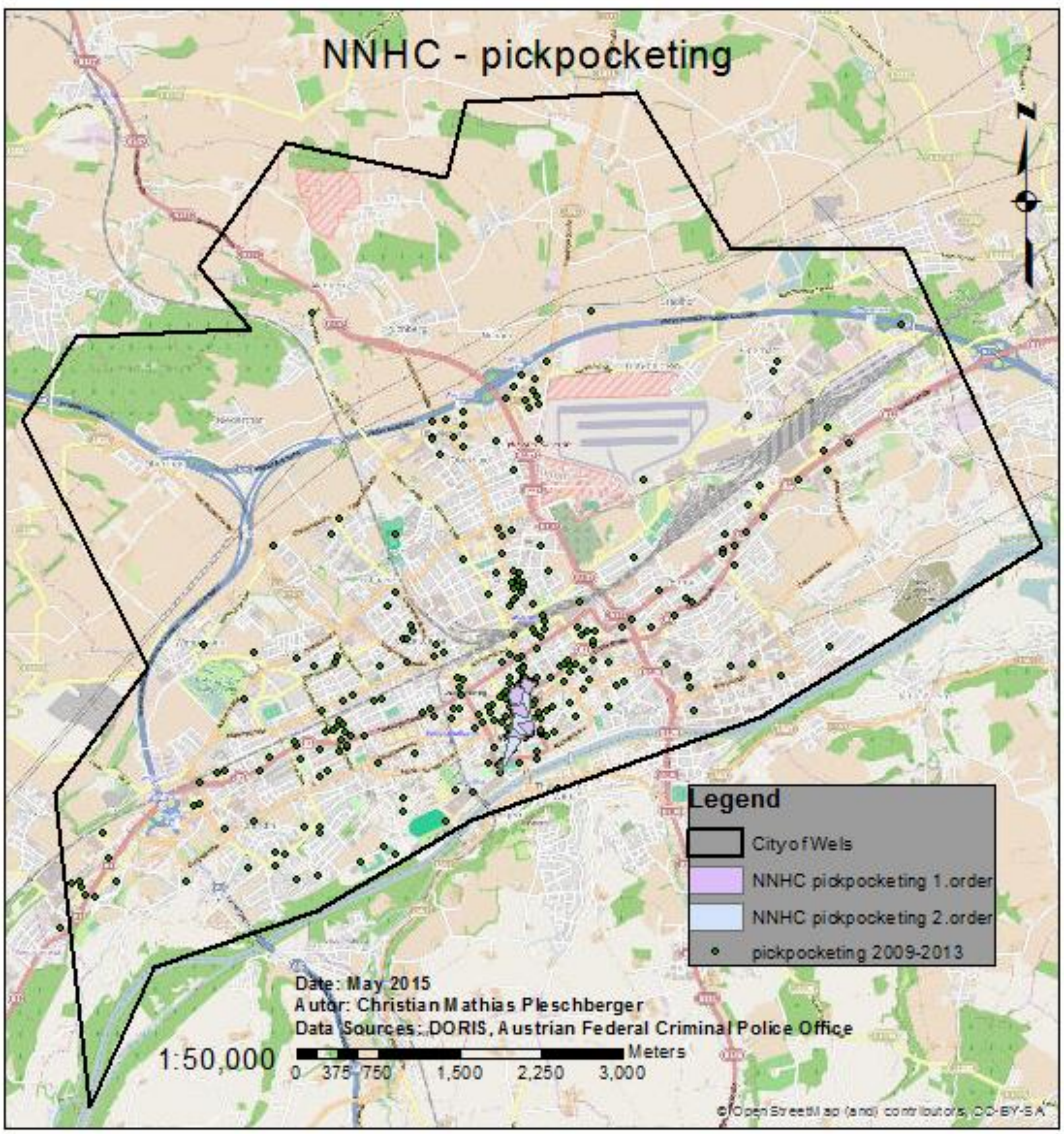

Figure 16 - Results of NNHC (pickpocketing)

As seen in Figure 16 the polygons (first and second order) show the calculated hot spots for the crime event pickpocketing. The hot spots are more divided in the study area.

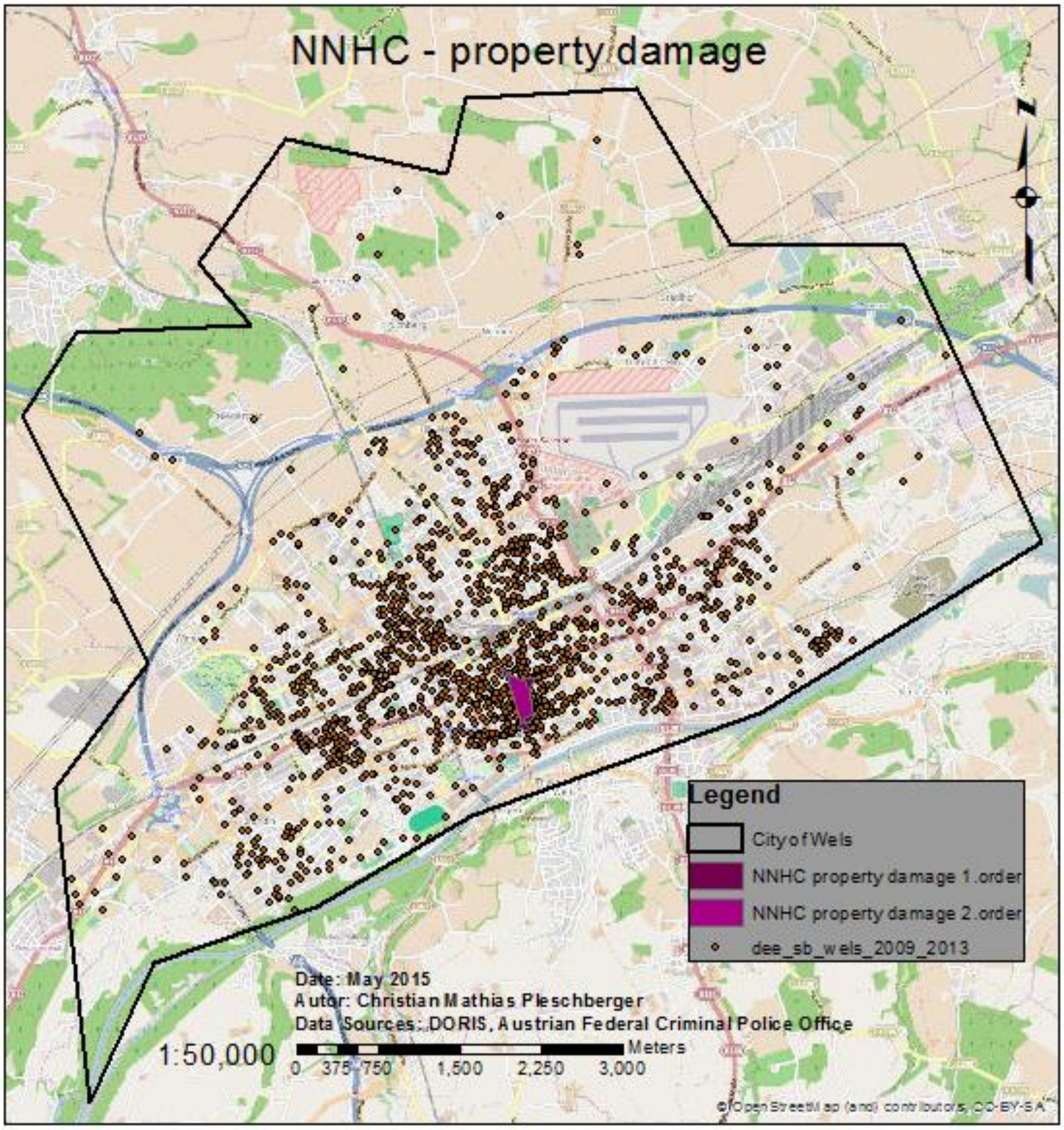

Figure 17 - Results of NNHC (property damage)

As seen in Figure 17 the polygons (first and second order) shows the calculated hot spots for the crime event property damage. The hot spots are located in the middle-south of city of Wels.

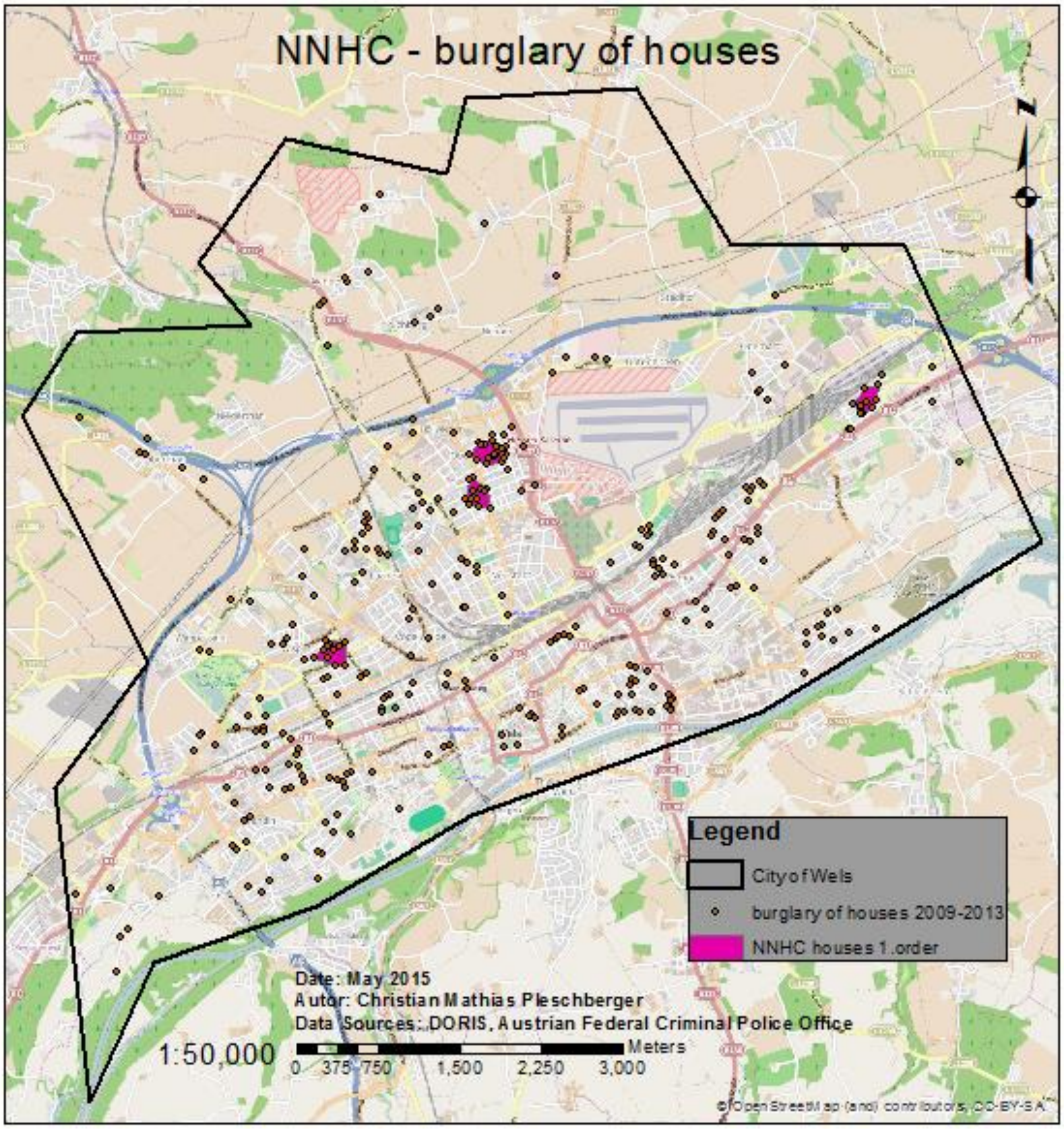

Figure 18 – Results of NNHC (burglary of houses)

As seen in Figure 18 the polygons (first and second order) show the calculated hot spots for the crime event burglary of houses. The hot spots are more divided in the study area.

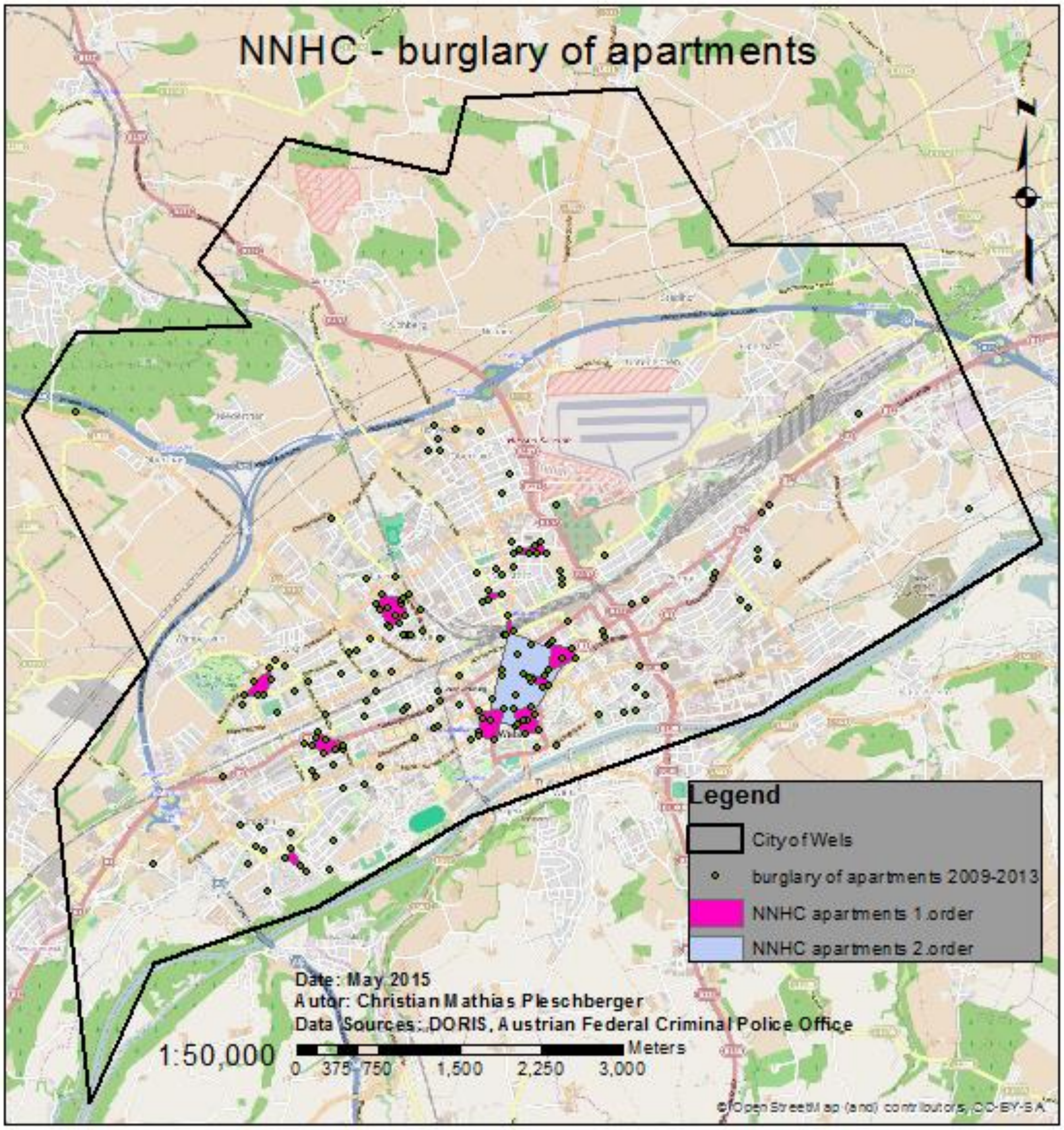

Figure 19 - Results of NNHC (burglary of apartments)

As seen in Figure 19 the polygons (first and second order) show the calculated hot spots for the crime event burglary of apartments. The hot spots are located south-west of the study area.

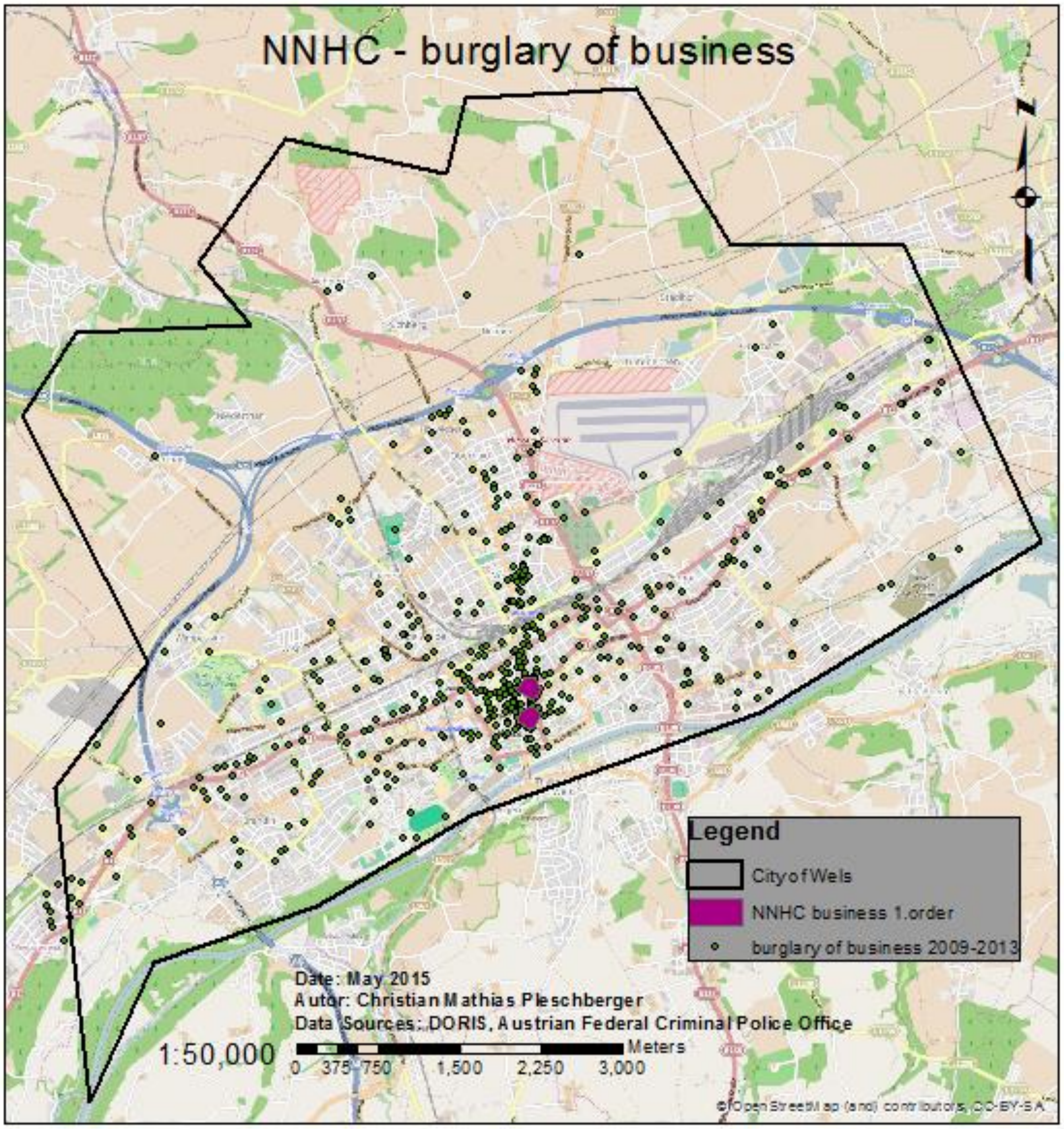

Figure 20 - Results of NNHC (burglary of business)

As seen in Figure 20 the polygons (first and second order) show the calculated hot spots for the crime event burglary of business. The hot spots are located in the south of the study area.

4.2. Results of the Near Repeat Analysis

The final results of the Near Repeat Calculation are displayed in ArcGIS and can be seen in the figures 21 – 25. The indicator for the initial crime event is the originator blue points. The red points are the near repeat points that are crime events which happened after the initial event in the spatial neighborhood of 140 meters and in the temporal proximity (30 days) after the originator incident. These points are displayed in red that means the results show where a near repeat crime happened within 30 days and proximity 140 meters. In Figure 21 the results of the Near Repeat Calculator for pickpocketing is shown.

Near repeat originators					
Data Name	**2009**	**2010**	**2011**	**2012**	**2013**
Pickpocketing	134	190	122	120	157
Property damage	657	628	742	677	590
Burglary in houses	6	8	48	28	14
Burglary in apartments	19	15	24	14	4
Burglary in business	183	109	123	107	52

Table 10 – number of near repeat originators per year

The Table 10 shows the counts of the near repeat originator points per year and crime event. The highest rate of near repeat originator points are for pickpocketing in the year 2010 (190), for property damage in the year 2011 (742), for burglary in houses in the year 2011 (48), for burglary in apartments in the year 2011 (24) and for burglary in business in the year 2009 (183).

Near repeat					
Data Name	**2009**	**2010**	**2011**	**2012**	**2013**
Pickpocketing	112	187	124	114	180
Property damage	595	629	745	675	658
Burglary in houses	-	5	16	11	3
Burglary in apartments	21	15	21	15	6
Burglary in business	166	96	127	124	75

Table 11 – number of near repeat points per year

The Table 11 shows the counts of the near repeat points per year and crime event. The highest rate of near repeat points are for pickpocketing in the year 2010 (187), for property damage in the year 2011 (745), for burglary in houses in the year 2011 (16), for burglary in apartments in the year 2011 (21) and for burglary in business in the year 2009 (166).

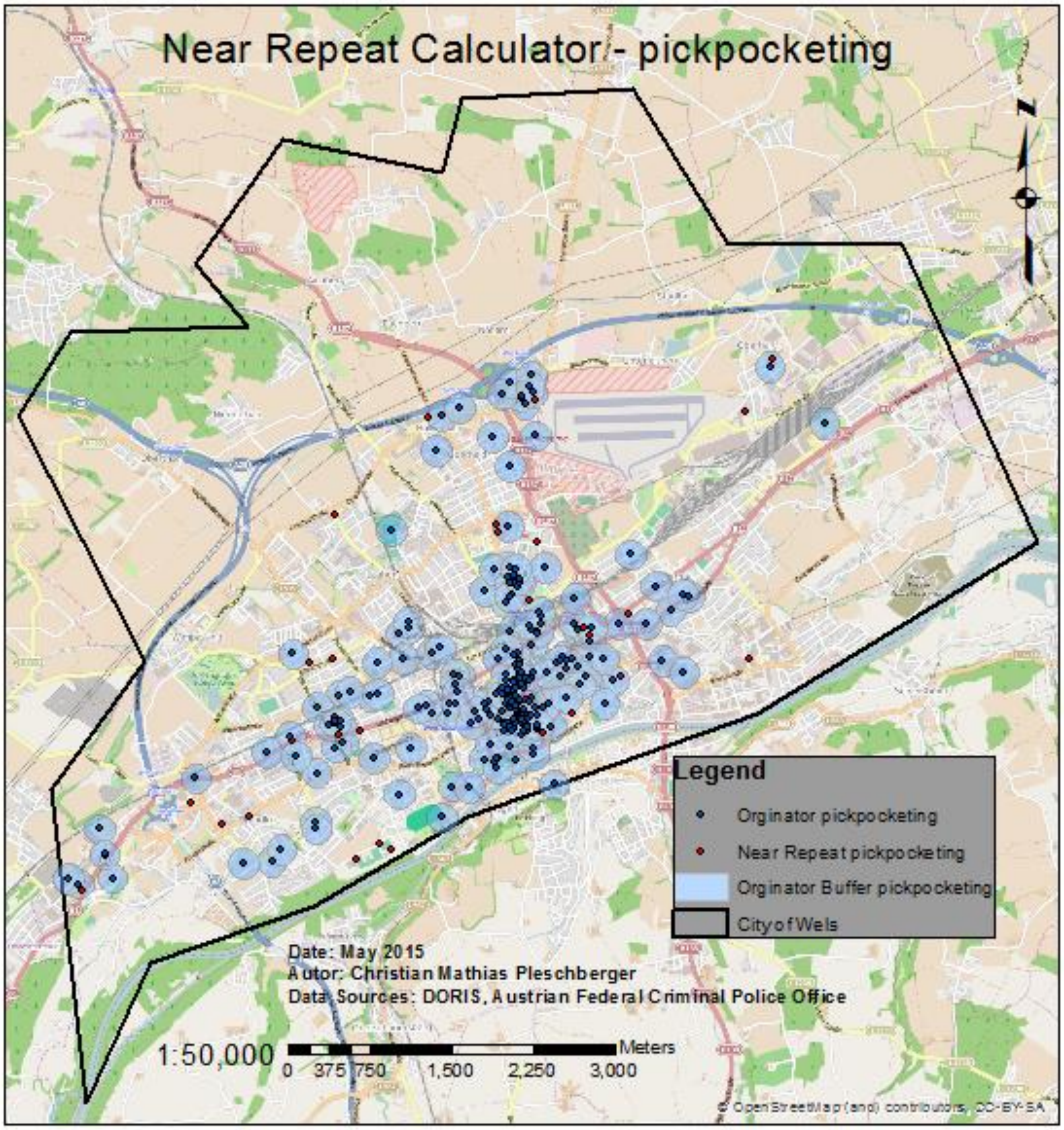

Figure 21 – Results of the Near Repeat Calculator (pickpocketing)

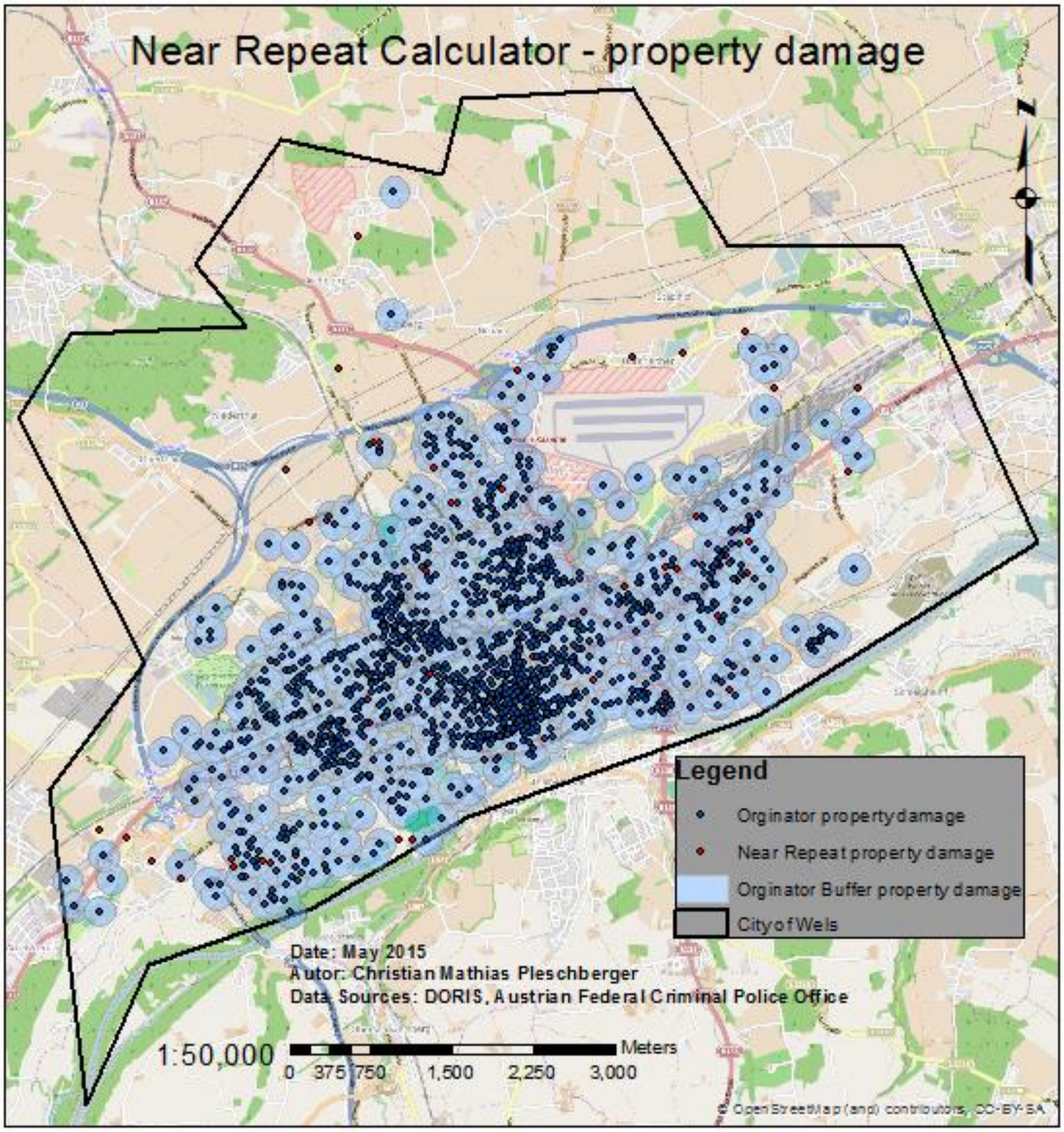

Figure 22 - Results of the Near Repeat Calculator (property damage)

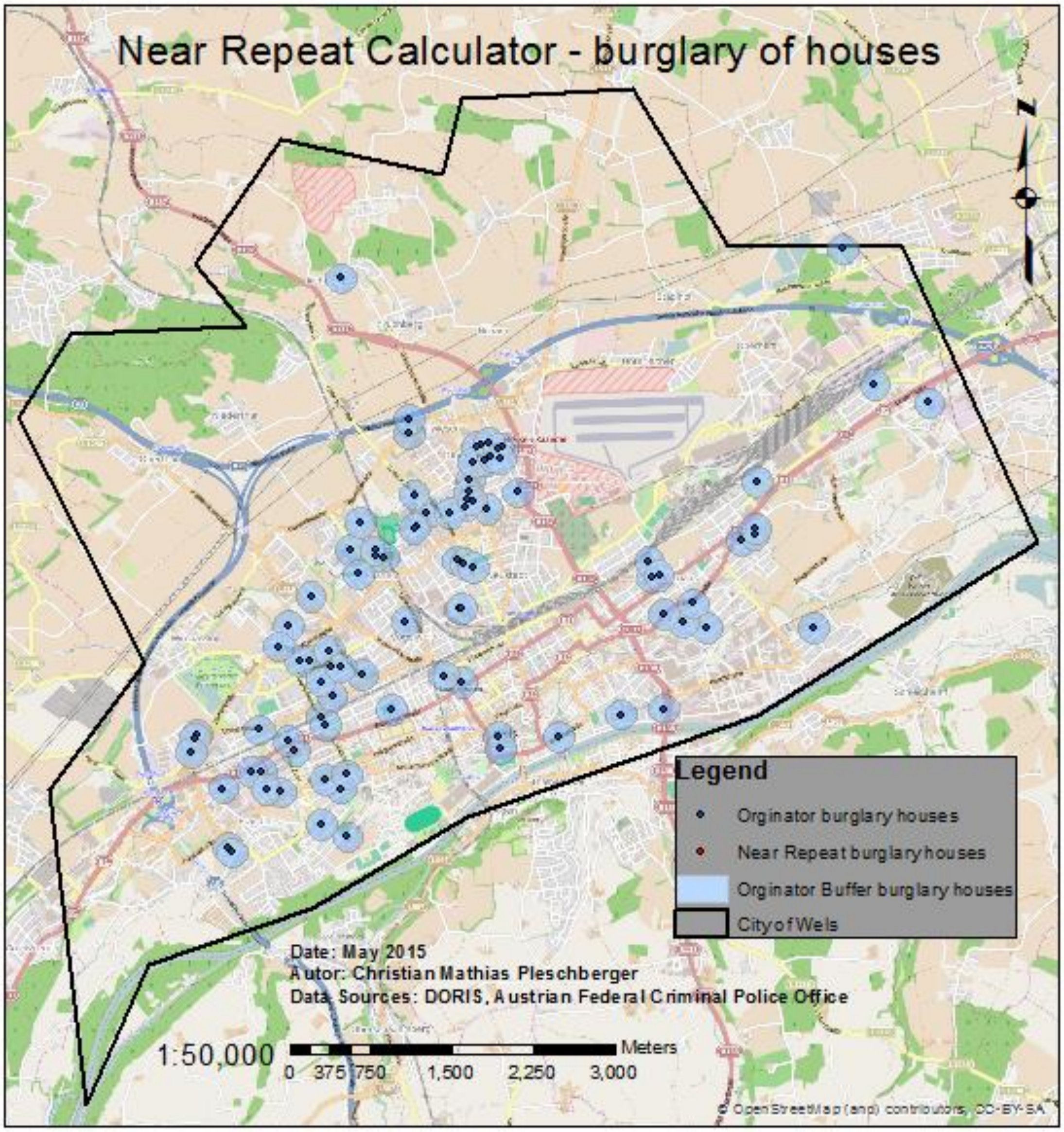

Figure 23 - Results of the Near Repeat Calculator (burglary of houses)

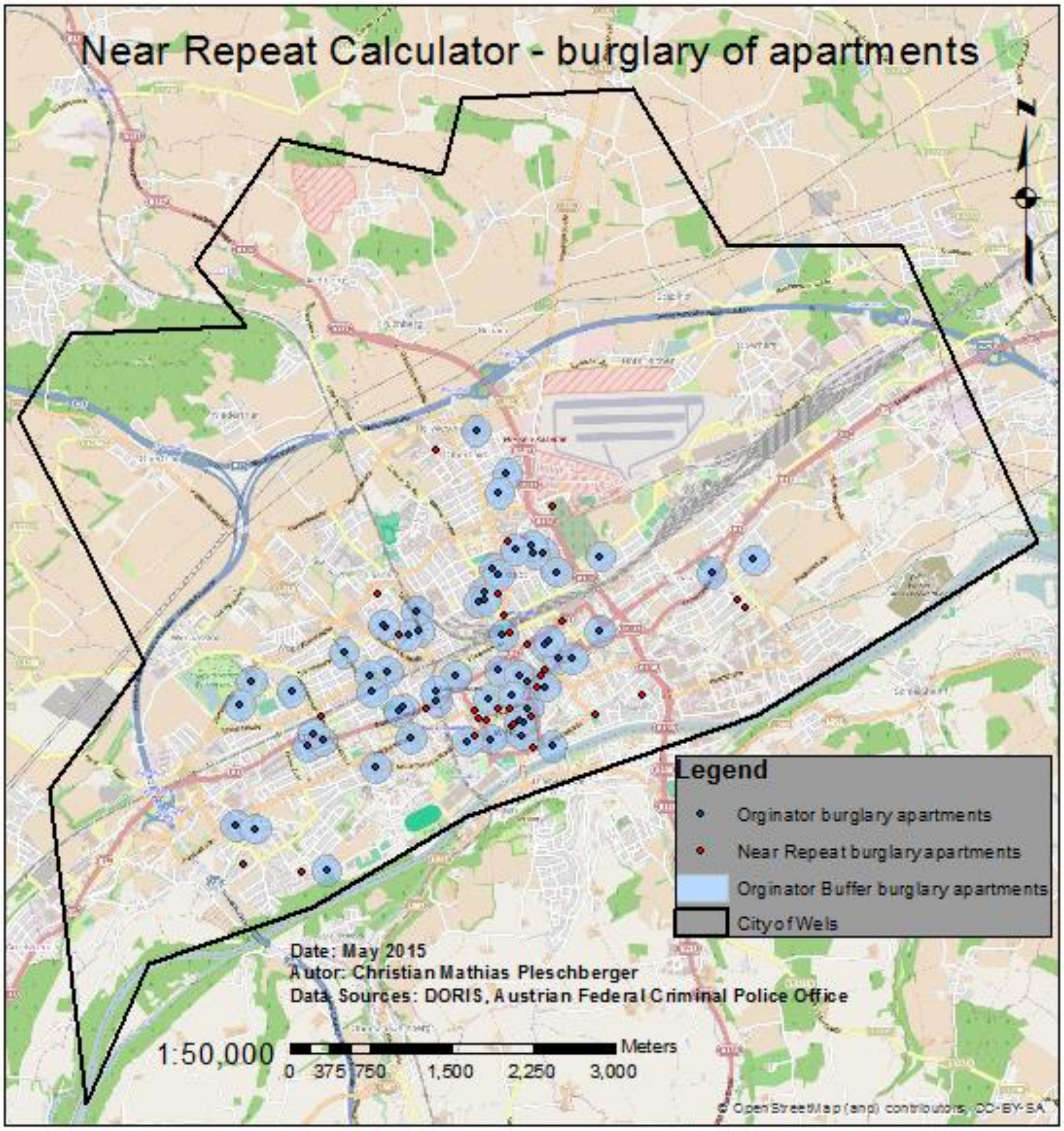

Figure 24 - Results of the Near Repeat Calculator (burglary of apartments)

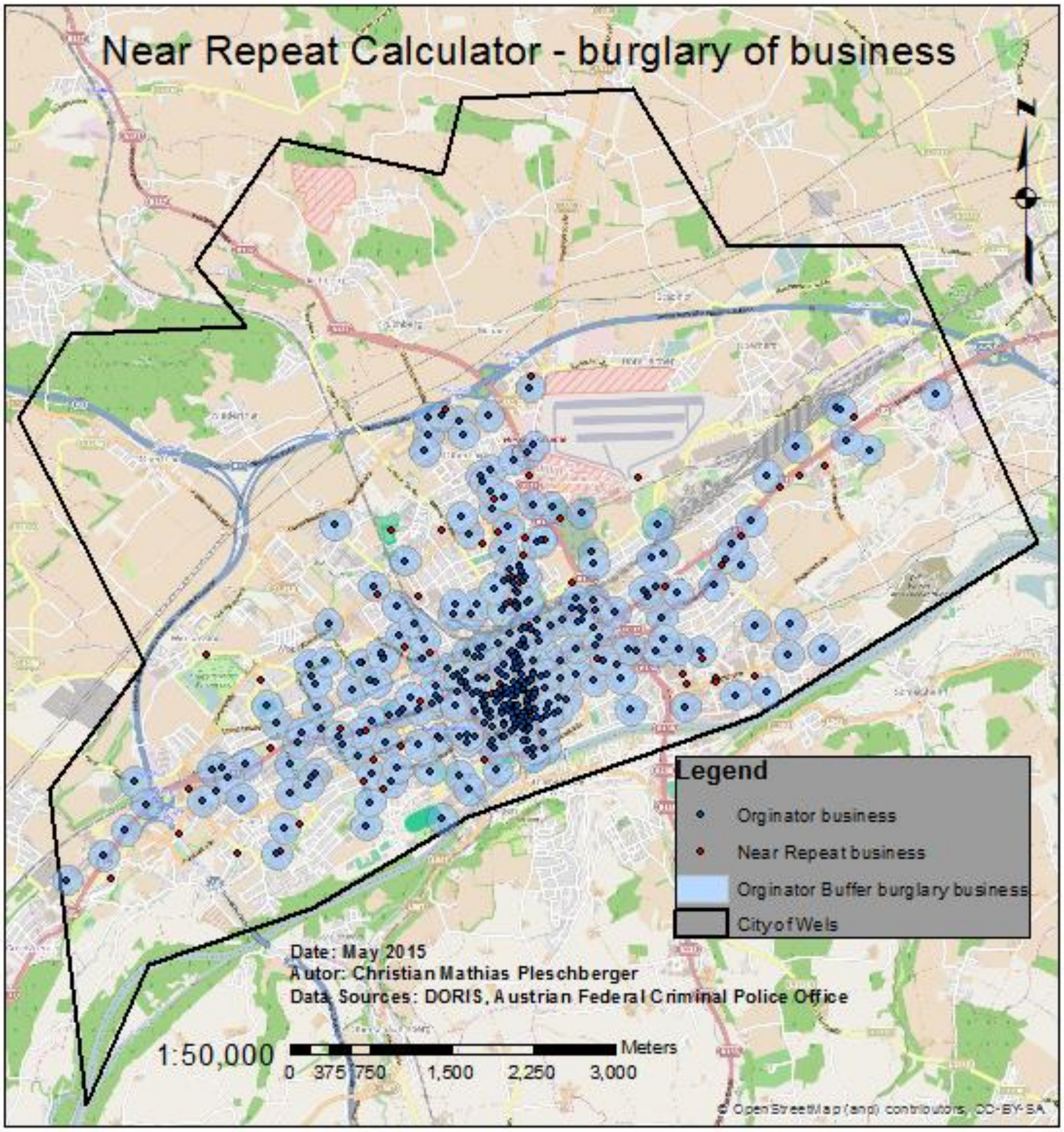

Figure 25 - Results of the Near Repeat Calculator (burglary of business)

4.2.1. Interpretation of the Near Repeat Analysis

After a criminal event happens, there is an over-representation of events in this local area in a certain amount of time. As a result there may be a crime prevention value. Within 1 to 140 meters near repeats are overrepresented for up to 30 days. The statistical specifics for burglary of business are presented in the following tables. The red color indicates that the statistical probability is at the best possible level for the chosen number of iterations (p=0.001). The dark red color indicates that the statistical probability is at least p=0.05 or better. The table shows that the chance of another incident is about 76 percent greater.

Table 12 – Statistical specifics burglary of business

	0 to 30 days	31 to 60 days	61 to 90 days
Same location	8,17	1,62	1,71
1 to 140 meters	1,76	0,94	1,01
141 to 280 meters	1,22	0,90	1,03
281 to 420 meters	1,12	0,99	1,15
421 to 560 meters	1,18	0,91	1,00
561 to 700 meters	0,96	0,94	1,13
701 to 840 meters	1,00	1,04	1,12

The next table shows that the chance of another crime event (burglary of houses) is about 528 percent greater than if there were no repeat criminal pattern.

Table 13 – Statistical specifics of burglary of houses

	0 to 30 days	31 to 60 days	61 to 90 days
Same location	6,28	2,56	0,00
1 to 140 meters	1,47	1,02	1,39
141 to 280 meters	1,13	0,95	1,08
281 to 420 meters	1,29	1,26	1,21
421 to 560 meters	1,08	1,29	1,20
561 to 700 meters	1,17	1,32	0,96

Table 12 shows that the chance of another crime event (property damage) is about 215 percent greater than if there were no repeat criminal pattern.

Table 14 – Statistical specifics of property damage

	0 to 30 days	31 to 60 days	61 to 90 days
Same location	**3,15**	**1,47**	**1,33**
1 to 140 meters	**1,12**	0,98	0,91
141 to 280 meters	**1,05**	0,98	0,98
281 to 420 meters	1,01	1,00	0,97
421 to 560 meters	0,99	0,99	0,99
561 to 700 meters	0,98	**1,04**	1,01

The chance of another crime event (pickpocketing) is about 87 percent greater than if there were no repeat criminal pattern.

Table 15 – Statistical specifics of pickpocketing

	0 to 30 days	31 to 60 days	61 to 90 days
Same location	**1,87**	**1,51**	**1,19**
1 to 140 meters	1,04	0,90	0,91
141 to 280 meters	0,98	0,96	0,97
281 to 420 meters	0,95	0,97	1,00
421 to 560 meters	**1,11**	1,00	1,05
561 to 700 meters	1,03	1,05	1,01

The chance of another crime event (burglary of apartments) is about 1356 percent greater than if there were no repeat criminal pattern.

Table 16 – Statistical specifies of burglary of apartments

	0 to 30 days	31 to 60 days	61 to 90 days
Same location	**14,56**	0,25	1,18
1 to 140 meters	1,04	1,28	**1,77**
141 to 280 meters	0,80	1,08	**1,51**
281 to 420 meters	1,23	0,94	1,25
421 to 560 meters	1,12	0,84	0,72
561 to 700 meters	0,87	0,91	**1,33**

4.3. Results of the Risk Terrain Modeling

To interpret the results easier, the legend was defined by the autor. Low risk are values < the mean, medium risk is defined as > mean and < one standard deviation, high risk > than one standard deviation and < than two standard deviation. And all values more than two standard deviations are defined as highest risk areas. The Figures 26 – 30 show the result of the RTM Analysis.

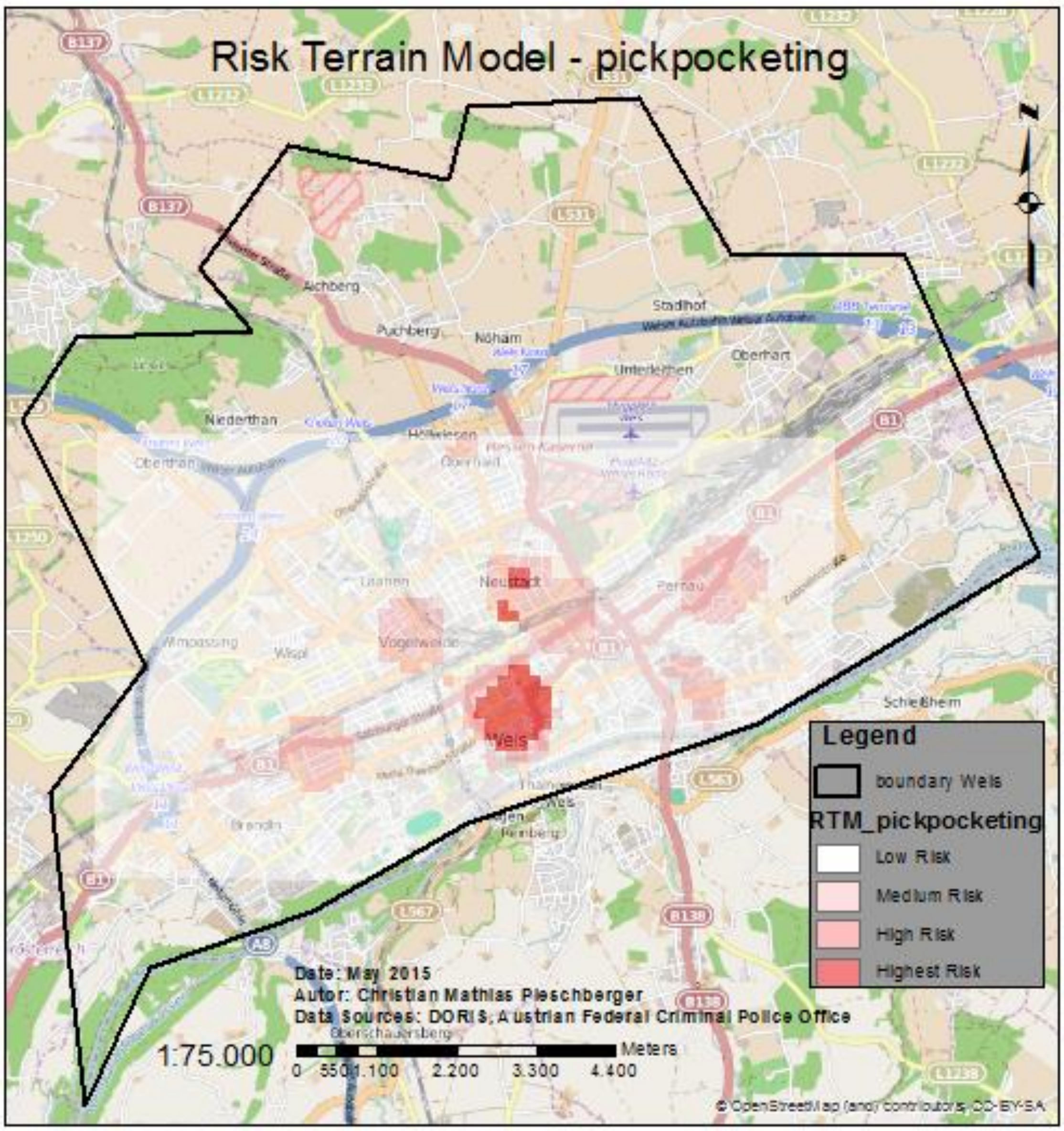

Figure 26 – Risk Terrain Model of pickpocketing

The map in Figure 26 shows the results of the risk terrain modelling with the generated low risk until highest risk areas, generated from the four risk factors

(Table 17). As seen, the highest risk areas are located in the south of the study area.

These 7 risk factors generated 42 variables that were tested for significance. This testing process began by building an elastic net penalized regression model assuming a Poisson distribution of events. Through cross validation, this process selected 8 variables as potentially useful. These variables were then utilized in a bidirectional step-wise regression process starting with a null model to build an optimal model by optimizing the Bayesian Information Criteria (BIC). This score balances how well the model fits the data against the complexity of the model. The stepwise regression process was conducted for both Poisson and Negative Binomial distributions with the best BIC score used to select between the distributions.

The RTMDx Utility determined that the best risk terrain model as shown in Table 17 was a Negative Binomial type II model with 4 risk factors and a score of 1075.2. The model also includes an intercept term that represents the background rate of events and an intercept term that represents overdispersion of the event counts:

Type	Name	Operationalization	Spatial Influence	Coefficient	Relative Risk Value
Rate	Bankomaten Wels	Proximity	420	19.558	70.696
Rate	NightclubsBars Wels	Density	420	13.278	37.727
Rate	Postfilialen Wels	Proximity	280	11.860	32.740
Rate	Geschaefte Wels	Density	140	10.542	28.697
Rate	Intercept	--	--	-44.745	--
Overdispersion	Intercept	--	--	11.091	--

Table 17 – „Best“ Model Specification for pickpocketing with the RTMDx Utility

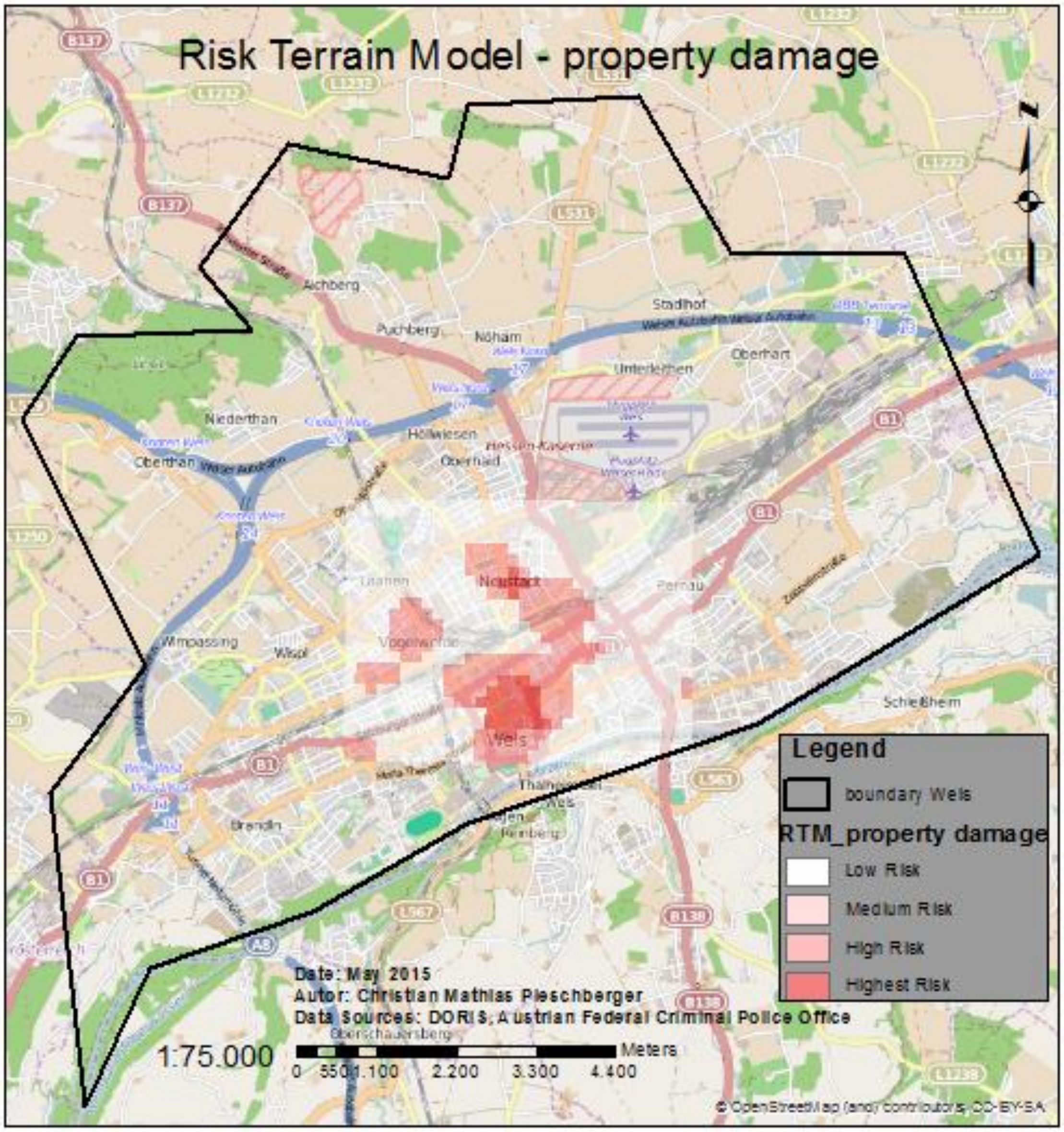

Figure 27 – Risk Terrain Model of property damage

The map in Figure 27 shows the results of the risk terrain modelling with the generated low risk until highest risk areas, generated from the four risk factors (Table 18). As seen the highest risk areas are located in the south of the study area.

These 7 risk factors generated 42 variables that were tested for significance. This testing process began by building an elastic net penalized regression model assuming a Poisson distribution of events. Through cross validation, this process selected 13 variables as potentially useful. These variables were then utilized in a bidirectional step-wise regression process starting with a null model to build an optimal model by optimizing the Bayesian Information Criteria (BIC). This score balances how well the model fits the data against the complexity of the model. The stepwise regression process was conducted for both Poisson and Negative Binomial distributions with the best BIC score used to select between the distributions.

The RTMDx Utility determined that the best risk terrain model as seen in Table 18 with "4" risk factors and a BIC score of 3000. The model also includes an intercept term that represents the background rate of events and an intercept term that represents overdispersion of the event counts:

Type	Name	Operationalization	Spatial Influence	Coefficient	Relative Risk Value
Rate	Banken Wels	Proximity	420	16.878	54.076
Rate	Schulen Wels	Density	420	0.9578	26.060
Rate	NightclubsBars Wels	Density	280	0.7578	21.336
Rate	Postfilialen Wels	Density	420	0.6330	18.833
Rate	Intercept	--	--	-30.124	--
Overdispersion	Intercept	--	--	0.4720	--

Table 18 – „Best" Model Specification for property damage with the RTMDx Utility

For the analysis of burglary of houses there was no result, because there are no criminogenic factors which correlates with the crime events. No risk factors could be found which significantly correlated with the outcome event data. Also the calculation with all available risk factors was not successful (Figure 28).

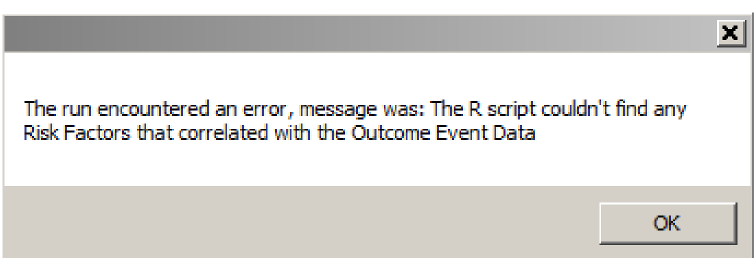

Figure 28- Error report for RTM analysis for burglary of houses

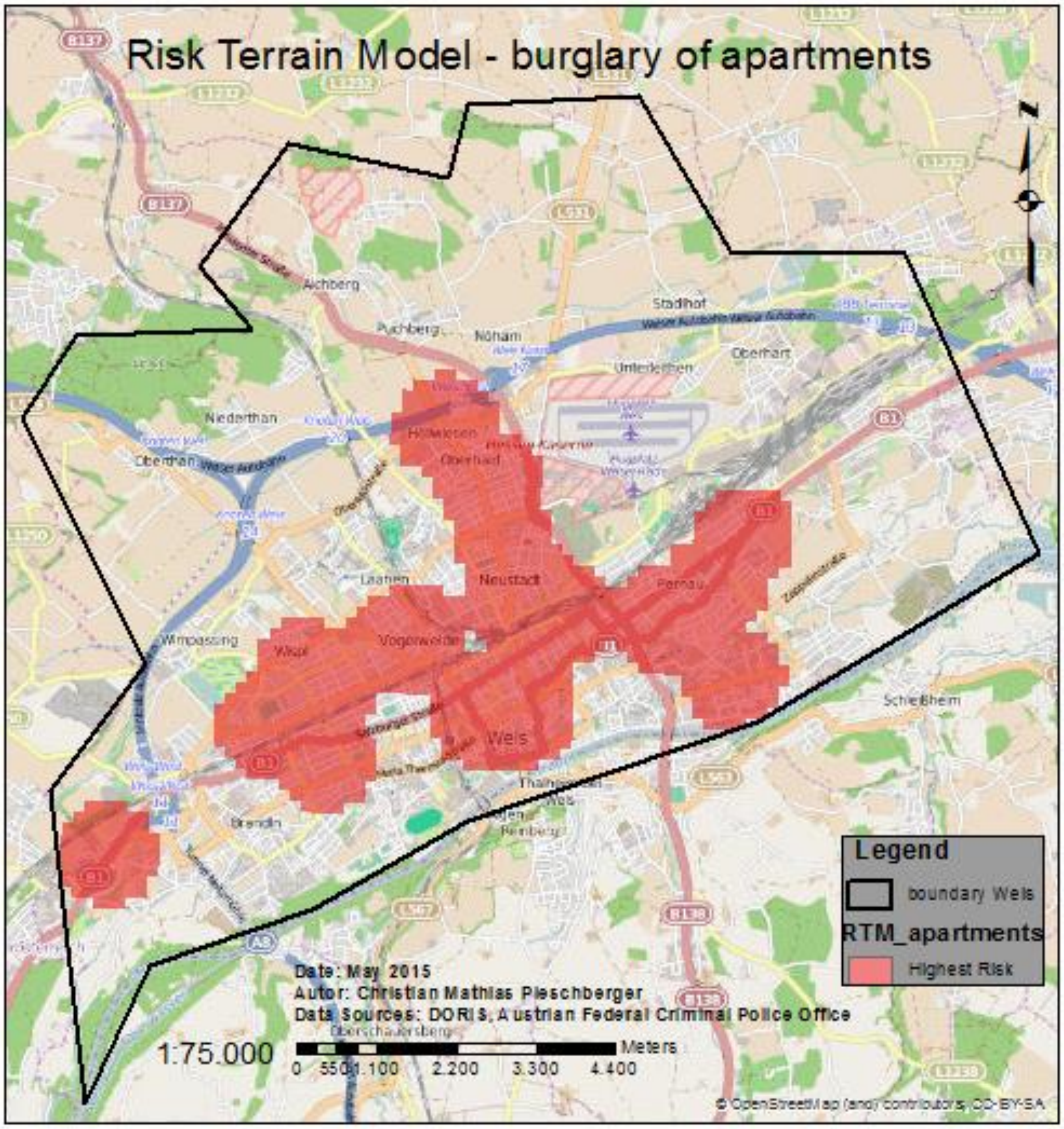

Figure 29 – Risk Terrain Model of burglary of apartments

The map in Figure 29 shows the results of the risk terrain modelling with the generated highest risk areas, influenced by one risk factor (Table 19).

These 7 risk factors generated 42 variables that were tested for significance. This testing process began by building an elastic net penalized regression model assuming a Poisson distribution of events. Through cross validation, this process selected 3 variables as potentially useful. These variables were then utilized in a bidirectional step-wise regression process starting with a null model to build an optimal model by optimizing the Bayesian Information Criteria (BIC). This score balances how well the model fits the data against the complexity of the model. The stepwise regression process was conducted for both Poisson and Negative Binomial distributions with the best BIC score used to select between the distributions.

The RTMDx Utility determined that the best risk terrain model as seen in Table 19 was a Negative Binomial type II model with 1 risk factor and a BIC score of 300.89. The model also includes an intercept term that represents the background rate of events and an intercept term that represents overdispersion of the event counts.

Table 19 - Best‟ Model Specification for burglary of apartments with the RTMDx Utility

Type	Name	Operationalization	Spatial Influence	Coefficient	Relative Risk Value
Rate	Banken Wels	Proximity	420	23.288	102.656
Rate	Intercept	--	--	-61.832	--
Overdispersion	Intercept	--	--	-10.008	--

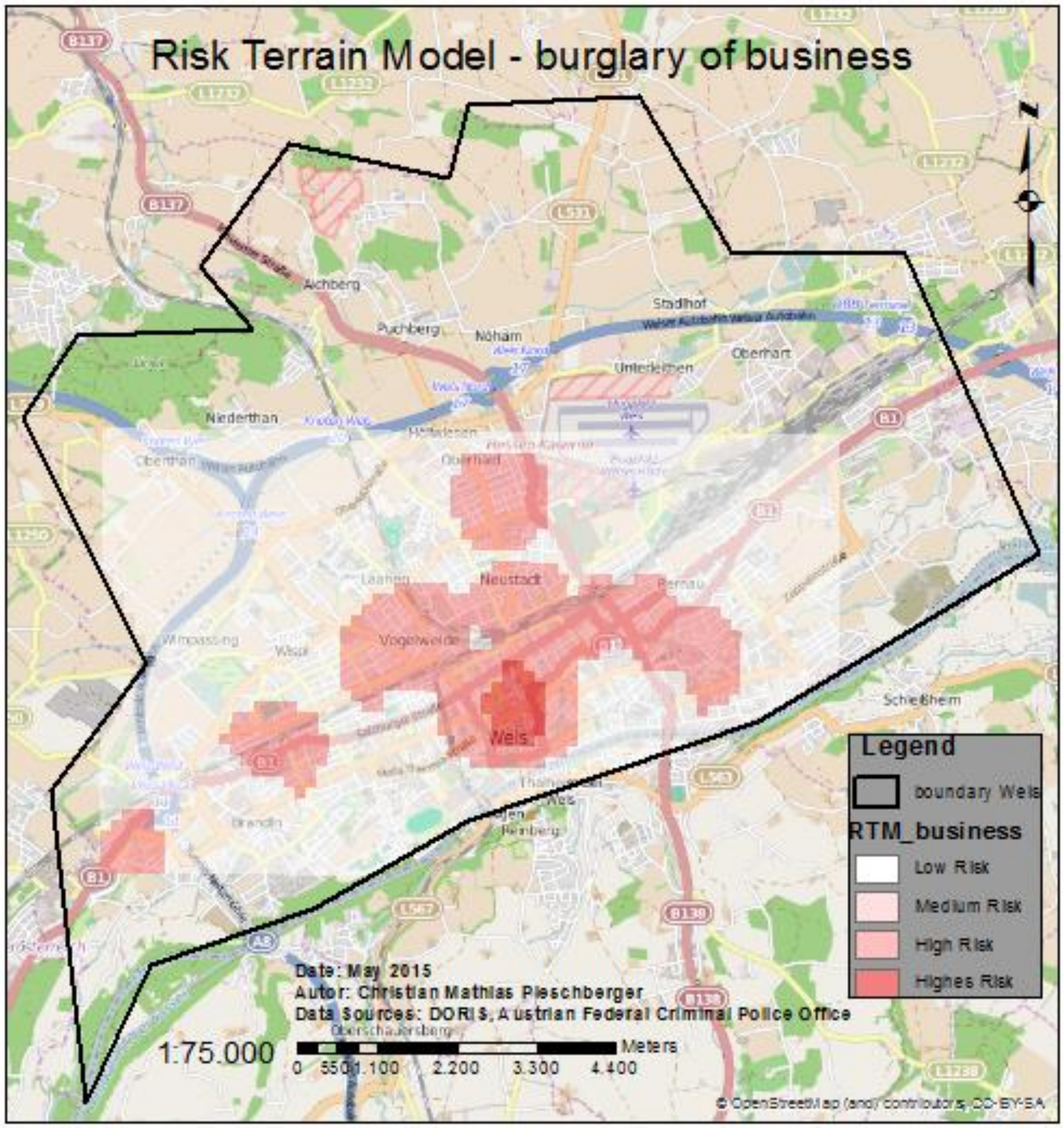

Figure 30 - Risk Terrain Model of burglary of business

The map in Figure 30 shows the results of the risk terrain modelling with the generated highest risk areas, influenced by three risk factors (Table 20).

These 7 risk factors generated 42 variables that were tested for significance. This testing process began by building an elastic net penalized regression model assuming a Poisson distribution of events. Through cross validation, this process selected 10 variables as potentially useful. These variables were then utilized in a bidirectional step-wise regression process starting with a null model to build an optimal model by optimizing the Bayesian Information Criteria (BIC). This score balances how well the model fits the data against the complexity of the model. The stepwise regression process was conducted for both Poisson and Negative Binomial distributions with the best BIC score used to select between the distributions.

The RTMDx Utility determined that the best risk terrain model was a Negative Binomial type II model with 3 risk factors and a BIC score of 990.87. The model also includes an intercept term that represents the background rate of events and an intercept term that represents overdispersion of the event counts:

Table 20 – Best Model Specification for burglary of business with the RTMDx Utility

Type	Name	Operationalization	Spatial Influence	Coefficient	Relative Risk Value
Rate	Geschaefte Wels	Density	280	17.135	55.483
Rate	Banken Wels	Proximity	420	13.952	40.358
Rate	NightclubsBars Wels	Proximity	420	10.573	28.786
Rate	Intercept	--	--	-47.222	--
Overdispersion	Intercept	--	--	-0.5753	--

4.4. Evaluation of the spatial hot spot methods and the RTM with the PAI and the Hit Rate

The individual parts of the formula had to be found out in ArcGIS. "n" is the number of crime incidents from 2014 that fall into the predicted hot spots from 2009-2013. First, a layer with the right hot spot category had to be calculated with "Selection/ Create Layer from selected features".

For the spatial fuzzy mode, a circle was drawn around the point corresponding to the radius of the nearest neighbor analysis. After that was determined with „Select by Location" the number of points (incidents 2014) fall into this circle.
For Kernel Density Estimation the Z-scores were divided into 5 classes with equal interval, so that every class contains 20% of the data. From the highest class the layer for the hot spots was built.

For the nearest neighbor hierarchical clustering method the convex hulls as polygons exist and they were used as the hot spot category. For City of Wels the clusters of first and second order were merged to gain the total area of hot spots. The layer with the selected hot spot categories from the different methods and the pointlayer from the 2014 crime incidents were overlapped and cut with the tool "Intersect". "N" is the total number of incidents for 2014 and can be found in the pointlayer for city of Wels. For the areas of the hot spots a new column was added in the shapefile and it was calculated with the tools "Calculate Field" (!shape.area!) and the sum was gained with the tool "Summary Statistics". For the entire area of the city of Wels was taken from the boundary-shapefile (the sum at statistics). The raster cells of the RTM analysis was converted into polygons and the same steps as described in this chapter were done. For the calculation and evaluation only the "Highest risk" cells of the RTM output were used. Then the PAI was calculated with Microsoft Excel.

The results of the evaluation of the different hot spot methods are shown in the next figures for the different crime types. Shown are the crime incidents that happened in 2014 and the calculated hot spots from the crime data from 2009 – 2013 and the RTM analysis from 2013.

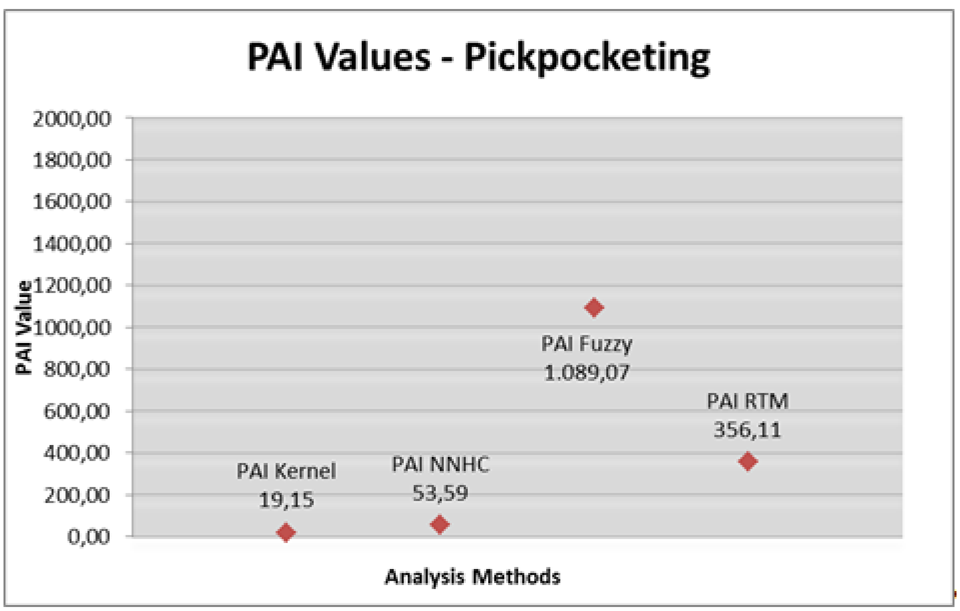

Figure 31 - PAI Values for pickpocketing

In Figure 31 the highest PAI calculated with fuzzy mode is 1.089,07. The area of hot spots for the kernel density is 0,184 km², for the NNHC 0,139 km², for the fuzzy mode 0,00126 km² and for the RTM 0,028 km². Compared to the study area of

46,33 km² quite small. The incidents which are in these areas are for the kernel density 18 events, for the NNHC 38 points, for the fuzzy mode 7 points and for the RTM 51 points.

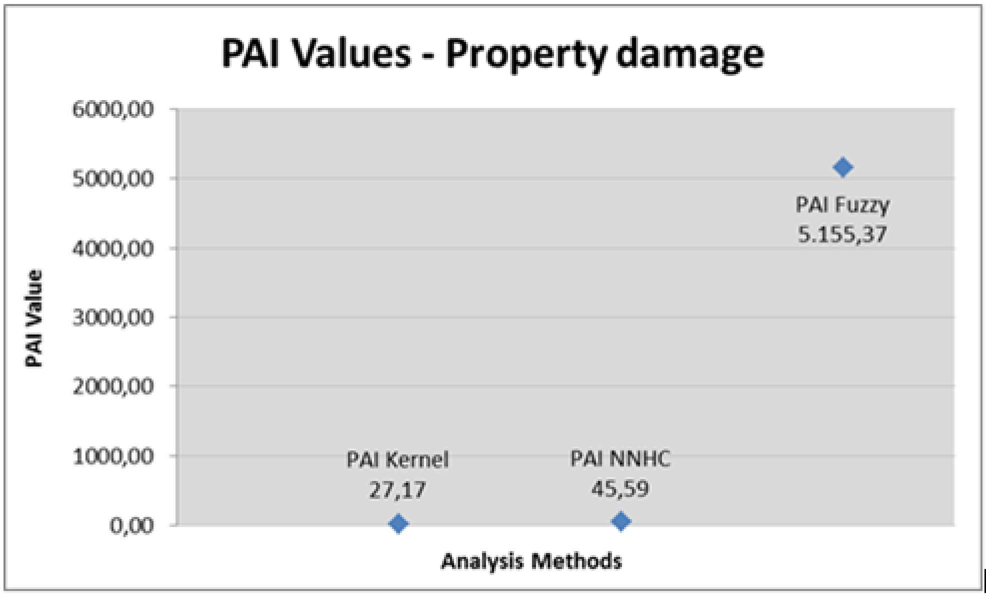

Figure 32 - PAI Values for property damage

In Figure 32 the highest PAI calculated with fuzzy mode is 5.155,37. The area of hot spots for the kernel density is 0,276 km², for the NNHC 0,0771 km², for the fuzzy mode 0,00054 km² and for the RTM 0,0933 km². Compared to the study area of 46,33 km² quite small. The incidents which are in these areas are for the kernel density 108 events, for the NNHC 18 points, for the fuzzy mode 14 points and for the RTM no points are in the predicted area.

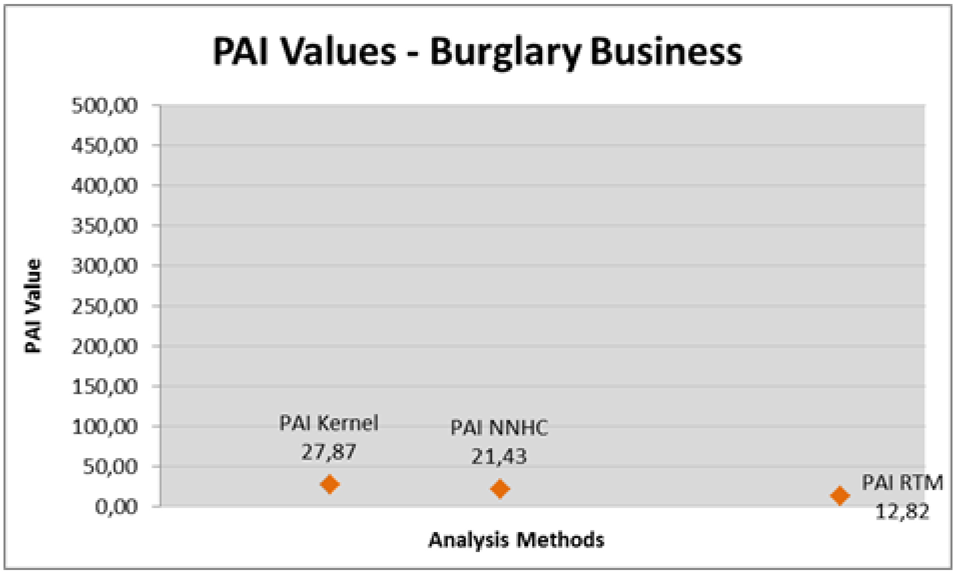

Figure 33 - PAI Values for burglary of houses

In Figure 33 the highest PAI calculated with the Kernel Destiny is 27,87. The area of hot spots for the kernel density is 0,230 km², for the NNHC 0,0547 km², for the fuzzy mode 0,00302 km² and for the RTM 0,351 km². Compared to the study area of 46,33 km² quite small. The incidents which are in these areas are for the kernel density 21 events, for the NNHC 6 points, for the fuzzy mode no points and for the RTM 23 points.

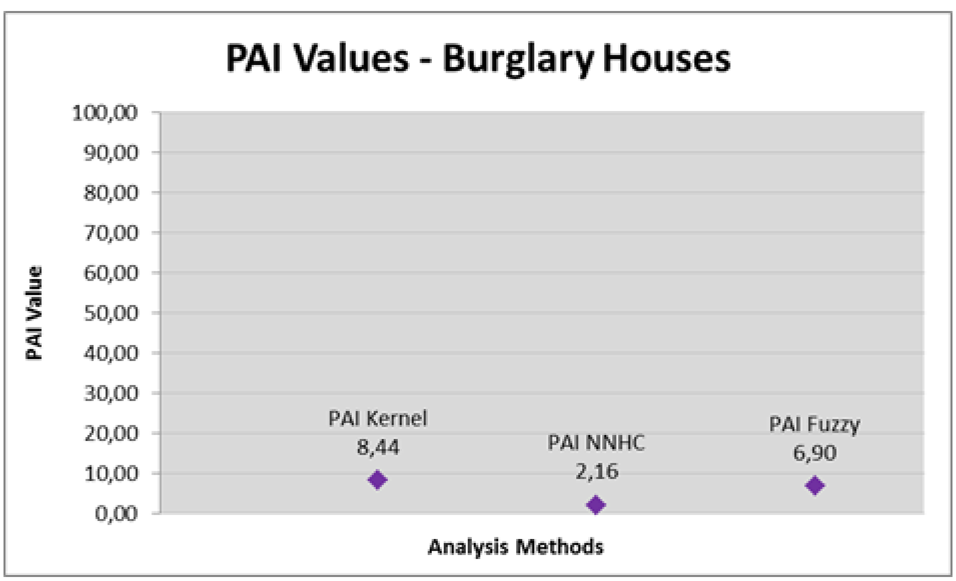

Figure 34 - PAI Values for burglary of houses

In Figure 34 the highest PAI calculated with the Kernel Destiny is 8,44. The area of hot spots for the kernel density is 0,257 km², for the NNHC 0,181 km², for the fuzzy mode 0,284 km² and no result for the RTM. Compared to the study area of 46,33 km² quite small. The incidents which are in these areas are for the kernel density 3 events, for the NNHC 2 points, for the fuzzy mode 1 point and no result for the RTM.

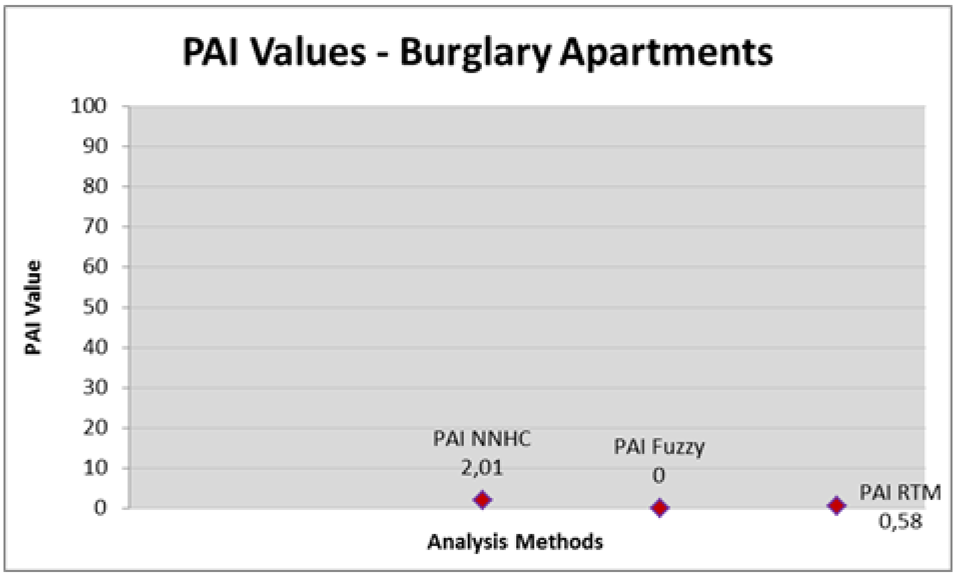

Figure 35 - PAI Values for burglary of apartments

In Figure 35 the highest PAI calculated with the NNHC is 2,01. The area of hot spots for the kernel density is 0,091 km², for the NNHC 0,680 km², for the fuzzy mode 0,243 km² and for the RTM 0,980 km². Compared to the study area of 46,33 km² quite small. The incidents which are in these areas are for the kernel density zero events, for the NNHC 7 points, for the fuzzy mode zero points and for the RTM 29 points.

5. Discussion

This chapter describes the critical reflection of the work. Subsequently it describes whether the methods chosen are suitable for forecasting crime in city of Wels and whether the expected results of scientific work have been achieved.

5.1. Critical reflection

How good the analyses are working depends on the data source. The quality of the data source of the BKA (Bundeskriminalamt) cannot be influenced. The self-captured data are influenced by the researcher. The better the data research, the higher the quality of data. The quality of results depends on the choice of parameters. Analyses done with CrimeStat and New Repeat Calculator are simple applicable and give approximately good results. As quite difficult to operate are the analyses with the RTM, because the RTM highly depends on the self-captured criminogenic factors. It also cannot be valued how accurate these self-captured data really are, because they based on internet research. Another challenge was to bring the self-captured data together with the specifications of RTM.

5.2. Are the applied methods appropriate?

On the whole, the used and applied methods for crime analysis of the city of Wels are applicable. The least amount of effort has been the analyses with Hot Spot Methods. The application of CrimeStat method with using the program description is very easily and quickly to carry out. The Near Repeat Calculator affords a greater challenge for non-users because the data must be processed so that they are readable by the program. Also the results of the Near Repeat Calculator have to be shown with ArcGIS and interpreted correctly. The biggest challenge and the greatest effort of data preparation through to the way of the presentation of the results is the method with the RTM. To get a map with the RTM results many individual partial results are needed, which are brought together with the help of ArcGIS to a single card. The program produces results which must be implemented with the help of GIS software in order to obtain correct results. In summary, all three methods for crime analysis are applicable. However, depending on whether the analyses are carried out by an expert or layman.

5.3. Have the expected results and goals of the thesis been reached?

The expected results and goals of this research thesis were reached. The analysis methods hot spot, Near Repeat Calculator and RTM were applied for the five crime events pickpocketing, property damage, burglary of business, burglary of houses and burglary of apartments. Based on evaluation results crime prediction analysis for the year 2014 was done. During the research project following findings were carried out: The easiest way to analyze crime events is the hot spot analysis (Kernel Density Estimation, NNHC and the Spatial Fuzzy Mode). The advantages of the hot spot analysis are the simple calculation in CrimeStat and the uncomplicated interpretation of the results. The disadvantages of the near repeat calculator and the RTMDx are the numerous steps to find out the results and the complicated usage for non-experts. In summary all methods are usable for crime analysis and are supplying acceptable results.

6. Conclusions and future work

This chapter provides a summary of the scientific work and, subsequently, possible analysis which can be implemented in future research.

6.1. Summary

This research project shows the predictions for five different crime events, including pickpocketing, property damage, burglary of business, burglary of houses and burglary of apartments for the city of Wels. For this analysis three methods were used and applied. The aim of this project was to compare and evaluate three main groups of crime analysis methods in order to identify the method that makes the most accurate predictions. The practical application of these methods was tested, advantages and disadvantages are shown.

6.2. Conclusions and Future work

Assumed can be said that the all applied methods for crime prediction can be used and done. For future work based on a new project or next thesis the analyses could be extended. The analyses could be itemized for example in seasonal data or monthly division. To get more quality in data source it would be necessary to work together with public institutions. Especially for the crime analyses police should get data source from government or district centers. With this research thesis it is shown that the different evaluation methods could be applied and that the results differ regarding the method. It was important to show the different analyses for crime factors and to develop the most important base map layers and predicted areas. For the user it allows an easier and visualized interpretation. In particular the applied method of the RTM showed that there a differences between the accuracy of prediction. Furthermore, this work should provide future projects to support decision-making and appropriate preventive measures to reduce crime in the Austrian cities.

References

Anders, K.H. (2004): Parameterfreies hierarchisches Graph-Clustering Verfahren zur Interpretation raumbezogener Daten.
http://www.ifp.uni-stuttgart.de/publications/dissertationen/AndersDiss.pdf
Last accessed 29/04/2015

Anselin, Luc (2014): An Introduction to Point Pattern Analysis using CrimeStat.
https://geodacenter.asu.edu/system/files/points.pdf
Last accessed 29/04/2015

Azavea, 2015, Clients
http://www.azavea.com/clients/phicams-crime-analysis-and-mapping/
Last accessed 15/04/2015

Bundeskriminalamt "Die Entwicklung der Kriminalität in Österreich 2004 bis 2013"
http://www.bmi.gv.at/cms/BK/publikationen/krim_statistik/2013/2732014_KrimStat_2013_Broschuere.pdf
Last accessed 25/04/2015

Caplan, J.M., Kennedy, L.W. 2011 Risk Terrain Modeling Compendium
http://www.rutgerscps.org/rtm/RiskTerrainModelingCompendium_CaplanKennedy2011.pdf
Last accessed 25/04/2015

Caplan, J. M., Kennedy, L. W., 2010. Risk Terrain Modeling Manual.

Chainey S., Ratcliffe J., 2005, GIS and Crime Mapping, Wiley & Sons, Ltd.; West Sussex PO198SQ, England

Chainey, S., Tompson, L., and Uhlig, S. 2008. The Utility of Hotspot Mapping for Predicting Spatial Patterns of Crime [online]. Security Journal, 21. Available from: http://discovery.ucl.ac.uk/112873/1/PREPRINT_-Chainey%2C_Tompson_%26_Uhlig_2008.pdf Last accessed 25/04/2015

Dalmatiner H., 2014, Comparison of selected crime prediction methods for an U.S. and an Austrian urban area

Duke University Libraries, 2015, What is ArcGIS [online] http://guides.library.duke.edu/content.php?pid=22371&sid=159904
Last accessed 25/04/2015

Eck, J., Chainey, S., Cameron, J. G., Leitner, M., and Wilson, R. E. 2005. Mapping Crime: Understanding hot spots. U.S. Department of Justice, National Institute of Justice, Special Report, August 2005.
https://www.ncjrs.gov/pdffiles1/nij/209393.pdf
Last accessed 25/04/2015

Grubesic, Tony H. and Alan T. Murray. (2001). Detecting Hot Spots Using Cluster Analysis and GIS. *Proceedings from the Fifth Annual International Crime Mapping Research Conference.* Dallas, TX.
http://www.tonygrubesic.net/hot_spot.pdf
Last accessed 01/05/2015

Jusline 2015. StGB [online]. Available from:
http://www.jusline.at/Strafgesetzbuch_(StGB).html
Last accessed 03/05/2015

Kampitsch, K., Leitner, M., Schabauer, H. 2008
http://www.agit.at/php_files/myAGIT/papers/2008/6834.pdf
Last accessed 25/04/2015

Kennedy L., Caplan J., Piza E., 2011; Hotspot Mapping, Near Repeat Analysis, and Risk Terrain Modeling - Joint Operational Utility; http://www.ucl.ac.uk/secret/secret-student-seminars-11/hotspot-mapping
Last accessed 25/04/2015

Kocher M., 2014, Forecasting Crime Events Applying Risk Terrain Modeling

Leitner, M., Helbich, M. (2009), Auswirkungen der Hurrikans Katrina und Rita auf raumzeitliche Kriminalitätscluster in Houston, TX. Ein Scan Statistik Ansatz
http://koenigstuhl.geog.uni-heidelberg.de/publications/2010/Helbich/Helbich_Leitner_AGIT2010.pdf
Last accessed 25/04/2015

IfmPt Institut für musterbasierte Prognosetechnik, 2015; Near Repeat Prediction Method – Predictive Policing made in Germany [online]
http://www.ifmpt.de/
Last accessed 28/04/2015

Ned Levine, CrimeStat IV: A Spatial Statistics Program for the Analysis of Crime Incident Locations (version 4.02). Ned Levine & Associates, Houston, TX, and the National Institute of Justice, Washington, DC. January 2015.
http://www.nij.gov/topics/technology/maps/pages/crimestat-downloads.aspx#program
Last accessed 26/04/2015

Neubauer, Gerhard (2008). Statistik als Werkzeug der strategischen Polizeiarbeit, SIAK-Journal – Zeitschrift für Polizeiwissenschaft und polizeiliche Praxis (4), 19-27, http://dx.doi.org/10.7396/2008_4_C
Last accessed 25/04/2015

PREDPOL 2015. [online].
http://www.predpol.com
Last accessed 25/04/2015

Ratcliffe, J. H. 2008. Near Repeat Calculator – Program Manual for Version 1.3. Temple University, Philadelphia, PA and the National Institute of Justice, Washington, DC. Available from:
http://www.temple.edu/cj/misc/nr/access.asp?ac=emsub
Last accessed 25/04/2015

Statistik Austria, 2015: Politische Bezirke
http://www.statistik.at/web_de/klassifikationen/regionale_gliederungen/politische_bezirke/index.html
Last accessed 21/04/2015

Smith S.C., Bruce C.W., 2008. CrimeStat III, User Workbook
http://www.icpsr.umich.edu/CrimeStat/workbook.html
Last accessed 25/04/2015

Wels. (2015, April 22). In Wikipedia, The Free Encyclopedia. Retrieved 19:02, May 12, 2015, from http://en.wikipedia.org/w/index.php?title=Wels&oldid=658348212

Wilson R., 2013. Using Near-Repeat Analysis to Measure the Concentration of House Choise Voucher Program Participants, Cityscape: A Journal of Policy Development and Research
http://www.huduser.org/portal/periodicals/cityscpe/vol15num3/ch23.pdf
Last accessed 25/04/2015

Zach E., 2010: Freie autonome Kulturarbeit in Oberösterreich am Beispiel des Kulturvereins „waschaecht“ Wels
http://othes.univie.ac.at/11685/1/2010-10-18_0504435.pdf
Last accessed 21/04/2015

List of Figures

List of Table

Appendix