Fachhochschule Kärnten
Carinthia University of Applied Sciences
School of Engineering & IT
Department of Geoinformation &
Environmental Technologies
Spatial Information Management

MASTER THESIS

Application & Evaluation of CriPA Demonstrator to Forecast Crime

Submitted in partial fulfilment of the requirements of the degree
Master of Science in Engineering

Author: Bala Venkata Tejomayee Paladugu, B.Tech
Registration Number: 1410362009

Supervisor: Prof. Dr. Michael Leitner
Department of Geography & Anthropology, *Louisiana State University, Baton Rouge, LA, USA*

Second Supervisor: FH-Prof. Mag. Dr. Gernot Paulus, MSc. MAS
School of Geoinformation, Carinthia University of Applied Sciences, Villach, Austria

Villach, September 2016

STATUTORY DECLARATION

I hereby declare that

- The Master Thesis has been written by myself without any external unauthorized help, and that it has not been submitted to any institution to achieve an academic grading.
- I have not used sources or means without citing them in the text; any thoughts from others or literal quotations are clearly marked.
- The enclosed Master Thesis is the same version as the version evaluated by the supervisors.
- One copy of the Master Thesis is deposited and made available in the CUAS library (§ 8 Austrian Copyright Law [UrhG]).

I fully understand that I am responsible myself for the application for a patent, trademark or ornamental design and that I have to prosecute any resultant claims myself.

Villach, 7th of September, 2016 Bala Venkata Tejomayee Paladugu, B.Tech

Abstract:

Risk analysis of crime trends and reliable predictions are vital for strategic crime prevention for the Austrian law enforcement management. To support police with its strategic and tactical decision-making process a recently concluded KIRAS – Security Research study on Crime Predictive Analytics (CriPA) has developed a demonstrator to forecast crime. The primary goal of this research is to use the CriPA demonstrator for multiple cities' data and assess its crime forecasting results. It is planned to develop this demonstrator into a full-fledged software application, if testing and evaluation continue to be promising. The overall goal is to integrate the final CriPA software into the dashboard of the Austrian law enforcement management. The application and assessment of the demonstrator will be accomplished using various burglary types across three different cities in Austria, i.e. Vienna, Graz, and Linz. The second objective is to evaluate the forecasting accuracy of the CriPA demonstrator using three evaluation measures, namely Hit Rate, Predictive Accuracy Index, and Recapture Rate Index along with the Decline Rate. Results from this research will provide valuable input to enhance the current version of the CriPA demonstrator with a better set of parameters. The identification of new attributes and parameter settings that could impact the forecasting quality of the CriPA demonstrator is the third objective of this research.

Keywords: CriPA, Crime Forecasting, Burglaries, Hit Rate.

Acknowledgements

This project would not have been possible without the support of many people. I would like to use the opportunity to express my deepest gratitude to all of them.

First and foremost, I would like to express my sincere gratitude to my supervisor Prof. Dr. Michael Leitner of Department of Geography and Anthropology at Louisiana State University in Baton Rouge, Louisiana, USA, for the opportunity to do my research at the Louisiana State University. His continuous support, patience, immense knowledge and vital guidance helped me complete this research and amplify my knowledge on crime analysis.

I am thankful to FH-Prof. Dr. Gernot Paulus, and FH-Prof. Dr.-Ing. Karl-Heinrich Anders at the Department of Geoinformation & Environmental Technologies, Carinthia University of Applied Sciences for their constructive feedback and encouragement.

I am thankful to the Austrian Federal Criminal Police Office for providing the essential data without which the implementation of this thesis would not have been possible.

I am truly grateful to the Austrian Marshall Plan Foundation, Vienna. Their scholarship gave me the necessary financial aid and a memorable time abroad to achieve my research goals at the Louisiana State University, Baton Rouge, USA.

Finally, I would like to thank my friends and family for their support and motivation throughout the duration of my thesis.

This thesis is dedicated to my husband, Dipl.-Ing Dinesh Koya for boundless love and patience. Without his consistent support and motivation nothing would have been possible.

Table of Contents

List of Abbreviations

CriPA	Crime Predictive Analytics
DR	Decline Rate
GIS	Geographical Information Systems
HR	Hit Rate
Nnh	Nearest neighbor Hierarchal
NR	Near repeat Radius
OR	Original Radius
ORNR	Original Radius Near repeat Radius
PAI	Predictive Accuracy Index
RRI	Recapture Rate Index
RTM	Risk Terrain Modelling
RTMDx	RTM Diagnostics Utility

1. Introduction

1.1. Motivation

According to statistics of the Federal Ministry of the Interior, 85,487 burglaries are reported in Austria in 2014. Of this total, 39,472 burglaries happened in the capital city Vienna, which is equivalent to 108 burglaries per day ((KVB) & Austrian Insurance Association (VVÖ), 2015). Despite the fact that burglaries have increased by 76% since 2009, only 41% of Austrians have taken basic safety measures to better protect their apartments, homes, or businesses from burglaries. The average loss from a burglary in Austria is around €2,200 ((KVB) & Austrian Insurance Association (VVÖ), 2014). Although injuries to homeowners are rare during burglaries, preventive measures should be considered in order to protect properties and avoid financial losses. This is just one example of how crime can affect someone at the individual level, as well as the society, as a whole.

The ability to forecast locations of future crime events can serve as a valuable source of knowledge for law enforcement, both from tactical and strategic perspectives. From a traditional policing perspective, predictive analytics can inform a police department's deployment efforts, helping to allocate patrols more efficiently, and reduce response times. Prevention of crimes by predictive analytics is thus very important and today it is one of the “hot topics” in law enforcement research and application.

Over the past 5-10 years, the private sector and academia have developed a number of predictive analytics tools to forecast crime. Among those developed by the private sector include Blue CRUSH, COPLINK, IBM SPSS Crime Prediction and Prevention Tool Kit, PredPol, Crime Spike Detector, Web FOCUS RStat, Command Central Predictive, ATAC Workstation, Hunch lab, and Precobs. On the other hand, academia has developed the Near Repeat Calculator, CrimeStat, and the Risk Terrain Modeling (RTM) approach.

The main drawback of the private sector software packages is that their forecasting algorithms are unknown to the public and thus function as a “black box” approach. Another drawback are the associated costs for the purchase. Since models are unknown outside of the company, these software packages have not been tested, evaluated, and compared with other forecasting tools by researchers.

In contrast, all three academic software packages, since they were originally funded by taxpayer's money, are open-source and (almost) free of charge. In addition, their forecasting algorithms have been published and critiqued in scientific journals and presented at conferences. In general, there have been few scientific comparisons and evaluations across different crime forecasting tools in order to identify, which software packages perform the "best".

In a recently concluded KIRAS – Security Research study on Crime Predictive Analytics (CriPA), one of the main tasks was to develop a demonstrator to forecast crime. This so-called CriPA demonstrator is based on the near repeat concept and, so far, has only been tested in two districts of Vienna and Vienna as a whole with burglary data. Nevertheless, results have been very promising and efforts are currently underway to develop the demonstrator into a full-fledged software application. However, this requires, among other things, additional testing and evaluation of the demonstrator.

1.2. Problem Definition

According to the report on 'CriPA - Crime Predictive Analytics' the primary objective for the project which ended in October 2015 will be the acquisition of funding for adaptations, extensions, and further tests in the coming months. And this research focuses on the testing and partially on the extensions of the CriPA demonstrator.

While the aim of the project until 2015 was to predict future events and be able to take corresponding measures, such as better planning of police personnel deployment and to find out which methods are particularly suitable for daily simulations. For police organizations reliable forecasts and risk assessments over the short to medium term crime trends are a valuable tool for the strategic fight against crime, a further optimization of prevention work - in particular under the framework condition scarcer human resources - and ensuring public safety, in general.

While the initial parameter settings are known, it is essential to increase the forecasting quality of the demonstrator to achieve very good results. Because precision and accuracy of the demonstrator results are the backbone of the overall decision support system aimed to be provided to the Austrian law enforcement agency. So, enhancement of the existing tool and regression testing are required.

Reliability of the CriPA demonstrator results will be questioned, if utilized without proper parameter settings and testing, as the list of potential parameters is very long with numerous combinations. Each crime type or area require different settings based on the nature of crime, study area geography, climate, timeframe, etc. And this cannot be subjective to chance or negligence when the application is for law enforcement and a response system.

Therefore, this goal for the CriPA demonstrator is being addressed and broken down into three objectives in this research which are explained in the following Section 1.3. While this research would not fulfil the goal of the CriPA demonstrator development completely, it will certainly be the next step of the research concluded with the original demonstrator.

1.3. Objectives

The first main objective of this Master Thesis research is thus to use the CriPA demonstrator to test and assess its forecasting quality across different urban areas in Austria and different crime types. A second main objective is to evaluate the forecasting results from the CriPA demonstrator using the evaluation measures (Hit Rate, Predictive Accuracy Index, and Recapture Rate Index) along with Decline Rate. Results from this research will provide valuable input to enhance the current version of the CriPA demonstrator with additional and essential tools. The development of such tools and their possible implementation into the CriPA demonstrator is the third main objective of this Master Thesis research.

1.4. Research Questions

The following questions will be addressed in this thesis:

- Is CriPA Demonstrator software stable during the whole application?
- How do the results of Graz & Linz data vary in comparison to Vienna?
- Is the forecasting accuracy higher for individual districts than for the whole city?

- Are output results consistent for different burglary types across cities during different years?
- Does the merged radius type yield better results than the original and near repeat radius?
- How accurate are the results of the CriPA demonstrator across all parameters?
- Is there a further requirement for additional parameter settings and development in the CriPA demonstrator?

With the constant and rapid evolution of the CriPA project, the questions mentioned above are finalized and completely addressed in this research.

1.5. Research Problems

Potential problems that can be anticipated in this research is mainly with the datasets. Assuming that the python script written for the CriPA demonstrator is absolutely correct and the prototype works appropriately, the duplicates, irregular geocoding, or null values in the attribute table of each dataset can impact the quality of the output result. This can be avoided only if the provided datasets are absolutely accurate. Another issue could be the availability of risk factors and their quality for each dataset. These are used in the risk terrain modelling forecasting method. As the method is relatively new, availability of data is uncertain. The only solution for this is to change study areas to those which have risk factor data. Otherwise, no other potential problems could be anticipated at this time in the research.

1.6. Audience

In general, many groups of people will be interested in these research results. Primarily, the following are directly involved in this research to be the immediate audience:

- Department of Geoinformation and Environmental Technologies, CUAS
- Dr. Michael Leitner, Department of Geography, LSU
- Mr. Philip Glasner, SynerGIS
- Stakeholders of the CriPA Project

- Crime Analysis researchers
- Law Enforcement Agencies primarily in Austria
- Public and Private Security Organizations
- Public in general

The general public benefits from this project, as it will be aware of the possible crime occurrence areas in their locality along with security and law enforcements agencies.

1.7. Expected Results

The overall expectation is that the output results of the CriPA demonstrator will be superlative in terms of forecasting quality and precision. The tool is expected to be absolutely stable at all times of usage. The results for Graz and Linz, although believed to be accurate are expected to possess a lower accuracy when compared to Vienna, because of the vast difference in the number of crime events among these cities.

Output results are expected to be consistent for every crime type across different timeframes, but vary in case of different radius types. It is expected that the merged radius type results in a better crime forecast. Across all output results in this research, the accuracy is expected to be consistent.

Potential attributes that can be included in the parameters list and existing parameters' optimal values can be identified during the course of this study. Conclusively, it is expected that an "ideal" set of parameter ranges for the CriPA demonstrator can be found that results in the highest forecasting quality across different crime types and study areas.

Note:

All the literature presented in this research about the Crime Predictive Analytics and its demonstrator is based on the 'CriPA – Crime Predictive Analytics' report (Bayr, et al., 2015).

2. State of the Art & Literature Review

2.1. Theoretical Background

Crime is defined as the integrated result of economic, social, environmental, and political conditions that occur at a specific time and in a specific geographical area (Harries, 1999). Analysis of the crime in terms of why and where it happened is very important to understand the nature and path of crime. Drug crimes, organized crimes, political or white collar crimes, and street crimes are the main categories of crime events (Boba, 2005). These are subdivided into the following types of crimes, for example robbery, assault, burglary, and auto theft are the crime types of the street crime category. Every type of crime should be analyzed to understand its distribution in order to reduce or prevent it from happening in the future.

Crime analysis can be defined as a process to analyze data obtained from the police agencies and their communities by a set of quantitative and qualitative techniques (Analysts, 2014). The analysis of crime, criminals, victims, police operations, traffic issues, etc. is done in the support of police agencies in crime investigation, patrol activities, crime prediction and prevention, strategies to reduce crime, and evaluations. Crime analysis relies on the comparison of current crime events to past crime events. This helps in the detection of crime patterns and trends (Acadamey, 2003). Law enforcement agencies, politicians, researchers, governments are the stakeholders in crime mapping and analysis.

Crime theories are used to understand the spatial phenomenon of crime. Geographical Information Systems (GIS) and crime prediction models are used for crime prevention or reduction. In the section below crime theories related to GIS and crime forecasting concepts are explained.

2.1.1. **Crime Theories & Forecasting using GIS**

Traditional criminology is about the root causes of crime and offender reasoning to commit a crime, whereas the environmental criminology is about crime patterns, crime committing opportunities, prevention of victimization, and environmental conditions prone to crime. The motive of criminology is to understand the distribution of environmental factors and opportunistic behavior supporting any crime occurrence (Brantingham & Brantingham, 1981). The following three crime theories that explain the appealing and easy opportunities which influence people to commit a crime include:

- Crime pattern theory
- Rational choice theory
- Routine activity theory

In common, all three theories describe the behavior of an offender and a victim, reasoning for the intersection of their activities, and crime opportunities creation.

As per the crime pattern theory, crime takes place at the intersection of the offender(s) and victim(s) daily activities. Crime patterns implicate that the opportunity to commit crime is an output of the relationship between individuals and the physical environment around them. The main components used in this theory are:

- Node: A crime dense area which is the intersection of the routine activities.
- Edge: The boundary of the daily activity area.
- Road: Connecting paths for nodes, in which individuals pass through during daily activities (Felson & Clarke, 1998)

According to the rational choice theory, offenders evaluate the decision to commit a crime with respect to the consequences having to face after the event. In case of a suitable environment and opportunity prevailing, any individual may intend to commit a crime. As per the theory, if the risk of being caught is high and the income or price is lesser than expected, people do not prefer to involve in a criminal activity. This theory is said to be a reliable guide for crime prevention, as law enforcement officers and analysts increase the risk for any offender. Also the rational choice theory suggests that the offender becomes clear on the decision to commit a crime, when risks are proportionate higher compared to the price or earnings. But most of the times, offenders are not able to objectively evaluate the price. This is why rational choice theory is considered as an approach along with the other theories in combination (Chainey & Ratcliffe, 2005). According to this theory, in order to repeat a crime again, offenders usually prefer environmental conditions, which are quick and clear than the evaluation of multiple activity steps.

The routine activity theory is a well-known theory providing a straightforward explanation about why crimes occur. It is used as a practical tool for crime reduction by analysis. The theory suggests that when a crime occurs, the following three incidents happen simultaneously in the same space:

- Availability of a suitable target;
- Suitable guardian is lacking;
- Presence of a likely and motivated offender

Figure 1: Crime Triangle (Johani, 2008)

A suitable target could be a person, object, or a place. The term target is chosen to be more appropriate rather than victim or other words. A capable guardian, through his/her presence is assumed to discourage a crime from happening. A guardian could be a person or a thing, such as police patrols, locks, fences, security guards, neighbors, CCTV systems, etc. (Beach, 2007). These can be formal or informal. If and when a suitable target is unprotected by the guardian, the offender is likely to be present. The routine activity theory looks at the crime from an offender's point of view. A crime can take place, only if the offender thinks a target is suitable and a guardian is absent. It is therefore the offender's assessment of a situation that determines whether a crime will take place. The ability to analyze from the offender's point of view will increase the effectiveness of the crime prediction concept.

The routine activity theory is illustrated by the crime triangle shown in Figure 1. The crime triangle can also be explained as the basis of environmental criminology. In addition to the three theories, the situational crime prevention approach (SCPA) should also be considered. In environmental criminology, with the identification of the conditions providing crime opportunities, measures for crime prevention can be defined. Based on the crime triangle and theories, the measures are classified into the following five groups in this approach:

- To increase the offender's perceived effort (Example: Inserting alarm systems).
- To increase the offender's perceived risk (Example: Increase the number of street lamps).
- To reduce the offender's rewards (Example: Having as less amount of money as possible)
- To reduce the offender's motivation (Example: Limiting the number of people entering the facilities)
- To remove excuses for crime (Example: Putting warning boards) (Boba, 2005)

Crime mapping is a subset of the crime analysis process. A continuous development in computer technology innovated Geographical information technology (GIS) is originated from the continuous development of the computer technology for geographical studies (Harries, 1999). In order, to archive, query, and manipulate crime data, crime patterns updating, spatial analysis, and to develop crime prediction models, crime maps are created using GIS. In crime prediction and pro-active policing, during the stages of data collection, data evaluation, and data analysis, crime mapping plays an important role.

There are many areas crime mapping can be applied to, like predicting crime, mapping crime activities, identifying hotspots and patterns, and monitoring the impact of crime prediction measures. Precise software tools are developed for crime analysis in law enforcement agencies and some of them are ATAC, Crimeview, CrimeStat, and Geobalance (Boba, 2005). The spatial crime analysis software tools are capable of data entry, manipulation, pattern identification, clustering, data mining, and geographic profiling. Crime analysis using a software is complex, but it is an advanced and reliable method to reach satisfactory results.

In crime analysis using maps, the current status of incidents is analyzed. Incidents often show spatial patterns by clustering in certain locations at specific times. Hence, it indicates that there is a relation between crime incidents and geography. And it is observed that different crime types have different geography influences. Spatial patterns help detect hot spots that are defined as a geographical area with higher than average crime (Chainey & Ratcliffe, 2005).

Crime forecasting is a way to predict repeated actions of offenders and different rates and types of future crimes (Criminology, 2005). Forecasting techniques can be classified into long-term and short-term models. Long-term models are for policy and planning applications and short-term forecast models for tactical decision making. The short-term forecasting is preferred over the other in case of crime prediction, as it is considered one step ahead of offenders (Gorr & Harries, 2003). Usually, weekly or monthly forecasts are used by police departments to predict crime (Gorr & Olligschlaeger, 1997).

2.1.2. Spatial Criminal Analysis

For combating crime, geoinformation technology is now an important part of law enforcement agencies. During the second half of the 19th century, geographers have started important and influential studies on the geography of crime (Harries, 1999). In the 1970's, the association between distance and crime was the focus of several research studies. For example, 'Crime and distance: An analysis of offender behavior in space' by Capone and Nichols in 1975 studied the distance travelled by burglars between their homes and crime scenes (Capone & Nichols, 1975). During the same period, criminologists, lawyers, planners, and sociologists started to show interest in spatial aspects of crime. In the following decades, the diffusion of geographical concepts, methods, and techniques of spatial criminal analysis into other non-geographic disciplines rose to significance (LeBeau & Leitner, 2011). In the development of spatial criminal analysis, significant milestones were the publication of the Spatial and Temporal Analysis of Crime (STAC) software, the establishment of the Crime Mapping Research Center (CMRC) from the US National Institute of Justice (NIJ), which is later renamed to the Mapping and Analysis for Public Safety (MAPS). The development of the spatial analysis software, CrimeStat, is one of the main achievements of MAPS (Levine, 2015).

In summary, it can be said that the development of spatial crime analysis clearly shows that innovation and research have taken place until recently mainly in the research and academic sector. Only in the last five to ten years it has been recognized the importance and the use of geographic information technology for the spatial analysis of crime in a broader view.

While this was the state of spatial crime analysis in the last century, currently the technology and its knowledge is being spread at an international level. The present day research focuses on exploratory analysis of spatial and temporal trends in mass crimes or the identification of spatial and temporal hot spots of crime events (Helbich & Leitner, 2011), the impact of current sex offender legislation on the availability of residential sites and the associated mobility (Hart & Zandbergen, 2012), and many more. In the 2014 Annual Training Conference of the International Association of Crime Analysts (IACA) in Bellevue, WA, United States, the main topics of the lectures were crime predictive analytics and the use of social media in crime analysis and modeling.

In general, the difference in forecasting crime between retrospective and prospective methods is explained next. Retrospective methods are based on the approach that past crimes in places (hot spots) occur where crime will happen in the future. This approach is based on the use of different spatial or spatio-temporal hot spot methods for crime forecasting. Another retrospective approach is the "Near Repeat" phenomenon. This approach states that, when a specific location, e.g. a house was burglarized, the likelihood increases that the same house is burglarized a second time together with neighboring houses within a certain distance during the coming weeks. The Near Repeat phenomenon has not only been proven for break-ins, but also for other types of crime.

An important recent prospective approach to crime is the Risk Terrain Modeling (RTM) (Caplan & Kennedy, 2010). The RTM is a risk assessment approach, in which individual GIS layers that each include the impact and intensity of a criminogenic variable ("crime risk factor") in each region of the study area, are placed and superimposed in a Geographic Information System (GIS). All GIS layers are then combined to a risk landscape ("risk terrain"). The modeled risk landscape shows where conditions for committing future crime are particularly suitable. For the first time, both retrospective and prospective prediction methods have been applied and evaluated in Austria as part of the CriPA project.

2.1.3. **Spatial Risk Analysis Methods**

The estimate of the future development of selected types of crime has to deliver the objective of a decision support for the derivation and assessment of security policy and strategy for crime prevention and control. Age structure, migration, employment structure, building structure, etc. are integrated to characterize regions as drivers of crime trends in Austria and their forecasts. These models allow estimates for larger, similarly structured regions. Based on findings of the first phase of the project and the results of the expert interviews provided a forecast horizon of a few months to more than one year for such models and used as highest spatial aggregation level Austrian districts.

For crime data at the district level statistical time series models (Functional Time Series Analysis) have been developed to predict and evaluate the course of years' certain crime facts. Especially, for offense types and regions, which are characterized by strong seasonal fluctuations of frequencies, this approach has proven to be a useful forecasting tool.

Another focus was on forecasting models with explanatory variables such as calendar effects and weather, which allow a prediction of crime for weeks or months. Microscale forecasts the occurrence of crime and a corresponding representation in a Geographic Information System (GIS) support the criminal lead in scheduling and planning of preventive measures. Methods for spatial risk analysis are selected hot spot analysis methods, Risk Terrain Modeling (RTM), and the Near Repeat concept. They were developed, implemented, and validated. In addition, the development of a spatio-temporal statistical forecasting model was used to estimate the crime risk at grid cell level, involving factors such as land use, demographics, and infrastructure. These forecasts with early detection of space-time-related patterns, the inclusion of meaningful criminogenic factors, and their temporal development and in particular the integration of methods in a GIS play a significant role.

As has been proven especially in short-term forecasts a precise as possible measure of the time of the crime is essential to the elaboration and implementation of estimating the time of the crime. To further improve the accuracy of forecasts the integration and systematic analysis of other sources of information were examined. In initial studies, the free text fields of the safety monitor (SIMO) proved a promising source for the extraction of information on clusters of specific methods or tools for burglary offenses and to identify potential serial offenses. This textual data is analyzed using text mining methods and results are incorporated into models so that they bring about an improvement in the forecasting accuracy.

Hot spot analysis, near repeat victimization, and risk terrain modelling are concepts utilized in different software tools to be applied and evaluated in this research project. Hot spots are typically referred to as areas of concentrated crime (Eck, et al., 2005). Single addresses, blocks, cluster of blocks (Eck, et al., 2005), neighborhoods, or entire cities can be referred to as hot pots depending on the scale defined for the analysis (Smith & Bruce, 2008). In other words, a hot spot area is one having a greater than average number of crime events, or one with people having higher than average risk of victimization. This implicates that some hot spots may be hotter than others by how far above average they vary. Also cool spots (areas with a less than average amount of crime) existence is indicated (Eck, et al., 2005).

The known and most researched hot spot analysis approaches are spatial mode, spatial fuzzy mode, and kernel density estimation, nearest neighbor hierarchical clustering (Nnh), among others. The spatial mode is the location with the largest number of incidents. The mode is a very simple measure, but one that can be very useful. Spatial fuzzy mode analysis includes the selection of an appropriate search radius that is drawn around each event and adding up the total number of points within each circle. This method is useful for comparing two or multiple hot spot areas. This analysis can be applied for purposes, such as the number of drug arrests in an area, shootings in a park, etc. (Analysts, 2013). It falls under the point location type of cluster analysis. This is the most intuitive type of cluster involving the number of incidents occurring at different locations. Locations with the most number of incidents are defined as hot spots (Levine, 2015).

Kernel density interpolation is an approach which falls under the density techniques type of cluster analysis methods. Density analysis is also known as grid cell mapping analysis (Gorr & Kurland, 2012). This method compensates for the limitations of choropleth and standard deviation analysis. Surface estimation techniques are applied in density analysis, illustrating the geographical area's surface with rasters (Ratcliffe, 2004). Instead of adding up all the points within a radius like in simple density analysis, kernel density interpolation applies a kernel over each event location. Other incidents closer to any of the kernel centers are given a greater weight (Eck, et al., 2005). Density analysis does not depict physical boundaries and gives a realistic image of the hot spot distribution (Hill & Paynich, 2010). Its advantages over point pattern maps is that overlapping points are accumulated and represented with a chosen color scheme (Harries, 1999).

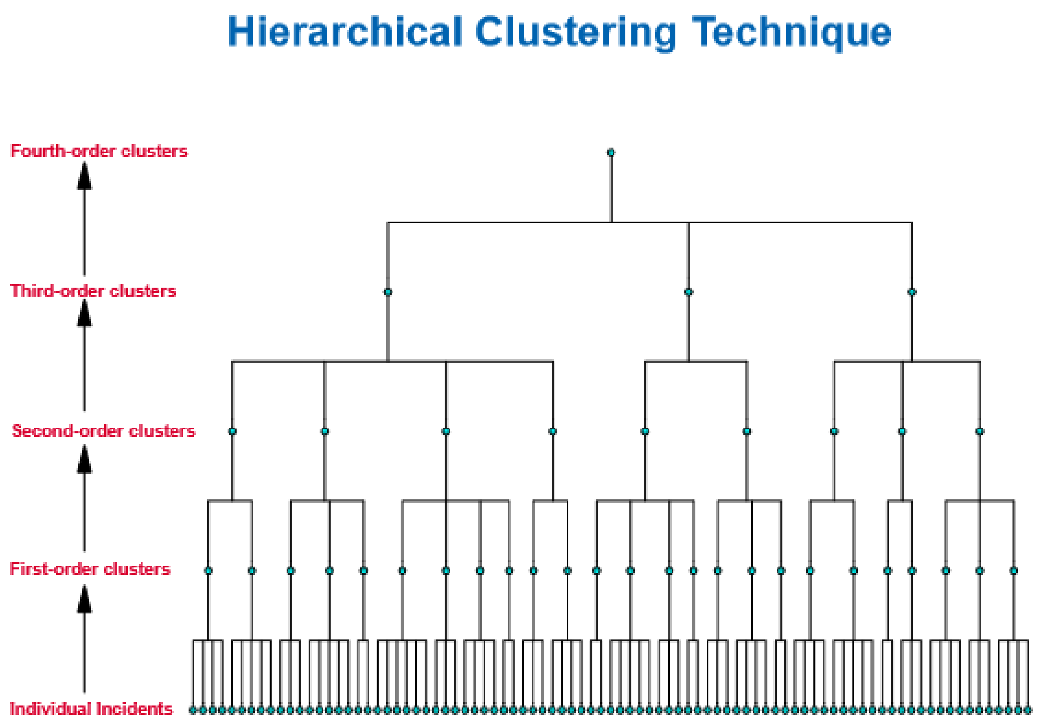

Figure 2: Dendrogram of Nearest Neighbor Hierarchical Cluster method (Levine, 2015)

Hierarchical cluster techniques can be visualized by an inverted tree diagram in which two or more incidents are grouped based on defined criteria. These groups are referred to as second order clusters, and these clusters are further grouped into third order clusters, and so on. This process is continued until grouping criteria fail. This can be visualized with a dendrogram like the one shown in Figure 2.

Near repeat analysis is regarded as a measure of spatial and temporal relationships of crime. According to research, multiple crime incidents can occur at the same location or nearby places within short time periods. It happens so because the geographical area within which crime incidents occur, possess the commonalities in the form of crime opportunities. The first law of geography according to Waldo Tobler is "Everything is related to everything else, but near things are more related than distant things" (Tobler, 1970) . The near repeat concept is rooted in this law, as near things because of their common characteristics are spatially dependent based on proximity. The near repeat victimization concept incorporates the temporal sequence of crime incident locations within a series of increasing distances between the incidents according to this law.

If previous crime incidents are considered solely as the isolated indicator of future victimization, the near repeat hypothesis will be a parallel crime analysis approach based on hot spots. Therefore, near repeats can be described with the "contagion effects" phenomenon, which is an extension of hot spot analysis. Near repeat models are based on the assumption that if a crime event occurs at a specific location, the probability of future crime occurrence in the same or nearby locations increases.

If we consider the past experience with crime as an isolated indicator of future victimization, this would parallel crime analysis approaches based on event dependence, such as hotspots (discussed above). As an extension of, or companion to, hotspot analysis, the phenomenon of contagion effects has been labeled near repeats (Ratcliffe & Rengert, 2008) and explains how past crime incidents can serve as predictors of new crime incidence (Bowers & Johnson, 2005). Near-repeat models assume that if a crime occurs in a location, the chances of a future crime occurring nearby increases. In the studies that have been done to-date, researchers have found evidence to support the near-repeat phenomenon in a variety of crime types and settings. Investigations of near repeats provide an important extension of hotspot analysis as they account for the temporal link between crime events and do not just assume that behavior that takes place in close proximity at whatever time in a set frame (e.g., a month or a year) has anything to do with other behavior located nearby.

The risk terrain modelling (RTM) approach has been developed by Joel M. Caplan and Leslie W. Kennedy at the Rutgers University, USA (Caplan & Kennedy, 2010). As opposed to retrospective methods, in which previous events are taken as reference, RTM uses the dynamic interaction between social, physical, and behavioral factors (Kennedy, et al., 2011). This implies that risk factors have a bearing on the environment. Otherwise known as the criminogenic factors, these show the increase in risk probability of a crime to be committed because conditions at the potential crime area look favorable to offenders. In the RTM

Compendium from the official website, a list of factors for 17 crime types is included (Caplan & Kennedy, 2011). For each individual factor a risk map layer is created and all individual risk layers with different weights are combined to make a final risk terrain map. Locations or areas with the highest risk of future crime occurrence are shown in the final map. Crime analysts can use these approaches to develop strategic models and to make predictions, where crime may be an issue.

2.1.4. Crime Predictive Analytics

Crime Predictive Analytics (CriPA) in general, is dedicated to the predictive analysis of crime in the form of projections and includes quantitative methods that help identify meaningful patterns and dependencies in databases for prediction of possible future events and to be able to assess potential responsive methods for these events.

This tool is based on the Near Repeat Concept, which allows the identification of space-time related patterns. The testing of this tool started with apartment burglaries in Vienna for the year 2014. Basic knowledge of python scripting and ArcGIS is necessary for using this tool, while altering and testing it would require advanced python scripting skills because the CriPA demonstrator is still in a prototype stage and principles and parameters for the analysis are declared by python scripting. Hence, the functionality is based entirely on the user's definition and not predefined, like in other prediction software that is available. This is an advantage because while predicting crime, several parameters are to be filtered to get the desired result. But as an end product, after the completion of its development, this tool is expected to be a full-fledged software application with best preset parameter settings and no requirement of python scripting knowledge from the user. The overall goal is to integrate the CriPA software into the Austrian law enforcement management's dashboard. Moreover, the CriPA demonstrator should be able to make long-term, large-scale predictions about developments in crime and trend models such as generalized additive models.

Forecast results for crime are subjected to different requirements depending on the application or usage of these results. Among those, the following are addressed in the CriPA project:

- Long-term, large-scale forecasting and trend estimates, and
- Short-term, small-scale forecasts and risk assessments.

Based on these requirements, appropriate algorithms, methods, and software components to validate the methods are developed. The CriPA project's overall objective is the developing and implementing of opportunities and conditions for a future integration of the developed predictive analytics approaches into the dashboard of the criminal leadership of Austria.

By means of model approaches for long-term, large-scale projections, the assessment of the future development of the crime forecasting based on crime type selection with the aim of a decision support for the derivation and assessment of security policy and strategy for crime prevention and control supply can be met. As the present social changes such as demography (aging, migration, etc.) and structure of employment are key factors for the occurrence of crime, the impact of these factors to the crime forecasting should be analyzed and, among other possible risk factors, be included as conditions in the forecasts.

When considering the occurrence of crime in a particular geographical area which is influenced to a considerable extent by long-term global trends, then the main question to be addressed is: "When and at which location did the crime happen". Although it is difficult to answer this question precisely and with absolute certainty, quantitative space-time-related risk assessments can be made to assess the future crime occurrence. Methods and models (Risk Terrain Modeling, Near Repeat, hot spot analysis, etc.) which should be used here, originated from disciplines, such as geo-statistics or Geoinformatics. These small-scale forecasts and risk assessments can assist the law enforcement in the scheduling and planning of preventive measures. For the presentation of estimates and forecasts an interactive editing integration was required in a geographical information system. Objectives fulfilled so far by the CriPA project are as follows:

- Exploration and application of models for long-term, large-scale forecasts.
- Exploration of methods and models for short-term, small-scale forecasting and risk models.
- A process for the systematic recording of expertise to improve forecasting quality.
- GIS-based reference system for forecasting and risk assessment.

2.1.5. **Evaluation Measures**

The first measure for an evaluation of predictive accuracy is the Hit Rate. This measure is easy to calculate and to understand. But the disadvantage of this measure is that hot spot areas are not considered along with the total study area. But the Predictive Accuracy Index (PAI) covers this flaw. This measure is created to address the problem the Hit Rate may produce. That is that the PAI takes sizes of hotspots and the study area into consideration. In comparison to the Hit Rate percentage, the PAI can dissolve the effect of the study area on the prediction information used for tactical determination.

Also the higher the PAI value, the more accurate the forecasting method is for predicting crime. The third predictive accuracy measure is the Recapture Rate Index (RRI). It was proposed by Levin in a response to the PAI creation (Hart & Zandbergen, October, 2012). The RRI does not take the sizes of hotspots or the study area into consideration. Similar to the Hit Rate and the PAI, a higher RRI corresponds to a more accurate forecasting method for crime prediction.

2.2. Technical Background

2.2.1. **Existing Open Software**

For police organizations reliable forecasts and risk assessments over the short to medium term regarding crime trends are a valuable tool for the strategic fight against crime, a further optimization of prevention work, in particular under the framework condition of scarcer human resources and ensuring public safety, in general. Crime Predictive Analytics is generally dedicated to the predictive analysis of crime in the form of projections and includes quantitative methods that help to identify meaningful patterns and dependencies in databases to possible future events and to be able to assess potential options for action. Different demands are on such forecasts, depending on the application of the results. Two particularly significant areas are long-term, large-scale forecasting and trend estimates and short-term, small-scale forecasts and risk assessments, as mentioned earlier.

In this project requirements and any appropriate algorithms, methods, and software components to validate the methods are developed. In developing and implementing these methods, the opportunities and conditions for a future integration of the developed predictive analytics approaches in the dashboard of the criminal leadership of Austria should be considered. An assessment of the future development of the crime situation (based on selected types of crime) with the aim of a decision support for the derivation and assessment of security policy and strategy for crime prevention and control supply can be met by means of model approaches for long-term, large-scale projections. Due to social changes, such as in demography (aging, migration ...) and structure of employment as key factors for the development of crime, the impact of these factors should be analyzed and among other possible risk factors be included as conditions in the forecasts.

In the context of crimes occurring locally, which is of course influenced to a considerable extent by long-term global trends, the main interest lies in the question: "When will a crime occur and at which location?" Although, it is not possible to answer these questions precisely and with absolute certainty, quantitative space-time related risk assessments can be made to assess the future crime scene. Methods and models (Risk Terrain Modeling, Near Repeat, hot spot analysis,) which should be used here, originate mostly from Geographic Information Science (GISc). These small-scale forecasts and risk assessments can assist in the scheduling and planning of preventive measures.

For the hot spot analysis forecasting method, the CrimeStat software is used. It is a spatial statistics program and is used for crime analysis. This software tool is developed by Ned Levin & Associates in Houston, TX and is provided for free at the website of National Institute of Justice. It is a Windows based desktop application which was initially used for the analysis of car accidents alone. On the basis of various statistical analyses, it provides results for the prediction of crime events. The software offers more than 100 statistical functions which can be used for the analysis of spatial patterns. Spherical and projected coordinates are supported by CrimeStat (Levine, 2015).

Input files need to be in the form of a shapefile or .dbf file which are to be selected as shown in the Figure 3. Then the X & Y coordinates columns need to be selected from the dropdown and then if necessary a reference file tab is opened and coordinates are provided manually (E.g., in case of the Kernel Density Estimation method).

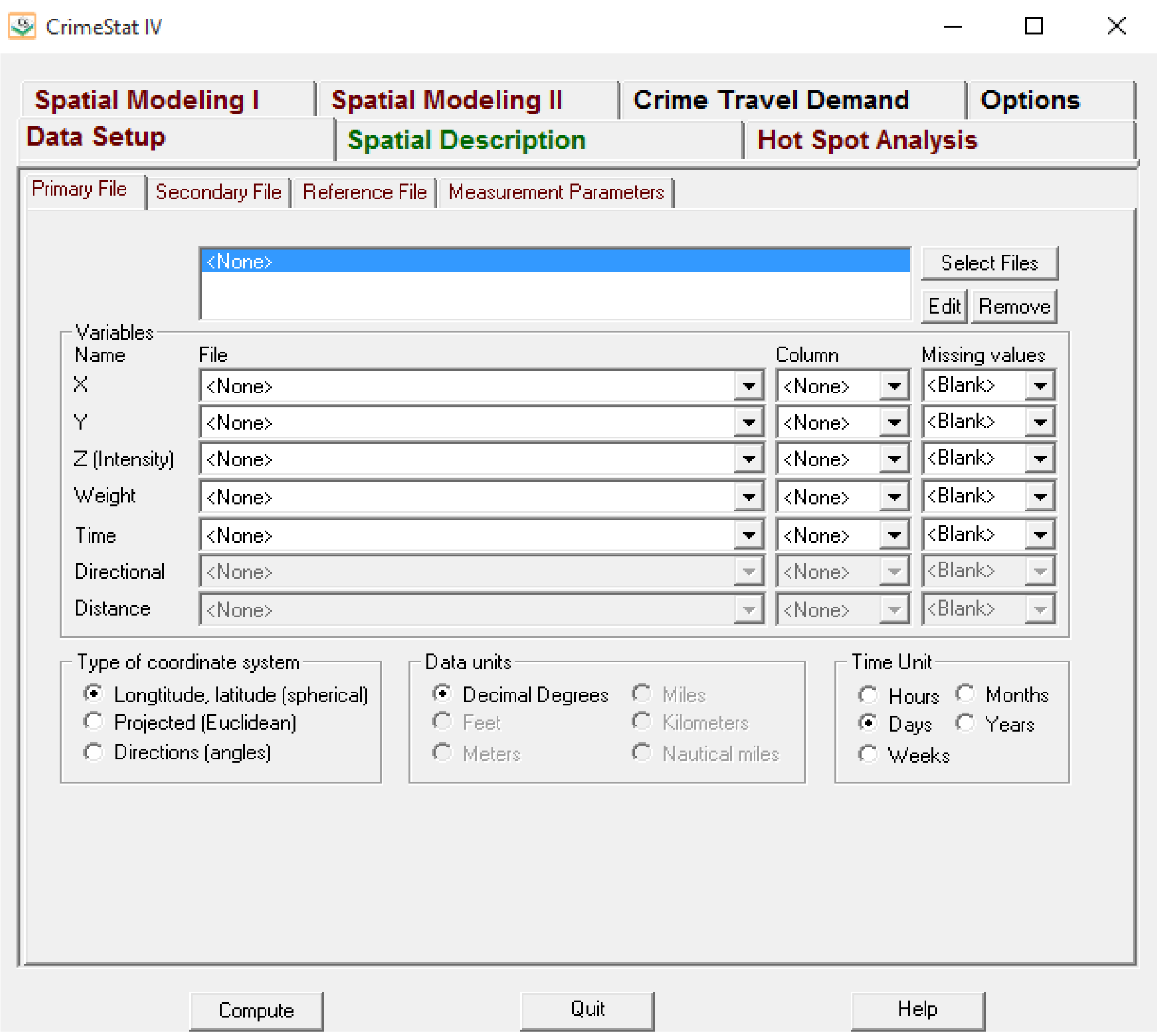

Figure 3: CrimeStat IV Input page (Levine, 2015)

As a next step, the Hot Spot Analysis tab needs to be opened, where the spatial mode, the spatial fuzzy mode, and Nnh parameters are to be specified as shown in the Figure 4. The radius length and its unit for the spatial fuzzy mode and the distance, minimum points per cluster, and the search radius for Nnh need to be input by the user. Also the folder for saving the output files is to be specified, as well.

In the Spatial Modelling I tab, parameters for the kernel density estimation are to be specified by the user. The minimum sample size, method of interpolation, area units, and output units are the main parameters. The dataset and study area along with certain requirements influence the parameter specification for all of these methods.

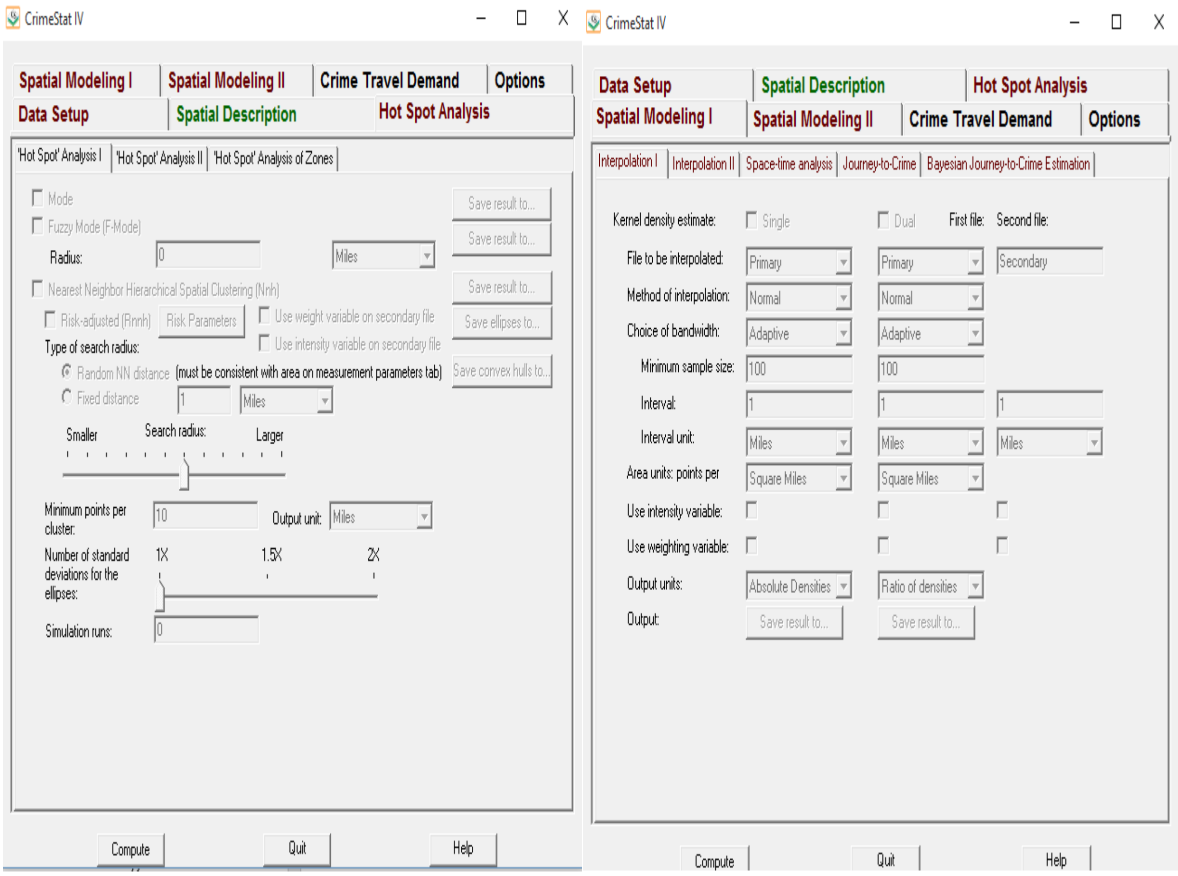

Figure 4: Hot Spot Analysis & Spatial modelling I tabs in CrimeStat (Levine, 2015)

For the near repeat victimization forecasting method, the near repeat calculator is used. It is developed by Jerry H. Ratcliffe, Department of Criminal Justice at Temple University in Philadelphia, USA (Ratcliffe, 2009). The software compares the actual pattern of spatio-temporal relation between crime events to the pattern one would expect if there are no near repeat occurrences taking place. The random reallocation is performed many times to get significant results. The standard minimum threshold for statistical significance is p = 0.05 which can be achieved with 20 reallocations. But the best statistical significance level the program can achieve is p = 0.001, which is reached with 1000 reallocations.

The higher the number of reallocations, the more accurate or reliable the results are. As the input file is uploaded, the distance units are to be given by the user (as seen in the Figure 5). There are two distance settings available, including the Manhattan distance and the Euclidean distance. 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.

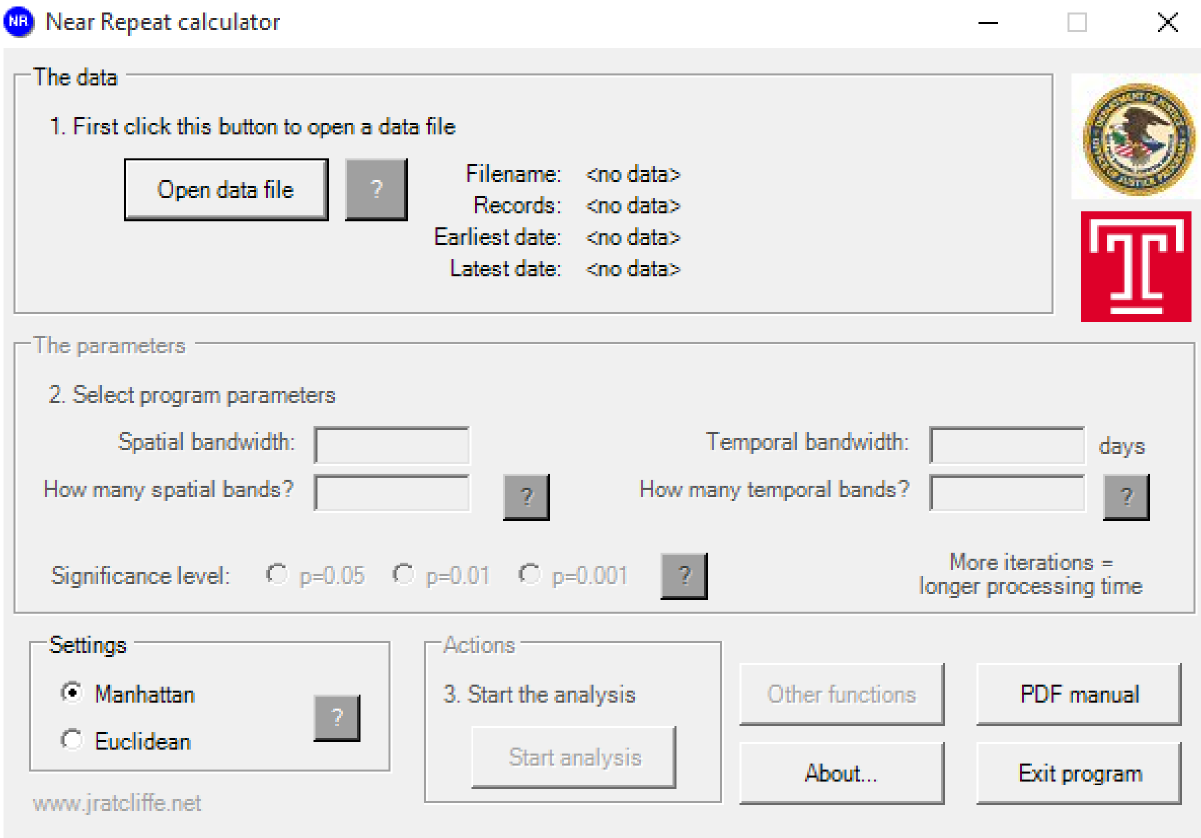

Figure 5: Near Repeat Calculator software input page (Ratcliffe, 2009)

The difference between the Manhattan and Euclidean distances is shown graphically in the Figure 6. Output files are an .html format summary file and a comma separated value (csv) file, which reports the significance and frequency of crime events. For the determination of the original and the near repeat event, the "other function" is used. A choice between the spatial and temporal frame is offered to the user. This output csv file reports about how many times an event was the originator and how many times it was the near repeat event, helping in the identification of hotspots (Ratcliffe 2008, p. 12).

Figure 6: Manhattan and Euclidean distances

The RTM Diagnostics Utility (RTMDx) is the software with mostly automated steps for the Risk Terrain Modeling technique. In the process, every risk factor is examined in terms of its spatial influence on the resulting event (crime). The most correlated risk factors are identified and included in the calculations to produce the risk terrain model. Of the two versions available, the free educational version will be used for this research project.

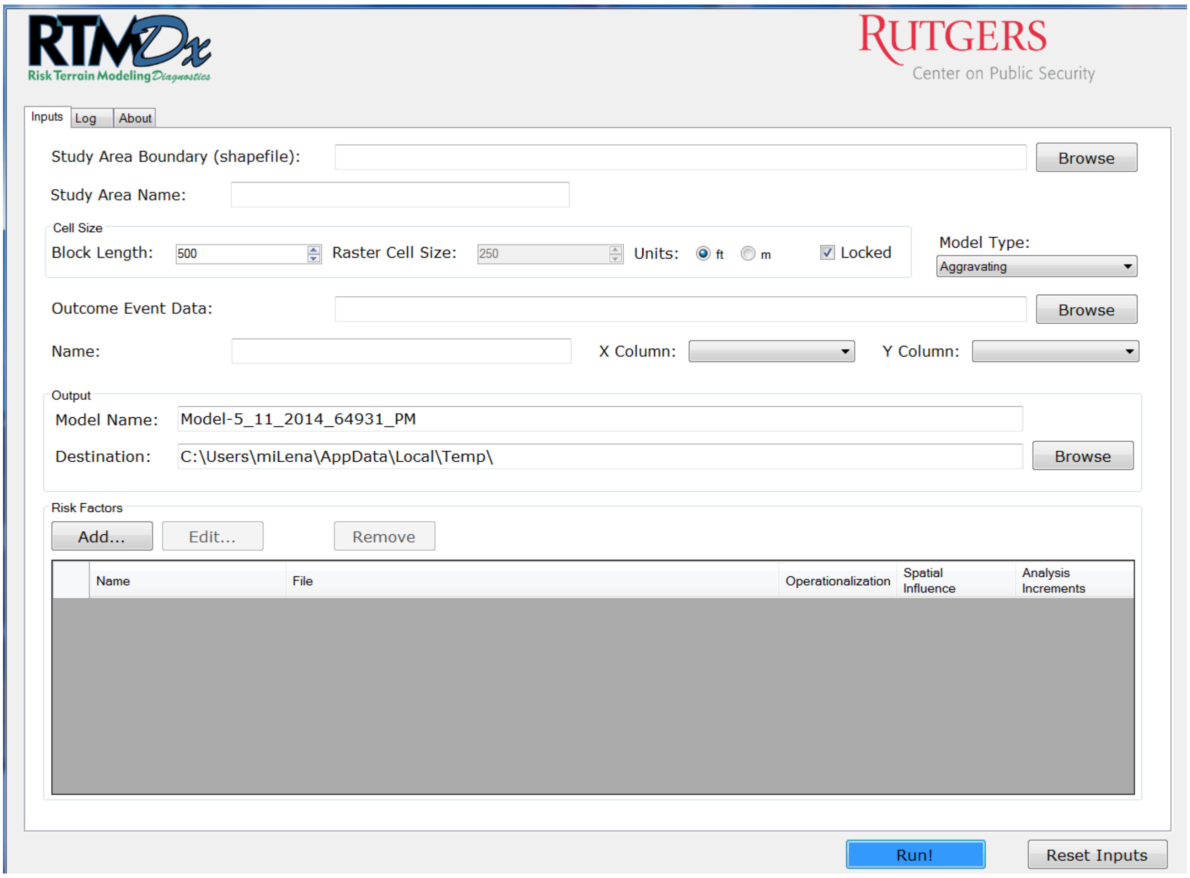

Figure 7: RTMDx software first display page (Caplan & Kennedy, 2010)

The software includes the “Inputs”, “Log”, and “About” tabs. As an input, a shapefile of the study area’s dataset is to be specified, then the block length and raster cell size are to be set. Units provided are feet and meters for selection as shown in the Figure 7. According to the user manual the settings for the value for the block length is the mean length of a block face in the study area and the value for the raster cell size to be one-half of it. The final risk terrain model can either be an aggravating or a protective model type. Further in the process, risk factors are to be included. For each added risk factor further parameters have to be set. Advantages of using the RTMDx Utility software compared to manually produced risk terrain models is the reduction of time, because statistical tests are computed automatically by the software. Further, statistical methods used in the software were improved too.

2.2.2. CriPA Demonstrator

The technical background for this tool can be acquired only from the methodology and conclusion of the CriPA report. This information forms the basic foundation principles of the demonstrator. The focus of the CriPA project was on property crimes (including residential, housing, basement, and business burglaries, car theft and car burglary, and pickpocketing) and robbery. Depending on the frequency of occurrence, different spatial and temporal aggregation of data and different analysis prove to be meaningful and promising.

Though the near-repeat approach states that it is very likely in a short time of an original event occurrence, another offense occurs within the immediate vicinity. In the preliminary testing of this tool there is no clear definition, what spatial and temporal proximities are appropriate. Thus, parameters of 350 meters and 4 days were then reduced to 100 meters and for 3 days.

This setting in turn could barely indicate any forecasting areas and was therefore considered to be unsatisfactory. It is also agreed that a near repeat pair must have the same type of entry, which is only one of these: "DOOR BREAK", "WINDOW BREAK", "DRILLING" "NACHSPERREN" (Breaking the Lock) and "RIEGELZUG DOPPELFLUEGELTUER” (Interlocking Double Door). This measure is targeted to catch serial offenders, due to the same type of entry in a spatially and temporally limited apartment burglary.

In addition, only those burglaries are to be considered, in which the start and end of the offense is not more than 72 hours (considering a weekend) apart. After the first test phase of the CriPA demonstrator, it was agreed to perform a simulation study with different basic parameter settings with the CriPA demonstrator, to define an optimum parameter setting.

And based on the near-repeat approach different spatial parameters of 200, 300, and 400 meters, different temporal parameters of 1, 3, and 5 days for locating a near repeat as well as different chronological parameters of 1, 2, and 3 days for the validity of the prediction area, and for finding predicted offenses are evaluated. In the analysis, the forecast area (in the form of a buffer) is drawn either around the original event, the near repeat event, or a combined area of the two as seen in the Figure 8.

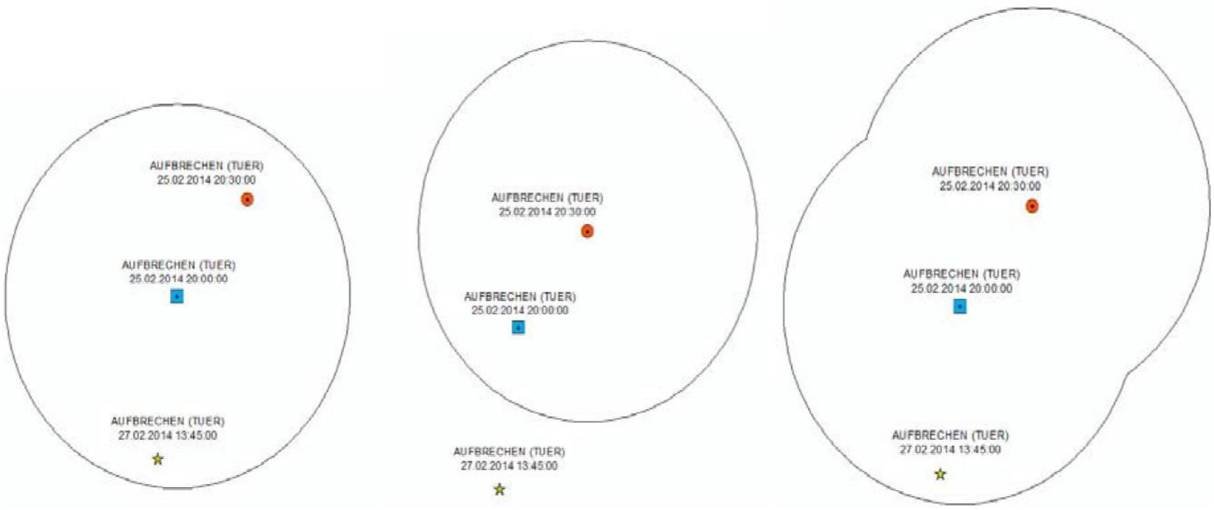

Figure 8: Forecast areas drawn around the original event, the near repeat, and the merging of both

In the simulation study conducted by SynerGIS for each day a Near Repeat query is performed for selected crime data. Assuming that the spatial and temporal parameters were checked for every original event having at least one near repeat event, a pair is formed. Therefore for every day, there are a number of offenses with at least one near repeat. In the first case (Figure 8, left) is the forecast area for the original event marked with the radius and checked how many crimes in the next few days (forecasting period) are in this forecast area. In the second case (Figure 8, middle) the same radius is assigned to the near repeat and the number of events inside the circle during the specified timeframe is observed. In the third case (Figure 8, right) both areas are merged into one large forecast area. Simulations are run for all three combinations of forecast areas and evaluations were made. The following characteristics are considered:

- A hit must meet the criterion of the 72 hours between the beginning and end of the time of the crime.
- A query of results in a forecast area does not start immediately after a near repeat pair has been detected, but only from the next day. This has been designed, since the CriPA application does not recognize near repeat pairs in real-time. Results are only starting to be counted with the following day.
- Overlapping forecast areas were combined into one area. This has the advantage that a closed area is available and an offense in one day is not

repeatedly counted as a hit. In the example shown in Figure 9, which is referenced from the CriPA report, three offenses were detected on 02/25/2014. Forecast areas around the near repeat events can be seen at 20:00 and 20:30. Instead of two forecast areas for each, overlapping areas are merged resulting in a single forecast area.

Figure 9: Merging of overlapping prediction regions of the same date

- The retrospective analysis has to be done by considering an offense as a hit. This offense is usually one of the events which took place in the following days and other offenses are eliminated. An offense is without exception only once counted as a hit.
- In analyzing hit rates of individual districts, results are district limited. A forecast area does not go beyond the borders of a district, so no offenses from neighboring districts are counted as a hit.

Testing and validation of the tool

The test operation was launched in April, 2015. In the first test phase meaningful forecasting for the next few days was created that allowed a targeted application and design, with likely vulnerable regions being highlighted or marked in detail. The forecast area is a circle around the Near Repeat. Over a 30-day period, different queries are created using CriPA. Both 'real' predictions as well as retrospective predictions were created. After the experience of the first test phase some revisions, extensions, and adjustments were made to the system and at the end of May 2015 a second test phase was launched. In addition, a retrospective evaluation study for burglaries from 2012 to 2014 with different parameter settings of the near repeat approach was carried out for two districts of Vienna and Vienna as a whole. This study showed very promising results (forecasts), especially in hot spot area districts.

2.2.3. Evaluation Measures

For the comparison of forecasting methods and assessment of the pros and cons of the CriPA demonstrator, three different standard measures, which are commonly referred as predictive accuracy measures, are used. The three standard measures are:

1. Hit Rate Percentage
2. Predictive Accuracy Index
3. Recapture Rate Index

The Hit Rate Percentage (HR) is defined as the percentage of crimes that are hitting the calculated retrospective period. The Hit Rate Percentage is calculated as:

$$Hit\ Rate = \frac{n}{N} \times 100 \qquad \textit{Formula 1}$$

Where *n* is the number of crimes in the forecast that are hitting the calculated retrospective period and *N* is the number of all crimes in the forecast period. The higher the hit rate, the more accurate the hotspot technique is (Hart & Zandbergen, 2012).

The Predictive Accuracy Index (PAI) is specifically designed to consider the size of localized hot spots and the size of the study region in a form that allows direct comparison of the hot spot prospective accuracy between different study regions (Patten, et al., 2010). The PAI is derived from a ratio of the hit rate (the number of crimes in retrospective hot spots compared to the study area) to the area percentage that consists of hot spots in the selected time interval, as shown in the following equation (Swain, 2012):

$$Predictive\ Accuracy\ Index = \frac{Hit\ Rate}{Area\ Percentage} = \frac{n/N}{a/A} \qquad \textit{Formula 2}$$

Where *n* is the number of crimes in the predicted crime area, *N* is the number of crimes in the study area, while *a* is the total area of predicted crimes, and *A* is the size of the study area.

The Recapture Rate Index (RRI) is an adjustment to the PAI, which measures the recapture of prospective crime incidents by comparing the rate of change from a measured time period to a predicted time period.

$$Recapture\ Rate\ Index = \frac{Hot\ Spot\ Crime\ Ratio}{Total\ Crime\ Ratio} = \frac{n1/n2}{N1/N2} \qquad \textit{Formula 3}$$

Where, *n1* is number of crimes in hotspot areas in a year,*n2* is number of crimes in hotspot areas in the consecutive year, *N1* is total number of crimes in a year, *N2* is total number of crimes in the consecutive year. (Fan , 2014)

This measure does not consider the size of hot spots or the study area. Like the hit rate, higher PAI and RRI values correspond to more accurate forecasting results.

2.3. Related Works

The joint utility of all crime analysis methods mentioned above is researched in a paper (Caplan, et al., 2012). According to this paper the joint utility offers law enforcement agencies a unique opportunity to reduce violent crimes immediately by allocating resources to existing hotspots. In addition, authors also suggest that violent crimes can be prevented through interventions at places that are most attractive to motivated offenders given certain characteristics of the environment. The research results confirm that violent crimes occur at places with higher environmental risks, especially if violent crimes occurred there already previously. With the known assumption that the presence of past violent crimes can be a significant predictor of future similar crimes, the authors suggest that the near repeat analysis can be used to categorize violent crime incidents according to their temporal nature; that is, as instigator or near repeat event. The spatial-temporal linkage of such incidents was identified using the "Other functions" tool of the Near Repeat Calculator. Environmental risk remains significant to locations of near repeats even when controlling for the presence of instigator events at micro-level places. Their research supports the theory that near repeat phenomena have a relationship with environmental risks above-and-beyond crime incidents themselves (Caplan, et al., 2012).

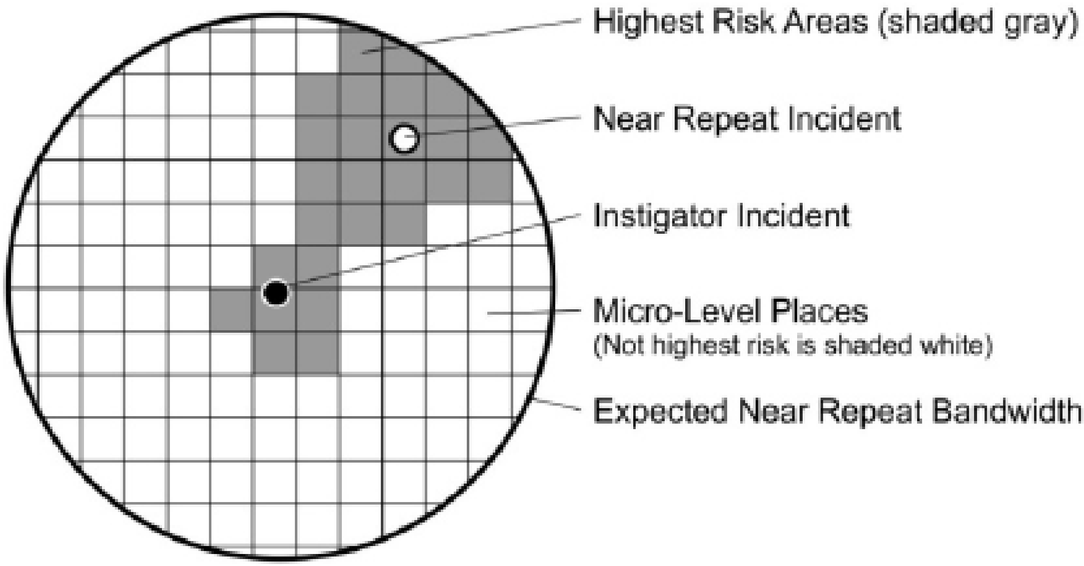

Figure 10: Integration result of hot spot analysis, near repeat concept and RTM (Caplan, et al., 2012)

Figure 10 illustrates that violent crimes that cannot be prevented which serve as the instigator events or the original events for near repeats are most likely to attract near repeat accidents at nearby places which possess high environmental risk. The advantage of knowing that the near repeat phenomenon exists for violent crimes is the ability to prioritize every new crime event according to its proximity to the original or near repeat events. Also assuming that every new crime incident is a potential instigator for near repeats, priority has to be given to new crimes that occur at high risk places with other high risk places in close proximity. Place-based environmental risk assessment with RTM permits real-time evaluation of the propensity for a new crime to become an instigator for near repeats.

In the same research article, the authors came up with a three-part integration of the three techniques for crime analysis and forecasting based on information about each step as shown in the diagram below. Step 1 is the hot spot analysis to assess if and where crimes cluster spatially in the study area. The second step is to model environmental risks with risk terrain modelling to identify high-risk places for criminogenesis (meaning ‘origin of crime’, a term used in the article).

The joint utility of information derived from steps 1 and 2 as shown in the 'A' part in the diagram (Figure 11), is to determine if crime hotspots occur at high risk places or within high-risk clusters.

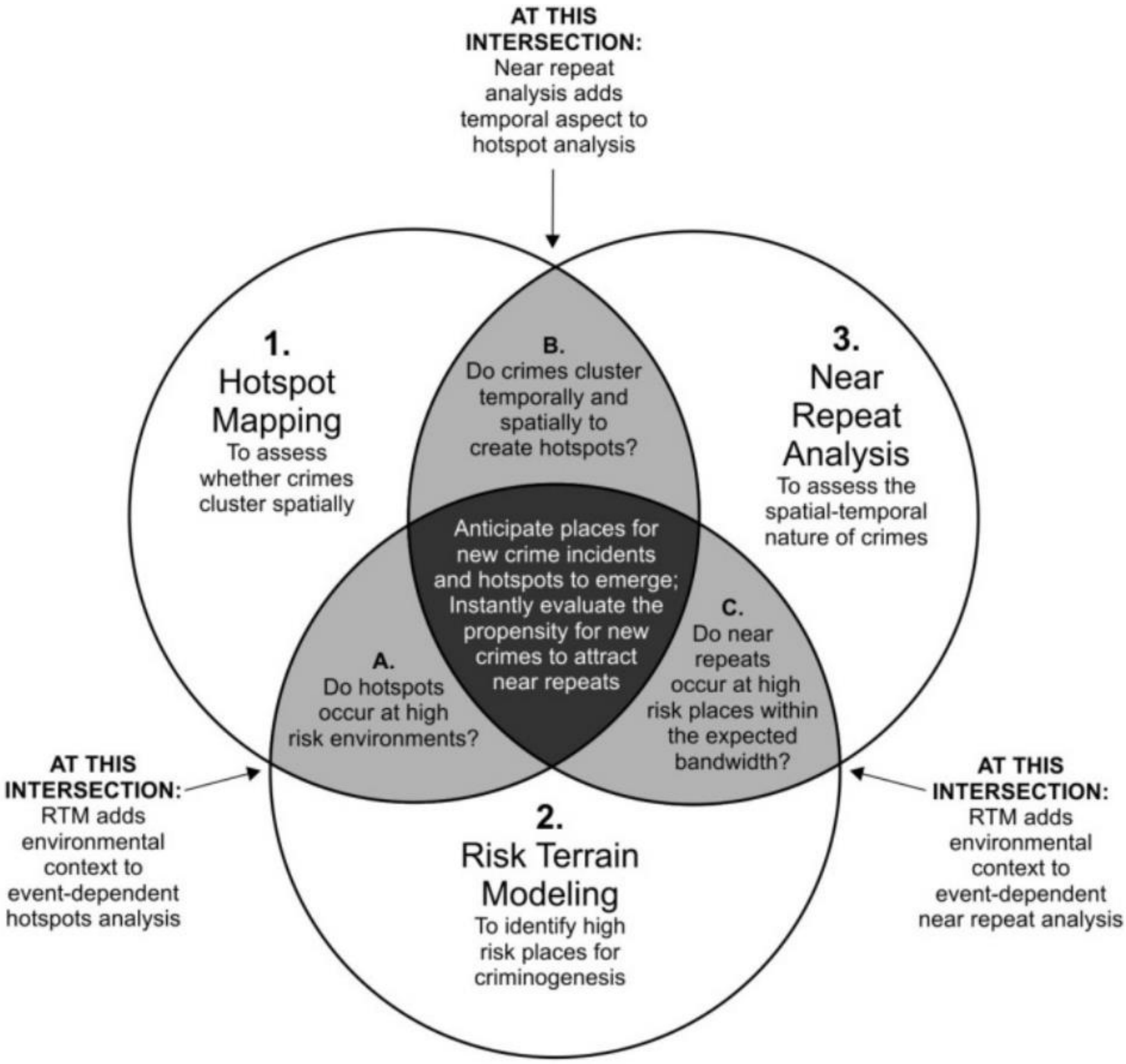

Figure 11: Joint Utility 3-part integration of crime analysis techniques (Caplan, et al., 2012)

This helps in explaining the underlying environmental risk factors that may attract and generate hotspots. The third step is the near repeat analysis to assess the spatial-temporal nature of past crimes. The joint utility of step 1 and 3 as shown in the diagram (Figure 11) at B explains the event-dependent and temporal nature of crime hotspots in the study area. If a near repeat phenomenon exists, then the C (Figure 11) joint utility helps in the evaluation of the propensity for new crime incidents to become instigators for near repeats based upon the proportion of high-risk places within the expected near repeat bandwidth.

The short and long-term strategic planning can be achieved with the combined utility of the three steps. The information output – A helps better the response effectiveness of the police to concentrated areas, while output – B gives the temporal frame in which near repeat crimes are most likely to follow new crime events. This can help reduce the deploying costs for extra resources for long or uncertain lengths of time following new crime incidents. While output – C allows police to prioritize place-based deployments of resources by comparing new crime incidents relative to all others according to the surrounding environments suitability for hosting new near repeat incidents (Caplan, et al., 2012).

Though there is numerous other significant research that has been done on these forecasting methods individually, only this joint utility research paper is relevant to this research project, since the CriPA demonstrator is based on the integration of the three techniques and not anyone individually.

2.4. Summary

GIS and multi-method crime analysis procedures can be reliable for shaping police department policies and practices regarding officer deployments, based on the information from above sections. Many police departments are already known to focus activities on various situational and environmental risk factors at certain locations. The CriPA demonstrator is a software which is based on such joint interpretation and though there are few other private software packages for law enforcement agencies, this prototype has already shown significantly similar and at times better results.

3. Methodology

3.1. Study Area

As the CriPA demonstrator is being developed for the purpose of assisting law enforcement agencies in Austria, the study area should logically be within the geographical boundaries of this country. The CriPA demonstrator has so far been used for Vienna as a whole and some of its individual districts, only. Thus, for the application and evaluation of this software, multiple cities would be ideal in this research, since this allows a comparison and assessment of the results obtained from the CriPA demonstrator. Therefore, the three largest cities in the country, i.e. Vienna, Graz, and Linz are selected as study area in this research. The geographical location and city boundaries for these cities are shown in the Figure 12.

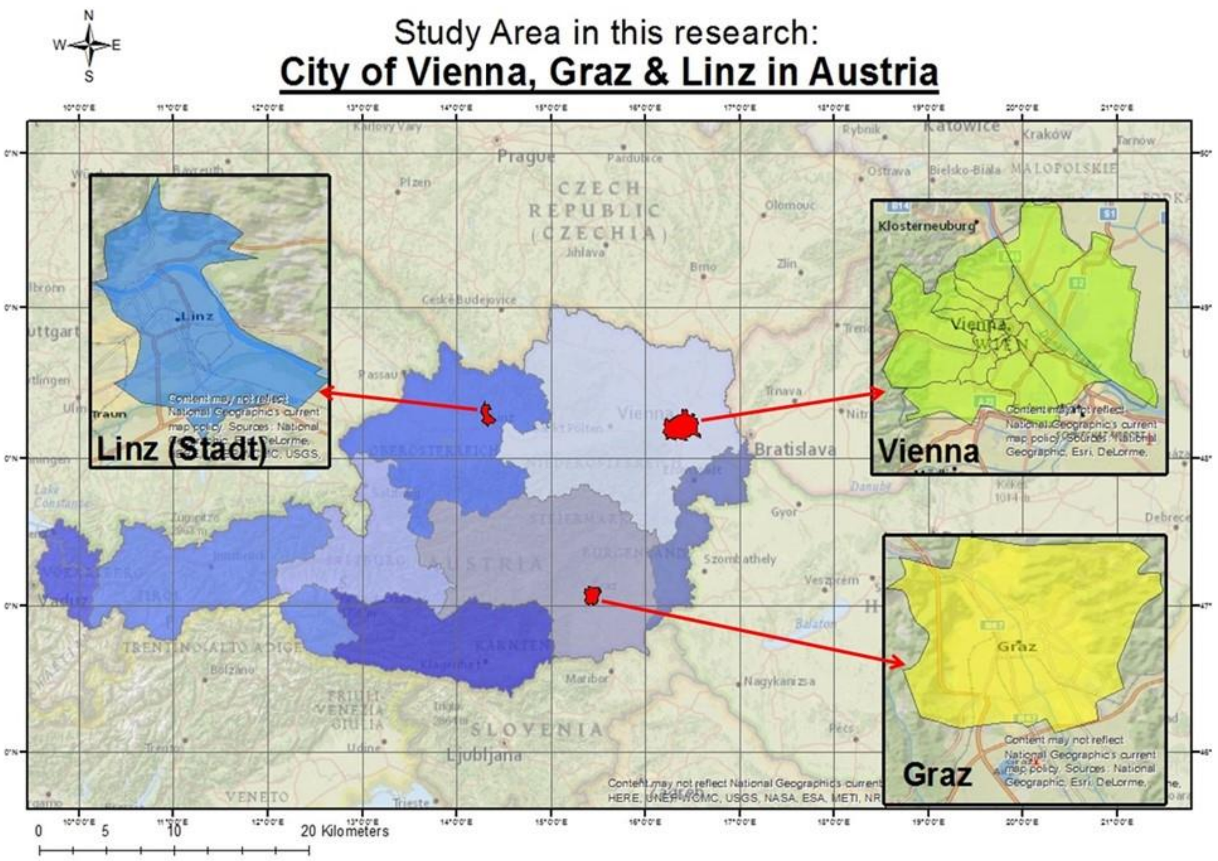

Figure 12: Selected study areas used in this research

Of the 8,700,471 people living in Austria as of 2016, 1,797,337 live in Vienna itself. As the capital city of Austria it spreads over an area of 414.6484 square kilometers. Vienna is also the city with the highest crime rate in the country. It is expected that the largest number of hits will occur in this city, than any other city, as the near repeat phenomenon occurs more often in hotspots. Graz is the capital of the state of Styria and the second largest city in Austria with a population of 274,207 and an area of 127.4816 square kilometers. Linz is the capital of the state of Upper Austria, with a population of 197,427 distributed over 95.9869 square kilometers (AUSTRIA, 2015). It is located to the south of the Czech border. It is considered as the northern center of Austria, making it vulnerable to cross-border crime offenders.

3.2. Crime Data

The Security Monitor (in German: Sicherheitsmonitor - SIMO) which has been in operation from the end of 2003 is used as a tool for nationwide data analysis and storage system (Lattacher, 2004). The data is stored centrally and can be accessed by the law enforcement officers only. From this tool, data can be queried by time, city, state, crime types, and other parameters and extracted into an excel spreadsheet.

id	tatzeit_von	tatzeit_bis	bdl	bezirk	plz	ort	delikt	schlagwort	geklaert	versuch
5214633	01.01.2009 00:30	01.01.2009 06:30	Wien	Josefstadt	1080	Wien	129	WohnungsED	Nein	Nein
5124879	01.01.2009 23:05	02.01.2009 23:05	Wien	Margareten	1050	Wien	129	KFZ-ED	Ja	Nein
5469732	02.01.2009 06:30	02.01.2009 11:30	Wien	Donaustadt	1220	Wien	129	WohnhausED	Nein	Nein
5131856	03.01.2009 05:00	03.01.2009 15:00	Wien	Donaustadt	1220	Wien	129	WohnhausED	Nein	Nein
5749711	04.01.2009 11:00	04.01.2009 23:00	Wien	Favoriten	1100	Wien	129	WohnungsED	Nein	Nein
5748941	06.01.2009 09:45	06.01.2009 11:45	Wien	Meidling	1120	Wien	129	KFZ-ED	Nein	Nein
5749494	11.01.2009 09:50	11.01.2009 09:50	Wien	Donaustadt	1220	Wien	129	WohnhausED	Nein	Nein
5797163	15.01.2009 08:00	15.01.2009 16:00	Wien	Innere Stadt	1010	Wien	129	WohnungsED	Nein	Nein
5146166	20.01.2009 11:35	20.01.2009 18:35	Wien	Floridsdorf	1210	Wien	129	WohnungsED	Nein	Nein

Table 1: Example of the Excel spreadsheet from SIMO with pseudo data

In a similar manner, the Austrian Federal Criminal Police Office also known as Bundeskriminalamt (Bk) in German, has provided crime data for this research.

An excel file comprising of crime data for each city in individual sheets was provided. Multiple crime types are reported and available in the SIMO database, like apartment burglary, business robbery, bank robbery, company burglary, car theft, car burglary, house burglary, handbag robbery, mobile phone theft, among others. According to the Austria 2015 Crime and Safety Report, residential break-ins and pickpocketing continue to be the most prevalent crimes. Especially in the more affluent neighborhoods, residential burglaries, like house and apartment burglaries continue to be a significant concern (OSAC, 2015).

Each dataset comprises of the following 27 attributes (in German): id, tatzeit_von, tatzeit_bis, bdl, bezirk, plz, ort, strasse, delict, schlagwort, geklaert, versuch, Wochentag, kw, monat, Jahr, anmerkung, begehung, begehung_beschreibung, oertlichkeit, oertlichkeit_beschreibung, gut, gut_beschreibung, Kfz_Marke, Kfz_Typ, x, and y. A selection of these column headings, together with some filled-in pseudo data are shown in the Table 1.

The data provided by Austrian Federal Police consist of only three crime types, namely car burglaries, house burglaries, and apartment burglaries reported from 2009-2015 for each of the three cities. For the research objectives in this thesis, of all the attributes only the following are needed:

- Id (unique identification number)
- tatzeit_von (start time of the crime)
- tatzeit_bis (end time of the crime)
- bdl (state name)
- bezirk (district name)
- plz (postal code)
- schlagwort (crime type)
- monat (month)
- Jahr (year of crime occurrence)
- Begehung (modus operandi)
- X coordinate
- Y coordinate

It can be assumed that most crime events are correctly geocoded using the address column. The X and Y coordinates are assigned based on the WGS84 spatial reference system (EPSG: 4326). Also the information shown in Table 1 is randomly generated and sensitive columns, such as address, etc. are deleted so as not to share the original data for security and privacy reasons.

3.3. Method of Solutions

The objective of this methodology and implementation is to know how accurate and consistent the results of the CriPA Demonstrator are. Also, to identify what improvements are required to enhance its performance.

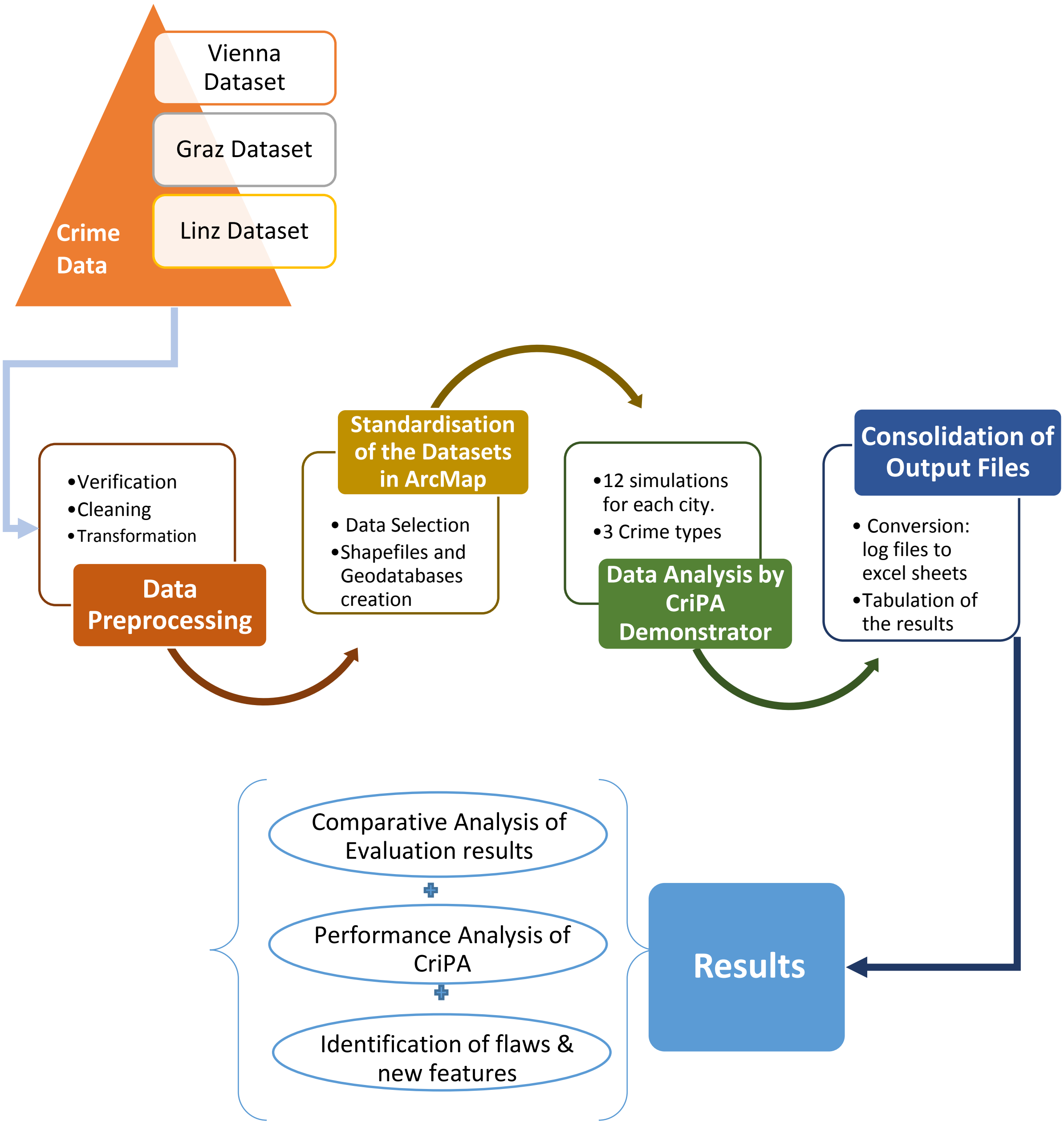

Figure 13: Methodological framework

The methodology, as shown in the Figure 13, is broken down into the following steps for this research project:

- Data preprocessing
- Standardization of datasets in ArcMap
- Data analysis with the CriPA demonstrator
- Consolidation of results
- Analysis & interpretation of results

Data Preprocessing:

As explained in the above Sections 3.1 and 3.2, datasets are to be obtained in an excel file.

The main objective of this step is to eliminate any errors or mistakes in the data and make the data usable for further analysis. Usually, this includes data validation, cleaning, and transformation. First, the information given in all attributes is to be checked manually and corrected. Then, data are visualized in ArcMap so as to check if the X and Y coordinates assigned to each reported crime is correct or not.

Afterwards, the final step would be a transformation, in which, if necessary, any of the attributes are changed in format and new columns are created so as to have all attributes that required for a CriPA demonstrator simulation.

Standardization of the Datasets in ArcMap

Once the data preprocessing is done, the data should be ready for segregation and normalization in anyway, if necessary. For this research, all data are in the format of a shapefile in order to run it with the CriPA demonstrator. So, each of the three datasets are classified and then saved as a shapefile in a geodatabase, which is then used by the CriPA demonstrator. The analysis is done for different crime types for each of the three cities over a selected number of years. Based on this, using the 'Selection' function in ArcMap 10.3.1, datasets are extracted into different layers and saved in their respective city's geodatabase.

Data Analysis with CriPA Demonstrator:

The CriPA demonstrator is still in a prototype stage and it uses the python scripter. Principles and parameters in python script for the analysis are defined based on the near repeat phenomenon. So, the functionality is entirely defined by the user and not predefined as shown in other software available for users.

The following three application functionalities are checked in this research:

- Application: Analyze the three datasets as one dataset and individually to compare the consistency of results.
- Accuracy Evaluation: Evaluation measures are used to assess the accuracy of CriPA demonstrator results.
- Improvements & Limitations: Observation of any drawbacks of the software.

For obtaining best forecasting results from the CriPA demonstrator only a "trial and error method" using different cases can be applied. Various attributes are considered individually in the first set of trials. Then a combination of these attributes will be tested in the second set.

Simulations can be divided at the top level into four segments, i.e. simulations of the single geodatabase having all cities data combined, Vienna geodatabase, Graz geodatabase, and Linz geodatabase. In each of these segments, three different simulations are done for one crime type at a time. The analysis parameters and process is explained in detail in Section 4.3 of the Implementation chapter.

Consolidation of the Results:

The resulting log files are all transferred into excel sheets as output files of the CriPA demonstrator are a text document having columns separated by spaces. Hence, each trial result is tabulated by transferring the data into an excel sheet. All columns are labelled, filtered, and sorted accordingly. Then, new tables are created to cumulate the number of predictions and hits for each of the radii in each simulation across different years. This will further help in the calculation of evaluation measures which is explained in detail in the Results chapter. For example, the area of the city or hotspot area is not obtained in the log file but needs to be calculated separately as it is a variable in the PAI formula. This is one of the three evaluation measures used for comparison.

As all results are standardized in the same manner, required values are noted. These results are then interpreted using tables and charts prepared for the analysis and interpretation of the CriPA demonstrator results.

Analysis & Interpretation of results:

Results of this research project are explained in the following steps:

- Performance & Quality: Analyzed by application of the CriPA demonstrator for the study area as a whole and for three individual cities. Then results are assessed by compared.
- Crime forecasting accuracy: Assessed relatively by comparing results of different filter selections (city, crime type, district, year) using evaluation measures.
- Tool requirement: Development of additional features/tools for better results during the application and evaluation.

Results of the data analysis with the CriPA demonstrator are analyzed and examined extensively in this section. In addition to this, additional features required with their reasoning and possible implementation process are included here.

The next set of results will be the crime forecasting accuracy from comparative evaluation measures. Anticipating that the relative accuracy of the CriPA demonstrator would vary for different datasets and average relative accuracy is obtained which determines which of the software provide crime forecasting results with high accuracy.

The input for the Hit Rate percentage measure is the following:

- Number of crimes in the forecast that hit the calculated retrospective period (n)
- Number of all crimes in the forecast period (N)

The input for the Predictive Accuracy Index measure is the following:

- Number of crimes in the predicted crime area (n)
- Number of crimes in the study area (N)
- Total area of predicted crime (a)
- Size of study area (A)

The input for the Recapture Rate Index measure is the following:

- Number of crimes in retrospective hotspot areas in retrospective period (n1)
- Number of 'future' crimes in retrospective hotspot areas (n2)

- Total number of crimes in retrospective period (N1)
- Total number of ‘future’ crimes in forecasting period (N2)

These evaluation measure indexes for each output are tabulated for each dataset. Then the average mean of all tables will be taken so as to create one final table with three rows for all three datasets and then these are combined and a final table is created.

3.4. Summary

The overall objective of this chapter is to explain the choice of the study area, contents of crime data, and providing an overview of the methodology and workflow, which is the basic structure of the implementation process. In the first subsection along with the reasoning for selection, the basic statistics (population, size, crime) of the study area are mentioned. Multiple attributes and crime types are listed. The collected crime data are described in the second subsection. In the method of solutions subsection, the methodology shown in a flowchart is explained and its implementation details can be found in the following chapter.

4. Implementation

The implementation process is broken down into four steps and explained in Section 3.3. The detailed procedure and statistics are mentioned in this chapter. During implementation the crime data are corrected and analyzed to obtain crime forecasting results from the CriPA demonstrator. These results are then assessed and evaluated by using the evaluation measures. The procedure starts from the step of "data pre-processing" after the crime data have been obtained.

4.1. Data Preprocessing

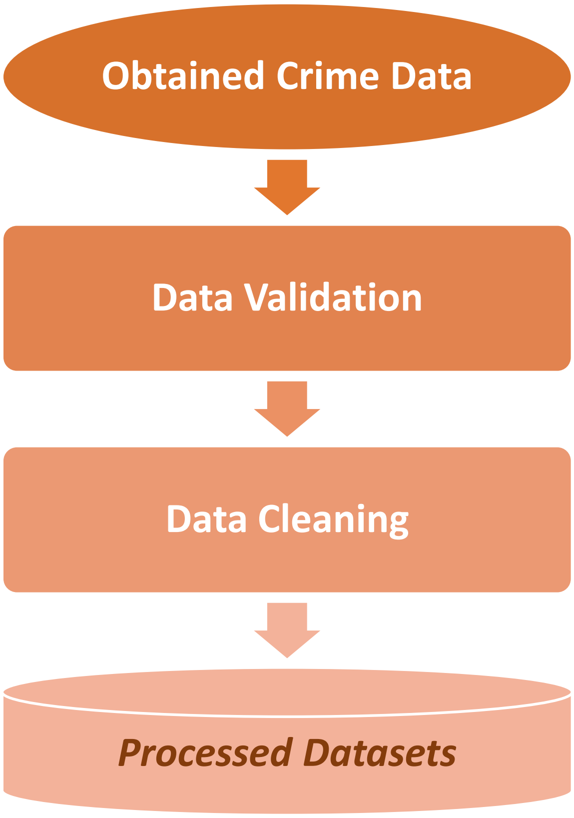

Figure 14: Data Preprocessing Steps

Data preprocessing consists of three steps as shown in Figure 14. Data validation, cleaning, and transformation help identify and correct errors in the data and enhance the usability of them.

Data Validation & Cleaning

For any data, validation is the process of mistake identification and cleaning is the process of eliminating or correcting all types of mistakes later. But for these data both steps are done simultaneously. While the data consist of 27 attributes, validation is done only for attributes used in this research, which are State, City, and Postal code, X coordinate, Y coordinate, crime type, and Unique ID. All these columns are checked for blanks first and for incorrect data, second.

Error Type	Vienna	Graz	Linz
Missing PLZ code	**165**	**99**	**0**
Coordinates outside of Graz	**511**	**45**	**407**
Missing street name	**60**	**5**	**29**
Missing city name	**0**	**99**	**0**
Incorrect PLZ code	**77**	**2**	**0**

Table 2: List of errors identified in obtained crime datasets

No blanks were found in the State, X coordinate, Y coordinate, crime type, and Unique ID columns. This meant that no geocoding was necessary for any of the points. But as shown in Table 2, a list of errors were identified in the postal code, street name, and city columns. Of the three data sets, it was expected that Vienna would have a higher number of errors, because of its huge database.

But the 407 points being found outside of Linz, which is approximately 8% of the whole data, reduces the completeness quality of the data. In contrast and as shown in Table 3, of the 135,742 points included in the Vienna dataset, "only" 511 addresses were found to having coordinates, which are outside of the city's boundaries.

Study Area	Provided No. Of Points	No. Of Points in District Boundaries	No. Of Points beyond District Boundaries	Percentage
Vienna	135742	135231	511	0,38%
Graz	8071	8026	45	0,56%
Linz	5285	4878	407	7,70%

Table 3: Number of crime locations included in the data set that are inside or outside of the three study areas' boundaries

Likewise, in the Graz and Linz datasets out of 8,701 and 5,285 points, 45 and 407 points were found to be outside their respective city boundaries. It is clear that although, the number of incorrectly located points is higher in Vienna dataset, it is clear that the Linz dataset has the poorest completeness quality.

But this is because many of the points outside the boundaries are located under the city outskirts and can be taken into consideration.

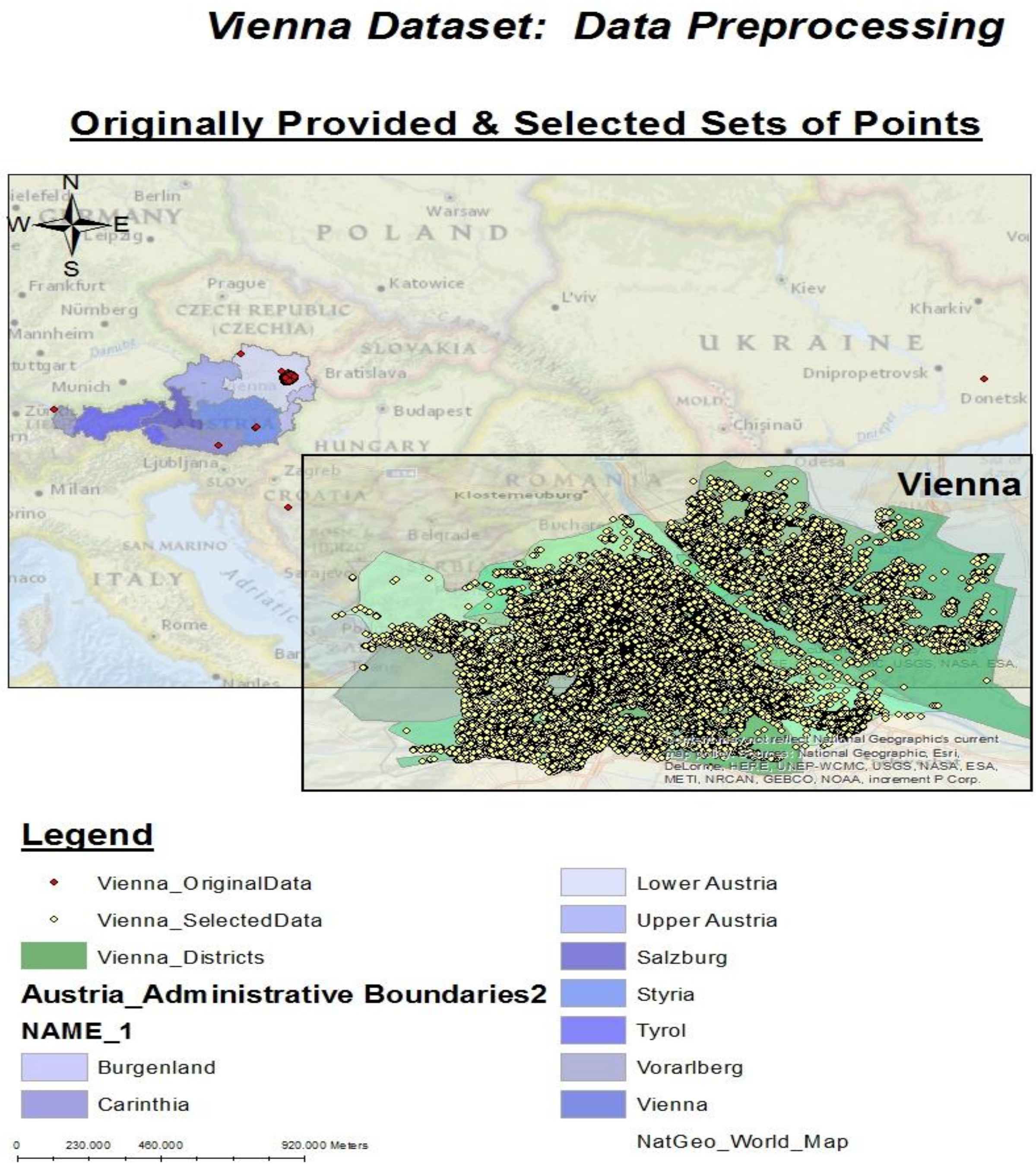

Figure 15: Original data and extracted points inside the state boundary for Vienna

The blanks and the incorrectly located crimes were corrected manually in the excel file with reference to the street attribute and then the data were visualized in ArcMap. By overlaying the data with the city boundary map, points located outside the city boundary were identified and cleaned. This was done by using the function 'Selection by Location' and exporting data as new layers in ArcMap as shown in the Figure 15. This whole procedure done individually for Vienna dataset and then repeated for Graz & Linz datasets.

4.2. Standardization of Datasets for CriPA

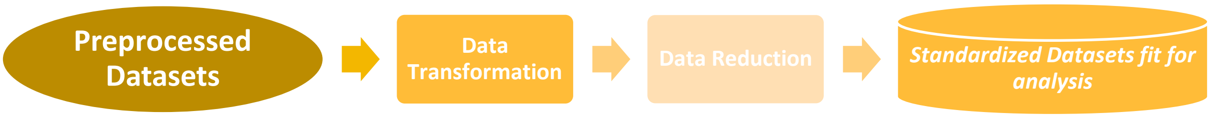

Figure 16: Standardization process of datasets

The next two steps in this process will help change the format of the data and its attributes in such a way that it is ready for analysis with the CriPA demonstrator as shown in the Figure 16.

Data transformation involves normalization of data, its aggregation, and the construction of new attributes. As the existing data have been corrected in this research implementation, the normalization and new attribute creation is done in the step based on requirements of the CriPA demonstrator's script. Usually, the type of entry and stolen goods attribute columns would have required normalization as the columns consist of codes instead of names.

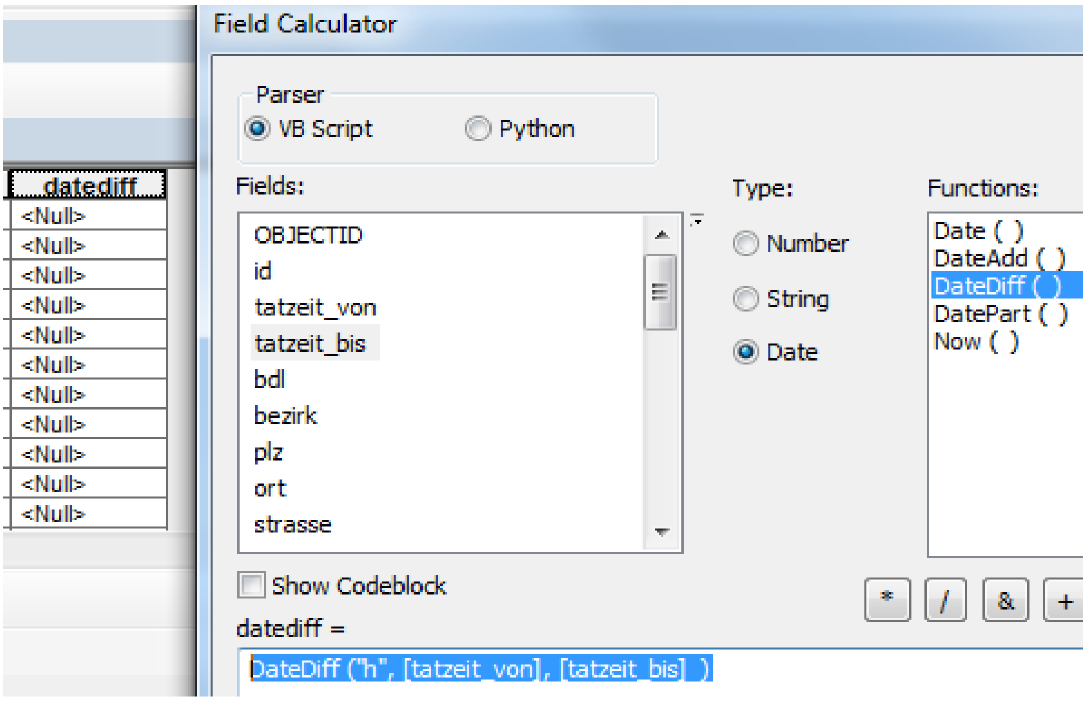

Figure 17: Attribute 'datediff' calculation using the field calculator

The main reason is that in the python script parameters, these attributes are filtered by name and not by number. But as the objective of this research is to assess the quality of CriPA demonstrator results and their variation with attributes, these two attributes are not changed. So the transformation required here in the construction of the date difference, a new attribute abbreviated in the dataset and script as 'datediff'.

This can be done in the excel file initially or in ArcMap in this step. After adding a field in the attribute table using the 'Field Calculator', this new attribute is calculated. In Figure 17, this step is shown where the DateDiff () function is used.

Attributes are named differently in the provided datasets and the CriPA demonstrator's script. In either of these the names can be changed to have one filter name across both. This was done in the script as it is easier to change it in the script at this point. The final attribute table still has all columns labelled in German, but has all essential attributes. A snapshot of the attribute table for the Vienna dataset can be seen in Table 4.

Table

Wien_Points inside the boundary

OBJEC	bezirk	gut	gek	x	y	Tatzeit Ende	beg	Tatzeit Beginn	plz	datediff	Bun	Schlagwort	id
1	Josefstad	817, 829,	Nein	16,347406	48,208988	01.01.2009 00:30:00	443	01.01.2009 00:30:0	1080	0	Wien	WohnungsED	325
2	Margarete	898	Ja	16,35622	48,194369	01.01.2009 02:45:00	448	31.12.2008 17:50:0	1050	8,916667	Wien	KFZ-ED	325
3	Donausta	872	Nein	16,491378	48,229466	01.01.2009 02:30:00	443	31.12.2008 19:00:0	1220	7,5	Wien	WohnhausED	325
4	Donausta	854, 872,	Nein	16,491378	48,229466	01.01.2009 03:00:00	443	31.12.2008 19:30:0	1220	7,5	Wien	WohnhausED	325
5	Favoriten	898	Nein	16,368317	48,174325	01.01.2009 03:00:00	443	31.12.2008 15:00:0	1100	12	Wien	WohnungsED	325
6	Meidling	811, 812,	Nein	16,343071	48,186297	01.01.2009 03:45:00	448	01.01.2009 01:45:0	1120	2	Wien	KFZ-ED	325
7	Donausta	833, 854,	Nein	16,491378	48,229466	01.01.2009 02:50:00	443	31.12.2008 18:45:0	1220	8,083333	Wien	WohnhausED	325
8	Innere Sta	872, 899,	Nein	16,374969	48,208984	01.01.2009 02:00:00	443	31.12.2008 20:00:0	1010	6	Wien	WohnungsED	325
9	Floridsdor	854, 872	Nein	16,424555	48,256444	01.01.2009 03:35:00	443	31.12.2008 18:30:0	1210	9,083333	Wien	WohnungsED	325

Table 4: Attribute table of Vienna dataset after data preprocessing

As this procedure was finished for the Vienna dataset, it is repeated for both the Graz and the Linz datasets.

After all datasets include the required attributes in the desirable format, a geodatabase is created for each city, as well as for the combined dataset. A folder is created for each of the datasets and a geodatabase is created in each. Data in the shapefile format are saved in these geodatabases. These geodatabases are the place from where the data shapefiles are analyzed by the CriPA demonstrator.

To be accurate and reduce time of filtering during any simulations of the datasets, multiple shapefiles are created for each city based on crime type attribute. The final output of this step in the workflow has nine shapefiles in three different geodatabases, one for each city as shown in the Figure 18 which is a screenshot of the ArcMap catalog.

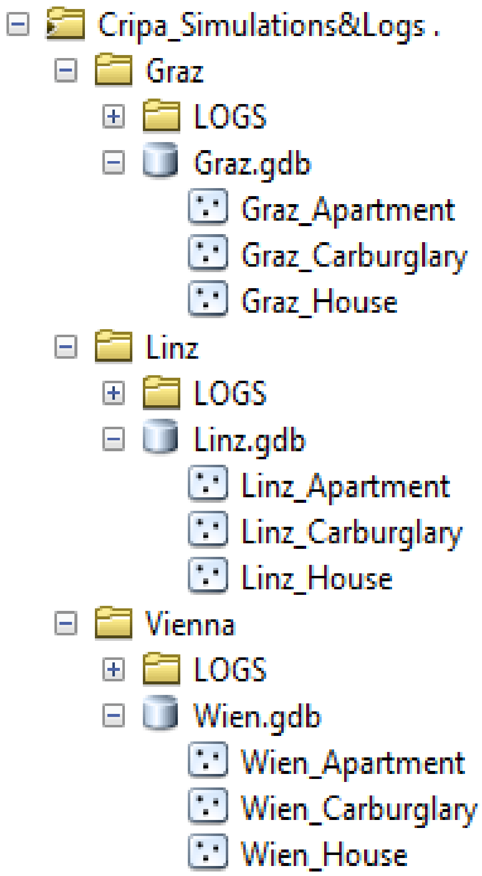

Figure 18: Geodatabases created as input in CriPA demonstrator

4.3. Data Analysis with CriPA Demonstrator

The basic principle for obtaining high quality results from the CriPA demonstrator would only be the trial and error method. Multiple trials with selection of the different parameter settings needs to be done to analyze CriPA demonstrator's results. While altering the script to run simulations in accordance with research goals, changes made in variables and relevant parameters are explained below in sequence of their occurrence in the script:

- The import of arcpy, date time, time, system, and os is constant in every simulation
- The log file location is provided in either of the below formats:

log_file = u'C:\\Desktop\\CriPA\\City\\Logs\\burg.log'

(Or)

log_file = r'C:\Desktop\CriPA\City\Logs\burg.log'

- Similarly, the location of the shapefile is listed next in the same format
- Finally, the simulation start date and time need to be specified. This is in the format: 31.12.2008 23:59:59. Also, the timeframe for the simulation is provided as the number of days from the start date. In this research it is always 2,556 days (7 years).
- Basic parameters to be set for any simulation are the following:
  - Forecast Radius (spaceband list): This parameter has significant impact on the prediction accuracy. Ideal range for this is 200 to 400 meters. By trial and error methods comparing multiple simulations, it is proven that a 400 meter radius gives best results.
  - Observation Period (timebandlist): This is the time period chosen by the user to examine and analyze already reported crime in the area during this time. The ideal range is 1 to 5 days
  - Forecasting Period (prognosedayslist): It is the duration during which the near repeats are forecasted. The ideal range is 1 to 3 days.

400 meters, 5 days and 3 days is the best set for these parameters to get good quality result. This conclusion is reached after running simulations with all possible combinations and assessing the results.

- In each simulation, the data as a whole (in this case the entire city) and each of the two districts (postal code areas) can be analyzed, individually
- The districts of the city (postal codes) falling under the hot spot areas are chosen and they are listed in the Table 5 along with the number of points.
- The filter parameters for each layer are to be defined. The ones used in this research's simulations are Bezirk (District), schlagwort (crime type), and date difference. For each cities simulation, the district is set to its name. For example, for the Linz dataset "bezirk = 'Linz'" and for each crime type simulation it is set as "schlagwort = 'WohnungsED'" for apartment burglaries, "schlagwort = ' KFZ-ED'" for car burglaries, and "schlagwort = ' WohnhausED'" for house burglaries, respectively.

Study Area	Crime Type	PLZ Code	No. of Crime Events
Vienna	Car Burglaries	**1100**	8,631
		1220	6,983
	House Burglaries	**1220**	2,793
		1210	1,555
	Apartment Burglaries	**1100**	4,708
		1030	3,286
Graz	Car Burglaries	**8010**	1,138
		8020	1,039
	House Burglaries	**8010**	315
		8020	225
	Apartment Burglaries	**8010**	1,350
		8020	852
Linz	Car Burglaries	**4020**	1,276
		4030	568
	House Burglaries	**4020**	300
		4030	269
	Apartment Burglaries	**4020**	1,044
		4030	393

Table 5: Postal Codes of areas with highest number of crime events

- The date difference which is calculated in hours is set to 72 hours for all simulations. This helps in exclusively selecting crimes happening within 72 hours of their start time.
- The logger columns were given sequential labels, such as:
  - Analysedatum {}
  - Space {}
  - Time {}
  - PrognoseTime {}
  - O_G_L {}
  - O_ED_L {}
  - O_G_4020 {}

- O_ED_4020 {}
- O_G_4030 {}
- O_ED_4030 {}
- NR_G_L {}
- NR_ED_L {}
- NR_G_4020 {}
- NR_ED_4020 {}
- NR_G_4030 {}
- NR_ED_4030 {}
- M_G_L {}
- M_ED_L {}
- M_G_4020 {}
- M_ED_4020 {}
- M_G_4030 {}
- M_ED_4030 {}

The description of each of the columns is included in Section 4.3. As the script alteration is finished, each time it is saved under a different file name rather than overwriting the same file every time for future reference and check. Then simulations are run. As the Vienna dataset has 135,231 crime events it took the longest time for its simulations to be completed. Each of these three simulations took a minimum of around 18 hours, while the Graz and Linz simulations were finished within three hours each. This duration is for one crime type in each dataset. None of the other parameters, such as stolen goods, type of entry, etc. are used in these simulations in order to assess the quality of results solely based on the basic variables used in crime analysis, in general. Once all simulations are finished, resulting log files can be found in the 'Logs' folder, as designated.

4.4. Consolidation of the CriPA Output files

This step involves the post processing of output files. The output file contains all the logger components, as shown in Table 6. Every output log file is first imported into MS excel. The output data are transformed so as to make them usable for calculations and tabulations. Once data are transformed, all label columns are deleted and each data column is given a title. The output table for each crime type of every city would look exactly like the one shown in Table 7.

Graz_Houseburglary_allyears - Notepad

File Edit Format View Help

```
Sun Jun 25 19:28:39 2016 Analysedatum 2008-12-31 23:59:59 Space 400 Time 5 PrognoseTime 3 O_G_G - O_ED_G - O_
Sun Jun 25 19:28:43 2016 Analysedatum 2009-01-01 23:59:59 Space 400 Time 5 PrognoseTime 3 O_G_G - O_ED_G - O_
Sun Jun 25 19:28:45 2016 Analysedatum 2009-01-02 23:59:59 Space 400 Time 5 PrognoseTime 3 O_G_G - O_ED_G - O_
Sun Jun 25 19:28:47 2016 Analysedatum 2009-01-03 23:59:59 Space 400 Time 5 PrognoseTime 3 O_G_G - O_ED_G - O_
Sun Jun 25 19:28:49 2016 Analysedatum 2009-01-04 23:59:59 Space 400 Time 5 PrognoseTime 3 O_G_G - O_ED_G - O_
Sun Jun 25 19:28:51 2016 Analysedatum 2009-01-05 23:59:59 Space 400 Time 5 PrognoseTime 3 O_G_G - O_ED_G - O_
Sun Jun 25 19:28:53 2016 Analysedatum 2009-01-06 23:59:59 Space 400 Time 5 PrognoseTime 3 O_G_G - O_ED_G - O_
Sun Jun 25 19:28:55 2016 Analysedatum 2009-01-07 23:59:59 Space 400 Time 5 PrognoseTime 3 O_G_G - O_ED_G - O_
Sun Jun 25 19:28:59 2016 Analysedatum 2009-01-08 23:59:59 Space 400 Time 5 PrognoseTime 3 O_G_G - O_ED_G - O_
Sun Jun 25 19:29:03 2016 Analysedatum 2009-01-09 23:59:59 Space 400 Time 5 PrognoseTime 3 O_G_G - O_ED_G - O_
Sun Jun 25 19:29:05 2016 Analysedatum 2009-01-10 23:59:59 Space 400 Time 5 PrognoseTime 3 O_G_G - O_ED_G - O_
Sun Jun 25 19:29:07 2016 Analysedatum 2009-01-11 23:59:59 Space 400 Time 5 PrognoseTime 3 O_G_G - O_ED_G - O_
Sun Jun 25 19:29:09 2016 Analysedatum 2009-01-12 23:59:59 Space 400 Time 5 PrognoseTime 3 O_G_G - O_ED_G - O_
Sun Jun 25 19:29:11 2016 Analysedatum 2009-01-13 23:59:59 Space 400 Time 5 PrognoseTime 3 O_G_G - O_ED_G - O_
Sun Jun 25 19:29:13 2016 Analysedatum 2009-01-14 23:59:59 Space 400 Time 5 PrognoseTime 3 O_G_G - O_ED_G - O_
```

Table 6: Resulting log file of the CriPA simulation for house burglaries in Graz

The column 'Analysedatum' defines the date and time when the crime occurred. Columns 'Space', 'Time', and 'PrognoseTime' are the forecast radius, observation period, and forecast period, which was already discussed above. Column 'O_G_L' is the number of days during which at least one near repeat is predicted, and 'G' in the column label suggests this. The letter 'O' suggests that this is calculated, when the radius is drawn around the original crime in the observation period. The last letter 'L' stands for Linz. Similarly, G stands for Graz and V for Vienna. 'O_G_4020' and 'O_G_4030' are the same columns labels, but instead for the entire city, 4020, 4030, etc. define the districts through postal codes.

Analysedatum		Space	Time	PrognoseTime	O_G_G	O_ED_G	O_G_8010	O_ED_8010	O_G_8020	O_ED_8020	NR_G_G	NR_ED_G	NR_G_8010	NR_ED_8010	NR_G_8020	NR_ED_8020	M_G_G	M_ED_G	M_G_8010	M_ED_8010	M_G_8020	M_ED_8020
31.12.2008	23:59:59	400	5	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
01.01.2009	23:59:59	400	5	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
02.01.2009	23:59:59	400	5	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
03.01.2009	23:59:59	400	5	3	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
04.01.2009	23:59:59	400	5	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
05.01.2009	23:59:59	400	5	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
06.01.2009	23:59:59	400	5	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
07.01.2009	23:59:59	400	5	3	2	0	1	0	0	0	2	0	1	0	0	0	2	0	1	0	0	0
08.01.2009	23:59:59	400	5	3	3	1	2	0	1	1	3	1	2	0	1	1	3	1	2	0	1	1

Linz_Carburglary_allyears | Linz_Houseburglary_allyears | Linz_Apartmentburglary_allyears | Linz_Results | Linz_Calculations

Table 7: Excel sheet with results car burglaries in Linz

'O_ED_L' has the same radius as O_G_L, but is the number of near repeats occurring during the specified forecasting period. This is represented by letters 'ED' in the column label. 'O_ED_4020' and 'O_ED_4030' are the same but instead of the entire city Linz, the labels refer to specific districts, based on their postal code.

'NR_G_L' is the number of days during which at least one near repeat is predicted and 'G' in the column label suggests this. The letter 'NR' suggests that this is calculated, when the radius is drawn around the near repeat event. The last letter 'L' stands for Linz and similarly, G stands for Graz, and V stands for Vienna. In general, this indicates the part of the study area where the simulation was carried out. 'NR_G_4020' and 'NR_G_4030' are the same but instead of the entire city Linz, both labels refer to the two districts in Linz.

'NR_ED_L' has the same radius as NR_G_L, but is the number of near repeats that occurred during the specified forecasting period. This is represented by the letters 'ED' in the column label. 'NR_ED_4020' and 'NR_ED_4030' are the same but instead of for the entire city Linz, both labels refer to the two districts in Linz.

'M_G_L' is calculated, when both the OR and NR circles are merged (M) into one buffer area. This is also the number of days during which at least one near repeat is predicted, and 'G' in the column label suggests this. The letter 'O' suggests that this is calculated, when the radius is drawn around the original crime in the observation period. The last letter 'L' stands for Linz and similarly, G stands for Graz, and V stands for Vienna. In general, this indicates the part of the study area where the simulation was carried out. 'M_G_4020' and 'M_G_4030' are the same but instead of the entire city Linz, both labels refer to the two districts in Linz.

'M_ED_L' has the same radius as M_G_L, but is the number of near repeats that occurred during the specified forecasting period. This is represented by the letters 'ED' in the column label. 'M_ED_4020' and 'M_ED_4030' are the same, but instead of the entire city Linz, both labels refer to the two districts in Linz.As the last letters of the column label would change with another city and its two postal area codes, the rest of the columns remain the same. This step is repeated for each crime type simulation in Vienna and then is repeated for the other two cities, accordingly. Finally there are thus three excel files having the following spreadsheets for each city: car burglary results, house burglary results, apartment burglary results, accumulated result tables, and calculations.

The following tables (Table 8, 9, and 10) are for the accumulated results for the Graz dataset to provide an overview of how the accumulated results look like.

Graz_Apartment Burglaries

Year	O_G_G	O_ED_G	O_G_8010	O_ED_8010	O_G_8020	O_ED_8020	NR_G_G	NR_ED_G	NR_G_8010	NR_ED_8010	NR_G_8020	NR_ED_8020	M_G_G	M_ED_G	M_G_8010	M_ED_8010	M_G_8020	M_ED_8020
2009	40	5	22	5	12	1	40	4	22	2	12	1	40	5	22	3	12	1
2010	51	14	36	12	9	2	50	8	34	6	11	2	50	14	35	12	11	2
2011	46	9	19	4	1	0	47	7	20	3	1	0	46	9	19	4	1	0
2012	77	14	38	6	12	1	77	13	38	5	11	1	77	14	39	6	13	1
2013	23	2	13	2	7	0	23	2	13	2	7	0	23	2	13	2	7	0
2014	26	8	15	4	11	4	26	9	16	6	9	2	26	10	17	6	11	4
2015	79	24	45	15	32	6	81	20	45	12	33	7	77	28	45	16	31	9
Total	342	76	188	46	84	14	344	63	188	36	84	13	339	82	190	49	86	17

Table 8: Accumulated CriPA results of apartment burglaries in Graz

Graz_Car burglaries

Year	O_G_G	O_ED_G	O_G_8010	O_ED_8010	O_G_8020	O_ED_8020	NR_G_G	NR_ED_G	NR_G_8010	NR_ED_8010	NR_G_8020	NR_ED_8020	M_G_G	M_ED_G	M_G_8010	M_ED_8010	M_G_8020	M_ED_8020
2009	99	35	40	23	27	8	100	34	37	21	28	7	99	37	41	23	30	9
2010	65	21	27	15	21	3	66	19	27	14	22	3	65	21	27	15	22	3
2011	55	11	31	9	10	0	54	11	29	10	9	0	54	12	31	10	9	0
2012	22	2	8	0	8	1	22	2	7	0	9	1	22	2	8	0	9	1
2013	31	3	6	1	16	2	31	4	6	2	15	2	31	4	6	2	16	2
2014	29	4	7	0	15	4	29	4	7	0	15	4	29	4	7	0	15	4
2015	69	24	20	13	32	11	68	23	21	11	32	11	67	28	21	14	33	14
Total	370	100	139	61	129	29	370	79	134	58	130	28	367	108	141	64	134	33

Table 9: Accumulated CriPA results of car burglaries in Graz

Graz_House Burglaries

Year	O_G_G	O_ED_G	O_G_8010	O_ED_8010	O_G_8020	O_ED_8020	NR_G_G	NR_ED_G	NR_G_8010	NR_ED_8010	NR_G_8020	NR_ED_8020	M_G_G	M_ED_G	M_G_8010	M_ED_8010	M_G_8020	M_ED_8020
2009	15	0	2	0	2	0	15	0	2	0	2	0	15	0	2	0	2	0
2010	17	2	4	1	5	0	16	1	14	11	25	20	16	1	5	2	7	0
2011	22	1	0	0	5	0	22	1	0	0	5	0	22	1	0	0	5	0
2012	23	1	5	0	6	1	23	1	2	0	6	1	23	1	5	0	6	1
2013	11	0	3	0	0	0	11	0	2	0	0	0	11	0	3	0	0	0
2014	4	0	0	0	0	0	4	0	0	0	0	0	4	0	0	0	0	0
2015	13	2	0	0	1	0	13	2	0	0	1	0	13	2	0	0	1	0
Total	105	6	14	1	19	1	104	5	20	11	39	21	104	5	15	2	21	1

Table 10: Accumulated CriPA results of house burglaries in Graz

These results are then used to calculate all variables needed for the Hit Rate percentage, PAI, and RRI formulae. This, together with calculations of the evaluation measures, is included in an additional excel sheet. This is explained clearly in the next chapter.

4.5. Summary

This chapter is written with the sole objective of describing each and every step of the implementation carried out in this research in order to assess the application and evaluation of the CriPA demonstrator. For all steps in Sections 4.1 (Data Preprocessing) and 4.2 (Standardization of the Datasets) the MS Excel and ArcMap 10.3.1 are used as tools. By the end of both sections the data are ready for the main analysis with the CriPA demonstrator. In Section 4.3 it is seen that after all analysis is completed with the CriPA demonstrator, output files are used to assess and evaluate the software in the following chapter. Section 4.4 discussed how to consolidate and transform CriPA output files so as to make these output files usable for the evaluation process.

5. Results & Interpretation

In this chapter the results from the CriPA demonstrator are interpreted and analyzed as part of the objectives in this research. This chapter is classified into three major sections, one for each city and their comparison is presented at the end of each section. In each of these three subsections, both the best radius and burglary types with the best forecasting results are identified. At the end, after all three city results are discussed, the comparison of these cities is done.

In each subsection, the "ORNR" radius type in the results table includes PAI values that are 'incomputable'. The reason being that the size for the forecasting study area i.e. 'a' is unknown, because the area of the two merged circles is unknown for each point in the output file. Similarly, the RRI values for 2015 and RRI values for the total of all seven years is also 'incomputable' in each of the 27 Tables in Appendix A, as the number of points in the successive year 'n2' (which is 2016) were not collected, since these data were not available, when the writing of this Master Thesis started at the beginning of 2016.

5.1. Vienna

5.1.1. Apartment Burglary

The number of offenses reported over the seven years in Vienna and the two selected districts with postal codes 1100 and 1030 are 51,382, 4,709 and 3,286, respectively. The number of offenses along with the number of days when at least one event has a near repeat and the number of near repeats in a year are included in Appendix Tables B1, B2, and B3.

5.1.1.1. Radius Type: OR

Results for this radius type can be found in the Appendix Table A1. Across the seven years from 2009 to 2015 the Decline Rate varies from 0.04 to 0.17, which means that only about 4 to 17% of offenses possess near repeats. The Hit Rate percentage varies from 34 to 79%, while PAI values vary from 0.06 to 8.59, and RRI values vary from 0.61 to 2.66.

The total of all seven years is seen in the last three rows of the Appendix Table A1. While Vienna as a whole has a Decline Rate of 0.10 and a Hit Rate of 0.60, the district with the postal code "1100", with the highest number of crime events, has a Decline Rate of 0.08 and a Hit Rate of 0.54. The Decline and Hit Rates are slightly higher by 2% and 6%, respectively, for the entire city. If Vienna is compared to the area with the second highest crime events (district with postal code "1030"), then the accuracy is slightly higher for the district area as the Decline Rate for the 1030 district is 0.12 and the Hit Rate is 0.61.

5.1.1.2. Radius Type: NR

Results for this radius type can be found in the Appendix Table A2. Across the seven years from 2009 to 2015 the Decline Rate varies from 0.03 to 0.16, which means that only about 3 to 16% of offenses possess near repeats. The Hit Rate percentage varies from 31 to 73%, while PAI values vary from 0.10 to 17.18, and RRI values vary from 0.61 to 2.38.

The total of all seven years is seen in the last three rows of the Appendix Table A2. While Vienna as a whole has a Decline Rate of 0.09 and a Hit Rate of 0.53, the district with the postal code "1100", with the highest number of crime events has a Decline Rate of 0.07 and a Hit Rate of 0.48. The Decline and Hit Rates are slightly higher by 2% and 5%, respectively, for the entire city. If Vienna is compared to the area with the second highest crime events (district with postal code "1030"), then the accuracy is slightly higher for the district area as the Decline Rate for the 1030 district is 0.11 and the Hit Rate is 0.57.

5.1.1.3. Radius Type: ORNR

Results for this radius type can be found in the Appendix Table A3. Across the seven years from 2009 to 2015 the Decline Rate varies from 0.05 to 0.19, which means that only about 5 to 19% of offenses possess near repeats. The Hit Rate percentage varies from 42 to 91%, while RRI values vary from 0.58 to 2.65.

The total of all the seven years is seen in the last three rows of the Appendix Table A3. While Vienna as a whole has a Decline Rate of 0.11 and a Hit Rate of 0.71, the district with the postal code "1100", with the highest number of crime events, has a Decline Rate of 0.09 and a Hit Rate of 0.63. The Decline and the Hit Rates are slightly higher by 2% and 8%, respectively, for the entire city. The Decline and Hit Rates for the district with the second highest crime events (district with postal code "1030") are 0.13 and 0.70, respectively. This Decline Rate is 2% higher, but the Hit Rate is 1% lower compared to Vienna as a whole.

5.1.1.4. Comparison of Radius Types

Year	Radius Type	HR	DR	PAI	RRI
Total	OR	0,60	0,10	0,06	Incomputable
	NR	0,53	0,09	0,10	
	ORNR	0,71	0,11	Incomputable	

Table 11: Evaluation measures of apartment burglaries for Vienna

Year	Radius Type	HR	DR	PAI	RRI
Total	OR	0,60	0,10	0,06	Incomputable
	NR	0,48	0,07	1,18	
	ORNR	0,63	0,09	Incomputable	

Table 12: Evaluation measures of apartment burglaries in the Vienna district 1100

Year	Radius Type	HR	DR	PAI	RRI
Total	OR	0,61	0,12	0,81	Incomputable
	NR	0,57	0,11	1,32	
	ORNR	0,70	0,13	Incomputable	

Table 13: Evaluation measures of apartment burglaries in the Vienna district 1030

The consolidated results for Vienna and its districts can be seen in Table 11, 12 and 13. When analyzing all three radius types measures for the whole city and the two districts, it can be concluded that the best output can be expected from the merged area ("ORNR") in case of apartment burglaries in Vienna as a whole.

5.1.2. Car Burglary

The number of offenses reported over the seven years in Vienna, and the two selected districts with postal codes 1100 and 1220 are 15,040, 1,672 and 707 respectively. The number of offenses along with the number of days when at least one event has a near repeat and the number of near repeats in a year are included in Appendix Tables B4, B5, and B6.

5.1.2.1. Radius Type: OR

Results for this radius type can be found in the Appendix Table A4. Across the seven years from 2009 to 2015 the Decline Rate varies from 0.03 to 0.35, which means that only about 3 to 35% of offenses possess near repeats. The Hit Rate percentage varies from 24 to 152%, while PAI values vary from 0.35 to 5.65, and RRI values vary from 0.20 to 3.10.

The total of all seven years is seen in the last three rows of the Appendix Table A4. While Vienna as a whole has a Decline Rate of 0.21 and a Hit Rate of 1.05, the district with the postal code "1100", with the highest number of crime events, has a Decline Rate of 0.19 and a Hit Rate of 1.01. The Decline and the Hit Rates are slightly higher by 2% and 4%, respectively, for the entire city. If Vienna is compared to the area with the second highest crime events (district with postal code "1220"), then the accuracy is also slightly lower for the district area as the Decline Rate for the 1220 district is 0.10 and the Hit Rate is 0.67.

5.1.2.2. Radius Type: NR

Results for this radius type can be found in the Appendix Table A5. Across the seven years from 2009 to 2015 the Decline Rate varies from 0.03 to 0.27, which means that only about 3 to 27% of offenses possess near repeats. The Hit Rate percentage varies from 24 to 116%, while PAI values vary from 0.06 to 10.99, and RRI values vary from 0.22 to 3.62.

The total of all seven years is seen in the last three rows of the Appendix Table A5. While Vienna as a whole has a Decline Rate of 0.18 and a Hit Rate of 0.87, the district with the postal code "1100", with the highest number of crime events, has a Decline Rate of 0.17 and a Hit Rate of 0.87. The Decline Rate is slightly higher for the whole city by 1% and the Hit Rate is the same.

If Vienna is compared to the area with the second highest crime events (district with postal code "1220"), then the accuracy is also slightly lower for the district area as the Decline Rate for the 1220 district is 0.09 and the Hit Rate is 0.61.

5.1.2.3. Radius Type: ORNR

Results for this radius type can be found in the Appendix Table A6. Across the seven years from 2009 to 2015 the Decline Rate varies from 0.03 to 0.38, which means that only about 3 to 38% of offenses possess near repeats. The Hit Rate percentage varies from 29 to 169% while RRI varies from 0.24 to 2.78.

The total of all seven years is seen in the last three rows of the Appendix Table A6. While Vienna as a whole has a Decline Rate of 0.23 and a Hit Rate of 1.22, the district with the postal code "1100", with the highest number of crime events, has a Decline Rate of 0.22 and a Hit Rate of 1.15. The Decline and the Hit Rates are slightly higher by 1% and 7, respectively, for the entire city. The Decline and Hit Rates for the district with the second highest crime events (district with postal code “1220”) are 0.11 and 0.73 respectively. The Decline rate is 12% higher and Hit Rate is 49% lower for the district when compared to Vienna as a whole.

5.1.2.4. Comparison of Radius Types

Year	Radius Type	HR	DR	PAI	RRI
Total	OR	1,05	0,21	0,06	Incomputable
	NR	0,87	0,18	0,06	
	ORNR	1,22	0,23	Incomputable	

Table 14: Evaluation Measures of car burglaries for Vienna

Year	Radius Type	HR	DR	PAI	RRI
Total	OR	1,01	0,19	0,51	Incomputable
	NR	0,87	0,17	0,50	
	ORNR	1,15	0,22	Incomputable	

Table 15: Evaluation Measures of car burglaries in the Vienna district 1100

Year	Radius Type	HR	DR	PAI	RRI
Total	OR	0,67	0,10	0,52	Incomputable
	NR	0,61	0,09	0,78	
	ORNR	0,73	0,11	Incomputable	

Table 16: Evaluation measures of car burglaries in the Vienna district 1220

Evaluation measures for Vienna as a whole and the two districts are shown in Tables 14, 15, and 16. By analyzing all three radius types’ measures, it can be concluded that the best output can be expected from the merged radius area (“ORNR”) in case of the car burglaries in Vienna as a whole.

5.1.3. House Burglary

The number of offenses reported over the seven years in Vienna, and the two selected districts with postal codes 1220 and 1210 are 11,555, 2,809 and 1,576 respectively. The number of offenses along with the number of days when at least one event has a near repeat and the number of near repeats in a year are included in Appendix Tables B7, B8, and B9.

5.1.3.1. Radius Type: OR

Results for this radius type can be found in the Appendix Table A7. Across the seven years from 2009 to 2015 the Decline Rate varies from 0.00 to 0.06, which means that only about 0 to 6% of offenses possess near repeats. The Hit Rate percentage varies from 0 to 37%, while PAI values vary from 0.00 to 7.33, and RRI values vary from 0.21 to 4.81. Only one value across the whole table is 'indeterminate', because the number of hits in the year 2015 for the district 1210 is zero.

The total of all seven years is seen in the last three rows of the Appendix Table A7. While Vienna as a whole has a Decline Rate of 0.02 and a Hit Rate of 0.21, the district with the postal code "1220", with the highest number of crime events, has a Decline Rate of 0.02 and a Hit Rate 0.22. The Hit Rate is slightly higher for the district city by 1% and the Decline Rate is same for the district "1220". If Vienna is compared to the area with the second highest crime events (district with postal code "1210"), then the accuracy is also slightly lower for the district area as the Decline Rate for the 1210 district is 0.01 and the Hit Rate is 0.14.

5.1.3.2. Radius Type: NR

Results for this radius type can be found in the Appendix Table A8. Across the seven years from 2009 to 2015 the Decline Rate varies from 0.00 to 0.06, which means that only about 0 to 6% of offenses possess near repeats. The Hit Rate percentage varies from 0 to 37%, while PAI values vary from 0.74 to 54.97, and RRI values vary from 0.21 to 2.37. Four values across the whole table are 'indeterminate', because the number of hits in the years 2013 and 2015 for the district 1210 is zero.

The total of all seven years is seen in the last three rows of the Appendix Table A8. While Vienna as a whole has a Decline Rate of 0.02 and a Hit Rate of 0.20, the district with the postal code "1220", with the highest number of crime events, has a Decline Rate of 0.02 and a Hit Rate of 0.22. The Hit Rate is slightly lower for the district city by 2% but the Decline Rate is the same for Vienna. If Vienna is compared to the area with the second highest crime events (district with postal code "1210"), then the accuracy is also slightly lower for the district area as the Decline Rate for the 1210district is 0.01 and the Hit Rate is 0.12.

5.1.3.3. Radius Type: ORNR

Results for this radius type can be found in the Appendix Table A9. Across the seven years from 2009 to 2015 the Decline Rate varies from 0.00 to 0.06, which means that only about 0 to 6% of offenses possess near repeats. The Hit Rate percentage varies from 0 to 39% while RRI varies from 0.21 to 3.22. Only one value across the whole table is 'indeterminate', because the number of hits in the year 2015 for the district 1210 is zero.

The total of all seven years is seen in the last three rows of the Appendix Table A9. While Vienna as a whole has a Decline Rate of 0.02 and a Hit Rate of 0.23, the district with the postal code "1220", with the highest number of crime events, has a Decline Rate of 0.03 and a Hit Rate of 0.25. The Hit Rate is slightly lower for the district city by 2% and Decline Rate by 1%. If Vienna is compared to the area with the second highest crime events (district with postal code "1210"), then the accuracy is also slightly lower for the district area as the Decline Rate for the 1210 district is 0.01 and the Hit Rate is 0.14. Decline Rate is 1% higher and the Hit Rate is 9% higher for Vienna as a whole.

5.1.3.4. Comparison of Radius Types

Year	Radius Type	HR	DR	PAI	RRI
Total	OR	0,21	0,02	0,15	Incomputable
	NR	0,20	0,02	0,74	
	ORNR	0,23	0,02	Incomputable	

Table 17: Evaluation measures of house burglaries for Vienna

Year	Radius Type	HR	DR	PAI	RRI
Total	OR	0,22	0,02	0,55	Incomputable
	NR	0,22	0,02	2,55	
	ORNR	0,25	0,03	Incomputable	

Table 18: Evaluation measures of car burglaries in the Vienna district 1220

Year	Radius Type	HR	DR	PAI	RRI
Total	OR	0,14	0,01	0,80	Incomputable
	NR	0,12	0,01	5,81	
	ORNR	0,14	0,01	Incomputable	

Table 19: Evaluation measures of car burglaries in the Vienna district 1210

When analyzing all three radius types' measures for the whole city and the two districts, it can be concluded that the best output can be expected from the merged area ("ORNR") in case of house burglaries in Vienna. Although the Decline Rate is same for this burglary type, the Hit Rate and PAI support this conclusion. All the measure values for each burglary type for Vienna are tabulated in the Table 17, 18, and 19 respectively.

5.1.4. Comparison of Burglary Types

The highest Hit Rate for apartment burglaries is 71%, while for car and house burglaries, it is 122% and 25%, respectively. This indicates that car burglaries can be better forecasted than the other two crime types for Vienna. Apartment burglaries have the second best forecasting and house burglaries have the lowest forecasting quality. One explanation may be that the number of house burglary events is lower, than the other two burglary types with the area and timeframe being exactly the same. This conclusion is also supported by the results of the Decline Rate and the PAI included in Tables 11 to 19.

5.2. Graz

5.2.1. Apartment Burglary

The number of offenses reported over the seven years in Graz, and the two selected districts with postal codes 8010 and 8020 are 3,008, 1,351 and 852 respectively. This along with the number of days when at least one event has a near repeat and the number of near repeats in a year is included in Appendix Table B10, B11, and B12. In the following three sections, some the output values discussed are described as 'indeterminate' in the Appendix Tables A10, A11, and A12 because over the 2011 and 2013 years the number of near repeats is zero for the district 8020.

5.2.1.1. Radius Type: OR

Results for this radius type can be found in the Appendix Table A10. Across the seven years from 2009 to 2015 the Decline Rate varies from 0.00 to 0.07, which means that only about 0 to 7% of offenses possess near repeats. The Hit Rate percentage varies from 0 to 36%, while PAI values vary from 0.00 to 8.38, and

RRI values vary from 0.00 to 4.25. Two values across the whole table are 'indeterminate'.

The total of all seven years is seen in the last three rows of the Appendix Table A10. While Graz as a whole has a Decline Rate of 0.03 and a Hit Rate of 0.22, the district with the postal code "8010", with the highest number of crime events, has a Decline Rate of 0.03 and a Hit Rate of 0.24. The Decline Rate is same in both cases, but the Hit Rate is slightly higher for the district by 2%. If Graz is compared to the area with the second highest crime events (district with postal code "8020"), then the accuracy is higher for the city as a whole. Because the Decline Rate of the 8020 district is 0.02 and the Hit Rate is 0.17.

5.2.1.2. Radius Type: NR

Results for this radius type can be found in the Appendix Table A11. Across the seven years from 2009 to 2015 the Decline Rate varies from 0.00 to 0.05, which means that only about 0 to 5% of offenses possess near repeats. The Hit Rate percentage varies from 0 to 38%, while PAI values vary from 0.74 to 28.17, and RRI values vary from 0.00 to 23.04. Four values across the whole table are 'indeterminate', because over the 2011 and 2013 years the number of near repeats is zero.

The total of all seven years is seen in the last three rows of the Appendix Table A11. While Graz as a whole has a Decline Rate of 0.02 and a Hit Rate of 0.18, the district with the postal code "8010", with the highest number of crime events, has a Decline Rate of 0.03 and a Hit Rate of 0.19. Both evaluation measures are slightly lower by 1% for Graz as a whole. If Graz is compared to the area with the second highest crime events (district with postal code "8020"), then the accuracy is slightly higher for the city as a whole as the Decline Rate for the 8020 district is 0.02 and Hit Rate is 0.15.

5.2.1.3. Radius Type: ORNR

Results for this radius type can be found in the Appendix Table A12. Across the seven years from 2009 to 2015 the Decline Rate varies from 0.00 to 0.07, which means that only about 0 to 7% of offenses possess near repeats. The Hit Rate percentage varies from 0 to 38% while PAI in 'Incomputable', and RRI values vary from 0.00 to 4.25. Three values across the whole table are 'indeterminate', because over the 2011 and 2013 years the number of near repeats is zero.

The total of all seven years is seen in the last three rows of the Appendix Table A12. While Graz as a whole has a Decline Rate of 0.03 and a Hit Rate of 0.24, the district with the postal code "8010", with the highest number of crime events, has a Decline Rate of 0.04 and a Hit Rate of 0.26. Both evaluation measures are lesser for the city as a whole (Decline Rate by 1% and Hit Rate by 2%). If Graz is compared to the area with the second highest crime events (district with postal code "8020"), then the accuracy is higher for the whole city data by a large margin. As the Decline Rate for the 8020 area is 0.01 and Hit Rate is 0.02 for the district, the Decline Rate is higher by 2% and the Hit Rate is higher by 22% for Graz as a whole.

5.2.1.4. Comparison of Radius Types

Year	Radius Type	HR	DR	PAI	RRI
Total	OR	0,22	0,03	0,16	Incomputable
	NR	0,18	0,02	0,74	
	ORNR	0,24	0,03	Incomputable	

Table 20: Evaluation measures of apartment burglaries in Graz city

Year	Radius Type	HR	DR	PAI	RRI
Total	OR	0,24	0,03	0,33	Incomputable
	NR	0,19	0,03	1,35	
	ORNR	0,26	0,04	Incomputable	

Table 21: Evaluation measures of apartment burglaries in district 8010 of Graz

Year	Radius Type	HR	DR	PAI	RRI
Total	OR	0,17	0,02	0,50	Incomputable
	NR	0,15	0,02	3,02	
	ORNR	0,02	0,01	Incomputable	

Table 22: Evaluation measures of apartment burglaries in district 8020 of Graz

Tabulated in Tables 20, 21, and 22 are the different radius type's results for Graz, districts 8010 and 8020. For Graz as a whole, the "ORNR" radius type gives the best forecasting results, which is also the case in district 8010. But for the district 8020 the best forecasting results are from "OR" radius type. Hence by average, "ORNR" radius type is still yields best forecasting results.

5.2.2. **Car Burglary**

The number of offenses reported over the seven years in Graz, and the two selected districts with postal codes 8010 & 8020 are 3,267, 1,145 and 1,039 respectively. This along with the number of days when at least one event has a near repeat and the number of near repeats in a year are included in Appendix Table B13, B14, and B15. In the following three sections, some of the output values discussed are described as 'indeterminate' in the Appendix Tables A13, A14, A15, because over the 2012 and 2014 years the number of near repeats is zero for the district 8010.

5.2.2.1. Radius Type: OR

Results for this radius type can be found in the Appendix Table A13. Across the seven years from 2009 to 2015 the Decline Rate varies from 0.00 to 0.12, which means that only about 0 to 12% of offenses possess near repeats. The Hit Rate percentage varies from 0 to 58%, while PAI values vary from 0.00 to 6.23, and RRI values vary from 0.00 to 3.69. Two values across the whole table are 'indeterminate'.

The total of all seven years is seen in the last three rows of the Appendix Table A13. While Graz as a whole has a Decline Rate of 0.03 and a Hit Rate of 0.25, the district with the postal code "8010", with the highest number of crime events, has a Decline Rate of 0.05 and a Hit Rate of 0.39. Both evaluation measures are slightly lower for Graz as a whole (Decline Rate by 2% and Hit Rate by 14%). If Graz is compared to the area with the second highest crime events (district with postal code "8020"), then the accuracy is slightly higher for the whole city data as the Decline Rate for the 8020 district is 0.03 and Hit Rate is 0.24.

5.2.2.2. Radius Type: NR

Results for this radius type can be found in the Appendix Table A14. Across the seven years from 2009 to 2015 the Decline Rate varies from 0.00 to 0.10, which means that only about 0 to 10% of offenses possess near repeats. The Hit Rate percentage varies from 0 to 57%, while PAI values vary from 0.60 to 28.17, and RRI values vary from 0.00 to 3.69. Four values across the whole table are 'indeterminate'.

The total of all seven years is seen in the last three rows of the Appendix Table A14. While Graz as a whole has a Decline Rate of 0.03 and a Hit Rate of 0.24, the district with the postal code "8010", with the highest number of crime events, has a Decline Rate of 0.05 and a Hit Rate of 0.38. Both evaluation measures are slightly lower for Graz as a whole (Decline Rate by 2% and Hit Rate by 14%). If Graz is compared to the area with the second highest crime events (district with postal code "8020"), then the accuracy is slightly higher for the city a s a whole as the Decline Rate for the 8020 district is 0.03 and Hit Rate is 0.23.

5.2.2.3. Radius Type: ORNR

Results for this radius type can be found in the Appendix Table A15. Across the seven years from 2009 to 2015 the Decline Rate varies from 0.00 to 0.12, which means that only about 0 to 12% of offenses possess near repeats. The Hit Rate percentage varies from 0 to 58% while PAI is 'Incomputable', and RRI values vary from 0.00 to 3.69. Four values across the whole table are 'indeterminate'.

The total of all seven years is seen in the last three rows of the Appendix Table A15. While Graz as a whole has a Decline Rate of 0.03 and a Hit Rate of 0.27, the district with the postal code "8010", with the highest number of crime events, has a Decline Rate of 0.06 and a Hit Rate of 0.40. Both evaluation measures are slightly lower for the city (Decline Rate by 3% and Hit Rate by 13%). If Graz is compared to the area with the second highest crime events (district with postal code "8020"), then the accuracy is higher for Graz as a whole as the Decline Rate for the 8020 area is 0.04 and Hit Rate is 0.26.

5.2.2.4. Comparison of Radius Types

Year	Radius Type	HR	DR	PAI	RRI
Total	OR	0,25	0,03	0,15	Incomputable
	NR	0,24	0,03	0,60	
	ORNR	0,27	0,03	Incomputable	

Table 23: Evaluation measures of car burglaries in Graz city

Year	Radius Type	HR	DR	PAI	RRI
Total	OR	0,39	0,05	0,63	Incomputable
	NR	0,38	0,05	1,67	
	ORNR	0,40	0,06	Incomputable	

Table 24: Evaluation measures of car burglaries in district 8010 of Graz

Year	Radius Type	HR	DR	PAI	RRI
Total	OR	0,24	0,03	0,41	Incomputable
	NR	0,23	0,03	1,71	
	ORNR	0,26	0,04	Incomputable	

Table 25: Evaluation measures of car burglaries in district 8020 of Graz

Unlike the results of apartment burglaries in Graz, in this case the results are constant. The "ORNR" radius type gives the best forecasting accuracy in all three cases for car burglaries in Graz. The values of Hit Rate, Decline Rate, PAI and RRI for this selection are seen in the Tables 23, 24 and 25.

5.2.3. House burglary

The number of offenses reported over the seven years in Graz, and the two selected districts with postal codes 8010 & 8020 are 1,772, 319 and 225 respectively. This along with the number of days when at least one event has a near repeat and the number of near repeats in a year is included in Appendix Table B16, B17, and B18.

In the following three sections, several the output values discussed are described as 'indeterminate' in the Appendix Tables A16, A17, and A18, because over the number of near repeats is zero in a few CriPA output results. This would be for the year 2009, 2013 and 2014 for the whole Graz city data and for the district 8010 it is over six years i.e. 2009, 2011, 2012, 2013, 2014 and 2015. Also for the district 8020 the number of near repeats is zero for six years i.e. 2009, 2010, 2011, 2013, 2014 and 2015.

5.2.3.1. Radius Type: OR

Results for this radius type can be found in the Appendix Table A16. Across the seven years from 2009 to 2015 the Decline Rate values are mostly zero, with only two occurrences of 0.01 and one occurrence of 0.02 & 0.03, which means that only about 0 to 3% of offenses possess near repeats. The Hit Rate percentage varies from 0 to 25%, while PAI values vary from 0.00 to 15.84, and RRI values vary from 0.00 to 2.55. Twenty-two values across the whole table are 'indeterminate'.

The total of all seven years is seen in the last three rows of the Appendix Table A16. While Graz as a whole has a Decline Rate of 0.00 and a Hit Rate of 0.06, the district with the postal code "8010", with the highest number of crime events, has a Decline Rate of 0.00 and a Hit Rate of 0.07. Both evaluation measures are slightly lower for the city (Decline Rate being zero is both cases but Hit Rate by 1%). If Graz is compared to the area with the second highest crime events (district with postal code "8020"), then the accuracy is higher for Graz as a whole as the Decline Rate for the district 8020 is 0.00 and Hit Rate is 0.05.

5.2.3.2. Radius Type: NR

Results for this radius type can be found in the Appendix Table A17. Across the seven years from 2009 to 2015 the Decline Rate varies from 0.00 to 0.67, which means that only about 0 to 67% of offenses possess near repeats. The Hit Rate percentage varies from 0 to 80%, while PAI values vary from 2.41 to 42.25, and RRI values vary from 0.00 to 1.39. But a large portion of the table, precisely thirty values across the whole table are 'indeterminate'.

The total of all seven years is seen in the last three rows of the Appendix Table A17. While Graz as a whole has a Decline Rate of 0.00 and a Hit Rate of 0.05, the district with the postal code "8010", with the highest number of crime events, has a Decline Rate of 0.03 and a Hit Rate of 0.55. Both evaluation measures are lower for Graz (Decline Rate by 3% and Hit Rate by 50%). If Graz is compared to the area with the second highest crime events (district with postal code "8020"), then the accuracy is again lower for Graz as a whole by a large margin as the Decline Rate for the district 8020 is 0.09 and Hit Rate is 0.54. This major variation between the whole Graz city data and the individual districts is because very few offenses, which is less than 2000, are spread over an area of 127.4816 square kilometers.

5.2.3.3. Radius Type: ORNR

Results for this radius type can be found in the Appendix Table A18. Across the seven years from 2009 to 2015 the Decline Rate values are mostly zero, with only three occurrences of 0.01 and one occurrence of 0.02 & 0.05, which means that only about 0 to 5% of offenses possess near repeats. The Hit Rate percentage varies from 0 to 40% while PAI is 'Incomputable', and RRI values vary from 0.00 to 1.39. Four values across the whole table are 'indeterminate'.

The total of all seven years is seen in the last three rows of the Appendix Table A18. While Graz as a whole has a Decline Rate of 0.00 and a Hit Rate of 0.05, the district with the postal code "8010", with the highest number of crime events, has a Decline Rate of 0.01 and a Hit Rate of 0.13. Both evaluation measures are lower for the city (Decline Rate by 1% and Hit Rate by 8%). If Graz is compared to the area with the second highest crime events (district with postal code "8020"), then the accuracy is equal for both as the Decline Rate for the district 8020 is 0.00 and Hit Rate is 0.05.

5.2.3.4. Comparison of Radius Types

Year	Radius Type	HR	DR	PAI	RRI
Total	OR	0,06	0,00	0,14	Incomputable
	NR	0,05	0,00	2,41	
	ORNR	0,05	0,00	Incomputable	

Table 26: Evaluation measures of house burglaries in Graz city

Year	Radius Type	HR	DR	PAI	RRI
Total	OR	0,07	0,00	1,29	Incomputable
	NR	0,55	0,03	12,67	
	ORNR	0,13	0,01	Incomputable	

Table 27: Evaluation measures of house burglaries in district 8010 of Graz

Year	Radius Type	HR	DR	PAI	RRI
Total	OR	0,05	0,00	0,70	Incomputable
	NR	0,54	0,09	6,50	
	ORNR	0,05	0,00	Incomputable	

Table 28: Evaluation measures of house burglaries in district 8020 of Graz

The "ORNR" radius type does not have higher accuracy results in all the three cases as shown in the Table 26, 27, and 28. Reasoning for this kind of an output is very varied. Because it depends on numerous parameters like time, area, number of events reported and so on. On an average, the "NR" has better forecasting quality in case of house burglaries in Graz.

5.2.4. Comparison of Burglary Types

The highest Hit Rate percentage of Car burglaries is 27% while for apartment and house burglaries, it is 24% and 6% respectively. This, along with the values of Decline Rate and PAI, indicates that the car burglaries can be better forecasted than the other two crime types for Graz. Apartment burglaries have second best forecasting and house burglaries have the lowest forecasting quality.

In comparison with the results for Vienna, CriPA results for Graz vary in analysis conclusion. In case of apartment and car burglaries, the "ORNR" radius type has the best forecasting accuracy. But in case of house burglaries the 'OR' radius type performs much better than both the 'NR' and the "ORNR" radius type, in case of the Hit Rat. So, the "ORNR" radius type does not necessarily always yield the best accuracy results.

5.3. Linz

5.3.1. Apartment Burglary

The number of offenses reported over the seven years in Linz, and the two selected districts with postal codes 4020 & 4030 are 1,922, 1,156 and 397 respectively. This along with the number of days when at least one event has a near repeat and the number of near repeats in a year is included in Appendix Table B19, B20 AND B21.

5.3.1.1. Radius Type: OR

Results for this radius type can be found in the Appendix Table A19. Across the seven years from 2009 to 2015 the Decline Rate varies from 0.00 to 0.06, which means that only about 0 to 6% of offenses possess near repeats. The Hit Rate percentage varies from 0 to 69%, while PAI values vary from 0.00 to 21.21, and RRI values vary from 0.00 to 10.81. Eight values across the whole table are 'indeterminate'. The reason some of these indeterminate values is that for the year 2012, the number of near repeats is absolutely zero.

The total of all seven years is seen in the last three rows of the Appendix Table A19. While Linz as a whole has a Decline Rate of 0.01 and a Hit Rate of 0.17, the district with the postal code "4020" with the highest number of crime events, has a Decline Rate of 0.02 and a Hit Rate of 0.22. The Decline Rate is higher by 1% and the Hit Rate is slightly higher by 2% for the 4020 district. If Linz as a whole is compared to the area with the second highest crime events (district with postal code "4030"), then the accuracy is higher for Linz as the Decline Rate for the district 4030 is 0.00 and Hit Rate is 0.05.

5.3.1.2. Radius Type: NR

Results for this radius type can be found in the Appendix Table A20. Across the seven years from 2009 to 2015 the Decline Rate varies from 0.00 to 0.04, which means that only about 0 to 4% of offenses possess near repeats. The Hit Rate percentage varies from 0 to 44%, while PAI values vary from 1.27 to 63.62, and RRI values vary from 0.00 to 3.55. Four values across the whole table are 'indeterminate', because over the 2011 and 2012 years the number of near repeats is zero.

The total of all seven years is seen in the last three rows of the Appendix Table A20. While Linz as a whole has a Decline Rate of 0.02 and a Hit Rate of 0.18, the district with the postal code "4020", with the highest number of crime events, has a Decline Rate of 0.03 and a Hit Rate of 0.19. Both evaluation measures are lower for the city as a whole by 1% only. If Linz is compared to the area with the second highest crime events (district with postal code "4030"), then the accuracy is higher for Linz as a whole as the Decline Rate for the district 4030 is 0.02 and Hit Rate is 0.15.

5.3.1.3. Radius Type: ORNR

Results for this radius type can be found in the Appendix Table A21. Across the seven years from 2009 to 2015 the Decline Rate varies from 0.00 to 0.07, which means that only about 0 to 7% of offenses possess near repeats. The Hit Rate percentage varies from 0 to 38% while PAI in 'Incomputable', and RRI values vary from 0.00 to 4.25. Three values across the whole table are 'indeterminate', because over the 2011 and 2013 years the number of near repeats is zero.

The total of all seven years is seen in the last three rows of the Appendix Table A21. While Linz as a whole has a Decline Rate of 0.03 and a Hit Rate of 0.24, the district with the postal code "4020" with the highest number of crime events, has a Decline Rate of 0.04 and a Hit Rate of 0.26. Both evaluation measures are lower for Linz (Decline Rate by 1% and Hit Rate by 2%). If Linz is compared to the area with the second highest crime events (district with postal code "4030"), then the accuracy is higher for Linz as a whole by a large margin. This is because, the Decline Rate for the district 4030 is 0.01 and Hit Rate is 0.02 which indicates that the Decline Rate is higher by 2% and the Hit Rate is higher by 22% for Linz as a whole.

5.3.1.4. Comparison of Radius Types

Year	Radius Type	HR	DR	PAI	RRI
Total	OR	0,17	0,01	0,21	Incomputable
	NR	0,14	0,01	1,27	
	ORNR	0,19	0,01	Incomputable	

Table 29: Evaluation measures of apartment burglaries in Linz city

Year	Radius Type	HR	DR	PAI	RRI
Total	OR	0,22	0,02	0,44	Incomputable
	NR	0,18	0,02	1,95	
	ORNR	0,26	0,02	Incomputable	

Table 30: Evaluation measures of apartment burglaries in district 4020 of Linz

Year	Radius Type	HR	DR	PAI	RRI
Total	OR	0,05	0,00	0,39	Incomputable
	NR	0,05	0,00	8,68	
	ORNR	0,05	0,00	Incomputable	

Table 31: Evaluation measures of apartment burglaries in district 4030 of Linz

As seen in the Table 31, evaluation measures for the district 4030 have same value in case of all radius types. But for the other district 4020 and whole Linz city, the ascending of values is seen in the Tables 29 and 30. This concludes that the "ORNR" radius type yields better results for apartment burglaries in Linz. For the overall view, until this section, this is same conclusion for all the crime types in Vienna and two burglaries in Graz.

5.3.2. Car Burglary

The number of offenses reported over the seven years in Linz, and the two selected districts with postal codes 4020 & 4030 are 3267, 1145 and 1039 respectively. This along with the number of days when at least one event has a near repeat and the number of near repeats in a year is included in Appendix Table B22, B23 and B24. In the following three sections, some the output values discussed are described as 'indeterminate' in the Appendix Tables A22, A23, A24, because over the 2012 and 2014 years the number of near repeats is zero for the district 4020.

5.3.2.1. Radius Type: OR

Results for this radius type can be found in the Appendix Table A22. Across the seven years from 2009 to 2015 the Decline Rate varies from 0.00 to 0.12, which means that only about 0 to 12% of offenses possess near repeats. The Hit Rate percentage varies from 0 to 58%, while PAI values vary from 0.00 to 6.23, and RRI values vary from 0.00 to 3.69. Two values across the whole table are 'indeterminate'.

The total of all seven years is seen in the last three rows of the Appendix Table A22. While Linz as a whole has a Decline Rate of 0.03 and a Hit Rate of 0.25, the district with the postal code "4020", with the highest number of crime events, has a Decline Rate of 0.05 and a Hit Rate of 0.39. Both evaluation measures are lower for Linz as a whole (Decline Rate by 2% and Hit Rate by 14%). If Linz is compared to the area with the second highest crime events (district with postal code "4030"), then the accuracy is slightly higher for Linz as the Decline Rate for the 4030 area is 0.03 and Hit Rate is 0.24. Though in this case the Decline Rate is the same for both but the Hit Rate is higher by 1%.

5.3.2.2. Radius Type: NR

Results for this radius type can be found in the Appendix Table A23. Across the seven years from 2009 to 2015 the Decline Rate varies from 0.00 to 0.10, which means that only about 0 to 10% of offenses possess near repeats. The Hit Rate percentage varies from 0 to 57%, while PAI values vary from 0.60 to 28.17, and RRI values vary from 0.00 to 3.69. Four values across the whole table are 'indeterminate'.

The total of all seven years is seen in the last three rows of the Appendix Table A23. While Linz as a whole has a Decline Rate of 0.03 and a Hit Rate of 0.24, the district with the postal code "4020", with the highest number of crime events, has a Decline Rate of 0.05 and a Hit Rate of 0.38. Both evaluation measures are lower for Linz (Decline Rate by 2% and Hit Rate by 14%). If Linz is compared to the area with the second highest crime events (district with postal code "4030"), which has a Decline Rate of 0.03 and a Hit Rate of 0.23. With the Decline Rate being same for both but the Hit Rate is higher by 1%, Linz has a accuracy slightly high than the district 4030.

5.3.2.3. Radius Type: ORNR

Results for this radius type can be found in the Appendix Table A24. Across the seven years from 2009 to 2015 the Decline Rate varies from 0.00 to 0.12, which means that only about 0 to 12% of offenses possess near repeats. The Hit Rate percentage varies from 0 to 58% while PAI is 'Incomputable', and RRI values vary from 0.00 to 3.69. Four values across the whole table are 'indeterminate'.

The total of all seven years is seen in the last three rows of the Appendix Table A24. While Linz as a whole has a Decline Rate of 0.03 and a Hit Rate of 0.27, the district with the postal code "4020", with the highest number of crime events, has a Decline Rate of 0.06 and a Hit Rate of 0.40. Both evaluation measures are lower for the city (Decline Rate by 3% and Hit Rate by 13%). If Linz is compared to the area with the second highest crime events (district with postal code "4030"), then the accuracy is slightly higher for the whole city data as the Decline Rate for the 4030 area is 0.04 and Hit Rate is 0.26.

5.3.2.4. Comparison of Radius Types

Year	Radius Type	HR	DR	PAI	RRI
Total	OR	0,34	0,04	0,21	Incomputable
	NR	0,28	0,03	0,62	
	ORNR	0,37	0,05	Incomputable	

Table 32: Evaluation measures of car burglaries in Linz city

Year	Radius Type	HR	DR	PAI	RRI
Total	OR	0,37	0,05	0,37	Incomputable
	NR	0,31	0,04	1,01	
	ORNR	0,42	0,06	Incomputable	

Table 33: Evaluation measures of car burglaries in district 4020 of Linz

Year	Radius Type	HR	DR	PAI	RRI
Total	OR	0,22	0,02	0,87	Incomputable
	NR	0,17	0,01	3,53	
	ORNR	0,24	0,02	Incomputable	

Table 34: Evaluation measures of car burglaries in district 4030 of Linz

As seen in all the sections until now in this city as well as Graz and Vienna, the "ORNR" radius type shows better accuracy measures. In the case whole city, the difference between the merged radius and others is 3% and 9% as seen in the Table 32, 33 and 34.

5.3.3. **House Burglary**

The number of offenses reported over the seven years in Linz, and the two selected districts with postal codes 4020 & 4030 are 1772, 319 and 225 respectively. This along with the number of days when at least one event has a near repeat and the number of near repeats in a year is included in Appendix Table B25, B26 and B27.

In the following three sections, several the output values discussed are described as 'indeterminate' in the Appendix Tables A25, A26, A27, because over the number of near repeats is zero in a few CriPA output results. This would be for the year 2009, 2013 and 2014 for the whole Linz city data and for the district 4020 it is over six years i.e. 2009, 2011, 2012, 2013, 2014 and 2015. Also for the district 4030 the number of near repeats is zero for six years i.e. 2009, 2010, 2011, 2013, 2014 and 2015.

5.3.3.1. Radius Type: OR

Results for this radius type can be found in the Appendix Table A25. Across the seven years from 2009 to 2015 the Decline Rate values are mostly zero, with only two occurrences of 0.01 and one occurrence of 0.02 & 0.03, which means that only about 0 to 3% of offenses possess near repeats. The Hit Rate percentage varies from 0 to 25%, while PAI values vary from 0.00 to 15.84, and RRI values vary from 0.00 to 2.55. Twenty-two values across the whole table are 'indeterminate'.

The total of all seven years is seen in the last three rows of the Appendix Table A25. While Linz as a whole has a Decline Rate of 0.00 and a Hit Rate of 0.06, the district with the postal code "4020"), with the highest number of crime events, has a Decline Rate of 0.00 and a Hit Rate of 0.07. Both evaluation measures are slightly lower for the city; Decline Rate being zero is both cases but Hit Rate by 1%. If Linz is compared to the area with the second highest crime events (district with postal code "4030"), then the accuracy is higher for the whole city data by a large margin as the Decline Rate for the 4030 area is 0.00 and Hit Rate is 0.05.

5.3.3.2. Radius Type: NR

Results for this radius type can be found in the Appendix Table A26. Across the seven years from 2009 to 2015 the Decline Rate varies from 0.00 to 0.67, which means that only about 0 to 67% of offenses possess near repeats. The Hit Rate percentage varies from 0 to 80%, while PAI values vary from 2.41 to 42.25, and RRI values vary from 0.00 to 1.39. But a large portion of the table, precisely thirty values across the whole table are 'indeterminate'.

The total of all seven years is seen in the last three rows of the Appendix Table A26. While Linz as a whole has a Decline Rate of 0.00 and a Hit Rate of 0.05, the district with the postal code "4020", with the highest number of crime events, has a Decline Rate of 0.03 and a Hit Rate of 0.55. Both evaluation measures are lower for Linz by a large margin (Decline Rate by 3% and Hit Rate by 50%). If Linz is compared to the area with the second highest crime events (district with postal code "4030"), then the accuracy is again lower for Linz by a large margin as the Decline Rate for the 4030 area is 0.09 and Hit Rate is 0.54 giving a difference of 9% in the Decline Rate and 49% in the Hit Rate. This major variation between the whole Linz city data and the individual districts is because very few offenses, which is less than 2000, are spread over an area of 12,748.16 hectares.

5.3.3.3. Radius Type: ORNR

Results for this radius type can be found in the Appendix Table A27. Across the seven years from 2009 to 2015 the Decline Rate values are mostly zero, with only three occurrences of 0.01 and one occurrence of 0.02 & 0.05, which means that only about 0 to 5% of offenses possess near repeats. The Hit Rate percentage varies from 0 to 40% while PAI is 'Incomputable', and RRI values vary from 0.00 to 1.39. Four values across the whole table are 'indeterminate'.

The total of all seven years is seen in the last three rows of the Appendix Table A27. While Linz as a whole has a Decline Rate of 0.00 and a Hit Rate of 0.05, the district with the postal code "4020", with the highest number of crime events, has a Decline Rate of 0.01 and a Hit Rate of 0.13. Both evaluation measures considerably lower for Linz as a whole (Decline Rate by 1% and Hit Rate by 8%). If Linz is compared to the area with the second highest crime events (district with postal code "4030"), then the accuracy is equal as the Decline Rate for the 4030 area is 0.00 and Hit Rate is 0.05, same as that of Linz.

5.3.3.4. Comparison of Radius Types

Year	Radius Type	HR	DR	PAI	RRI
Total	OR	0,10	0,01	0,40	Incomputable
	NR	0,12	0,01	3,90	
	ORNR	0,12	0,01	Incomputable	

Table 35: Evaluation measures of house burglaries in Linz city

Year	Radius Type	HR	DR	PAI	RRI
Total	OR	0,05	0,00	0,53	Incomputable
	NR	0,05	0,00	10,05	
	ORNR	0,05	0,00	Incomputable	

Table 36: Evaluation measures of house burglaries in district 4020 of Linz

Year	Radius Type	HR	DR	PAI	RRI
Total	OR	0,11	0,01	1,06	Incomputable
	NR	0,11	0,01	10,05	
	ORNR	0,11	0,01	Incomputable	

Table 37: Evaluation measures of house burglaries in district 4030 of Linz

For this burglary type, all the radius types have the same or close values as seen in the Table 35, 36, and 37. Though the "ORNR" is not the radius type with the highest value, it definitely stays at the top in hierarchy of radius types.

5.3.4. Comparison of Burglary Types

The Hit Rate percentage for car burglaries is 37% and is the burglary type with highest forecasting quality. This is followed by the apartment burglary with 19% and house burglary with 12%. The same order follows in terms of the Decline Rate and PAI. Similar to Vienna, but unlike Graz, the results for Linz indicate the same conclusion unanimously i.e. "ORNR" radius type yields better forecasting results.

5.4. Comparison between Cities' Results

As the last level of comparison, results of the three cities are analyzed together. The results of "ORNR" radius type for the total 7 years' data are taken for this comparison. These results are of the whole city and not an individual district. The

Table 38 has these results for the apartment burglaries in the three cities of the study area in terms of only Hit Rate and Decline Rate. PAI and RRI are 'Incomputable' for this selection.

Year	City	HR	DR
Total	Vienna	0,71	0,11
	Graz	0,24	0,03
	Linz	0,19	0,01

Table 38: Hit Rate and Decline Rate of apartment burglaries

In this case of apartment burglaries, the highest forecasting quality is rendered by the Vienna data, followed by Graz and then Linz as the least one. This hierarchy is altered slightly when it came to the car burglaries. The results for this burglary type of the same selection as apartment burglaries are seen in the Table 39. While Vienna is still the city with highest forecasting quality, Graz is the city with lowest quality below Linz.

Year	City	HR	DR
Total	Vienna	1,22	0,23
	Graz	0,27	0,03
	Linz	0,37	0,05

Table 39: Hit Rate and Decline Rate of car burglaries

As also in case of house burglaries, it is the same case as that car burglaries with Vienna having the forecasting quality and Graz with the lowest leaving Linz in the middle. The values for the house burglaries are seen in the Table 40.

Year	City	HR	DR
Total	Vienna	0,23	0,02
	Graz	0,05	0,00
	Linz	0,12	0,01

Table 40: Hit Rate and Decline Rate of house burglaries

Apart from sorting of the cities split by burglary types, it is also observed that the quality of Vienna is far better that Graz and Linz by a larger difference. This difference for apartment burglaries is about 50% by average. The same for car burglaries is really high by about 90% and for house burglaries about 15% only.

Overall it can be concluded that the CriPA forecasting quality is higher for Vienna (city), Car Burglaries (burglary type) and merged radius (radius type – "ORNR").

6. Discussion

While there are many parameters that impact the quality of CriPA results, one of the most significant influence is the number of events in the study area. The evaluation measures value is directly proportional to the ratio of number of events to the study area's area. Hence the quality of CriPA results can always be compared internally or to other forecasting software results but can never be graded basing on a cut out margin for accuracy. But when it comes to the consistency of results, the most appropriate method to test or evaluate is by manual testing with multiple datasets and parameters. This is the approach applied in this research, and the results are fairly positive. Manual testing is chosen here, because none of the parameters or variables in the demonstrator's script or datasets is constant or consistent in any way. In accordance with such a large variation no testing method can evaluate the CriPA results across several divergent parameters.

The same reason of having such a big pool of parameters and the fact that the CriPA demonstrator has just finished its first phase of development create a potentially infinite number of testing simulations to absolutely conclude the testing and evaluation of CriPA. Hence, very precise research questions are addressed in this research. Each research question required analysis of the whole data by multiple simulations. Questions addressed in this research include the identification of a city, burglary type, and radius type with the best forecasting quality results. These results are significant in the overall CriPA project as they can also be used as base reference to future parameter testing. This is because only the basic and prominent parameters are included in the simulations and outputs are compared. When more parameters are included into the simulations for evaluation, results will be compared to those of this research to understand the change in their forecasting quality.

The only significant limitation observed in this research is that out of four evaluation parameters, only two can be calculated for all parameter selections analyzed. The PAI and RRI are evaluation measures that could not be calculated for the total number of years or for the merged radii. Nevertheless, the Hit Rate and Decline Rate are sufficient for the evaluation and comparison.

As the best parameter setting is analyzed and the accuracy of CriPA forecasting results is evaluated using four evaluation measures, two-thirds of the objectives are fulfilled. During the implementation and analysis for these two objectives the third objective is simultaneously satisfied. Multiple parameters and principles are recognized, which need to be evaluated further to develop CriPA completely. These are explained in detail in the section Future Work. Also results obtained are almost similar with the expected results with only two out of 18 cases being an exception.

7. Conclusion

The analysis of cities Vienna, Graz, and Linz for the past seven years from 2009 to 2015 is completed in this research for burglary types, apartment burglary, car burglary, and house burglary. The output of this analysis includes the following for each of the three cities in the study area:

- Forecasting results for each individual year comprising values for each day
- Forecasting results for three burglary types (apartment, car, and house burglaries) across seven years (2009 to 2015)
- Forecasting results for two districts of each city with highest crime events during the seven years

All results listed above are attained for three radii, i.e. original radius, near repeat radius, and merged radius. With this attained, the output of CriPA is evaluated using the following measures: Hit Rate percentage, Decline Rate, PAI, and RRI.

By this regress testing it can be concluded that the CriPA demonstrator is absolutely stable as it runs simulations for as much as 60,000 points in a dataset. Although this takes very long to be completed, the tool has run consistently across all simulations run. Results obtained for Vienna vary from Graz and Linz just as the data of these cities. Vienna yielded very promising forecasting results with the Hit Rate percentage going up to 122% for a few simulation results. In terms of the "ORNR" radius type, only one burglary type in Graz and Linz show less accuracy than the other two radii results. This could be due to many different reasons. Among all burglary type tested, car burglaries have results with the best forecasting quality in all three cities.

Considering the overall analysis, it can be said conclusively that the research goals are reached and the CriPA demonstrator results continue to be promising and to be a potential decision support system to the Austrian law enforcement agency for crime forecasting.

8. Future Work

The primary development phase of the CriPA demonstrator ended in October 2015. During this phase the python script was developed far enough to run a simulation and get the output log file which contains the number of days having at least one near repeat and the number of near repeats for each day of the specified time period.

Now a farfetched scope for this tool would be to have a user interface in the form of a dialog box at least so as to be usable without any prior knowledge of ArcGIS or python scripting. But before any development related to usability is done, it is essential to finalize the optimal values of each of the parameters considered during simulations. Also constructing an optimal set of parameters from the endless list of parameter combinations also needs to be done.

So far, the cumulative output of the research completed to address this with the CriPA demonstrator is as follows:

- Optimal value for the observation period
- Optimal value for the forecasting period
- Analysis of the radius (200, 300, and 400 meters)
- Data analysis of individual districts in Vienna
- Data analysis for burglary types
- Assessment of the three radius types
- Comparative evaluation of Vienna data results with CrimeStat
- Evaluation of CriPA demonstrator output accuracy using four evaluation measures
- Data analysis for the cities Graz and Linz and their results comparison with that of the city of Vienna

But several other parameters still need to be assessed. Among those, the following can be considered to have prominent impact on the CriPA demonstrator forecasting quality:

- Stolen Item: Inclusion of this attribute in the filters for creating a layer could give more narrowed results. This could be very helpful in forecasting burglaries which might need special skills to accomplish. Like opening vaults, unlocking cars, and disarming the alarm system, etc.

- Date difference: This is a new attribute calculated in ArcMap and used as a filter in the simulation, as well. So far in the research, date difference is defined with 72 hours. But near repeats could increase or decrease with the change in this timeframe.
- Forecast radius: While this parameter has been partially assessed already, it needs further analysis. Because radii beyond 400 meters could accumulate more near repeats while simultaneously reducing the number of original points. So to decide on whether or not to increase the radius further analysis is required.

Apart from analyzing these additional parameters, polishing the script for better format of the output will help in using the results directly without any required corrections or alterations. One example for polishing the script is the spacing between columns and having column labels.

As explained in the Conclusion chapter, the time taken for a simulation to complete depends on the number of points in the shapefile, number of filters, and specifications of the system that is used to run the simulation. But coming up with a possible way to reduce this time would greatly help the scope of this software, as it is intended to be used on a daily basis.

References

(KVB), A. R. S. B. & Austrian Insurance Association (VVÖ), 2014. *Two burglaries every hour in Austria.* [Online] Available at: http://www.thelocal.at/20141024/two-burglaries-every-hour-in-austria
[Accessed 26 September 2015].

(KVB), A. R. S. B. & Austrian Insurance Association (VVÖ), 2015. *Favoriten is Vienna's worst district for burglary.* [Online] Available at: http://www.thelocal.at/20150421/favoriten-is-viennas-worst-district-for-burglaries
[Accessed 26 September 2015].

Acadamey, T. J., 2003. *Crime Analysis.* [Online] Available at: http://www.justiceacademy.org/iShare/Library-CrimeAnalysis/historyofcrimeanalysis.pdf
[Accessed 7 January 2016].

Analysts, I. A. o. C., 2013. *Identifying High Crime Areas,* Overland Park, KS: Identifying High Crime Areas (White Paper 2013-02)..

Analysts, I. A. o. C., 2014. *Definition and Types of Crime Analysis,* Overland Park, KS: International Association of Crime Analysts (IACA).

AUSTRIA, S., 2015. *NUTS 3 ordered by municpalities , area and population,* Vienna: STATISTICS AUSTRIA.

Bayr, C. et al., 2015. *CriPA - Crime Predictive Analytics,* Graz, Austria: October.

Beach, C. o. N. M., 2007. *Routine Activity Theory (RAT).* [Online] Available at: http://www.citynmb.com/index.asp?SEC=3FD273E8-4654-4359-9AE1-9C86F704AF44&DE=7FE7466C-E018-411A-B5D5-368D05B6712C&Type=B_BASIC
[Accessed 7 January 2016].

Boba, R., 2005. *Crime Analysis and Crime Mapping.* 3 ed. USA: SAGE .

Brantingham, P. J. & Brantingham, P. J., 1981. *Environmental Criminology.* 18th ed. Beverly Hills, California: Sage Publications.

Caplan, J. M. & Kennedy, L. W., 2010. *Risk Terrain Modeling Manual,* s.l.: s.n.

Caplan, J. M. & Kennedy, L. W., 2011. *Risk Terrain Modeling Compendium.* s.l.:s.n.

Caplan, J. M., Kennedy, L. W. & Piza, E. L., 2012. *Joint Utility of Event-Dependent and Environmental Crime Analysis Techniques for Violent Crime Forecasting,* Newark, NJ, USA: sagepublications.

Capone, D. L. & Nichols, W. W. J., 1975. Crime and distance: an analysis of offender behavior in space. *Proceedings of the Association of American Geographers,* 1(7), pp. 45-49.

Chainey, S. & Ratcliffe, J., 2005. *GIS and Crime Mapping,* England: John Wiley.

Criminology, A. I. o., 2005. *Is crime predictable?.* [Online] Available at: http://www.aic.gov.au/publications/current%20series/crm/21-40/crm030.html
[Accessed 7 January 2016].

Eck, J. E. et al., 2005. *Mapping Crime: Understanding Hot Spots,* Washington, DC: National Institute of Justice .

Fan , S., 2014. *USING SPATIAL AND SPATIAL-TEMPORAL PREDICTIVE ACCURACY MEASURES TO ACCESS THE PERFORMANCE OF THE CRIME HOTSPOT MAPPING METHODS,* s.l.: CUAS.

Felson , M. & Clarke, R. V., 1998. *Opportunity Makes the Thief: Practical theory for crime prevention,* London: Police research Group.

Gorr, W. & Harries, R., 2003. Introduction to Crime Forecasting. *International Journal of Forecasting, Special Section on Crime Forecasting,* Volume 19, pp. 551-555.

Gorr, W. L. & Kurland, K. S., 2012. *GIS Tutorial for Crime Analysis,* Redlands, California: Esri Press.

Gorr, W. & Olligschlaeger, A., 1997. *Spatio-Temporal Forecasting of Crime: Application of Classical and Neural Network Methods.* Carnegie Mellon University: Working Papers of The Heinz School.

Harries, K., 1999. *Mapping Crime: Principle and Practice,* s.l.: National Institute of Justice, Office of Justice Programs, U.S. Department of Justice.

Hart, T. C. & Zandbergen, P. A., 2012. *Effects of Data Quality on Predictive Hotspot Mapping.* [Online] Available at: https://www.ncjrs.gov/pdffiles1/nij/grants/239861.pdf [Accessed 23 October 2015].

Hart, T. C. & Zandbergen, P. A., October, 2012. *Effects of Data Quality on Predictive Hotspot Mapping,* Washington, DC: National Institute of Justice.

Helbich, M. & Leitner, M., 2011. The impact of hurricanes on crime: a spatio-temporal analysis. *Cartography and Geographic Information Science,* 38(2), pp. 214-222.

Hill, B. & Paynich, R., 2010. *Fundamentals of Crime Mapping.* Sudbury, MA: Jones and Barlett.

Johani, F. R., 2008. *A Journey through Architecture.* [Online] Available at: http://jalakmas.blogspot.co.at/2008_06_01_archive.html [Accessed 7 January 2016].

Kennedy, L. W., Caplan, J. M. & Piza, E., 2011. Risk Clusters, Hotspots, and Spatial Intelligence: Risk Terrain Modeling as an Algorithm for Police Resource Allocation Strategies. *Journal of Quantitative Criminology,* 27(3), pp. 339-362.

Lattacher, S., 2004. *Das Magazin des Innenministeriums, Nr. 3-4/2004.* [Online] Available at: http://www.bmi.gv.at/cms/BMI_OeffentlicheSicherheit/2004/03_04/Artikel_09.aspx [Accessed 16 July 2016].

LeBeau, J. L. & Leitner, M., 2011. Introduction: Progress in Research on the Geography of Crime. *The Professional Geographer,* 63(2), pp. 161-173.

Levine, N., 2015. *CrimeStat Program and Documentation.* [Online] Available at: http://www.nij.gov/topics/technology/maps/pages/crimestat-downloads.aspx [Accessed 6 January 2015].

OSAC, 2015. *Austria 2015 Crime and Safety Report,* Vienna: Overseas Security Advisory Council (OSAC).

Patten, I. T. V., McKeldin-Coner, J. & Cox, D., 2010. *A Microspatial Analysis of Robbery: Prospective Hot Spotting in a Small City,* Radford: Radford University.

Ratcliffe, J. H., 2004. The Hotspot Matrix: A Framework for the Spatio-Temporal Targeting of Crime Reduction. *Police Practice and Research,* Volume 5, p. 05–23.

Ratcliffe, J. H., 2009. *Near Repeat Calculator (version 1.3).,* Philadelphia, PA and Washington, DC.: Temple University and the National Institute of Justice.

Smith, S. C. & Bruce, C. W., 2008. *CrimeStat III User Workbook,* Washington, DC: The National Institute of Justice.

Swain, A. W., 2012. *A Comparison of Hotspot Mapping for Crime Prediction.* [Online]
Available at: http://www.geos.ed.ac.uk/~gisteac/proceedingsonline/GISRUK2012/Papers/presentation-72.pdf
[Accessed 24 October 2015].

Tobler, W., 1970. A computer movie simulating urban growth in the Detroit region. *Economic Geography,* 2(46), pp. 234-240.

List of Figures

List of Tables

List of Appendix Tables

Appendix A

1. Vienna

1.1. Apartment Burglary

1.1.1. Radius Type: OR

Year	District	HR	DR	PAI	RRI
2009	Vienna	0,72	0,13	0,32	1,02
	1100	0,75	0,16	2,62	2,66
	1030	0,52	0,08	5,56	0,61
2010	Vienna	0,75	0,13	0,45	1,57
	1100	0,41	0,06	3,56	0,85
	1030	0,63	0,13	5,37	1,47
2011	Vienna	0,50	0,08	0,34	1,31
	1100	0,54	0,07	4,46	1,58
	1030	0,43	0,09	4,03	0,65
2012	Vienna	0,44	0,06	0,38	0,57
	1100	0,35	0,05	3,34	0,81
	1030	0,69	0,13	5,72	0,80
2013	Vienna	0,66	0,11	0,42	1,54
	1100	0,43	0,06	4,12	1,51
	1030	0,79	0,17	5,64	1,37
2014	Vienna	0,50	0,07	0,42	1,37
	1100	0,34	0,04	5,61	0,74
	1030	0,67	0,12	6,28	1,69
2015	Vienna	0,38	0,05	0,40	Incomputable
	1100	0,51	0,05	8,59	
	1030	0,41	0,07	5,54	
Total	Vienna	0,60	0,10	0,06	
	1100	0,54	0,08	0,63	
	1030	0,61	0,12	0,81	

Appendix Table A 1: Final evaluation results for apartment burglaries in Vienna of 'OR' radius type

1.1.2. Radius Type: NR

Year	District	HR	DR	PAI	RRI
2009	Vienna	0,65	0,12	0,45	1,07
	1100	0,66	0,14	3,51	2,38
	1030	0,53	0,08	10,85	0,66
2010	Vienna	0,66	0,12	0,59	1,45
	1100	0,40	0,06	8,59	0,80
	1030	0,60	0,12	8,87	1,33
2011	Vienna	0,48	0,08	0,67	1,34
	1100	0,56	0,08	8,33	1,58
	1030	0,42	0,09	9,16	0,65
2012	Vienna	0,40	0,06	0,87	0,61
	1100	0,36	0,05	9,70	1,03
	1030	0,71	0,14	8,41	0,89
2013	Vienna	0,56	0,10	0,63	1,46
	1100	0,34	0,05	9,48	1,30
	1030	0,73	0,16	7,05	1,62
2014	Vienna	0,45	0,07	0,83	1,34
	1100	0,32	0,04	16,49	1,17
	1030	0,52	0,10	9,37	1,43
2015	Vienna	0,35	0,05	1,06	Incomputable
	1100	0,31	0,03	17,18	
	1030	0,37	0,07	13,09	
Total	Vienna	0,53	0,09	0,10	
	1100	0,48	0,07	1,18	
	1030	0,57	0,11	1,32	

Appendix Table A 2: Final evaluation results for apartment burglaries in Vienna of 'NR' radius type

1.1.3. Radius Type: ORNR

Year	District	HR	DR	PAI	RRI
2009	Vienna	0,86	0,16	Incomputable	1,03
	1100	0,87	0,19		2,65
	1030	0,57	0,09		0,59
2010	Vienna	0,89	0,15		1,50
	1100	0,47	0,07		0,77
	1030	0,73	0,15		1,36
2011	Vienna	0,62	0,10		1,32
	1100	0,67	0,09		1,57
	1030	0,52	0,11		0,68
2012	Vienna	0,53	0,08		0,58
	1100	0,45	0,06		0,86
	1030	0,83	0,16		0,83
2013	Vienna	0,78	0,13		1,54
	1100	0,51	0,07		1,46
	1030	0,91	0,19		1,44
2014	Vienna	0,59	0,09		1,38
	1100	0,42	0,05		0,92
	1030	0,72	0,13		1,63
2015	Vienna	0,44	0,06		Incomputable
	1100	0,51	0,05		
	1030	0,43	0,08		
Total	Vienna	0,71	0,11		
	1100	0,63	0,09		
	1030	0,70	0,13		

Appendix Table A 3: Final evaluation results for apartment burglaries in Vienna of 'ORNR' radius type

1.2. Car Burglary

1.2.1. Radius Type: OR

Year	District	HR	DR	PAI	RRI
2009	Vienna	1,38	0,28	0,35	1,62
	1100	0,85	0,18	1,97	0,92
	1220	1,04	0,19	2,56	1,70
2010	Vienna	0,99	0,17	0,37	1,34
	1100	1,10	0,19	3,26	1,84
	1220	0,65	0,11	2,33	1,12
2011	Vienna	0,79	0,13	0,41	1,12
	1100	0,61	0,11	2,56	3,10
	1220	0,75	0,10	4,55	2,49
2012	Vienna	0,75	0,11	0,50	0,79
	1100	0,26	0,03	2,02	0,20
	1220	0,39	0,04	4,10	1,52
2013	Vienna	0,74	0,14	0,35	0,59
	1100	0,83	0,17	3,10	0,56
	1220	0,24	0,03	2,57	0,53
2014	Vienna	0,98	0,24	0,37	0,77
	1100	1,47	0,30	4,57	0,86
	1220	0,30	0,05	1,99	1,53
2015	Vienna	1,28	0,32	0,52	Incomputable
	1100	1,52	0,35	5,65	
	1220	0,26	0,03	2,86	
Total	Vienna	1,05	0,21	0,06	
	1100	1,01	0,19	0,51	
	1220	0,67	0,10	0,52	

Appendix Table A 4: Final evaluation results for car burglaries in Vienna of 'OR' radius type

1.2.2. Radius Type: NR

Year	District	HR	DR	PAI	RRI
2009	Vienna	1,13	0,24	0,24	1,54
	1100	0,76	0,16	2,35	0,88
	1220	0,91	0,17	2,44	1,67
2010	Vienna	0,87	0,16	0,37	1,29
	1100	1,00	0,18	2,92	1,56
	1220	0,58	0,10	3,52	1,07
2011	Vienna	0,73	0,12	0,51	1,19
	1100	0,67	0,11	4,29	3,62
	1220	0,72	0,09	6,15	2,14
2012	Vienna	0,65	0,10	0,65	0,79
	1100	0,25	0,03	7,93	0,22
	1220	0,42	0,04	10,18	1,67
2013	Vienna	0,65	0,13	0,46	0,64
	1100	0,71	0,14	3,70	0,58
	1220	0,25	0,03	10,85	0,65
2014	Vienna	0,79	0,20	0,36	0,78
	1100	1,14	0,24	2,96	0,89
	1220	0,24	0,04	6,87	1,30
2015	Vienna	0,99	0,26	0,38	Incomputable
	1100	1,16	0,27	3,57	
	1220	0,24	0,03	10,99	
Total	Vienna	0,87	0,18	0,06	
	1100	0,87	0,17	0,50	
	1220	0,61	0,09	0,78	

Appendix Table A 5: Final evaluation results for car burglaries in Vienna of 'NR' radius type

1.2.3. Radius Type: ORNR

Year	District	HR	DR	PAI	RRI
2009	Vienna	1,62	0,32	Incomputable	1,60
	1100	0,99	0,21		0,92
	1220	1,16	0,21		1,79
2010	Vienna	1,16	0,20		1,35
	1100	1,31	0,22		1,79
	1220	0,69	0,12		1,12
2011	Vienna	0,92	0,15		1,12
	1100	0,70	0,13		2,78
	1220	0,77	0,11		2,41
2012	Vienna	0,87	0,13		0,79
	1100	0,35	0,05		0,24
	1220	0,42	0,04		1,44
2013	Vienna	0,87	0,17		0,60
	1100	0,95	0,19		0,58
	1220	0,29	0,03		0,61
2014	Vienna	1,17	0,28		0,79
	1100	1,61	0,32		0,85
	1220	0,30	0,05		1,32
2015	Vienna	1,47	0,35		Incomputable
	1100	1,69	0,38		
	1220	0,29	0,04		
Total	Vienna	1,22	0,23		
	1100	1,15	0,22		
	1220	0,73	0,11		

Appendix Table A 6: Final evaluation results for car burglaries in Vienna of 'ORNR' radius type

1.3. House burglary

1.3.1. Radius Type: OR

Year	District	HR	DR	PAI	RRI
2009	Vienna	0,30	0,04	1,01	1,74
	1220	0,37	0,06	4,37	1,42
	1210	0,06	0,01	3,22	0,21
2010	Vienna	0,18	0,02	0,72	1,27
	1220	0,29	0,04	4,03	4,80
	1210	0,20	0,02	6,60	2,20
2011	Vienna	0,18	0,02	1,04	0,66
	1220	0,08	0,01	1,91	0,28
	1210	0,13	0,01	7,33	0,45
2012	Vienna	0,23	0,03	1,02	1,77
	1220	0,22	0,03	2,73	2,48
	1210	0,21	0,02	5,30	2,72
2013	Vienna	0,19	0,01	1,60	2,29
	1220	0,12	0,01	3,03	4,81
	1210	0,10	0,01	4,12	0,70
2014	Vienna	0,09	0,01	0,72	0,46
	1220	0,03	0,00	0,92	0,21
	1210	0,16	0,01	6,85	Indeterminate
2015	Vienna	0,17	0,01	1,06	Incomputable
	1220	0,16	0,01	4,03	
	1210	0,00	0,00	0,00	
Total	Vienna	0,21	0,02	0,15	
	1220	0,22	0,02	0,55	
	1210	0,14	0,01	0,80	

Appendix Table A 7: Final evaluation results for house burglaries in Vienna of 'OR' radius type

1.3.2. Radius Type: NR

Year	District	HR	DR	PAI	RRI
2009	Vienna	0,28	0,03	3,37	1,72
	1220	0,37	0,06	11,78	1,73
	1210	0,07	0,01	54,97	0,21
2010	Vienna	0,17	0,02	4,12	1,20
	1220	0,24	0,03	13,97	2,37
	1210	0,20	0,02	32,98	2,20
2011	Vienna	0,19	0,02	5,69	0,73
	1220	0,15	0,01	24,25	0,50
	1210	0,13	0,01	54,97	0,53
2012	Vienna	0,21	0,02	4,48	1,69
	1220	0,20	0,03	12,68	2,30
	1210	0,19	0,02	25,77	Indeterminate
2013	Vienna	0,18	0,01	8,33	1,81
	1220	0,12	0,01	24,99	1,60
	1210	0,00	0,00	Indeterminate	0,00
2014	Vienna	0,11	0,01	7,71	0,55
	1220	0,10	0,01	27,48	0,64
	1210	0,16	0,01	43,40	Indeterminate
2015	Vienna	0,17	0,01	6,25	Incomputable
	1220	0,16	0,01	25,77	
	1210	0,00	0,00	Indeterminate	
Total	Vienna	0,20	0,02	0,74	
	1220	0,22	0,02	2,55	
	1210	0,12	0,01	5,81	

Appendix Table A 8: Final evaluation results for house burglaries in Vienna of 'NR' radius type

1.3.3. Radius Type: ORNR

Year	District	HR	DR	PAI	RRI
2009	Vienna	0,33	0,04	Incomputable	1,76
	1220	0,39	0,06		1,37
	1210	0,06	0,01		0,21
2010	Vienna	0,19	0,02		1,24
	1220	0,32	0,05		3,22
	1210	0,20	0,02		2,20
2011	Vienna	0,21	0,02		0,67
	1220	0,14	0,01		0,43
	1210	0,13	0,01		0,40
2012	Vienna	0,25	0,03		1,76
	1220	0,23	0,03		2,66
	1210	0,24	0,03		3,11
2013	Vienna	0,21	0,02		2,11
	1220	0,12	0,01		1,60
	1210	0,10	0,01		0,70
2014	Vienna	0,11	0,01		0,48
	1220	0,10	0,01		0,46
	1210	0,16	0,01		Indeterminate
2015	Vienna	0,19	0,02		Incomputable
	1220	0,22	0,02		
	1210	0,00	0,00		
Total	Vienna	0,23	0,02		
	1220	0,25	0,03		
	1210	0,14	0,01		

Appendix Table A 9: Final evaluation results for house burglaries in Vienna of 'ORNR' radius type

2. Graz

2.1. Apartment Burglary

2.1.1. Radius Type: OR

Year	District	HR	DR	PAI	RRI
2009	Graz	0,13	0,01	0,79	0,31
	8010	0,14	0,01	1,57	0,24
	8020	0,08	0,01	1,76	0,37
2010	Graz	0,27	0,03	1,36	1,54
	8010	0,33	0,05	2,35	2,14
	8020	0,22	0,02	6,26	Indeterminate
2011	Graz	0,20	0,02	0,77	1,08
	8010	0,21	0,02	0,87	2,81
	8020	0,00	0,00	0,00	0,00
2012	Graz	0,18	0,03	0,60	4,25
	8010	0,16	0,03	1,05	2,11
	8020	0,08	0,01	1,76	Indeterminate
2013	Graz	0,09	0,01	0,96	0,22
	8010	0,15	0,01	3,00	0,46
	8020	0,00	0,00	0,00	0,00
2014	Graz	0,31	0,03	3,00	0,59
	8010	0,27	0,03	4,51	0,44
	8020	0,36	0,05	8,38	1,41
2015	Graz	0,30	0,05	0,97	Incomputable
	8010	0,33	0,07	1,88	
	8020	0,19	0,03	1,49	
Total	Graz	0,22	0,03	0,16	
	8010	0,24	0,03	0,33	
	8020	0,17	0,02	0,50	

Appendix Table A 10: Final evaluation results for apartment burglaries in Graz of 'OR' radius type

2.1.2. Radius Type: NR

Year	District	HR	DR	PAI	RRI
2009	Graz	0,10	0,01	6,34	0,44
	8010	0,09	0,01	11,52	0,32
	8020	0,08	0,01	21,12	0,37
2010	Graz	0,16	0,02	5,07	1,13
	8010	0,18	0,03	7,46	1,43
	8020	0,18	0,02	23,04	Indeterminate
2011	Graz	0,15	0,02	5,39	0,65
	8010	0,15	0,02	12,67	0,78
	8020	0,00	0,00	Indeterminate	0,00
2012	Graz	0,17	0,02	3,94	3,29
	8010	0,13	0,02	1,76	6,67
	8020	0,09	0,01	Indeterminate	23,04
2013	Graz	0,09	0,01	11,02	0,19
	8010	0,15	0,01	19,50	0,31
	8020	0,00	0,00	Indeterminate	0,00
2014	Graz	0,35	0,03	9,75	0,80
	8010	0,38	0,04	15,84	0,83
	8020	0,22	0,02	28,17	0,61
2015	Graz	0,25	0,04	3,13	Incomputable
	8010	0,27	0,05	5,63	
	8020	0,21	0,04	7,68	
Total	Graz	0,18	0,02	0,74	
	8010	0,19	0,03	1,35	
	8020	0,15	0,02	3,02	

Appendix Table A 11: Final evaluation results for apartment burglaries in Graz of 'NR' radius type

2.1.3. Radius Type: ORNR

Year	District	HR	DR	PAI	RRI
2009	Graz	0,13	0,01	Incomputable	0,31
	8010	0,14	0,01		0,24
	8020	0,08	0,01		0,37
2010	Graz	0,28	0,03		1,54
	8010	0,34	0,05		2,14
	8020	0,18	0,02		Indeterminate
2011	Graz	0,20	0,02		0,77
	8010	0,21	0,02		0,87
	8020	0,00	0,00		0,00
2012	Graz	0,18	0,03		4,25
	8010	0,15	0,03		2,11
	8020	0,08	0,01		Indeterminate
2013	Graz	0,09	0,01		0,17
	8010	0,15	0,01		0,31
	8020	0,00	0,00		0,00
2014	Graz	0,38	0,04		0,63
	8010	0,35	0,04		0,62
	8020	0,36	0,05		Indeterminate
2015	Graz	0,36	0,06		Incomputable
	8010	0,36	0,07		
	8020	0,00	0,00		
Total	Graz	0,24	0,03		
	8010	0,26	0,04		
	8020	0,02	0,01		

Appendix Table A 12: Final evaluation results for apartment burglaries in Graz of 'ORNR' radius type

2.2. Car Burglary

2.2.1. Radius Type: OR

Year	District	HR	DR	PAI	RRI
2009	Graz	0,35	0,05	0,91	1,17
	8010	0,58	0,08	3,64	1,27
	8020	0,30	0,04	2,78	1,74
2010	Graz	0,30	0,04	1,02	1,82
	8010	0,50	0,06	4,22	1,92
	8020	0,17	0,02	1,76	3,69
2011	Graz	0,19	0,02	0,74	2,41
	8010	0,26	0,03	1,97	Indeterminate
	8020	0,08	0,01	1,50	0,41
2012	Graz	0,10	0,01	0,79	0,70
	8010	0,00	0,00	0,00	0,00
	8020	0,18	0,02	4,19	0,65
2013	Graz	0,10	0,01	0,63	0,77
	8010	0,11	0,01	3,13	Indeterminate
	8020	0,16	0,02	2,11	0,55
2014	Graz	0,13	0,02	0,88	0,26
	8010	0,00	0,00	0,00	0,00
	8020	0,28	0,05	3,91	0,63
2015	Graz	0,32	0,06	1,04	Incomputable
	8010	0,57	0,12	6,23	
	8020	0,34	0,07	2,48	
Total	Graz	0,25	0,03	0,15	
	8010	0,39	0,05	0,63	
	8020	0,24	0,03	0,41	

Appendix Table A 13: Final evaluation results for car burglaries in Graz of 'OR' radius type

2.2.2. Radius Type: NR

Year	District	HR	DR	PAI	RRI
2009	Graz	0,34	0,04	2,53	1,25
	8010	0,57	0,07	6,85	1,24
	8020	0,25	0,04	9,05	1,52
2010	Graz	0,27	0,04	3,38	1,65
	8010	0,47	0,06	8,45	1,61
	8020	0,16	0,02	10,14	3,69
2011	Graz	0,19	0,02	4,02	2,41
	8010	0,31	0,04	7,92	Indeterminate
	8020	0,08	0,01	21,12	0,41
2012	Graz	0,10	0,01	8,18	0,56
	8010	0,00	0,00	Indeterminate	0,00
	8020	0,17	0,02	21,12	0,65
2013	Graz	0,13	0,02	6,34	0,96
	8010	0,22	0,03	28,17	Indeterminate
	8020	0,17	0,02	14,08	0,55
2014	Graz	0,13	0,02	6,67	0,27
	8010	0,00	0,00	Indeterminate	0,00
	8020	0,28	0,05	14,08	0,63
2015	Graz	0,31	0,06	3,29	Incomputable
	8010	0,46	0,10	10,56	
	8020	0,34	0,07	7,24	
Total	Graz	0,24	0,03	0,60	
	8010	0,38	0,05	1,67	
	8020	0,23	0,03	1,71	

Appendix Table A 14: Final evaluation results for car burglaries in Graz of 'NR' radius type

2.2.3. Radius Type: ORNR

Year	District	HR	DR	PAI	RRI
2009	Graz	0,37	0,05	Incomputable	1,24
	8010	0,56	0,08		1,27
	8020	0,30	0,05		1,96
2010	Graz	0,30	0,04		1,68
	8010	0,50	0,06		1,72
	8020	0,16	0,02		3,69
2011	Graz	0,21	0,02		2,61
	8010	0,29	0,04		Indeterminate
	8020	0,08	0,01		0,41
2012	Graz	0,10	0,01		0,56
	8010	0,00	0,00		0,00
	8020	0,17	0,02		0,65
2013	Graz	0,13	0,02		0,96
	8010	0,22	0,03		Indeterminate
	8020	0,16	0,02		0,55
2014	Graz	0,13	0,02		0,22
	8010	0,00	0,00		0,00
	8020	0,28	0,05		0,51
2015	Graz	0,38	0,07		Incomputable
	8010	0,58	0,12		
	8020	0,42	0,09		
Total	Graz	0,27	0,03		
	8010	0,40	0,06		
	8020	0,26	0,04		

Appendix Table A 15: Final evaluation results for car burglaries in Graz of 'ORNR' radius type

2.3. House burglary

2.3.1. Radius Type: OR

Year	District	HR	DR	PAI	RRI
2009	Graz	0,00	0,00	0,00	0,00
	8010	0,00	0,00	0,00	0,00
	8020	0,00	0,00	0,00	Indeterminate
2010	Graz	0,12	0,01	1,75	2,55
	8010	0,25	0,03	15,84	Indeterminate
	8020	0,00	0,00	0,00	Indeterminate
2011	Graz	0,05	0,00	0,52	1,39
	8010	Indeterminate	0,00	Indeterminate	Indeterminate
	8020	0,00	0,00	0,00	0,00
2012	Graz	0,04	0,00	0,48	Indeterminate
	8010	0,00	0,00	0,00	Indeterminate
	8020	0,17	0,02	7,04	Indeterminate
2013	Graz	0,00	0,00	0,00	Indeterminate
	8010	0,00	0,00	0,00	Indeterminate
	8020	Indeterminate	0,00	Indeterminate	Indeterminate
2014	Graz	0,00	0,00	0,00	0,00
	8010	Indeterminate	0,00	Indeterminate	Indeterminate
	8020	Indeterminate	0,00	Indeterminate	Indeterminate
2015	Graz	0,15	0,01	3,00	Incomputable
	8010	Indeterminate	0,00	Indeterminate	
	8020	0,00	0,00	0,00	
Total	Graz	0,06	0,00	0,14	
	8010	0,07	0,00	1,29	
	8020	0,05	0,00	0,70	

Appendix Table A 16: Final evaluation results for house burglaries in Graz of 'OR' radius type

2.3.2. Radius Type: NR

Year	District	HR	DR	PAI	RRI
2009	Graz	0,00	0,00	Indeterminate	0,00
	8010	0,00	0,00	Indeterminate	0,00
	8020	0,00	0,00	Indeterminate	0,00
2010	Graz	0,06	0,01	15,84	1,27
	8010	0,79	0,29	18,11	Indeterminate
	8020	0,80	0,67	10,14	Indeterminate
2011	Graz	0,05	0,00	11,52	1,39
	8010	Indeterminate	0,00	Indeterminate	Indeterminate
	8020	0,00	0,00	Indeterminate	0,00
2012	Graz	0,04	0,00	11,02	Indeterminate
	8010	0,00	0,00	Indeterminate	Indeterminate
	8020	0,17	0,02	42,25	Indeterminate
2013	Graz	0,00	0,00	Indeterminate	Indeterminate
	8010	0,00	0,00	Indeterminate	Indeterminate
	8020	Indeterminate	0,00	Indeterminate	Indeterminate
2014	Graz	0,00	0,00	Indeterminate	0,00
	8010	Indeterminate	0,00	Indeterminate	Indeterminate
	8020	Indeterminate	0,00	Indeterminate	Indeterminate
2015	Graz	0,15	0,01	19,50	Incomputable
	8010	Indeterminate	0,00	Indeterminate	
	8020	0,00	0,00	Indeterminate	
Total	Graz	0,05	0,00	2,41	
	8010	0,55	0,03	12,67	
	8020	0,54	0,09	6,50	

Appendix Table A 17: Final evaluation results for house burglaries in Graz of 'NR' radius type

2.3.3. Radius Type: ORNR

Year	District	HR	DR	PAI	RRI
2009	Graz	0,00	0,00	Incomputable	0,00
	8010	0,00	0,00		0,00
	8020	0,00	0,00		Indeterminate
2010	Graz	0,06	0,01		1,27
	8010	0,40	0,05		Indeterminate
	8020	0,00	0,00		Indeterminate
2011	Graz	0,05	0,00		1,39
	8010	Indeterminate	0,00		Indeterminate
	8020	0,00	0,00		0,00
2012	Graz	0,04	0,00		Indeterminate
	8010	0,00	0,00		Indeterminate
	8020	0,17	0,02		Indeterminate
2013	Graz	0,00	0,00		Indeterminate
	8010	0,00	0,00		Indeterminate
	8020	Indeterminate	0,00		Indeterminate
2014	Graz	0,00	0,00		0,00
	8010	Indeterminate	0,00		Indeterminate
	8020	Indeterminate	0,00		Indeterminate
2015	Graz	0,15	0,01		Incomputable
	8010	Indeterminate	0,00		
	8020	0,00	0,00		
Total	Graz	0,05	0,00		
	8010	0,13	0,01		
	8020	0,05	0,00		

Appendix Table A 18: Final evaluation results for house burglaries in Graz of 'ORNR' radius type

3. Linz

3.1. Apartment Burglary

3.1.1. Radius Type: OR

Year	District	HR	DR	PAI	RRI
2009	Linz	0,07	0,01	0,52	0,18
	4020	0,11	0,01	1,18	0,18
	4030	0,00	0,00	0,00	Indeterminate
2010	Linz	0,39	0,04	2,68	3,72
	4020	0,69	0,06	8,20	10,81
	4030	0,00	0,00	0,00	0,00
2011	Linz	0,16	0,01	1,59	2,76
	4020	0,08	0,01	1,13	Indeterminate
	4030	0,33	0,02	21,21	Indeterminate
2012	Linz	0,05	0,00	0,43	1,01
	4020	0,00	0,00	0,00	0,00
	4030	0,00	0,00	0,00	Indeterminate
2013	Linz	0,08	0,00	1,13	0,80
	4020	0,08	0,01	1,13	0,75
	4030	Indeterminate	0,00	Indeterminate	Indeterminate
2014	Linz	0,08	0,00	1,33	0,23
	4020	0,14	0,01	3,90	0,19
	4030	0,00	0,00	0,00	Indeterminate
2015	Linz	0,20	0,02	1,27	Incomputable
	4020	0,32	0,04	3,17	
	4030	0,00	0,00	0,00	
Total	Linz	0,17	0,01	0,21	
	4020	0,22	0,02	0,44	
	4030	0,05	0,00	0,39	

Appendix Table A 19: Final evaluation results for apartment burglaries in Linz of 'OR' radius type

3.1.2. Radius Type: NR

Year	District	HR	DR	PAI	RRI
2009	Linz	0,07	0,01	7,07	0,29
	4020	0,11	0,01	10,60	0,29
	4030	0,00	0,00	Indeterminate	Indeterminate
2010	Linz	0,25	0,02	6,82	3,55
	4020	0,44	0,04	11,93	Indeterminate
	4030	0,00	0,00	Indeterminate	0,00
2011	Linz	0,11	0,01	10,05	1,84
	4020	0,00	0,00	Indeterminate	Indeterminate
	4030	0,33	0,02	63,62	Indeterminate
2012	Linz	0,05	0,00	9,09	1,01
	4020	0,00	0,00	Indeterminate	0,00
	4030	0,00	0,00	Indeterminate	Indeterminate
2013	Linz	0,08	0,00	14,68	0,80
	4020	0,08	0,01	14,68	0,75
	4030	Indeterminate	0,00	Indeterminate	Indeterminate
2014	Linz	0,08	0,00	15,91	0,20
	4020	0,14	0,01	27,27	0,17
	4030	0,00	0,00	Indeterminate	Indeterminate
2015	Linz	0,23	0,02	6,36	Incomputable
	4020	0,37	0,04	10,05	
	4030	0,00	0,00	Indeterminate	
Total	Linz	0,14	0,01	1,27	
	4020	0,18	0,02	1,95	
	4030	0,05	0,00	8,68	

Appendix Table A 20: Final evaluation results for apartment burglaries in Linz of 'NR' radius type

3.1.3. Radius Type: ORNR

Year	District	HR	DR	PAI	RRI
2009	Linz	0,07	0,01	Incomputable	0,18
	4020	0,11	0,01		0,18
	4030	0,00	0,00		Indeterminate
2010	Linz	0,39	0,04		3,72
	4020	0,69	0,06		10,81
	4030	0,00	0,00		0,00
2011	Linz	0,16	0,01		2,76
	4020	0,08	0,01		Indeterminate
	4030	0,33	0,02		Indeterminate
2012	Linz	0,05	0,00		1,01
	4020	0,00	0,00		0,00
	4030	0,00	0,00		Indeterminate
2013	Linz	0,08	0,00		0,40
	4020	0,08	0,01		0,37
	4030	Indeterminate	0,00		Indeterminate
2014	Linz	0,17	0,01		0,35
	4020	0,29	0,01		0,29
	4030	0,00	0,00		Indeterminate
2015	Linz	0,27	0,03		Incomputable
	4020	0,42	0,05		
	4030	0,00	0,00		
Total	Linz	0,19	0,01		
	4020	0,26	0,02		
	4030	0,05	0,00		

Appendix Table A 21: Final evaluation results for apartment burglaries in Linz of 'ORNR' radius type

3.2. Car Burglary

3.2.1. Radius Type: OR

Year	District	HR	DR	PAI	RRI
2009	Linz	0,56	0,09	1,47	2,20
	4020	0,66	0,14	2,04	2,57
	4030	0,00	0,00	0,00	Indeterminate
2010	Linz	0,29	0,04	0,83	1,35
	4020	0,34	0,05	1,22	1,95
	4030	0,00	0,00	0,00	0,00
2011	Linz	0,24	0,03	1,14	0,46
	4020	0,26	0,03	2,64	2,51
	4030	0,30	0,03	5,73	0,55
2012	Linz	0,58	0,06	2,74	7,81
	4020	0,11	0,01	1,06	0,69
	4030	0,67	0,06	14,14	Indeterminate
2013	Linz	0,07	0,01	0,34	0,34
	4020	0,20	0,02	2,54	2,09
	4030	0,00	0,00	0,00	0,00
2014	Linz	0,25	0,02	2,39	1,56
	4020	0,09	0,01	1,58	0,88
	4030	0,40	0,04	15,27	Indeterminate
2015	Linz	0,13	0,01	1,08	Incomputable
	4020	0,08	0,01	1,33	
	4030	0,00	0,00	0,00	
Total	Linz	0,34	0,04	0,21	
	4020	0,37	0,05	0,37	
	4030	0,22	0,02	0,87	

Appendix Table A 22: Final evaluation results for car burglaries in Linz of 'OR' radius type

3.2.2. Radius Type: NR

Year	District	HR	DR	PAI	RRI
2009	Linz	0,46	0,07	2,58	2,17
	4020	0,57	0,12	3,18	2,74
	4030	0,00	0,00	Indeterminate	0,00
2010	Linz	0,24	0,03	2,89	1,63
	4020	0,27	0,04	3,67	1,26
	4030	0,17	0,01	31,81	Indeterminate
2011	Linz	0,17	0,02	4,66	0,33
	4020	0,32	0,03	10,05	2,01
	4030	0,00	0,00	Indeterminate	0,00
2012	Linz	0,56	0,06	4,66	Indeterminate
	4020	0,15	0,02	9,54	Indeterminate
	4030	0,67	0,06	21,21	Indeterminate
2013	Linz	0,00	0,00	Indeterminate	0,00
	4020	0,00	0,00	Indeterminate	0,00
	4030	0,00	0,00	Indeterminate	0,00
2014	Linz	0,25	0,02	9,54	4,68
	4020	0,09	0,01	17,35	0,88
	4030	0,40	0,04	38,17	Indeterminate
2015	Linz	0,04	0,00	8,30	Incomputable
	4020	0,08	0,01	15,91	
	4030	0,00	0,00	Indeterminate	
Total	Linz	0,28	0,03	0,62	
	4020	0,31	0,04	1,01	
	4030	0,17	0,01	3,53	

Appendix Table A 23: Final evaluation results for car burglaries in Linz of 'NR' radius type

3.2.3. Radius Type: ORNR

Year	District	HR	DR	PAI	RRI
2009	Linz	0,64	0,10	Incomputable	2,40
	4020	0,75	0,16		2,95
	4030	0,00	0,00		0,00
2010	Linz	0,31	0,04		1,29
	4020	0,35	0,05		1,62
	4030	0,17	0,01		0,33
2011	Linz	0,27	0,03		0,49
	4020	0,32	0,03		2,01
	4030	0,30	0,03		0,55
2012	Linz	0,60	0,06		8,15
	4020	0,16	0,02		1,03
	4030	0,67	0,06		Indeterminate
2013	Linz	0,07	0,01		0,34
	4020	0,20	0,02		2,09
	4030	0,00	0,00		0,00
2014	Linz	0,25	0,02		1,56
	4020	0,09	0,01		0,88
	4030	0,40	0,04		Indeterminate
2015	Linz	0,13	0,01		Incomputable
	4020	0,08	0,01		
	4030	0,00	0,00		
Total	Linz	0,37	0,05		
	4020	0,42	0,06		
	4030	0,24	0,02		

Appendix Table A 24: Final evaluation results for car burglaries in Linz of 'ORNR' radius type

3.3. House burglary

3.3.1. Radius Type: OR

Year	District	HR	DR	PAI	RRI
2009	Linz	0,00	0,00	0,00	Indeterminate
	4020	0,00	0,00	0,00	Indeterminate
	4030	0,00	0,00	0,00	Indeterminate
2010	Linz	0,00	0,00	0,00	0,00
	4020	Indeterminate	0,00	Indeterminate	Indeterminate
	4030	0,00	0,00	0,00	Indeterminate
2011	Linz	0,20	0,02	3,82	1,32
	4020	0,00	0,00	0,00	0,00
	4030	0,00	0,00	0,00	0,00
2012	Linz	0,15	0,01	2,26	Indeterminate
	4020	0,14	0,01	3,90	Indeterminate
	4030	0,20	0,03	7,63	Indeterminate
2013	Linz	0,00	0,00	0,00	Indeterminate
	4020	0,00	0,00	0,00	Indeterminate
	4030	Indeterminate	0,00	Indeterminate	Indeterminate
2014	Linz	0,00	0,00	0,00	0,00
	4020	0,00	0,00	0,00	Indeterminate
	4030	Indeterminate	0,00	Indeterminate	0,00
2015	Linz	0,08	0,01	1,13	Incomputable
	4020	0,00	0,00	0,00	
	4030	0,20	0,02	7,63	
Total	Linz	0,10	0,01	0,40	
	4020	0,05	0,00	0,53	
	4030	0,11	0,01	1,06	

Appendix Table A 25: Final evaluation results for house burglaries in Linz of 'OR' radius type

3.3.2. Radius Type: NR

Year	District	HR	DR	PAI	RRI
2009	Linz	0,00	0,00	Indeterminate	Indeterminate
	4020	0,00	0,00	Indeterminate	Indeterminate
	4030	0,00	0,00	Indeterminate	Indeterminate
2010	Linz	0,00	0,00	Indeterminate	0,00
	4020	Indeterminate	0,00	Indeterminate	Indeterminate
	4030	0,00	0,00	Indeterminate	Indeterminate
2011	Linz	0,20	0,02	19,09	1,32
	4020	0,00	0,00	Indeterminate	0,00
	4030	0,00	0,00	Indeterminate	0,00
2012	Linz	0,15	0,01	14,68	Indeterminate
	4020	0,14	0,01	27,27	Indeterminate
	4030	0,20	0,03	38,17	Indeterminate
2013	Linz	0,00	0,00	Indeterminate	Indeterminate
	4020	0,00	0,00	Indeterminate	Indeterminate
	4030	Indeterminate	0,00	Indeterminate	Indeterminate
2014	Linz	0,00	0,00	Indeterminate	0,00
	4020	0,00	0,00	Indeterminate	Indeterminate
	4030	Indeterminate	0,00	Indeterminate	0,00
2015	Linz	0,15	0,01	14,68	Incomputable
	4020	0,00	0,00	Indeterminate	
	4030	0,20	0,02	38,17	
Total	Linz	0,12	0,01	3,90	
	4020	0,05	0,00	10,05	
	4030	0,11	0,01	10,05	

Appendix Table A 26: Final evaluation results for house burglaries in Linz of 'NR' radius type

3.3.3. Radius Type: ORNR

Year	District	HR	DR	PAI	RRI
2009	Linz	0,00	0,00	Incomputable	Indeterminate
	4020	0,00	0,00		Indeterminate
	4030	0,00	0,00		Indeterminate
2010	Linz	0,00	0,00		0,00
	4020	Indeterminate	0,00		Indeterminate
	4030	0,00	0,00		Indeterminate
2011	Linz	0,20	0,02		1,32
	4020	0,00	0,00		0,00
	4030	0,00	0,00		0,00
2012	Linz	0,15	0,01		Indeterminate
	4020	0,14	0,01		Indeterminate
	4030	0,20	0,03		Indeterminate
2013	Linz	0,00	0,00		Indeterminate
	4020	0,00	0,00		Indeterminate
	4030	Indeterminate	0,00		Indeterminate
2014	Linz	0,00	0,00		0,00
	4020	0,00	0,00		Indeterminate
	4030	Indeterminate	0,00		0,00
2015	Linz	0,15	0,01		Incomputable
	4020	0,00	0,00		
	4030	0,20	0,02		
Total	Linz	0,12	0,01		
	4020	0,05	0,00		
	4030	0,11	0,01		

Appendix Table A 27: Final evaluation results for house burglaries in Linz of 'ORNR' radius type

Appendix B

1. Vienna

1.1. Apartment Burglary

1.1.1. Radius Type: OR

Year	District	Offenses	Predictions	Hits
2009	Vienna	9795	1826	1312
2010	Vienna	7896	1373	1034
2011	Vienna	7366	1219	615
2012	Vienna	6449	940	411
2013	Vienna	7635	1306	860
2014	Vienna	6770	984	495
2015	Vienna	5471	776	291
Total	Vienna	51382	8424	5018
2009	1100	1085	236	177
2010	1100	637	95	39
2011	1100	733	99	53
2012	1100	654	86	30
2013	1100	651	86	37
2014	1100	453	50	17
2015	1100	496	49	25
Total	1100	4709	701	378
2009	1030	511	77	40
2010	1030	471	96	60
2011	1030	426	87	37
2012	1030	508	99	68
2013	1030	547	116	92
2014	1030	480	88	59
2015	1030	343	61	25
Total	1030	3286	624	381

Appendix Table B 1: Output results of 'OR' radius type from CriPA demonstrator & Offenses count for apartment burglaries in Vienna

1.1.2. Radius Type: NR

Year	District	Offenses	Predictions	Hits
2009	Vienna	9795	1840	1201
2010	Vienna	7896	1386	909
2011	Vienna	7366	1227	584
2012	Vienna	6449	951	381
2013	Vienna	7635	1319	745
2014	Vienna	6770	994	451
2015	Vienna	5471	778	273
Total	Vienna	51382	8495	4544
2009	1100	1085	235	154
2010	1100	637	96	38
2011	1100	733	99	55
2012	1100	654	85	31
2013	1100	651	87	30
2014	1100	453	50	16
2015	1100	496	48	15
Total	1100	4709	700	339
2009	1030	511	76	40
2010	1030	471	93	56
2011	1030	426	90	38
2012	1030	508	98	70
2013	1030	547	117	85
2014	1030	480	88	46
2015	1030	343	63	23
Total	1030	3286	625	358

Appendix Table B 2: Output results of 'NR' radius type from CriPA demonstrator & Offenses count for apartment burglaries in Vienna

1.1.3. Radius Type: ORNR

Year	District	Offenses	Predictions	Hits
2009	Vienna	9795	1783	1525
2010	Vienna	7896	1346	1195
2011	Vienna	7366	1198	745
2012	Vienna	6449	929	493
2013	Vienna	7635	1279	1001
2014	Vienna	6770	975	577
2015	Vienna	5471	770	338
Total	Vienna	51382	8280	5874
2009	1100	1085	233	203
2010	1100	637	96	45
2011	1100	733	100	67
2012	1100	654	84	38
2013	1100	651	86	44
2014	1100	453	50	21
2015	1100	496	49	25
Total	1100	4709	698	443
2009	1030	511	77	44
2010	1030	471	95	69
2011	1030	426	89	46
2012	1030	508	98	81
2013	1030	547	115	105
2014	1030	480	89	64
2015	1030	343	65	28
Total	1030	3286	628	437

Appendix Table B 3: Output results of 'ORNR' radius type from CriPA demonstrator & Offenses count for apartment burglaries in Vienna

1.2. Car Burglary

1.2.1. Radius Type: OR

Year	District	Offenses	Predictions	Hits
2009	Vienna	16136	3286	4547
2010	Vienna	12516	2206	2173
2011	Vienna	9885	1609	1278
2012	Vienna	8134	1241	935
2013	Vienna	8990	1746	1300
2014	Vienna	8881	2207	2173
2015	Vienna	8242	2050	2634
Total	Vienna	72784	14345	15040
2009	1100	1716	358	306
2010	1100	1589	279	308
2011	1100	1118	195	118
2012	1100	822	107	28
2013	1100	1113	222	185
2014	1100	1300	265	389
2015	1100	974	222	338
Total	1100	8632	1648	1672
2009	1220	1837	335	349
2010	1220	1350	231	151
2011	1220	1019	136	102
2012	1220	772	79	31
2013	1220	720	78	19
2014	1220	719	122	36
2015	1220	582	74	19
Total	1220	6999	1055	707

Appendix Table B 4: Output results of 'OR' radius type from CriPA demonstrator & Offenses count for car burglaries in Vienna

1.2.2. Radius Type: NR

Year	District	Offenses	Predictions	Hits
2009	Vienna	16136	3421	3856
2010	Vienna	12516	2248	1948
2011	Vienna	9885	1620	1190
2012	Vienna	8134	1262	823
2013	Vienna	8990	1777	1158
2014	Vienna	8881	2274	1794
2015	Vienna	8242	2159	2138
Total	Vienna	72784	14761	12907
2009	1100	1716	351	268
2010	1100	1589	282	283
2011	1100	1118	192	128
2012	1100	822	104	26
2013	1100	1113	223	159
2014	1100	1300	279	318
2015	1100	974	231	267
Total	1100	8632	1662	1449
2009	1220	1837	338	309
2010	1220	1350	234	136
2011	1220	1019	134	96
2012	1220	772	81	34
2013	1220	720	76	19
2014	1220	719	120	29
2015	1220	582	75	18
Total	1220	6999	1058	641

Appendix Table B 5: Output results of 'NR' radius type from CriPA demonstrator & Offenses count for car burglaries in Vienna

1.2.3. Radius Type: ORNR

Year	District	Offenses	Predictions	Hits
2009	Vienna	16136	3168	5131
2010	Vienna	12516	2149	2491
2011	Vienna	9885	1584	1454
2012	Vienna	8134	1219	1064
2013	Vienna	8990	1706	1489
2014	Vienna	8881	2112	2466
2015	Vienna	8242	1973	2904
Total	Vienna	72784	13911	16999
2009	1100	1716	357	355
2010	1100	1589	273	357
2011	1100	1118	200	140
2012	1100	822	105	37
2013	1100	1113	219	208
2014	1100	1300	261	419
2015	1100	974	219	370
Total	1100	8632	1634	1886
2009	1220	1837	336	389
2010	1220	1350	231	160
2011	1220	1019	140	108
2012	1220	772	81	34
2013	1220	720	77	22
2014	1220	719	122	36
2015	1220	582	76	22
Total	1220	6999	1063	771

Appendix Table B 6: Output results of 'ORNR' radius type from CriPA demonstrator & Offenses count for car burglaries in Vienna

1.3. House burglary

1.3.1. Radius Type: OR

Year	District	Offenses	Predictions	Hits
2009	Vienna	1987	244	73
2010	Vienna	1662	200	35
2011	Vienna	1627	146	27
2012	Vienna	1677	184	42
2013	Vienna	1346	99	19
2014	Vienna	1623	107	10
2015	Vienna	1633	131	22
Total	Vienna	11555	1111	228
2009	1220	448	70	26
2010	1220	417	59	17
2011	1220	353	36	3
2012	1220	459	65	14
2013	1220	325	33	4
2014	1220	391	30	1
2015	1220	416	32	5
Total	1220	2809	325	70
2009	1210	198	16	1
2010	1210	210	25	5
2011	1210	185	15	2
2012	1210	293	33	7
2013	1210	228	20	2
2014	1210	238	19	3
2015	1210	224	16	0
Total	1210	1576	144	20

Appendix Table B 7: Output results of 'OR' radius type from CriPA demonstrator & Offenses count for house burglaries in Vienna

1.3.2. Radius Type: NR

Year	District	Offenses	Predictions	Hits
2009	Vienna	1987	245	68
2010	Vienna	1662	200	33
2011	Vienna	1627	145	27
2012	Vienna	1677	184	38
2013	Vienna	1346	99	18
2014	Vienna	1623	107	12
2015	Vienna	1633	132	22
Total	Vienna	11555	1112	218
2009	1220	448	70	26
2010	1220	417	59	14
2011	1220	353	34	5
2012	1220	459	65	13
2013	1220	325	33	4
2014	1220	391	30	3
2015	1220	416	32	5
Total	1220	2809	323	70
2009	1210	198	15	1
2010	1210	210	25	5
2011	1210	185	15	2
2012	1210	293	32	6
2013	1210	228	20	0
2014	1210	238	19	3
2015	1210	224	16	0
Total	1210	1576	142	17

Appendix Table B 8: Output results of 'NR' radius type from CriPA demonstrator & Offenses count for house burglaries in Vienna

1.3.3. Radius Type: ORNR

Year	District	Offenses	Predictions	Hits
2009	Vienna	1987	244	80
2010	Vienna	1662	200	38
2011	Vienna	1627	145	30
2012	Vienna	1677	184	46
2013	Vienna	1346	99	21
2014	Vienna	1623	107	12
2015	Vienna	1633	131	25
Total	Vienna	11555	1110	252
2009	1220	448	71	28
2010	1220	417	59	19
2011	1220	353	35	5
2012	1220	459	65	15
2013	1220	325	33	4
2014	1220	391	30	3
2015	1220	416	32	7
Total	1220	2809	325	81
2009	1210	198	16	1
2010	1210	210	25	5
2011	1210	185	15	2
2012	1210	293	33	8
2013	1210	228	21	2
2014	1210	238	19	3
2015	1210	224	16	0
Total	1210	1576	145	21

Appendix Table B 9: Output results of 'ORNR' radius type from CriPA demonstrator & Offenses count for house burglaries in Vienna

2. Graz

2.1. Apartment Burglary

2.1.1. Radius Type: OR

Year	District	Offenses	Predictions	Hits
2009	Graz	509	40	5
2010	Graz	444	51	14
2011	Graz	439	46	9
2012	Graz	526	77	14
2013	Graz	319	23	2
2014	Graz	278	26	8
2015	Graz	493	79	24
Total	Graz	3008	342	76
2009	8010	234	22	3
2010	8010	228	36	12
2011	8010	163	19	4
2012	8010	212	38	6
2013	8010	149	13	2
2014	8010	137	15	4
2015	8010	228	45	15
Total	8010	1351	188	46
2009	8020	169	12	1
2010	8020	125	9	2
2011	8020	85	1	0
2012	8020	120	12	1
2013	8020	97	7	0
2014	8020	82	11	4
2015	8020	174	32	6
Total	8020	852	84	14

Appendix Table B 10: Output results of 'OR' radius type from CriPA demonstrator & Offenses count for apartment burglaries in Graz

2.1.2. Radius Type: NR

Year	District	Offenses	Predictions	Hits
2009	Graz	509	40	4
2010	Graz	444	50	8
2011	Graz	439	47	7
2012	Graz	526	77	13
2013	Graz	319	23	2
2014	Graz	278	26	9
2015	Graz	493	81	20
Total	Graz	3008	344	63
2009	8010	234	22	2
2010	8010	228	34	6
2011	8010	163	20	3
2012	8010	212	38	5
2013	8010	149	13	2
2014	8010	137	16	6
2015	8010	228	45	12
Total	8010	1351	188	36
2009	8020	169	12	1
2010	8020	125	11	2
2011	8020	85	1	0
2012	8020	120	11	1
2013	8020	97	7	0
2014	8020	82	9	2
2015	8020	174	33	7
Total	8020	852	84	13

Appendix Table B 11: Output results of 'NR' radius type from CriPA demonstrator & Offenses count for apartment burglaries in Graz

2.1.3. Radius Type: ORNR

Year	District	Offenses	Predictions	Hits
2009	Graz	509	40	5
2010	Graz	444	50	14
2011	Graz	439	46	9
2012	Graz	526	77	14
2013	Graz	319	23	2
2014	Graz	278	26	10
2015	Graz	493	77	28
Total	Graz	3008	339	82
2009	8010	234	22	3
2010	8010	228	35	12
2011	8010	163	19	4
2012	8010	212	39	6
2013	8010	149	13	2
2014	8010	137	17	6
2015	8010	228	45	16
Total	8010	1351	190	49
2009	8020	169	12	1
2010	8020	125	11	2
2011	8020	85	1	0
2012	8020	120	13	1
2013	8020	97	7	0
2014	8020	82	11	4
2015	8020	174	319	0
Total	8020	852	374	8

Appendix Table B 12: Output results of 'ORNR' radius type from CriPA demonstrator & Offenses count for apartment burglaries in Graz

2.2. Car Burglary

2.2.1. Radius Type: OR

Year	District	Offenses	Predictions	Hits
2009	Graz	773	99	35
2010	Graz	569	74	22
2011	Graz	565	64	12
2012	Graz	340	31	3
2013	Graz	318	40	4
2014	Graz	305	38	5
2015	Graz	397	78	25
Total	Graz	3267	424	106
2009	8010	282	40	23
2010	8010	234	30	15
2011	8010	269	34	9
2012	8010	111	11	0
2013	8010	69	9	1
2014	8010	67	10	0
2015	8010	113	23	13
Total	8010	1145	157	61
2009	8020	192	27	8
2010	8020	167	24	4
2011	8020	154	13	1
2012	8020	125	11	2
2013	8020	121	19	3
2014	8020	111	18	5
2015	8020	169	35	12
Total	8020	1039	147	35

Appendix Table B 13: Output results of 'OR' radius type from CriPA demonstrator & Offenses count for car burglaries in Graz

2.2.2. Radius Type: NR

Year	District	Offenses	Predictions	Hits
2009	Graz	773	100	34
2010	Graz	569	75	20
2011	Graz	565	63	12
2012	Graz	340	31	3
2013	Graz	318	40	5
2014	Graz	305	38	5
2015	Graz	397	77	24
Total	Graz	3267	424	103
2009	8010	282	37	21
2010	8010	234	30	14
2011	8010	269	32	10
2012	8010	111	10	0
2013	8010	69	9	2
2014	8010	67	10	0
2015	8010	113	24	11
Total	8010	1145	152	58
2009	8020	192	28	7
2010	8020	167	25	4
2011	8020	154	12	1
2012	8020	125	12	2
2013	8020	121	18	3
2014	8020	111	18	5
2015	8020	169	35	12
Total	8020	1039	148	34

Appendix Table B 14: Output results of 'NR' radius type from CriPA demonstrator & Offenses count for car burglaries in Graz

2.2.3. Radius Type: ORNR

Year	District	Offenses	Predictions	Hits
2009	Graz	773	99	37
2010	Graz	569	74	22
2011	Graz	565	63	13
2012	Graz	340	31	3
2013	Graz	318	40	5
2014	Graz	305	38	5
2015	Graz	397	76	29
Total	Graz	3267	421	114
2009	8010	282	41	23
2010	8010	234	30	15
2011	8010	269	34	10
2012	8010	111	11	0
2013	8010	69	9	2
2014	8010	67	10	0
2015	8010	113	24	14
Total	8010	1145	159	64
2009	8020	192	30	9
2010	8020	167	25	4
2011	8020	154	12	1
2012	8020	125	12	2
2013	8020	121	19	3
2014	8020	111	18	5
2015	8020	169	36	15
Total	8020	1039	152	39

Appendix Table B 15: Output results of 'ORNR' radius type from CriPA demonstrator & Offenses count for car burglaries in Graz

2.3. House burglary

2.3.1. Radius Type: OR

Year	District	Offenses	Predictions	Hits
2009	Graz	266	16	0
2010	Graz	193	17	2
2011	Graz	246	22	1
2012	Graz	342	23	1
2013	Graz	303	11	0
2014	Graz	169	4	0
2015	Graz	253	13	2
Total	Graz	1772	106	6
2009	8010	67	2	0
2010	8010	38	4	1
2011	8010	25	0	0
2012	8010	80	5	0
2013	8010	63	3	0
2014	8010	21	0	0
2015	8010	25	0	0
Total	8010	319	14	1
2009	8020	26	2	0
2010	8020	30	5	0
2011	8020	37	5	0
2012	8020	58	6	1
2013	8020	23	0	0
2014	8020	19	0	0
2015	8020	32	1	0
Total	8020	225	19	1

Appendix Table B 16: Output results of 'OR' radius type from CriPA demonstrator & Offenses count for house burglaries in Graz

2.3.2. Radius Type: NR

Year	District	Offenses	Predictions	Hits
2009	Graz	266	16	0
2010	Graz	193	16	1
2011	Graz	246	22	1
2012	Graz	342	23	1
2013	Graz	303	11	0
2014	Graz	169	4	0
2015	Graz	253	13	2
Total	Graz	1772	105	5
2009	8010	67	2	0
2010	8010	38	14	11
2011	8010	25	0	0
2012	8010	80	2	0
2013	8010	63	2	0
2014	8010	21	0	0
2015	8010	25	0	0
Total	8010	319	20	11
2009	8020	26	2	0
2010	8020	30	25	20
2011	8020	37	5	0
2012	8020	58	6	1
2013	8020	23	0	0
2014	8020	19	0	0
2015	8020	32	1	0
Total	8020	225	39	21

Appendix Table B 17: Output results of 'NR' radius type from CriPA demonstrator & Offenses count for house burglaries in Graz

2.3.3. Radius Type: ORNR

Year	District	Offenses	Predictions	Hits
2009	Graz	266	16	0
2010	Graz	193	16	1
2011	Graz	246	22	1
2012	Graz	342	23	1
2013	Graz	303	11	0
2014	Graz	169	4	0
2015	Graz	253	13	2
Total	Graz	1772	105	5
2009	8010	67	2	0
2010	8010	38	5	2
2011	8010	25	0	0
2012	8010	80	5	0
2013	8010	63	3	0
2014	8010	21	0	0
2015	8010	25	0	0
Total	8010	319	15	2
2009	8020	26	2	0
2010	8020	30	7	0
2011	8020	37	5	0
2012	8020	58	6	1
2013	8020	23	0	0
2014	8020	19	0	0
2015	8020	32	1	0
Total	8020	225	21	1

Appendix Table B 18: Output results of 'ORNR' radius type from CriPA demonstrator & Offenses count for house burglaries in Graz

3. Linz

3.1. Apartment Burglary

3.1.1. Radius Type: OR

Year	District	Offenses	Predictions	Hits
2009	Linz	285	27	2
2010	Linz	287	28	11
2011	Linz	291	19	3
2012	Linz	268	21	1
2013	Linz	272	13	1
2014	Linz	217	12	1
2015	Linz	302	30	6
Total	Linz	1922	150	25
2009	4020	171	18	2
2010	4020	173	16	11
2011	4020	170	13	1
2012	4020	152	12	0
2013	4020	187	13	1
2014	4020	140	7	1
2015	4020	163	19	6
Total	4020	1156	98	22
2009	4030	57	2	0
2010	4030	70	7	0
2011	4030	54	3	1
2012	4030	52	2	0
2013	4030	39	0	0
2014	4030	41	2	0
2015	4030	84	6	0
Total	4030	397	22	1

Appendix Table B 19: Output results of 'OR' radius type from CriPA demonstrator & Offenses count for apartment burglaries in Linz

3.1.2. Radius Type: NR

Year	District	Offenses	Predictions	Hits
2009	Linz	285	27	2
2010	Linz	287	28	7
2011	Linz	291	19	2
2012	Linz	268	21	1
2013	Linz	272	13	1
2014	Linz	217	12	1
2015	Linz	302	30	7
Total	Linz	1922	150	21
2009	4020	171	18	2
2010	4020	173	16	7
2011	4020	170	13	0
2012	4020	152	12	0
2013	4020	187	13	1
2014	4020	140	7	1
2015	4020	163	19	7
Total	4020	1156	98	18
2009	4030	57	2	0
2010	4030	70	7	0
2011	4030	54	3	1
2012	4030	52	2	0
2013	4030	39	0	0
2014	4030	41	2	0
2015	4030	84	6	0
Total	4030	397	22	1

Appendix Table B 20: Output results of 'NR' radius type from CriPA demonstrator & Offenses count for apartment burglaries in Linz

3.1.3. Radius Type: ORNR

Year	District	Offenses	Predictions	Hits
2009	Linz	285	27	2
2010	Linz	287	28	11
2011	Linz	291	19	3
2012	Linz	268	21	1
2013	Linz	272	13	1
2014	Linz	217	12	2
2015	Linz	302	30	8
Total	Linz	1922	150	28
2009	4020	171	18	2
2010	4020	173	16	11
2011	4020	170	13	1
2012	4020	152	12	0
2013	4020	187	13	1
2014	4020	140	7	2
2015	4020	163	19	8
Total	4020	1156	98	25
2009	4030	57	2	0
2010	4030	70	7	0
2011	4030	54	3	1
2012	4030	52	2	0
2013	4030	39	0	0
2014	4030	41	2	0
2015	4030	84	6	0
Total	4030	397	22	1

Appendix Table B 21: Output results of 'ORNR' radius type from CriPA demonstrator & Offenses count for apartment burglaries in Linz

3.2. Car Burglary

3.2.1. Radius Type: OR

Year	District	Offenses	Predictions	Hits
2009	Linz	482	73	41
2010	Linz	492	66	19
2011	Linz	350	41	10
2012	Linz	374	40	23
2013	Linz	381	41	3
2014	Linz	216	20	5
2015	Linz	202	23	3
Total	Linz	2497	304	104
2009	4020	293	62	41
2010	4020	331	53	18
2011	4020	179	19	5
2012	4020	180	19	2
2013	4020	185	15	3
2014	4020	129	11	1
2015	4020	113	12	1
Total	4020	1410	191	71
2009	4030	130	6	0
2010	4030	92	6	0
2011	4030	91	10	3
2012	4030	101	9	6
2013	4030	112	11	0
2014	4030	48	5	2
2015	4030	38	2	0
Total	4030	612	49	11

Appendix Table B 22: Output results of 'OR' radius type from CriPA demonstrator & Offenses count for car burglaries in Linz

3.2.2. Radius Type: NR

Year	District	Offenses	Predictions	Hits
2009	Linz	482	74	34
2010	Linz	492	66	16
2011	Linz	350	41	7
2012	Linz	374	41	23
2013	Linz	381	41	0
2014	Linz	216	20	5
2015	Linz	202	23	1
Total	Linz	2497	306	86
2009	4020	293	60	34
2010	4020	331	52	14
2011	4020	179	19	6
2012	4020	180	20	3
2013	4020	185	15	0
2014	4020	129	11	1
2015	4020	113	12	1
Total	4020	1410	189	59
2009	4030	130	8	0
2010	4030	92	6	1
2011	4030	91	10	0
2012	4030	101	9	6
2013	4030	112	11	0
2014	4030	48	5	2
2015	4030	38	2	0
Total	4030	612	54	9

Appendix Table B 23: Output results of 'NR' radius type from CriPA demonstrator & Offenses count for car burglaries in Linz

3.2.3. Radius Type: ORNR

Year	District	Offenses	Predictions	Hits
2009	Linz	482	73	47
2010	Linz	492	64	20
2011	Linz	350	41	11
2012	Linz	374	40	24
2013	Linz	381	41	3
2014	Linz	216	20	5
2015	Linz	202	23	3
Total	Linz	2497	302	113
2009	4020	293	63	47
2010	4020	331	51	18
2011	4020	179	19	6
2012	4020	180	19	3
2013	4020	185	15	3
2014	4020	129	11	1
2015	4020	113	12	1
Total	4020	1410	190	79
2009	4030	130	8	0
2010	4030	92	6	1
2011	4030	91	10	3
2012	4030	101	9	6
2013	4030	112	11	0
2014	4030	48	5	2
2015	4030	38	2	0
Total	4030	612	51	12

Appendix Table B 24: Output results of 'ORNR' radius type from CriPA demonstrator & Offenses count for car burglaries in Linz

3.3. House burglary

3.3.1. Radius Type: OR

Year	District	Offenses	Predictions	Hits
2009	Linz	86	4	0
2010	Linz	64	2	0
2011	Linz	122	10	2
2012	Linz	161	13	2
2013	Linz	146	3	0
2014	Linz	135	4	0
2015	Linz	150	13	2
Total	Linz	864	49	6
2009	4020	39	2	0
2010	4020	22	0	0
2011	4020	41	2	0
2012	4020	91	7	1
2013	4020	72	2	0
2014	4020	61	1	0
2015	4020	57	5	0
Total	4020	383	19	1
2009	4030	25	1	0
2010	4030	29	2	0
2011	4030	65	6	0
2012	4030	35	5	1
2013	4030	41	0	0
2014	4030	31	0	0
2015	4030	53	5	1
Total	4030	279	19	2

Appendix Table B 25: Output results of 'OR' radius type from CriPA demonstrator & Offenses count for house burglaries in Linz

3.3.2. Radius Type: NR

Year	District	Offenses	Predictions	Hits
2009	Linz	86	4	0
2010	Linz	64	2	0
2011	Linz	122	10	2
2012	Linz	161	13	2
2013	Linz	146	3	0
2014	Linz	135	4	0
2015	Linz	150	13	2
Total	Linz	864	49	6
2009	4020	39	2	0
2010	4020	22	0	0
2011	4020	41	2	0
2012	4020	91	7	1
2013	4020	72	2	0
2014	4020	61	1	0
2015	4020	57	5	0
Total	4020	383	19	1
2009	4030	25	1	0
2010	4030	29	2	0
2011	4030	65	6	0
2012	4030	35	5	1
2013	4030	41	0	0
2014	4030	31	0	0
2015	4030	53	5	1
Total	4030	279	19	2

Appendix Table B 26: Output results of 'NR' radius type from CriPA demonstrator & Offenses count for house burglaries in Linz

3.3.3. Radius Type: ORNR

Year	District	Offenses	Predictions	Hits
2009	Linz	86	4	0
2010	Linz	64	2	0
2011	Linz	122	10	2
2012	Linz	161	13	2
2013	Linz	146	3	0
2014	Linz	135	4	0
2015	Linz	150	13	2
Total	Linz	864	49	6
2009	4020	39	2	0
2010	4020	22	0	0
2011	4020	41	2	0
2012	4020	91	7	1
2013	4020	72	2	0
2014	4020	61	1	0
2015	4020	57	5	0
Total	4020	383	19	1
2009	4030	25	1	0
2010	4030	29	2	0
2011	4030	65	6	0
2012	4030	35	5	1
2013	4030	41	0	0
2014	4030	31	0	0
2015	4030	53	5	1
Total	4030	279	19	2

Appendix Table B 27: Output results of 'ORNR' radius type from CriPA demonstrator & Offenses count for house burglaries in Linz

s