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# MASTERARBEIT / MASTER'S THESIS

Titel der Masterarbeit / Title of the Master's Thesis

„Exploring Soccer-Related Graffiti by Applying Geospatial Technology, Geographic Information Systems and Statistical Approaches – A Case Study in Krakow, Poland."

verfasst von / submitted by

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## Abstract

The aim of this thesis is to create a "Graffiti-GIS" with which soccer-related graffiti data of Krakow can be stored, analyzed, modeled, and visualized. All relevant data are collected by a spatial video acquisition system (SVAS) which produces spatially referenced video data. The entire workflow of data acquisition from preparing the surveys to extracting the data out of the video files and integrating them into the GIS environment is described in this thesis. Thus, recommendations on the application of the technique are presented. Also some general background on the different and sometimes opposing frameworks and the social contexts in which graffiti are embedded is given, as well as some detailed knowledge on soccer-related graffiti.

In order to reveal the spatial pattern of soccer-related graffiti, statistical routines are applied using the software CrimeStat. These encompass descriptive methods such as centrographic statistics and distance analysis, spatial hotspots analysis for point locations, as well as kernel density interpolations which produce density maps. In addition, the 2018 data collection is compared to previous soccer-related graffiti data that were collected in 2016, which shows partly changes and partly consistency in the distributional pattern between both surveys. Finally, hotspots of graffiti and committed crimes are explored for correlation, in order to test the well-known "broken window theory".

Results are represented by tables or maps showing the spatial distributional pattern of soccer-related graffiti and crime incidents, thus dividing the study area into regions that are either dominated by graffiti and crime or unaffected. Hence, hotspots of each soccer club can be assigned to distinct areas. However, these concentrations are sometimes spatially close or even overlapping. The latter regions are referred to as "conflict zones", where graffiti of two or more rivaling soccer teams occur. In addition, medium to high density areas of graffiti show a correlation with the committed crimes tested in this research.

Findings of this research can contribute to the decision making, where graffiti removal actions shall take place and how future graffiti can be prevented, because detailed knowledge about the spatial distribution pattern and the temporal dynamics of graffiti has become known through this research.

# Kurzfassung

Das Ziel dieser Masterarbeit ist es ein „Graffiti-GIS“ zu erstellen, mit dem fußballbezogene Graffiti-Daten über Krakau gespeichert, analysiert, modelliert und visualisiert werden können. Alle relevanten Daten werden mit einem „spatial video acquisition system“ (SVAS) gesammelt, welches raumbezogene Videodateien produziert. Diese Arbeit liefert eine Beschreibung der einzelnen Arbeitsschritte der Datengewinnung, welche von der Planung der Feldbegehungen, bis hin zur Gewinnung der Daten aus den Videodateien und deren Integration in das GIS-Umfeld reicht. Dementsprechend können Empfehlungen bezüglich der optimalen Anwendung der Technologie gegeben werden. Außerdem wird ein allgemeines Hintergrundwissen zu Graffiti, welche in einen vielschichtigen und oftmals gegensätzlichen Rahmenkontext eingebettet sind, geliefert, sowie spezielle Informationen über fußballbezogene Graffiti vermittelt.

Damit die räumlichen Verteilungsmuster von fußballbezogenen Graffiti aufgedeckt werden können, werden mit Hilfe der Software CrimeStat statistische Methoden angewendet. Diese umfassen deskriptive Statistiken wie Lageparameter, Richtungsverteilungen und Nachbarschaftsanalysen, sowie Hot-Spot-Analysen und Kerndichteschätzungen. Zusätzlich wird der Datensatz von 2018 mit Graffiti-Daten von 2016 verglichen, wodurch Änderungen der Verteilungsmuster sowie Stetigkeiten festgestellt werden können. Schließlich werden Graffiti-Hot-Spots und Delikte auf Korrelation getestet, wodurch Bezug auf die „broken window theory“ genommen wird.

Die Ergebnisse werden in Form von Tabellen und Karten wiedergegeben, welche die räumlichen Verteilungsmuster von Fußball-Graffiti und Delikten aufzeigen und somit das Forschungsgebiet in Regionen aufteilt die stärker von Graffiti und Delikten geprägt sind als andere. Bestimmte Gegenden können dementsprechend als Hot-Spots für Graffiti eines bestimmten Fußballvereins ausgewiesen werden. Allerdings können diese Anhäufungen von Graffiti auch mehreren sich rivalisierenden Fußballvereinen zugeordnet werden, was zu Konfliktzonen führt, wenn diese räumlich nahe beieinander liegen oder sich sogar überlagern. Außerdem konnte festgestellt werden, dass Gegenden mit mittlerer oder hoher Graffiti-Dichte mit Delikten korrelieren.

Die Ergebnisse dieser Masterarbeit können dazu beitragen, wo Graffiti-Entfernungen vorgenommen werden können und wie die Anbringung zukünftiger Graffiti verhindert werden kann, da sich die räumliche Verteilung sowie deren zeitliche Dynamik erkennen lässt.

# Table of Contents

# List of Figures

# List of Tables

# List of Formulas

# 1 Introduction

The research proposed in this master thesis is part of the research project entitled: „The Geography of Graffiti: Applying Geospatial Technology to Explore Soccer-Related Graffiti in Krakow, Poland“, which was conducted by Professor Dr. Michael Leitner in the Institute of Geography and Spatial Management (IGSM) at the Jagiellonian University in Krakow, Poland. This study aims to create a "Graffiti-GIS" with which soccer-related graffiti data can be stored, analyzed, modeled, and visualized. All relevant data are collected by a spatial video acquisition system (SVAS) and are integrated into the "Graffiti-GIS". The acquired data are analyzed by different statistical and spatial analysis methods.
The first chapter consists of the problem definition and a discussion about the current state of research in graffiti, especially in Krakow. Moreover, the location where this study is performed is presented, as well as the research questions and the methods that are applied to answer them. It is also explained, why this topic is so important and who is benefitting from its outcome. Finally, an overview of the thesis's structure is given.

## 1.1 Problem Definition

Graffiti are a wide spread modern societal phenomenon and they are increasingly present in urban areas. Some are accepted as art or belonging to a city, whereas others are seen as illegal actions and are pursued by the police and the city government. There are also citizens criticizing graffiti in terms of their suspected correlation with the dangerousness of a place and the lacking of feeling safe in a public space, due to less protective efforts (cf. LUKAC 2014: 18f.).
In Krakow, soccer-related graffiti have a high impact on the cityscape and are spread throughout the whole city. The control of these tags or paintings, which can be placed on various surfaces like walls, bus shelters, etc., poses problems for the city government, because their creators are mostly anonymous and hard to identify. In order to organize graffiti removal actions, affected areas have to be detected first and the relevant graffiti have to be identified, which is a time-consuming and cumbersome task. There are mainly two problems that exacerbate this task. First, the fact that graffiti can be sprayed literally on almost every possible location results in a target area for graffiti sprayer that equals the urban area and beyond. Also, the planning and the implementation of a graffiti removal action are far more time-consuming than the actual creation of graffiti.

## 1.2 Existing Scientific Work

There are scientists from all over the world studying graffiti in different cities in the U.S. like SERKAN and GÜLSEN (2006) studying graffiti in New York, or MEGLER et al. (2014), which dedicate their research to graffiti in San Francisco. Similar work has also been completed in Australian cities, such as Sydney (HAWORTH et al. 2013), or the Netherlands (VANDERVEEN and VAN EIJK 2015).

In Poland, Dr. Piotr Trzepacz, currently an assistant professor in geography, compiled the first soccer-related graffiti map for the city of Krakow, collecting graffiti data on a bicycle in 2006. With this method Dr. Trzepacz was able to collect approximately 5,600 individual graffiti signs. His map (Figure 1), which has never been published in an academic journal, shows the spatial distribution of soccer-related graffiti, which can be allocated to either one of the three most popular soccer clubs in Krakow. According to Dr. Trzepacz, these are MKS Cracovia, Wisla Krakow, and Hutnik Krakow (Hutnik Nowa Huta). The research project, on which this master thesis is built upon, can be seen as an expansion of Dr. Trzepacz's work concerning the data collection, storage, analysis, modeling, and visualization. He has approved this proposed research and has agreed to collaborate. Similar to the first survey in 2006, Dr. Trzepacz started a second research in 2016 to compare the two graffiti maps with each other, which delivers the base for the survey trips to be conducted in this research, too.
Also LUKAC (2014) contributed scientific research on the topic of soccer-related graffiti in Krakow, but with special focus on anti-Semitism. Amongst other findings, he connected anti-Semitic graffiti to some extent with hooliganism. Further information on graffiti, especially its background information, is provided in the second chapter.

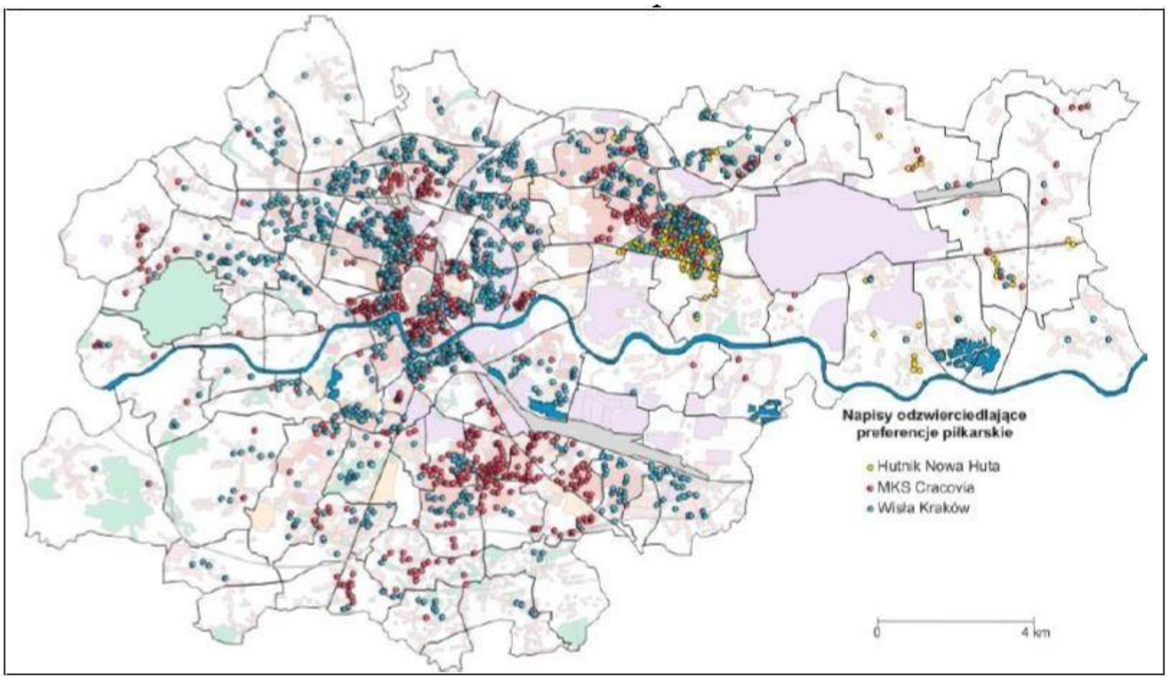



**Figure 1: Soccer-related graffiti map of Krakow 2006; Source: Dr. Piotr Trzepacz**

## 1.3 Study Area

The study area of this thesis is the city of Krakow, which is the capital of the subdivision Lesser Poland Voivodeship, also known as Małopolska Voivodeship (*województwo małopolskie*), which is located in southern Poland on the Vistula River. As of 2016, Krakow is the second largest city concerning both population (765,320) and surface area (326.8 km²) in Poland and has a population density of 2,341 persons per square kilometer (cf. Magiczny Kraków 2016; cf. GUS 2016). In total there are 18 districts whereof two are introduced shortly, because they are referred to occasionally for orientation purposes throughout this thesis (see Figure 2). District one, or also called Stare Miasto (old town), is the central district and the touristic hotspot of the city. The southern part of this district is a former historical district called Kazimierz, which has been influenced for centuries by Jewish culture. The other district to be considered is Howa Huta, or district 18, which is located in the east. It is home to the soccer ground of the team Hutnik Nowa Huta and therefore one of the locations, where later analyses take place (cf. Magiczny Krakow). The soccer stadiums of Wisla Krakow (Krowodrza district V) and Cracovia Krakow (Zwierzyniec district VII) are only a couple of hundred meters away from each other and are situated in the west of the city center, approximately 1.5 km away from the main square, which marks about the middle of the central district.

The city of Krakow is noticeably influenced by soccer, especially around derby times when the soccer clubs of MKS Cracovia and Wisla Krakow are playing against each other. This event, also termed “Holy War”, heats up the fan rivalry, often resulting in fights between them and the police or in vandalism. A particular situation is accessorily created, because of the geographic proximity between both stadiums (Bleacher Report 2008; MANN 2009; LUKAC 2014: 16 ff.; GYAN 2017; McGIRR 2017). This form of rivalry is expressed by graffiti, as well, and can be observed in large parts of the city. In his master thesis, LUKAC (2014: 18) describes that positions of soccer-related graffiti and their distribution in particular areas of Krakow “provides a risk indicator of some sort” that “informs the residents about how to navigate the city in a safe manner” and gives also information about the livability and attractiveness of areas.

According to CARDAIS and BOISSEVAIN (2011: 29), Krakow faces problems with graffiti in general and it is estimated that $45,000 annually are spent for graffiti removal actions, which is still a small contribution in comparison to expenditures in other countries (see Chapter 1.7). In summary, these local preconditions create a unique environment for the study of soccer-related graffiti and are the reasons for choosing Krakow as the study area.

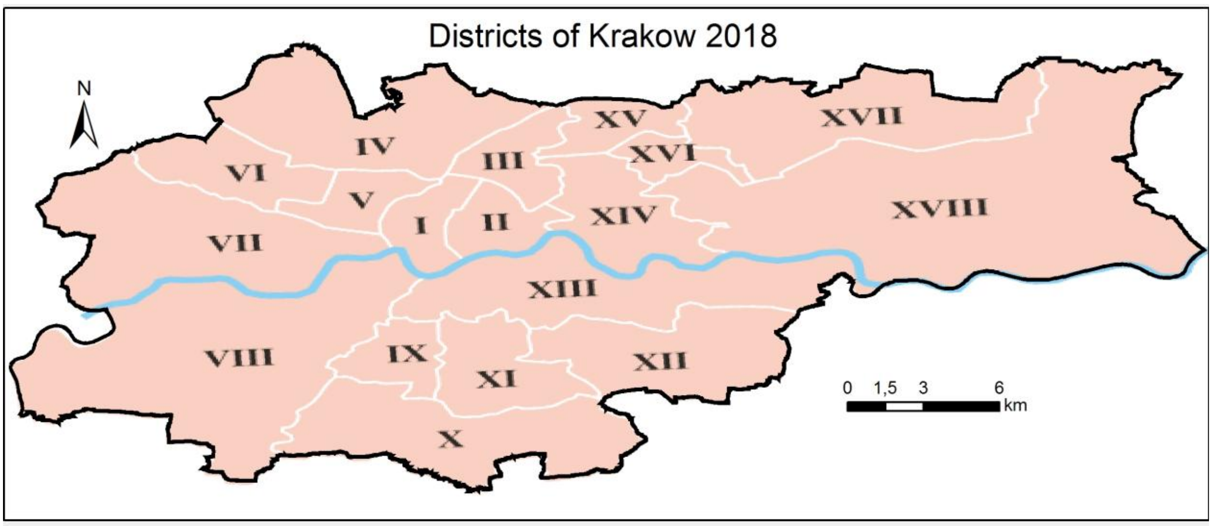



**Figure 2: Districts of Krakow; Source: Wikimedia**

## 1.4 Research Design

Similar to Dr. Trzepacz's work, one major task of this thesis's research is the data acquisition. In order to collect all relevant graffiti in Krakow, the SVAS technology was applied to deal with this time-consuming and cumbersome task. The SVAS technology that produces video information compatible with a GIS was provided by Professor Dr. Michael Leitner. Both SVAS hard- and software were provided free of charge to conduct the research in this thesis.
Graffiti data have to be extracted out of the video files and simultaneously integrated into a "Graffiti-GIS" for further spatial and statistical analysis. The extraction process was conducted by the use of two software programs which are the VLC (VideoLAN Client) media player and the Contour Storyteller application. Both programs are able to play various video formats but have some program specific advantages, which are explained in detail in Chapter 3.1.3. The integration of data into the GIS environment was performed by ArcMap, where also the statistical outputs were visualized as maps. The statistical analyses include spatial description, spatial hot spot analysis, and kernel density estimation, which were performed with the software CrimeStat version IV. The reason for applying these statistics is summarized by the following quotation of MEGLER et al. (2015: 64) who state that "by performing quantitative analysis of spatial patterns of graffiti (..), we seek to identify correlations that either help support existing hypotheses, or identify predictive factors that may lead to new research and new hypotheses".

## 1.5 Relevance of the Topic

It should be noted that to the best knowledge of the author, the analysis of such a unique dataset collected with the SVAS technology in combination with the statistical approaches and the integration into a GIS has never been done before. Consequently, the research methodology is highly innovative and there are several parties that can profit from this research. First of all, the city government will benefit, because this thesis's research provides useful information about the spatial distribution and the temporal dynamics of graffiti. There are a variety of sources reporting about costs that are caused by illicit graffiti spraying. According to WEISEL (2002: 2), an estimated amount of about $12 billion per year is spent on graffiti removal solely in the U.S and HALSEY and YOUNG (2002: 165) declare that "graffiti vandalism costs the Australian community approximately $200 million annually". In San Francisco, city agencies spent more than $20 million annually for graffiti abatement (cf. MEGLER et al. 2014: 63f.). By investing this topic, specific neighborhoods can be targeted and graffiti removal actions can be organized, plus strategies for preventing future graffiti can be developed in an economic manner.
Also, other stakeholders dealing with spatial analysis and modeling of crime, as well as institutions working in the field of geospatial technology, are benefitting from this research. There are also plenty of possibilities for ongoing research, since the technical development will lead to new methods of data acquisition that are more accurate and effective. Apart from a technological and monetary incentive, there is the social impact that graffiti may have on

communities, too. Some "existing research suggests that graffiti can have a negative impact on community perceptions of safety and public amenity" (MORGAN and LOUIS 2009: 1, 3).

## 1.6 Research Questions

The previously described problems with soccer-related graffiti and the suggested research design lead to the following research questions that are to be answered in the end of this thesis:

- How reliable is the SVAS technology in terms of graffiti data collection?
- What spatial pattern do soccer-related graffiti follow in terms of distribution?
- Where are spatial clusters of soccer-related graffiti in Krakow, and which fan group from which soccer club can they be assigned to?
- Are there regions where hotspots of rivaling fan groups overlap, thus creating distinct conflict zones?
- Are there changes concerning the distributional pattern and the amount of soccer-related graffiti in Krakow in comparison to 2016?
- Do committed crimes correlate with soccer-related graffiti?

In order to answer the last two questions, two additional datasets are integrated into this research, which are presented in detail in Chapter 4. One data set consists of collected graffiti data of 2016 and the other includes minor crimes that were committed between 2016 and 2018 in Krakow.

## 1.7 Structure of the Thesis

This thesis starts with an introductory chapter which provides general information about the problem definition and motivation, existing scientific literature, study area, research design, relevance of the topic, as well as, hypotheses. At the beginning of Chapter 2, graffiti and their different forms are defined, whereas the focus in the later subchapters is based on their role in modern society, including the special form of soccer-related graffiti. All methodological approaches, including the data collection with the SVAS technology and the statistical approaches are explained in Chapter 3. In the following chapter, the data examination and the findings are illustrated for the 2018 data, which will be also compared to the 2016 data. In the end of this chapter, graffiti and crime incidents are examined, whether there is a correlation between both activities. Finally, all approaches and findings are summarized and a conclusion, as well as, a future research example is given.

# 2 Graffiti

Graffiti as a phenomenon can be dated back until the early beginnings of society, such as cavemen during the late Pleistocene (cf. GUTHRIE 2005: 140, 198), the ancient Greek, the ancient Egypt or the Roman Empire (see BAIRD and TAYLOR 2011) and is still widespread in modern society. Despite its long history, the background information on graffiti in this thesis is limited to modern approaches. Furthermore, this chapter only highlights assorted issues on graffiti with special regard to soccer because the interest in graffiti from a scientific approach is very high and a lot of scientific research in various disciplines has been carried out before. At the beginning, Chapter 2 offers definitions and explanations for the term graffiti due to its multidisciplinary character. Afterwards, graffiti are examined concerning their role in modern society and their effects on it with special focus on soccer-related graffiti.

## 2.1 Definition and Elements of Graffiti

From an etymological aspect, the word graffiti is grounded in the Greek word ‘graphein’ and the Italian word ‘graffiare’ which means carve, paint, or write (cf. GRÜN 2016: 160). Scientific research concerning graffiti and their effects on the society, as well as their possible causes, has been carried out before in many different disciplines, including sociology, anthropology, architecture, geography, psychology, criminology, arts, urban planning, etc. This diversity is an indicator for the different environments for which graffiti are relevant.

For example, graffiti are strongly present in wide sections of arts. According to STOWERS (1997: para. 1f), “graffiti art is an art form”. He explains his opinion by stating the general problem of defining art, which can be discussed in the context of the famous saying “beauty is in the eye of the beholder”. Nevertheless, he comments on the problematic discussion of identifying graffiti as crime by saying “their markings would qualify as vandalism only if they appeared on private or public property without permission” (ibid: para. 2).

In their paper “The Meanings of Graffiti and Municipal Administration”, HALSEY and YOUNG (2002: 165) incorporate the aspect of vandalism, which is often associated with graffiti, and define graffiti as “both art and crime”. Similar to this, MORGAN and LOUIS (2009: 1) define graffiti “as the marking of other people’s property without their consent”, which makes graffiti illegal. Especially the last two definitions show that graffiti are often connected to criminal behavior. Following this, the Oxford Dictionary provides a definition that should be referred to when the term graffiti is mentioned in all further elaborations in this thesis. According to the Oxford dictionary graffiti are

“*writing or drawings scribbled, scratched, or sprayed illicitly on a wall or other surface in a public place*” (Oxford Dictionary).

Moreover, GRÜN (2016: 160) divides graffiti into three major elements: Tags, throw-ups, and pieces. A tag is representing the basic form of a graffito, for example a simple name or an individual symbol that is easy and fast to create. First of all, their aim is to demonstrate presence in order to gain reputation. Tags are neither a sign of quality nor challenging to create, but the most important symbol to represent the graffitist and the affiliation to a certain (fan) scene. (cf. WACLAWEK 2012: 14 f.; GRÜN 2016: 160)

The second elementary form is named throw-ups. They are bigger and more elaborated than tags and thus expressed by more detailed paintings, the use of more color, and more eccentric styles. (cf. WACLAWEK 2012: 16; GRÜN 2016: 161)

The masterpiece of a graffiti sprayer is the piece which is an improvement over throw-ups. In contrary to tags and throw-ups, a graffitist is showing technical expertise, when creating a piece, because quality and the design are prioritized (cf. WACLAWEK 2012: 18 f.; GRÜN 2016: 161). The graffiti integrated into the graffiti-GIS in this research are mainly tags, consisting mostly of symbols, abbreviations, or the names of the related soccer club.

To give a more detailed insight into the role of graffiti in modern society, the next chapter provides information about different frameworks of studies of graffiti and the special form of soccer-related graffiti.

## 2.2 The Role of Graffiti in Modern Society with Special Focus on Soccer-Related Graffiti

Graffiti appear in various forms and are “an issue of great significance” to different members of the modern society, such as “local communities, local government, police, public transport agencies, and young people”. “Individuals within these groups can be affected in various ways by graffiti”, which range from acceptance and tolerance to social decline and criminality. (HALSEY and YOUNG 2002: 165)

Hence, the way one graffito is seen may vary considerably from one individual to another and depends on the context in which the graffito, as well as the individual, is embedded. For the average street user, the media, or authorities, which are unfamiliar with “the underlying meaning and subcultural codes of graffiti”, graffiti spraying may be interpreted as criminal acts or at least as threats or forms of disrespect (cf. VANDERVEEN and VAN EIJK 2015: 107f.).

In addition, HAWORTH et al. (2013: 53) concur that “graffiti is a prominent feature of urban landscapes, and graffiti culture plays an important role in defining the identity of urban environments”. This idea is confirmed by different frameworks, in which graffiti are studied by researchers from all over the globe, examining the role of them in modern society.

### *2.2.1 Frameworks of Graffiti*

One framework in which graffiti are discussed is the duality of art and crime. For example, VANDERVEEN and VAN EIJK (2015) consider graffiti from a two-sided point of view as “art crimes”, which has already been mentioned in Chapter 2.1. In this context, it is challenging to “distinguish ‘artists’ from ‘criminals’”. This is the reason why these two contrary terms have to be used in the correct context in order not be misinterpreted (ibid.: 107). In line with this, LOMBARD (2012: 261) classifies graffiti into two forms – graffiti as urban/aerosol art “which is legal and commissioned by property owners” and graffiti as vandalism “which is a crime committed mainly by young people”. But as VANDERVEEN and VAN EIJK (2015: 108) assume, “there is no clear-cut distinction between graffiti and street art” and the opinions are divided on this issue.

One reason why graffiti are often seen as vandalism and a criminal phenomenon is described by the Broken Windows Theory. In their paper, WILSON and KELLING (1982) describe the process of vandalism, in this case broken windows, as a result of abandonment. They assume that “if a window in a building is broken and is left unrepaired, all the rest of the windows will soon be broken” (ibid.: 2). This assumption can be transferred to graffiti, too, for example in terms of uncleaned walls or bus stop shelters, as WEISEL (2002) supports. He observed that “graffiti has a serious cumulative effect; its initial appearance in a location appears to attract more graffiti” (ibid.: 1).

When sprayed illicitly on a wall, graffiti are a clearly visible form of criminal activity. By many sectors of the community they are considered as unsightly and “a threat to quality of life and community safety” (MORGAN and LOUIS 2009: 3). This is the reason why MORGAN and LOUIS (2009) describe graffiti as a sign of social disorder or antisocial behavior. Furthermore, they are “often linked (correctly or incorrectly) to other crime types” and gang-related activities, which spreads anxiety around communities. (ibid.)

To sum up the different opinions of researchers in this chapter, graffiti, if not dealt with and not considered as art, have the potential to lead to criminal acts due to their power of attracting other graffiti. Additionally, they can be interpreted as abandonment, which is again encouraging criminal behavior.

### *2.2.2 Soccer-Related Graffiti*

Supporters of soccer teams express their affiliation to their team in various ways. In the stadium they sing, shout, wave flags, hang banners, and create choreographies. Outside of the stadium these forms of expression are extended in particular by graffiti (cf. GRÜN 2016: 157).

Soccer-related graffiti can be assigned to the type of “gang graffiti”, since the graffiti artist expresses the affection to one soccer club and/or its allies. Graffiti sprayers are marking their territories while trying to convey threats and insults to rivaling soccer clubs and their supporters, sometimes even resulting in hate graffiti. Graffiti, which are driven by the latter motive are also called “ideological graffiti”. They are characterized by its offensive content or symbols that are addressed to rivals and sometimes even ethnical or racial minorities, not uncommonly turning into racist slogans (cf. WEISEL 2002: 3, 9).

Most graffiti that are in relation to soccer consist of a token or the name of a soccer club and/or the associated fan-club. This is the reason why tags, which are in particular suited for marking the public space, are the most popular element of soccer-related graffiti. Their

advantage is the comparatively easy and fast method of attaching the name of their city, club, or group, which informs members of the opposing team about their presence without great effort (GRÜN 2016: 161 f.).
As already mentioned, these graffiti can be of positive or negative nature. Besides, the artistic skill or design of the outcome plays a minor part for soccer-related graffitists, whereas awareness and the marking of territory are more important (cf. SOMMEREY 2010: 94). Following this, quantity and the presence in the cityscape outrank the quality of soccer-related graffiti. On the one hand, this is related to their own city or neighborhood, on the other hand to foreign cities in which the own name or token will be left behind. In this way fan groups can show rivals who is the dominant club in the region, especially when they are neighboring clubs. Additionally, graffiti are also a tool for criticism on the commercialized soccer. Therefore, the old name of the stadium, which in most cases does not bear the name of any sponsor, is often visualized around the new home ground (Blickfang Ultra 2008: 47; GRÜN 2016: 166).

# 3 Methodology and Data Preparation

Chapter 3 describes all methodological approaches that need to be applied in order to collect the relevant data and to perform the analyses to accomplish the research goals that were described earlier. At the beginning, software packages used for the statistical analyses and for the data extraction and integration process are presented. In the next subchapter, characteristics of the spatial video acquisition system (SVAS) and its application in the field are introduced. This also includes a description of the collected data and the conducted survey trips in Krakow as well as their planning process. Furthermore, the data extraction process of the video files and its integration into the GIS environment are explained. The following subchapters explain the statistical analysis tools, such as the spatial description (3.3), the spatial hot spot mapping (3.4), and the kernel density interpolation (3.5) which spatially analyze the graffiti information that was collected.

## 3.1 Software

Video files produced in this research need to be processed after the collection in order to make the data usable for further analyses and findings. The task of processing and analyzing the graffiti data was carried out by different software tools which are introduced below.

### *3.1.1 ArcGIS*

ArcGIS is the generic name of various spatial data processing software products, which are used for data analyses and visualization and was developed by Esri (cf. ArcGIS Resources I). The desktop version ArcMap 10.5, which is used in this research, includes various tools for data preparation, manipulation, and analysis. Some of these tools are applied to process the graffiti data and finally integrate them into the GIS. Furthermore, it allows displaying geospatial data and can be used to create maps, which is applied to visualize the findings of this thesis.

### *3.1.2 CrimeStat VI*

For the spatial analysis of individual crime events and point locations Dr. Ned Levine and his team created a statistics program called CrimeStat (Levine 2015), which is introduced hereinafter. The program's current version 4.02 is applied in this research and is compatible with most GIS, including ArcGIS. CrimeStat extends the ability of a GIS of providing "statistical summaries and models of crime incident data" and is primarily invented for large crime incident data sets collected by metropolitan police departments. However, LEVINE (2015: 1.1) suggests its use also for other kinds of "applications involving point locations, such as the location of arrests, motor vehicle crashes, emergency medical service pickups, or facilities (e.g., police stations)". It is a Windows based program that is able to process various

data types, for example ArcGIS Shape files, which are used in this study. The generated output can be divided into tables and graphical output, whereof the latter can be displayed in ArcGIS (cf. LEVINE 2015: 1.1 f.).
In this master thesis, CrimeStat is used for the spatial analysis and modeling of the collected data set, including centrographic statistics and distance analysis, as well as for the hotspot analyses, and the kernel density interpolation.

### *3.1.3 Contour Storyteller*

The Contour Storyteller software is developed by the company Contour and is used for the processing of video files recorded by Contour cameras. The software has mainly three benefits: First, it is able to play various video formats, for example .mp4 files, which are produced by surveys conducted in this thesis. Second, it can show the location of each viewed frame due to its link to a GPS signal, which is incorporated into the videos. Therefore, an additional window is provided on the screen, which pictures the current location on a Google Maps layer. Third, it is able to generate .gpx-files. “The generated and imbedded GPS data are saved as points which represent the camera’s position on the earth’s surface at a specific time and date” (SCHNEIDER 2018: 3). These files can be extracted directly out of the video file and are compatible with various GIS, e.g. ArcMap.

## 3.2 Spatial Video Acquisition System

In order to gain an on-site point of view, the spatial video acquisition system is applied in all kinds of research that demand impartial visual information (cf. CURTIS et al. 2007, SAGL 2008: 1). This technique produces information about ongoing processes (e.g., graffiti removal/accumulation), as well as the condition and location of objects (visible damage of buildings/walls). Furthermore, it is an “additional technique to GIS to improve the documentation and analysis” because the produced data are compatible with GIS (SAGL 2008: 1, II).

### *3.2.1 Introduction to the Spatial Video Acquisition System and its Technical Aspects*

One out of three main components of a SVAS, the digital video camcorder, provides spatial referenced digital video material, due to its link to a Global Positioning System (GPS) receiver, which is the second main component. The third component is the GPS encode/ decode unit. This electronic black box “either encodes received digital GPS signals from the external GPS antenna into a sequence of audio signals in the case of data acquisition, or decodes recorded audio signals from the camcorder into digital signals for data processing”. To provide a facile and efficient data acquisition in the Area of Interest (AoI), cameras are attached to a vehicle by window mounts. (SAGL 2008: 1, 44, 50). In this research, the Contour+2 Action Camera Model 1700 is employed to collect the video material (Figure 3). Its special features include a GPS receiver and a 170 degree wide angle lens. The wide angular view is favorable for recording graffiti in narrow streets, for example the Old Town of Krakow. Furthermore, it can be connected to other technical devices via a micro USB slot and stores the produced MP4 files on a mini SD card. Videos are recording in high definition (1080p) and run at 120 frames per second (cf. Contour Manual & Contour Store).


**Figure 3: Contour+2 Action Camera**

When acquiring data, there are mainly three limitations that can affect the process. First of all, the data acquisition is limited by weather conditions like rain, snow, mist, glare, etc., which reduce the visibility. Second, the AoI must be accessible in terms of drivable streets, which maybe blocked off by construction or closed gates providing access to private areas of apartment complexes, etc. Finally, in order to provide spatial information, the reception of GPS signals is compulsory (cf. SAGL 2008: 2).

In addition, MONTOYA (2003: 874) notes the obstruction in the visibility during typical delivery hours, when large vehicles park along the sidewalk and he mentions the difficulty in peak traffic hours that “can cause the recording time to increase considerably”. When these preconditions are taken into account, the SVAS technology is applicable in various fields for the on-site data-collection.

CURTIS et al. (2007), for example, elaborate on the geography of post-traumatic stress caused by Hurricane Katrina in August 2005 by using the SVAS technology. This work demonstrates that the technology is able to deliver “damage assessment information as well as capturing recovery related geographies associated with post-traumatic stress” (ibid.: 208). The article even reveals that by integrating SVAS into disaster response scenarios or during ongoing recovery operations, the recognition of geographic aspects in such events can be improved. In addition, the electronic approach of data collection has an advantage over the until recently used paper method due to paper method’s flaws in accuracy, efficiency, and transferability (cf. ibid.: 209).

SVAS, as a fast data acquisition method, has also been applied in urban disaster management, with the objective of classifying the building stock in terms of emergency response, planning missions, and capturing data. This data capture process leads to an up-to-date building inventory, which is similar to an inventory for graffiti. (cf. MONTOYA 2003: 872). Moreover, MONTOYA (2003: 874) adduces several reasons for choosing the SVAS technology for acquiring relevant data which are valid for the creation of a graffiti-database, too, and are listed hereinafter. First of all, classification and interpretation issues can be decided a posteriori. Second, due to the fact that the recording device can be attached to a vehicle, the recording process is less time-consuming. Third, the recording process does not require any technical expertise. At last, costs are low compared to manual surveys. Aside from that, the angular view of the camera system and the distance to the building's façade should be taken into account. Especially narrow roads require careful consideration, because the coverage will be limited if the view angle is not wide enough (cf. MONTOYA 2003: 872).

### *3.2.2 Planning and Conduct of Survey Trips*

The first creator of a soccer-related graffiti map of Krakow, Dr. Piotr Trzepacz, conducted two individual surveys of Krakow, the first one in 2006 and the second one in 2016, ten years after his first survey. His routes provide the basis for the surveys described subsequently. All routes that Dr. Trzepacz conducted in this research were recorded by the application Runtastic, which is able to track sport activities and "offers (..) services that all focus on gathering and managing sports data" (see Runtastic). The relevant routes, in total 31, were exported from Runtastic as .kml-files and imported into a personal Google Drive account, where tracks and routes can be displayed with the MyMaps function. A detailed explanation of this workflow can be found in the Appendix I. An example of an imported .kml-file into the Google Drive account is given by Figure 4 (route 20160815 – the name derives from the date the route was first driven by Dr. Trzepacz; 15/08/2016).


**Figure 4: Sample Route as .kml- file in Google My Maps; Source: Google MyMaps**

Since Dr. Trzepacz performed his tracks either by bike or on foot, these routes had to be adjusted for the use by a car. This process of route planning covered a considerable large part of this master's thesis, because one-ways, footpaths, or dead ends cause greater problems when driving a car instead of using a bicycle. Every predefined route needs to be checked in Google Maps for its drivability by a car and adjusted, if necessary. Therefore, PDF's - consisting of screenshots made in Google Maps - guarantee a smooth navigation process throughout the city of Krakow. Figure 5 displays one screenshot of such a route. In total 777 slides of PDF's were created to cover all 31 predefined routes. The sample route given by Figure 5 is also attached in Appendix II.
Nevertheless, routes often have to be adjusted during field trips, because of inaccuracies between Google Maps and the real street network. It appeared that particular landmarks of the urban area and landscape, such as petrol stations, bridges, rivers, cemeteries, etc., are very helpful for the orientation in unknown areas. For this reason, a large number of single tiles, similar to the one shown in Figure 5 have their start and/or end points at such landmarks. It should be added that the author of this thesis, as well as, Dr. Prof. Michael Leitner are novices to the city of Krakow and to the Polish language, which impeded the data collection process especially at the beginning.

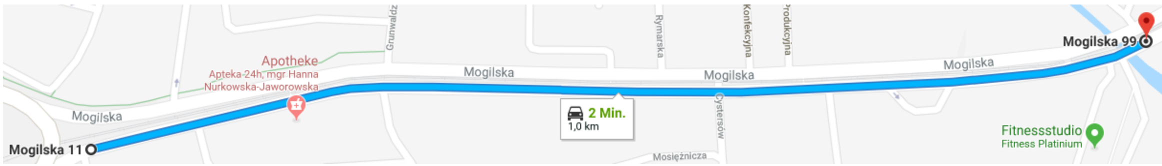



**Figure 5: Example of a PDF tile for navigation purpose; Source: Google Maps**

During each field trip, three cameras were mounted inside of the vehicle, one on the front window and two on each side of the car (Figure 6 and Figure 7). This procedure enables the recording of graffiti from three different angular perspectives and provides a continuous GPS signal, since every camera is able to provide a track of the driven route. When turning on the cameras for the first time, it is advisable to do so at a location with a minimum of objects of disturbance, such as trees or buildings. It appeared that the front camera was the most reliable concerning GPS signals and therefore was most often used for displaying the tracks for the evaluation of the video material (see subchapter 3.1.3). Additionally, a recharging unit which is compatible with a car lighter might be installed to keep all cameras running even on long survey trips (Figure 7).
The three cameras produced in total 2082 GB of video files after each of the 31 surveys was conducted. This equals an amount of 347 hours of video material (roughly 6 GB equals 1 hour of video). All videos are stored on two hard drives, each one storing the whole video material. How the information is extracted out of the videos and integrated into the GIS environment is explained in the next chapter.

**Figure 6: Cameras mounted on left and right backseat windows; Source: Prof. Dr. Michael Leitner**

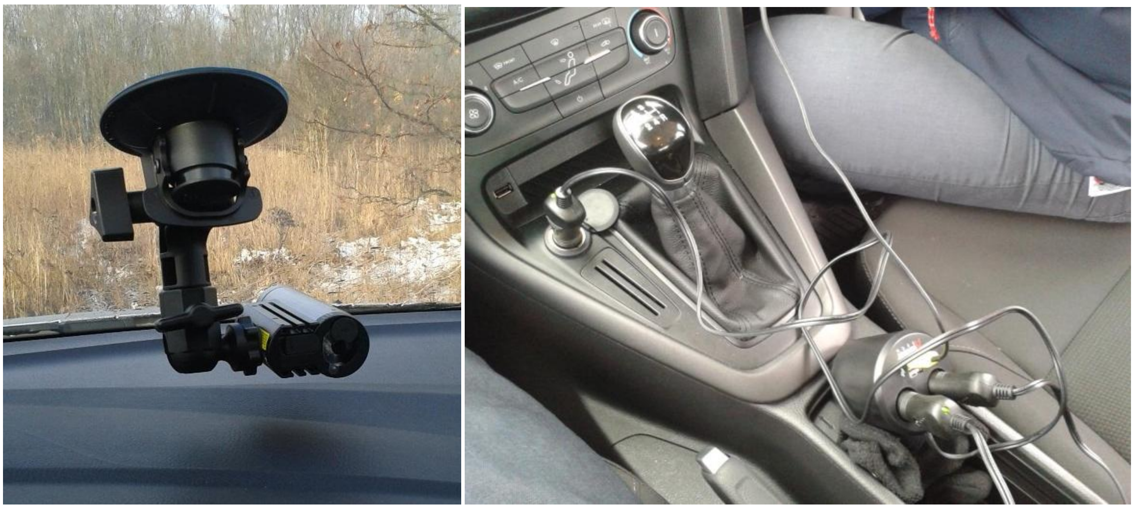


**Figure 7: Camera mounted on front window (left); recharging unit (right)**

### *3.2.3 Data Extraction and Integration Process*

Since the information about the graffiti is still embedded in videos from which the data have to be extracted, the following subchapter explains the data extraction process and its integration into the ArcMap software. First of all, the recorded videos, which are in the file format .mp4, are imported into the software Contour Storyteller, which allows acquiring GPS information. After extracting the GPS signals from the video, they are integrated into the software ArcMap, where they can be visualized as a line feature. Therefore, the data need to be converted and loaded into ArcMap by the tool “GPX to Features”, since data cannot be simply dragged and dropped into the software. This conversion creates a point-shapefile out of a .gpx-file. Finally, the tool “Point to Line” is applied to create a line feature out of a point feature. This resulting track is helpful for the digitization of graffiti, since it gives the data analyst an overview of the driven routes. The above explained working process is shown in detail in Appendix III.

Concerning the actual digitization of the graffiti, both software programs – ArcMap and Contour Storyteller – are used simultaneously. Correspondingly, the use of two screens (one software per screen) appears to be most favorable, because switching between the software programs can be both tiring and confusing (Figure 8).

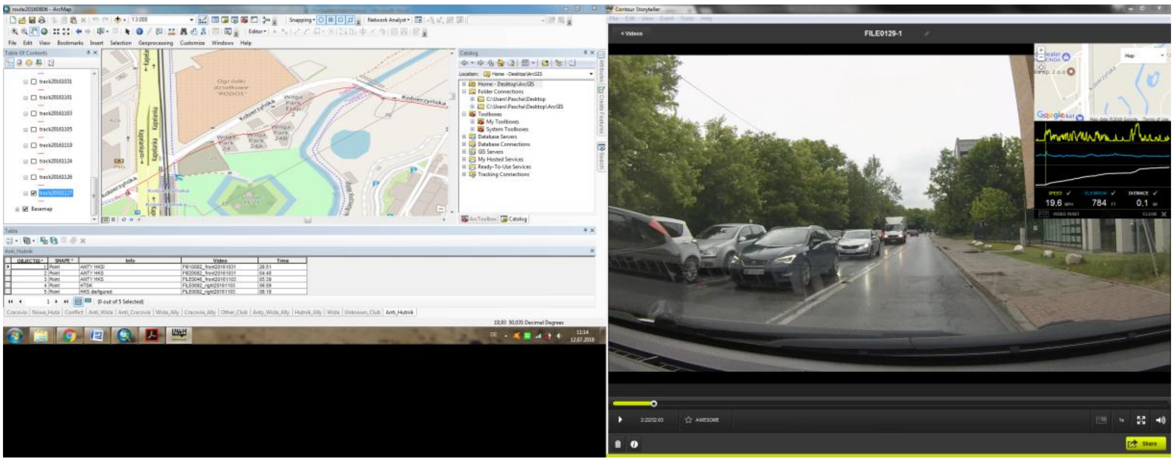



**Figure 8: Graffiti digitization on two screens**

Additionally, the VLC media player can be used, instead of the Contour Storyteller application, when the person digitizing the graffiti becomes more experienced. The advantage of the VLC media player is its fast-forward and rewind options. This is especially beneficial, for example, when watching video material with traffic jams, when the car drives slowly and doubling the speed of the video does not lead to missing any graffiti. By implication the VLC media player is also advantageous on speedways, when the car drives rather fast and slowing down the video helps to not miss any graffiti. Yet, the VLC player does not support any environmental information, which is why the user should be familiar with the displayed area.

When a graffito is spotted in the video the main goal is to determine its location. The Contour Storyteller application supports the user by its integrated map, which is based on Google Maps. Applicants can choose between two options – Map or Hybrid – to display the area either as a map or a digital aerial photograph (Figure 9). The map does not update automatically while watching the video, which is why a tool has to be selected every time a certain location needs to be displayed via the map function (red rectangle in Figure 9). The plus- and minus-tools stand for zooming options (green rectangle in Figure 9). There are additional information concerning the current speed, elevation, and covered distance, which are updated likewise by applying the “update-current-location”-tool (red rectangle in Figure 9).


**Figure 9: Contour Storyteller "Map" and "Hybrid" functions**

The spotted and located graffiti in the video can be transferred into the ArcMap document by editing a point shapefile. Figure 10 gives an overview of the different types of graffiti that appeared during the research. Mainly, there are four categories expanded by sub- and side-categories. For each soccer club – three in total – one category is established. The dominating color of the soccer team's emblem represents the club. A large number of graffiti is difficult to identify in terms of which fan group it can be allocated to, because graffiti are overwritten and/or disfigured by other graffiti sprayer and therefore categorized as "conflict" graffiti. This represents the fourth main category. Since there are three different teams that graffiti artists may support, subcategories need to be created, when a graffito's content is against one club. It appears that the rivalry between Wisla and Cracovia supporters is bigger, than both rivalries with Hutnik Nowa Huta. This is the reason for coloring an Anti-Cracovia-graffito in blue and an Anti-Wisla-graffito in red. Graffiti of allied clubs are counted as graffiti of the club that they are allied to. When the content of a graffito cannot be determined, but it is likely to be a soccer-related graffiti, then this graffito is categorized as an "Other_Unknown"-Graffito. Graffiti of soccer clubs other than the three main ones are also categorized to the "Other_Unknown" type.

The visualized track of each route based on GPS signals is taken into account, when a location of a graffito is digitized in the ArcMap document. Due to distorting elements, like infrastructure or trees, these tracks may vary greatly in some locations of the driven track as Figure 10 illustrates (SCHNEIDER 2018: 3). The base map of the ArcMap document plays an important role, too, because not only street names but also their numbers are displayed. This is in contrast to the Contour Storyteller map function, where this service is not included.

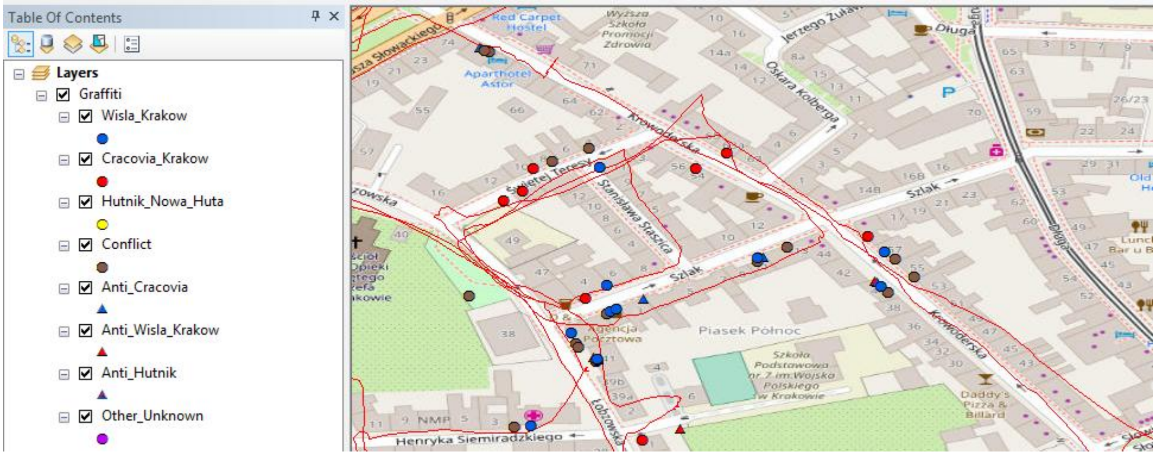



**Figure 10: Categories of digitized graffiti; Source: Own data & OpenStreetMap**

Every digitized graffito contains the values illustrated in the attribute table of Figure 11. The "FID" number counts every digitized graffito starting with zero. The column "Shape" has always the value "Point", since the graffiti are digitized as single point features. The field "Info" gives additional information about the content of the graffiti, for example, what is written, which color is used, or what kind of symbols are noticeable. The fields "Video" and "Time" are used for any subsequent analysis or additional information, because the "FILE…"-sequence determines in which video file the graffito can be spotted and the time stamp, identifying at what exact time (to the second), the graffito can be found in the video. The last two columns – "Point X" and "Point Y" – identify every graffito by its exact location in the ArcMap document stating geographical coordinates. The information about the coordinates can be added by the tool "Add XY Coordinates" (Data Management Tools – Features). The spherical coordinate system for displaying the graffiti is the World Geodetic System 1984 (WGS 84; EPSG: 4326).

Table

Cracovia

| FID * | Shape * | Info | Video | Time | POINT_X | POINT_Y |
|---|---|---|---|---|---|---|
| 1 | Point | Cracovia | FILE0022_front20160806 | 8:06 | 19,903436 | 50,027836 |
| 2 | Point | KSC | FILE0022_front20160806 | 17:17 | 19,895855 | 50,003859 |
| 5 | Point | PASY | FILE0022_front20160806 | 19:49 | 19,897297 | 49,999724 |
| 6 | Point | KSC | FILE0023_front20160806 | 31:16 | 19,979264 | 50,013044 |

1 (0 out of 1038 Selected)

Wisla | Cracovia | Nowa_Huta | Conflict | Anti_Wisla | Anti_Cracovia | Wisla_Ally | Cracovia_Ally | Other_Club | Anty_Wisla_Ally

**Figure 11: Attribute table of graffiti**

During the complete survey, a total amount of 5,098 graffiti was spotted while covering 1,872.68 kilometers of the street network in Krakow. Both layers, containing all routes and all graffiti, are pictured in Figure 12. The amount of graffiti of each category is listed in Table 1. The covered distance is calculated with the "Calculate Geometry" -function in ArcMap. By comparison with the survey of Dr. Trzepacz in 2016, ca. 211 more kilometers were covered inside the city boundaries of Krakow as Table 2 shows. The main reason for the routes to have different lengths is the use of a car instead of a bicycle to do the survey and the necessary adjustment of routes. Another reason is the fact that the driver as well as the

navigator were novices to the city, thus the 2018 survey in some instances has departed from the original routes. In his research in 2006, Dr. Trzepacz was able to collect approximately 5,600 individual graffiti signs, roughly 500 more than this research survey. However, the research in 2016 includes the least amount of spotted graffiti with 4,609. There are several possibilities that may have led to differences between the two surveys in 2016 and 2018, which are both based on similar survey routes.
At first, the routes have to be adjusted for the use with the car and therefore depart from the original routes. This leads to both a loss of the data that are located on the original routes and additional data along the new routes. In some places it is not possible to cover all parts of the route, for example, in the city center, where cars are not allowed, or in apartment complexes, when driveways are sometimes barred by gates. Also unpredictable events, such as ongoing construction work or parked cars should be listed. Next, the quality of the video material is essential for the data extraction process (see below for more detail). If parts of the video fail to visualize a minimum of quality, for example, due to light conditions or the distance to the building's façade, the data extraction process is impeded. However, due to dividing the data mining process into driving the routes on the one hand and spotting the graffiti in the videos on the other hand, the probability of detecting graffiti may increase in comparison to driving the car and spotting the graffiti at the same time. Also, graffiti removal actions have to be mentioned, as well as the creation of new graffiti.

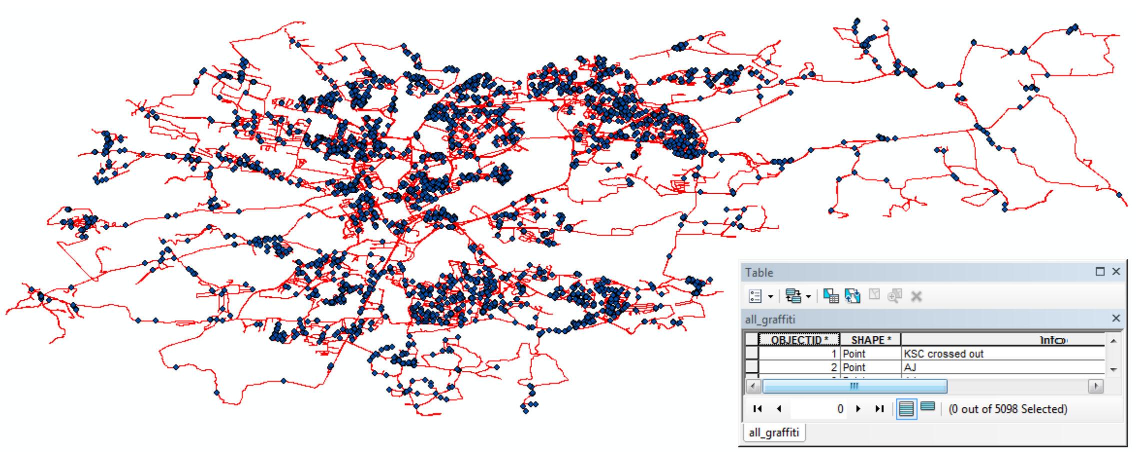



**Figure 12: Layers of all graffiti and all routes driven in Krakow**

| Category | Count | Percentage |
|---|---|---|
| Wisla Krakow | 1,521 | 29.84% |
| Cracovia Krakow | 1,075 | 21.09% |
| Hutnik | 304 | 5.96% |
| Conflict | 1,154 | 22.64% |
| Anti Cracovia | 608 | 11.93% |
| Anti Wisla | 402 | 7.89% |
| Anti Hutnik | 5 | 0.10% |
| Other and Unknown | 29 | 0.57% |
| All graffiti | 5,098 | 100.00% |

**Table 1: Count of graffiti per category**

| Drive 2016 | Distance (km) 2016 | Drive 2018 | Distance (km) 2018 | Slides |
|---|---|---|---|---|
| 05.08.2016 | 35.06 | 10.04.2018 | 10.9 | 5 |
| 06.08.2016 | 47.33 | 24.01.2018 | 58.77 | 24 |
| 09.08.2016 | 33.12 | 10.04.2018 | 32.1 | 16 |
| 11.08.2016 | 78.35 | 08.02.2018 | 93.72 | 34 |
| 13.08.2016 | 111.02 | 01.02.2018 | 127.52 | 42 |
| 15.08.2016 | 16.78 | 31.01.2018 | 23.63 | 12 |
| 16.08.2016 | 60.51 | 21.02.2018 | 73.8 | 27 |
| 18.08.2016 | 23.58 | 20.02.2018 | 18.2 | 8 |
| 19.08.2016 | 73.44 | 07.02.2018 | 84.83 | 26 |
| 03.09.2016 | 16.54 | 07.02.2018 | 26.53 | 18 |
| 04.09.2016 | 73.96 | 05.03.2018 | 96.62 | 39 |
| 11.09.2016 | 103.47 | 13.03.2018 | 126.25 | 56 |
| 13.09.2016 | 26.3 | 11.04.2018 | 15.39 | 7 |
| 15.09.2016 | 29.36 | 11.04.2018 | 25.07 | 13 |
| 16.09.2016 | no data | 05.06.2018 | 21.76 | 11 |
| 20.09.2016 | 34.58 | 12.04.2018 | 28.36 | 17 |
| 21.09.2016 | 25.72 | 30.01.2018 | 34.78 | 18 |
| 15.10.2016 | 65.66 | 07.03.2018 | 97.6 | 47 |
| 18.10.2016 | 21.1 | 13.03.2018 | 10.48 | 5 |
| 22.10.2016 | 54.39 | 19.03.2018 | 71.88 | 35 |
| 23.10.2016 | 69.02 | 20.03.2018 | 79.28 | 41 |
| 29.10.2016 | 74.6 | 17.04.2018 | 69.35 | 37 |
| 30.10.2016 | 70.72 | 21.04.2018 | 66.71 | 24 |
| 31.10.2016 | 54 | 13.04.2018 | 45.57 | 22 |
| 01.11.2016 | 60.67 | 15.05.2018 | 61.85 | 26 |
| 03.11.2016 | 68.9 | 21.04.2018 | 73.25 | 23 |
| 05.11.2016 | 67.47 | 23.04.2018 | 75.03 | 19 |
| 19.11.2016 | 63.62 | 19.04.2018 | 91.01 | 32 |
| 24.11.2016 | 75.01 | 16.05.2018 | 75.57 | 25 |
| 26.11.2016 | 83.64 | 09.05.2018 | 101.4 | 44 |
| 27.11.2016 | 43.23 | 05.06.2018 | 55.47 | 24 |
| | 1661.15 | | 1872.68 | 777 |

**Table 2: Routes of the 2016 survey by comparison with routes of the 2018 survey; Source: Own data and Dr. Piotr Trzepacz**

As already mentioned in subchapter 3.1, the quality of the video material that is needed to identify the graffiti depends on a variety of aspects, which will be discussed in detail next. To begin with, the reliability of the camera depends significantly on the weather conditions. It is favorable to avoid different kinds of heavy precipitation, for example, rain, snowfall, etc. or fog, because of the limited visibility. Especially the side windows, where no wiper is available, are affected by such weather conditions (see Figure 13).

**Figure 13: Limited visibility due to rain**

Another issue is the light condition, which can cause problems mainly in two different ways. Due to the fact that the position of the sun changes during the day, the quality of the video material can get fuzzy depending on the cameras direction during a survey. Figure 14 gives an example of how the quality is affected by a low sun angle above the horizon. Even though some graffiti can be detected on the wall at the right hand side, it is not possible to clearly identify them with the front camera.

**Figure 14: Limited quality due to the position of the sun**

Second, a decreasing or low amount of sunlight in general reduces the quality of the video material, which occurs mainly at dusk or dawn. Thus summer months are more favorable than winter months at certain latitudes concerning the use of this technology. Furthermore, narrow streets, where the distance to the building's façade may be too short to capture the whole scene, are unfavorable. In such cases the angle of the mounted cameras could be adjusted. Additionally, it should be emphasized that small cars are favorable in narrow streets, too. Both negative aspects, the small distance to the building's façade as well as the dusk /dawn periods, are exceedingly impaired by speed issues. Generally speaking, driving the vehicle at high speed should be avoided, since it increases the chance of missing data. An example of how high speed and limited light is affecting the video quality is illustrated by Figure 15.

**Figure 15: Limited quality due to dusk/dawn conditions and high speed**

Difficulties also arise during high traffic hours, especially when people go to and come back from work. The main reasons for avoiding these times of the day – roughly between 07:30am till 09:30am and from 04:00pm till 06:00pm – is the traffic density that leads to longer driving hours with fewer video material than normal to be produced. On the other hand, the absence of cars during working hours makes housing areas far more accessible, than usual, and people do not have their cars parked at home. Commonly, parked cars have a bad effect on the success of applying the SVAS technology, because they often block the view of the cameras on houses, garages, walls, etc., places, where graffiti are often attached to (cf. Figure 16). Similar to the problem, when driving in narrow streets, this issue can be partly solved by adjusting the angle of the mounted cameras.

**Figure 16: Parked cars block the view on graffiti**

Concerning the reliability of the technical aspects of the cameras it is to mention that for an unknown reason, some of the cameras stopped recording during some surveys and caused missing video material. This problem was solved by switching cameras off and on after every half an hour, due to the fact that after about 35 to 37 minutes of recording, the camera automatically saves a video file and starts recording a new file.

As stated earlier, one main group of graffiti is categorized as “Conflict”-graffiti and is explained more detailed next. Figure 17 illustrates an agglomeration of graffiti with all three major soccer clubs of Krakow being represented. The graffiti are not evenly distributed on the wall, but overwritten and disfigured and thus creating problems concerning their allocation to either one of the three clubs. For example, the swear word “Jebac” was originally addressed to Wisla supporters and the police (“JEBAC WISLE i POLICJE”), but later modified to “JEBAC CRAXE I POLICJE”, and so changed the meaning to humiliate Cracovia supporters. Since it is not always as clear as it is in this situation to answer the question of who sprayed the graffiti first, it is also a question of how to count the graffiti. Without looking at this in more detail, this graffito is allocated to Wisla supporters. Nevertheless, the original graffito must be allocated to Cracovia supporters. In order to avoid such conflict of defining the graffitist, the “Conflict” category is invented and applied to this case.


**Figure 17: Overwritten and disfigured graffiti**

In terms of the identification of the graffiti, the author of this thesis and Professor Dr. Michael Leitner were strongly supported by Dr. Piotr Trzepacz, who provided his “Urban vocabulary of Krakow” compendium, which explains a majority of the soccer-related graffiti and also translates their content from Polish to English, if necessary (see TRZEPACZ 2018). This Power Point Presentation, enclosing 486 slides, gives examples of graffiti that can be mainly allocated to any of the three major soccer clubs in Krakow and was developed during his research on this topic. Examples range from simple written names of the respective soccer club, abbreviations, special symbols, and signs, to rather incomprehensible designations like references to historical events or names of soccer fan clubs. Without this collection of soccer-related graffiti in Krakow, it would have been very likely to oversee a great number of graffiti in the video material.

## 3.3 Spatial Description

The term spatial description encompasses statistical methods, which are applied to characterize phenomena in space regarding their centers and spatial variability around these centers. In this thesis, centrographic statistics, which are the most basic type of spatial description, and distance analysis methods, including the nearest neighbor analysis, will be applied to the graffiti data. In general, spatial statistics are a 2-dimensional extension of the 1-dimensional descriptive statistics (cf. LEVINE 2015: 4.1).

### *3.3.1 Centrographic Statistics*

LEVINE (2015: 4.1) states that centrographic statistics are “the most basis type of descriptors for the spatial distribution of crime incidents”. The name centrographic comes from their two dimensional correlation to basic statistical moments of a single-variable distribution (cf. ibid.). Centrographic statistics represent global parameters, which are first-order properties. For example, they represent the dominant pattern of a distribution, namely the location, where points are centered or how far they are spread out (cf. LEVINE 2015: 6.1). The indices, which estimate the basic parameters about the distribution, are described next:

1. Mean Center:

The mean of the X and Y coordinates is called mean center and is the simplest descriptor of a distribution. This point represents the center of gravity, where all other points of the distribution are balanced if they, figuratively speaking, existed on a plane and the mean center equals the fulcrum. In that point, the sum of all differences between the mean and all other points is zero (cf. LEVINE 2015: 4.1, 4.4). The mean center is given as:

$$\bar{X} = \frac{\sum_{i=1}^{n} x_i}{n}; \bar{Y} = \frac{\sum_{i=1}^{n} y_i}{n}$$

where $x_i$ and $y_i$ are the coordinates for feature i, and n is equal to the total numbers of features.

**Formula 1: The mean center; Source: ArcGIS Pro Mean Center**

2. Median Center

The point where the median of the X coordinates and the median of the Y coordinates are crossing each other is called the median center. For a single variable it is the point at which 50% of the distributed points fall below and 50% fall above (cf. LEVINE 2015: 4.12). Therefore, the median center is robust to outliers in contrast to the mean center (cf. ArcGIS Pro). The following formula calculates the median center:

$$d_i^t = \sqrt{(X_i - X^t)^2 + (Y_i - Y^t)^2 + (Z_i - Z^t)^2}$$

where $x_i, y_i, and\ z_i$ are the coordniates for feature i, and n is equal to the total number of features.

**Formula 2: Median center; Source: ArcGIS Pro Median Center**

3. Center of Minimum Distance

The center of minimum distance is defined as the location from which the distance to all distributed incidents is the smallest. Although CrimeStat does not calculate the distances as actual travel times but as either direct or indirect distances, this indicator can still be used as the point, where travel distances are minimized (cf. LEVINE 4.12, 4.14). The center of minimum distance is:

$$\text{CMD} = \sum_{i=1}^{N} d_{iC} = min$$

"where $d_{ic}$ is the distance between a single point, i, and C, the center of minimum distance (with X and Y coordinates)" (ibid.).

**Formula 3: Center of minimum distance; Source: LEVINE 2015: 4.12**

4. Standard Deviations of the X and Y Coordinates

All three indices above describe the center of a spatial point pattern according to their method. Standard deviations of the X and Y coordinates measure the spatial distribution by describing the dispersion of a variable resulting in two statistics, one dispersion for each coordinate (cf. LEVINE 2015: 4.14, 4.16). The formulas for both coordinates are:

$$S_x = \sqrt{\sum_{i=1}^{N} \frac{(X_i - \bar{X})}{N-1}} \qquad S_y = \sqrt{\sum_{i=1}^{N} \frac{(Y_i - \bar{y})}{N-1}}$$

where $X_i$ and $Y_i$ are are the X and Y coordinates for individual points, $\bar{x}$ and $\bar{y}$ are the means of X and Y respectively, and N is the total number of points.

**Formula 4: Standard deviations of the X and Y coordinates; Source: LEVINE 2015: 4.14**

5. Standard Distance Deviation:

The standard distance deviation measures the average dispersion of all points from the spatial mean, resulting in a radius of a circle in a single summary statistic. It is a two-dimensional standard deviation with its center equivalent to the spatial mean. A small circle means highly clustered points around the mean, whereas a large circle indicates larger distances between all points and the mean (cf. LEVINE 2015: 4.16 ff.). Its formula is:

$$\text{SDD} = \sqrt{\sum_{i=1}^{N} \frac{(d_{iMC})^2}{N-2}}$$

**Formula 5: Standard distance deviation; Source: LEVINE 2015: 4.16**

6. Standard Deviational Ellipse

The standard deviational ellipse, in contrast to the standard distance deviation, considers the fact that point incidents are not always equally dispersed around the spatial mean. This characteristic is taken into account by the use of two axes along which points are dispersed around the mean (cf. LEVINE 2015: 4.19 f.). The resulting ellipse provides information about the distribution of features, whether they are elongated and hence have a particular orientation (cf. ArcGIS Resources II). The standard deviational ellipse is calculated as follows:

$$SDE_x = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{X})^2}{n}}; \; SDE_y = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \bar{Y})^2}{n}}$$

where $x_i$ and $y_i$are the coordinates for feature I, $\{\bar{X}, \bar{Y}\}$ represents the Mean Center for the features, and n is equal to the total number of features.

**Formula 6: Standard deviational ellipse; Source: ArcGIS Resources II**

### *3.3.2 Distance Analysis*

Distance analysis produces second-order properties that refer to local or "neighborhood" patterns within the overall distribution. These patterns may be influenced by sub-regional unique features that create distinct "hot spots" and are less related to the overall global distribution, but more to local environmental characteristics (cf. LEVINE 2015: 6.1). The nearest neighbor index, as an example for a second-order statistic, will be explained next.
The nearest neighbor index is the basis for many other types of distance statistics and can be dated back to the 1950s, when two botanists (Clark and Evans, 1954) used this statistic for their field work. It basically determines the type of a point pattern, whether points are distributed randomly, regularly, or if they are clustered by comparing "distances between nearest points and distances that would be expected on the basis of chance". The index is the ratio of two summary measures. First, the nearest neighbor distance is calculated. For each point, i, distances to all other points, j, are calculated and the minimum selected (the nearest neighbor). This process is repeated until all points have their nearest neighbor selected and is added to a sum of minimum distances. The total sum of minimum distances is divided by the sample size and produces an average minimum nearest neighbor distance (cf. LEVINE 2015: 6.3). The observed average minimum nearest neighbor distance of a distribution is given by the formula:

$$d_{NN} = \sum_{i=1}^{N} \sum_{i \neq j=1}^{N-1} \frac{Min(d_{ij})}{N}$$

where Min($d_{ij}$) is the distance between each point and its nearest neighbor and N is the number of points in the distribution.

**Formula 7: Observed average nearest neighbor distance; Source: LEVINE 2015: 6.3**

The second summary measure, the mean nearest neighbor random distance, calculates the nearest neighbor distances, if points were spatially distributed in a random manner. Since this calculation includes the size of the study area, the results depend on the area's definition (cf. LEVINE 2015: 6.3, 6.4). Its formula is:

$$d_{NN(ran)} = 0.5\sqrt{\frac{A}{N}}$$

where A is the area of the region and N is the number of incidents.

**Formula 8: Expected nearest neighbor distance; Source: LEVINE 2015: 6.3**

Finally, the nearest neighbor index is calculated by the ratio between the observed average nearest neighbor distance and the expected average nearest neighbor distance:

$$\text{NNI} = \frac{d_{NN}}{d_{NN(ran)}}$$

**Formula 9: Nearest neighbor index: Source: LEVINE 2015: 6.4**

A NNI with a ratio close to 1 corresponds to a spatial random distribution, while an index greater than 1 implies regularly distributed events. Conversely, ratios smaller than 1 suggest clustered events, because "the observed average distance is smaller than the mean random distance that is, points are actually closer together than would be expected on the basis of chance" (LEVINE 2015: 6.4).

## 3.4 Spatial Hot Spot Analysis

Crime is an unevenly distributed phenomenon across space. From one place to another, it varies from complete absence to large clusters and it is not geographically evenly distributed. A high spatial concentration of crime can be designated as a crime hot spot and particular environments that attract such incidents are called crime-generators. These hot spot areas can be defined by certain activities (e.g., drug dealing), by specific concentrations of land use (e.g., skid row areas, bars, adult bookshops) "and sometimes by interactions between activities and land uses, such as thefts at transit stations or bus stops" (LEVINE 2015: 7.1). The identification of such hot spots and its depiction on maps is termed 'spatial hot spot mapping'. In combination with underlying social conditions, these clusters are helpful for observing areas with high crime and disorder levels. ECK et al. (2005: 2) define the term hot spot of crime as "an area that has a greater than average number of criminal or disorder events, or an area where people have a higher than average risk of victimization" (cf. ECK et al. 2005: 1 f.; cf. LEVINE 2015: 7.1).

One useful aspect of hot spots is that they help the analyst or the police officer to focus on a special area, where crime is very likely to happen. Therefore, resources, such as time, can be economized. However, the concept of hot spots is also a perceptual construct, since these defined areas do not exist in reality. No barrier or border exists around the area, where clustered events happen. Yet an imaginary line is drawn to tag the arbitrary start and end points of hot spots, where the measured variables are continuous over the area (LEVINE 2015: 71 f.).

There are several standard methods that analysts can perform for cluster analyses. The methods used in this master thesis are explained next.

### *3.4.1 Point locations*

This intuitive type of clustering concentrates on the number of incidents occurring at different locations. Hot spots are locations with the highest number of incidents and are defined by two different techniques, namely *the Mode* and *Fuzzy Mode* (cf. LEVINE 2015: 7.2).

a) The Mode

The mode represents the locations with the largest number of incidents. Every occurred incident at a unique location, defined by its exact coordinates, will be first calculated, then sorted and finally ranked from the most to the least frequent. The result will be displayed as a 'dbf' file including four variables: The rank order of the location, the frequency of incidents at a location, and the X and Y coordinates of the location. (cf. ibid.: 7.9)

b) Fuzzy Mode

The main difference between the mode and the fuzzy mode is that the fuzzy mode allows the definition of a small search radius around a location to include nearby incidents. When each incident is assigned to a unique address and the addresses differ slightly from each other, the mode's result would show no clusters, even if incidents are dispersed only a couple of meters apart. For example, addresses of car thefts in a garage of a multi-building apartment complex are likely to differ from each other, because every car lot can be assigned to a certain address of the owner. "In this case, what is a highly concentrated set of vehicle thefts becomes dispersed, because owners live at different addresses within the complex." In turn, the fuzzy mode allows „the identification of locations, where a number of incidents may occur, but where there may not be precision in measurement" (LEVINE 2015: 7.12).
The applicant should keep in mind that, depending on the size of the search radius, the fuzzy mode tends to count incidents several times, if they fall into the search radius of more than one location. This changes the frequency of incidents at a location as well as the hierarchy in comparison to the mode. The advantage of the fuzzy mode is that it defines small hot spot areas, rather than exact single locations. Furthermore, the fuzzy mode exports the same 'dbf' file, including the four variables, as the output of the mode (cf. ibid.: 7.11 ff.).

### *3.4.2 Hierarchical Techniques*

Methods that fall under the term hierarchical techniques are identifying hot spot areas without focusing on single point incidents within or even centering on a cluster. Exemplary, the nearest neighbor hierarchical clustering (Nnh) is presented here. This method groups incidents that are spatially close repeatedly into clusters of a hierarchical order (first-order, second-order, third-order, etc.), which finally leads to either one single cluster or the clustering fails. There are basically two criteria that the grouping is based upon:
Criterion one is the threshold distance. It compares the threshold to the distance between the points and groups points that are closer than the specified threshold distance together. The threshold distance can be selected in CrimeStat either by a random nearest neighbor distance or a fixed distance. Before selecting either one of the two routines, the applicant should be aware of their special characteristics. If the random nearest neighbor distance routine is selected, it is very important that the area units are consistent with the data, because otherwise the routine may not be able to find points within the threshold distance. On the other hand, the fixed distance is a rather subjective method, since enlarging the distance leads to a greater likelihood that clusters will be found by chance (cf. LEVINE 2015: 7.16 ff.).
The second criterion is the minimum number of points. A large data set is able to produce hundreds or thousands of clusters, if a cluster is already defined by two or more points that are spatially close. To avoid very small clusters, the routine only includes clusters in which the minimum number of points is found (cf. ibid.: 7.20). The final output of the cluster can be visualized as an ellipse, a convex hull, or both (cf. LEVINE 2015: 7.21).

## 3.5 Kernel Density Interpolation

According to LEVINE (2015: 10.1), the "Kernel Density Interpolation (also called Kernel Density Estimation) is a technique for generalizing incident locations to an entire area". The approach interpolates discrete points over the complete study area by providing density estimates. This is also the main difference to the methods described before, because they "provide statistical summaries for the data incidents themselves" (ibid.). In fact, this is an improvement, especially in comparison to maps with events displayed as dots, because events will not overlap each other when they are spatially close. This also enhances the visual intelligibility in particular for large data sets with highly concentrated single events. The density estimate is valued over a regular raster and provides an intensity variable for each cell, a so-called Z-value. In detail, this value is created by "placing a symmetrical surface over each point and evaluating the distance from the point to a reference location based on a mathematical function". The values of all surfaces for all reference locations will be summed, resulting in a density surface (cf. ibid.: 10.1 ff.).

The outcome of a Kernel Density Estimation, either in the form of continuous surface maps or contour maps, is dependent on three parameters. The first parameter is the cell size of the density surface. Large cell sizes influence the outcome in terms of greater generalization, which leads to a speckled visualization. In turn, small cell sizes let the outcome appear fine-graded (cf. LEITNER n.y.: 55 f.).

The second influencing factor is the shape of the kernel function. LEVINE (2015: 10.7) gives an overview of five kernel functions, which are available in CrimeStat IV. These are the normal function, quartic function, triangular function, negative exponential function, and the uniform function. Each function interpolates the data to the grid in a different way and produces different shapes in the outcome. The user's choice of function depends on how near points should be weight relative to far points. In summary, if the difference between near and far points shall be weight more, the negative exponential or the triangular function is applied. Variations across the surface will be finer and peaks and valleys will be more emphasized. When all points are weight evenly, the normal distribution, the quartic, or the uniform functions should be applied, resulting in a more balanced outcome (cf. ibid.: 10.10). The exact mathematical explanations of each function are explained in detail in LEVINE (2015: 10.7 ff.).

The bandwidth of the kernel function is the third parameter and can be divided in either a fixed interval or an adaptive interval kernel density routine. By applying a fixed bandwidth, the user specifies the interval to be used as well as the units of measurement. This choice will be consistent for all point locations in the data set. However, the default bandwidth choice in CrimeStat is the adaptive bandwidth, which adjusts the bandwidth's interval so that a user-specified minimum number of points are found underneath the kernel function. This provides a high consistency within the whole data set, because wider bandwidths are chosen, if the points are more dispersed and narrower ones, if they are clustered (cf. LEITNER n.y.: 61; cf. LEVINE 2015: 10.16 f.).

# 4 Analyses and Results

In Chapter 4, results of the spatial and statistical analyses of the collected graffiti data are presented. The analyses are conducted in CrimeStat IV and results are depicted as tables and/ or as maps in ArcMap. This includes the statistical approaches discussed in the previous chapter. By doing so, spatial information about the dispersion pattern and clustering of soccer-related graffiti in Krakow is explored and used to answer the research questions discussed earlier. At first, some basic settings concerning the integration of data into the CrimeStat IV environment is described. Next, the general distribution pattern of the soccer-related graffiti is discussed and hotspots, as well as areas of high concentration are determined. In order to gain knowledge about the evolution of the dispersion of the graffiti, the collected data from 2018 is compared to the data from 2016. The latter data were provided by Dr. Trzepacz. Finally, additional datasets which provide information about committed delicts in Krakow are examined and analyzed in order to find correlations with the graffiti data.

## 4.1 Data Setup in CrimeStat IV

To begin with the analysis in Crime Stat, the data have to be set up first. CrimeStat IV has an own Data Setup section, which is introduced shortly. The primary file (tab “Primary File”) to be analyzed can be selected by the “Select Files”- button. The selected file will change during this analysis, because different data sets are studied, for example varying from all possible graffiti point features to soccer team related graffiti (e.g., Wisla Krakow point features). Even though CrimeStat is able to read three different types of input files, including ‘dbf’ and ‘ASCII’ files, only ArcGIS point ‘shp’-files are used here. CrimStat has to locate the data, which is why the x and y coordinates have to be defined. The associated values for the shapefile “all_graffiti”, which encompasses graffiti of all classes and are listed in the attribute table, are named “POINT_X” for the x-coordinate and “POINT_Y” for the y-coordinate. Since the graffiti are displayed by geographical coordinates the respective “Type of coordinate system” is defined as “Longitude, latitude (spherical)”, which automatically sets the “Data units” to “Decimal Degrees”. All these properties are shown in Figure 18. (cf. LEVINE 2015: 3.11 ff.)

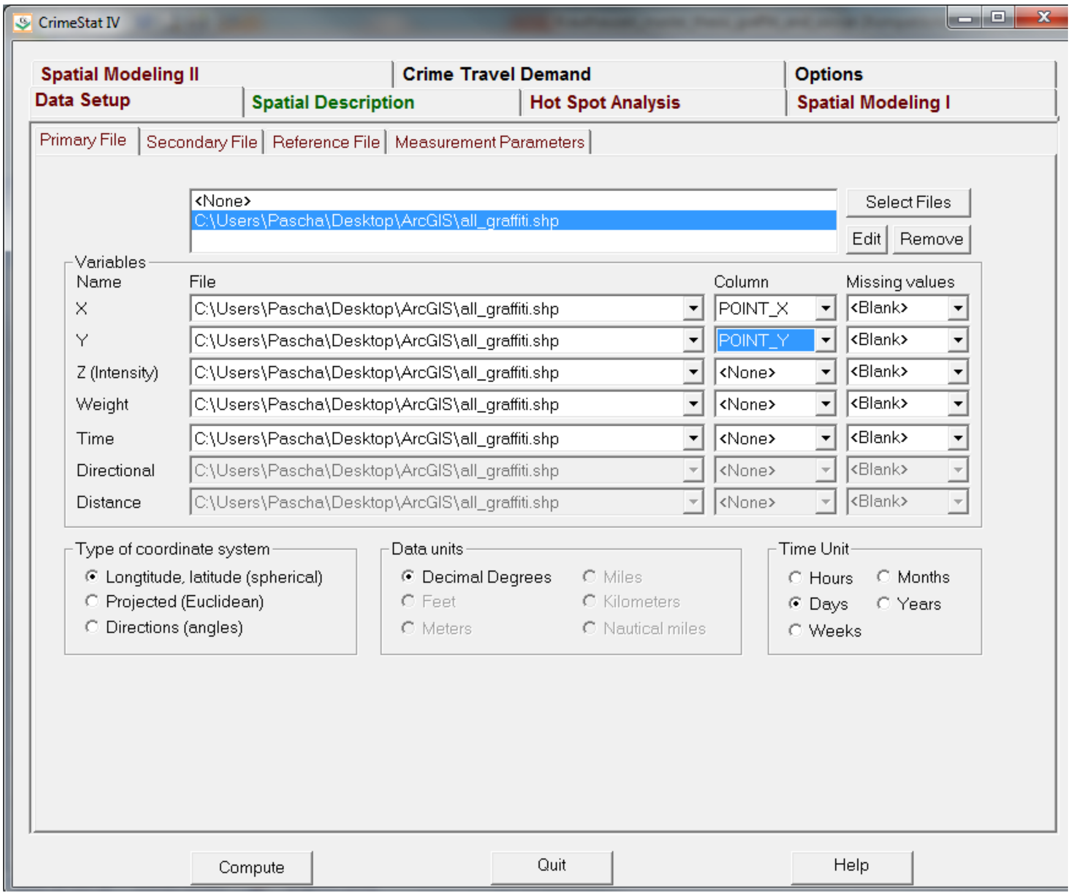



**Figure 18: Data setup in CrimeStat IV**

Some interpolation and clustering routines in CrimeStat "generalize the point data to all locations in the study area". Therefore, a reference file has to be defined manually covering the study area. The coordinates of this rectangular grid are shown in Figure 19 and are the basis for all analysis for which a reference file is needed (cf. LEVINE 2015: 3.20 ff).

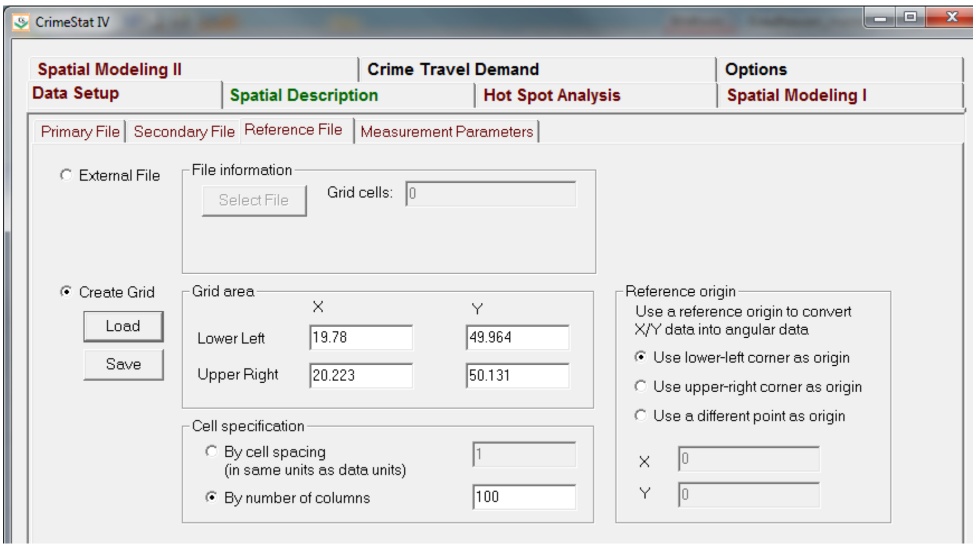



**Figure 19: Reference file in CrimeStat IV**

The data setup procedure is completed with the “Measurement Parameters” (cf. Figure 20). In this case, the geographical study area is defined with 327 km², the size of the area covering the city of Krakow. In the following analyses the distance between two points is calculated as the Euclidian distance in CrimeStat. The reason for selecting the Euclidean distance is the assumption that the street network of Krakow does not follow a rectangular grid-like structure. Since the point data are based on a spherical coordinate system, “the shortest distance between two points is a Great Circle line” (LEVINE 2015: 3.31). These standard settings are used for all the analyses. Depending on the method and the analyzed dataset, some properties may change by a certain degree.

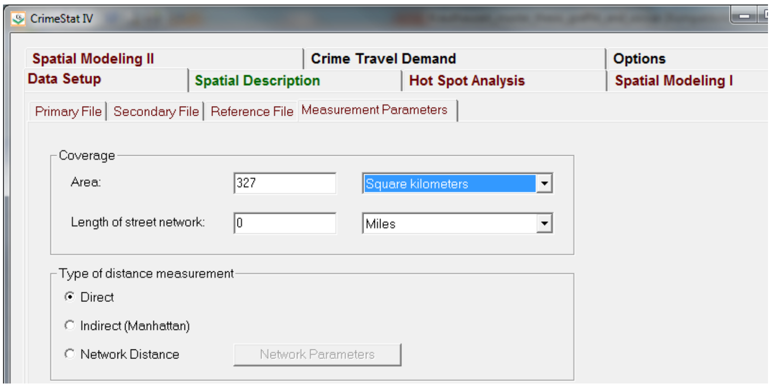



**Figure 20: Measurement parameters in CrimeStat IV**

## 4.2 General Distribution Pattern of Soccer-Related Graffiti in 2018

This chapter illustrates the results of the spatial descriptive methods, including the centrographic statistics, and the distance analysis of soccer-related graffiti in Krakow. It begins with the outcome of applying the centrographic statistics in CrimeStat IV for different graffiti categories and methods. Figure 21 displays three different spatial centers (spatial mean, spatial median, and center of minimum distance) for seven graffiti categories inside the city boundaries of Krakow. If all graffiti locations are counted with the same weight as one category, the three centers are located slightly east of the city center with the mean center orientated more south-eastwards and the median center more to the north compared to the center of minimum distance. This also indicates that there are slightly more graffiti locations in the north-eastern part of the city.

The same pattern occurs, when the three spatial centers of graffiti are observed for the Wisla category, the Cracovia category, the Anti Cracovia category, and for the Conflict category. For graffiti locations categorized as Anti Wisla, the mean center is also located the most east, but the center of minimum distance is situated slightly more south. According to the location of the three centers, graffiti attributed to Cracovia Krakow, respectively Anti Wisla, are distributed more in southern Krakow, whereas those of Wisla Krakow, respectively Anti Cracovia, are more detectable in the northern part of the city. In accordance with these findings, graffiti that are categorized as conflict graffiti are located in between the centers of those categories.

Graffiti of Hutnik Nowa Huta differ from all other graffiti categories, because their spatial descriptive statistics are centered far more east than the other spatial centers. A possible reason may be the fact that the stadium of Hutnik Nowa Huta is situated in the eponymous district Nowa Huta (district 18), which is located in the east of the city, whereas both stadiums of Wisla and Cracovia are located close to the city center. Also, all three spatial centers of Hutnik graffiti are closer together, with the median center and the center of minimum distance almost overlapping each other and the mean center located slightly to the north.

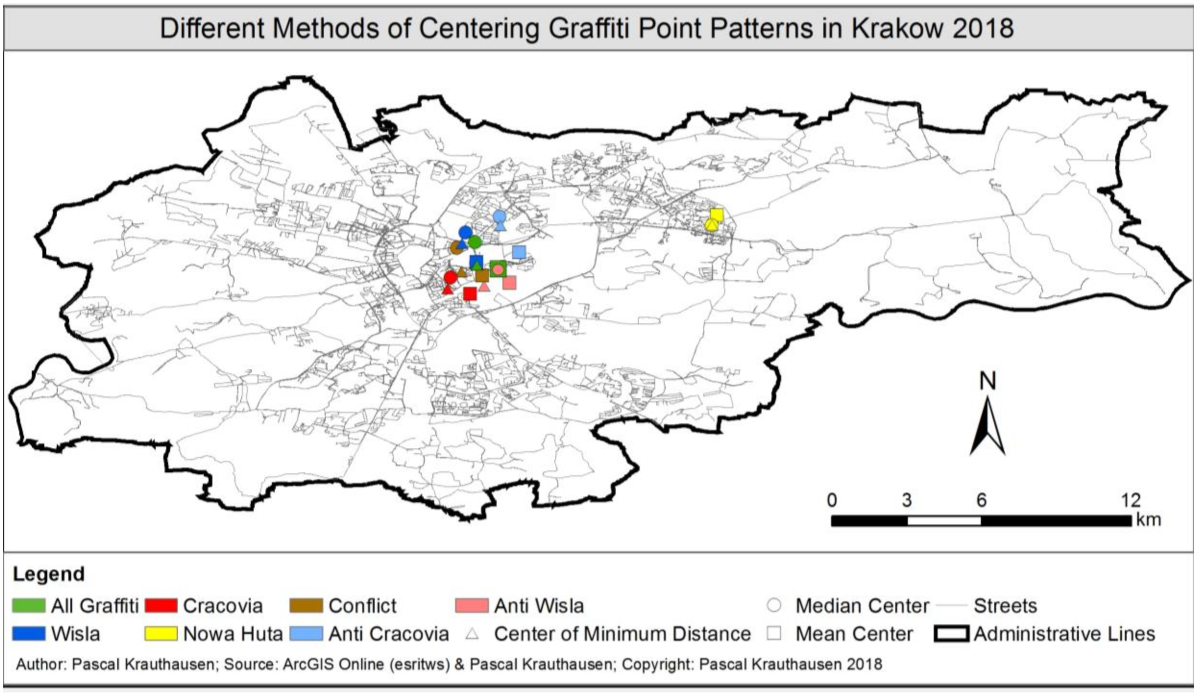



**Figure 21: Centering Methods of Graffiti 2018**

Figure 22 illustrates the standard distance deviations for all graffiti categories in Krakow. The average dispersion of the graffiti categories of Wisla, Cracovia, Conflict, Anti Wisla and Anti Cracovia from the spatial mean are almost similar large. In conclusion, these graffiti are very likely to be spotted in large parts of the city. The same applies to the category of all graffiti. In comparison, the standard distance deviation of Hutnik graffiti is indicated by a small radius and limited to the 17th and 18th district in the northeast, which implies that Hutnik graffiti are highly concentrated around the spatial mean.

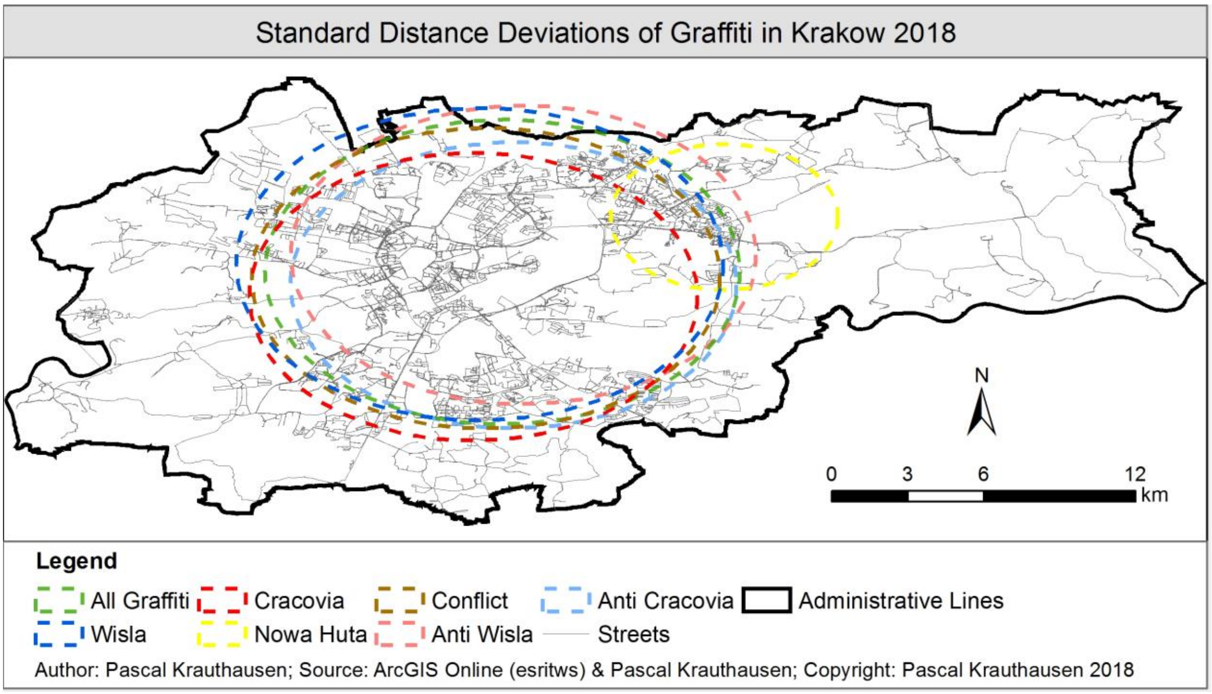



**Figure 22: Standard Distance Deviations of Graffiti 2018**

The method described before shows the average dispersion of points from the spatial mean but does not give any information about the orientation of a feature. Therefore, Figure 23 has been created. It depicts the two-standard deviational ellipses for the same seven categories, as shown before and provides an overview of their dispersions around the mean center. All seven graffiti categories show the same orientation of dispersion, with the major axis of the ellipses extending almost perfectly in the east-west direction. Therefore, graffiti locations are more spread out in east-west than in north-south direction, which is also consonant with the outline shape of Krakow being more stretched in east-west than in north-south direction. Strictly speaking, the pattern of the graffiti distribution shows a slightly southwest to northeast orientation, indicating that in the western part of the city more graffiti are located southwards and in the eastern part of the city more northwards. Except from graffiti located in Nowa Huta, all six ellipses have a rather long major axis, which indicates a great dispersion of graffiti along that direction. Therefore, graffiti locations for Hutnik are highly concentrated in comparison to the graffiti locations of the other two soccer fan groups. More precisely, Wisla graffiti are the most spatially distributed category, since their standard deviational ellipse has the biggest major axis of all graffiti categories. According to the calculated statistics, the area of the ellipse for Wisla graffiti amounts to 112,5659km² in comparison to 105,5658km² of the ellipse for all graffiti.

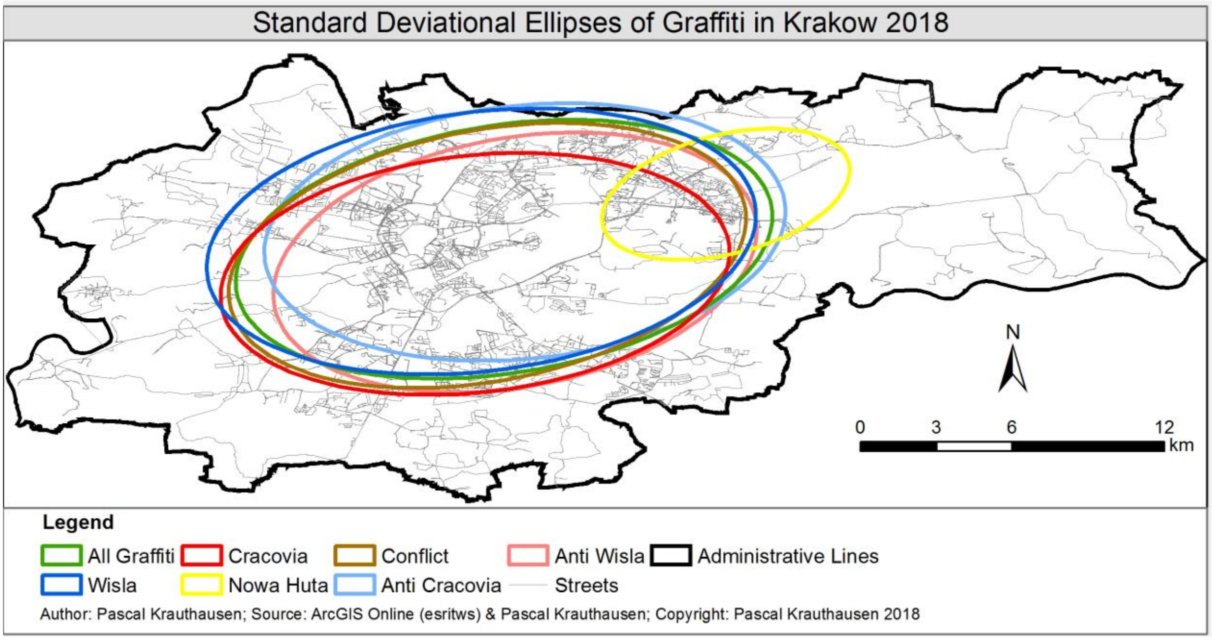



**Figure 23: Standard Deviational Ellipses 2018**

The results of another spatial statistical method, the nearest neighbor analysis, are presented next. Table 3 lists seven statistics for the same seven graffiti categories, as used previously. The nearest neighbor index (NNI), which is the ratio between the observed mean nearest neighbor distance and the expected mean random distance gives information on the distributional pattern, whether incidents are spatially dispersed, random, or concentrated. All NNI have values less than 1.0, which is an evidence for spatially concentrated events. Graffiti that can be allocated to Hutnik Nowa Huta have the lowest index (0.1936) and are therefore highly spatially concentrated in the Nowa Huta region. This assumption can be confirmed when the NNI for graffiti of Hutnik Nowa Huta is compared to that of Anti Wisla graffiti, which, in contrast, has the highest NNI, with 0.3958. This result states that the spatial distribution of graffiti of Huntik Nowa Huta relative to an expected random distribution appears to be more spatially concentrated, than that of Anti Wisla. However, this index does not prove, whether there are any hotspots of graffiti in Nowa Huta or in other parts of Krakow. But according to the relatively greater concentration of Hutnik Nowa Huta graffiti, the chance of hotspots is more likely. Additionally, both NNI's of both the conflict and Wisla categories are relatively low, especially when compared to the high spatial variability of their graffiti locations.

Moreover, all Z-values are highly significant, which results in the statement that the distribution of graffiti incidents in Krakow is significantly smaller, than what would be expected by a random distribution. The Z-value will not be used for comparison, since sample sizes are very large and differ much between categories. Accordingly, the much higher Z-value of the category 'all graffiti' is mainly due to the fact that it is by far the category with the largest sample size. However, the NNI test proves that graffiti locations for all seven categories are significantly spatially clustered. When combining the findings of the previous chapter with the findings in this chapter, then it can be concluded that graffiti locations of Hutnik Nowa Huta have the smallest spatial dispersion of all graffiti categories and also seem to be most spatially concentrated. In order to establish the existence of hotspots, cluster analyses are carried out, which is presented in the next chapter.

| Category | all graffiti | Anti Cracovia | Anti Wisla | conflict | Cracovia | Hutnik | Wisla |
|---|---|---|---|---|---|---|---|
| **Mean nearest neighbor distance (m)** | 29.07 | 134.86 | 178.50 | 83.58 | 94.52 | 100.38 | 72.09 |
| **Mean random distance (m)** | 126.63 | 366.68 | 450.95 | 266.16 | 275.77 | 518.57 | 231.84 |
| **Nearest neighbor index** | 0.23 | 0.37 | 0.40 | 0.31 | 0.34 | 0.19 | 0.31 |
| **Standard error (m)** | 0.93 | 7.77 | 11.76 | 4.10 | 4.40 | 15.55 | 3.11 |
| **Test Statistic (Z)** | -105.24 | -29.82 | -23.17 | -44.58 | -41.22 | -26.90 | -51.41 |
| **p-value (one tail)** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **p-value (two tail)** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Table 3: Nearest neighbor analysis of soccer-related graffiti in Krakow in 2018**

## 4.3 Cluster of Soccer-Related Graffiti in 2018

This chapter addresses different methods of hotspot analysis, which are applied in CrimeStat IV. Results are illustrated by maps created in ArcMap. The first and most intuitive method, the spatial mode, counts the number of incidents for each single location and ranks them according to their frequency from the most to the least frequent. The eighteen most frequent graffiti locations of Krakow are displayed by Figure 24, when all collected graffiti are taken into the account. The location with the highest frequency counts a total of eight graffiti and is detected only once. Locations with a count of seven graffiti appear seven times and those with a count of six appear ten times. An accumulation of spatial modes of graffiti is located in the middle-south of Krakow, where five of the most frequent graffiti locations are detectable close to each other. The remaining most frequent places are spread throughout the northern part of the city. The spatial pattern of this distribution reveals a remarkable lack of frequent graffiti locations, stretching from east to west and especially in the middle part of the city. This belt of absence even elongates to the southwest of the city.

Since the spatial mode assigns incidents to a single location, this method is limited, when the degree of resolution for the geo-referencing of incidents is low (cf. LEVINE 2015: 7.11). If two incidents are located just a couple of meters away from each other, but are not assigned to the exact same coordinates, the spatial mode will count both graffiti as two different locations. For example if a junction box is located right in front of a building’s façade and a graffito is attached to both, the façade and the junction box, the spatial mode statistics creates two distinct results. Another example are junctions that have more than one bus stop, each marked by graffiti. This characteristic is also the reason for mapping only one category with all collected graffiti, because some categories (e.g., Cracovia) have no single location with more than one graffito at the same location. A comparison of frequent graffiti locations by different categories would therefore not lead to new findings.

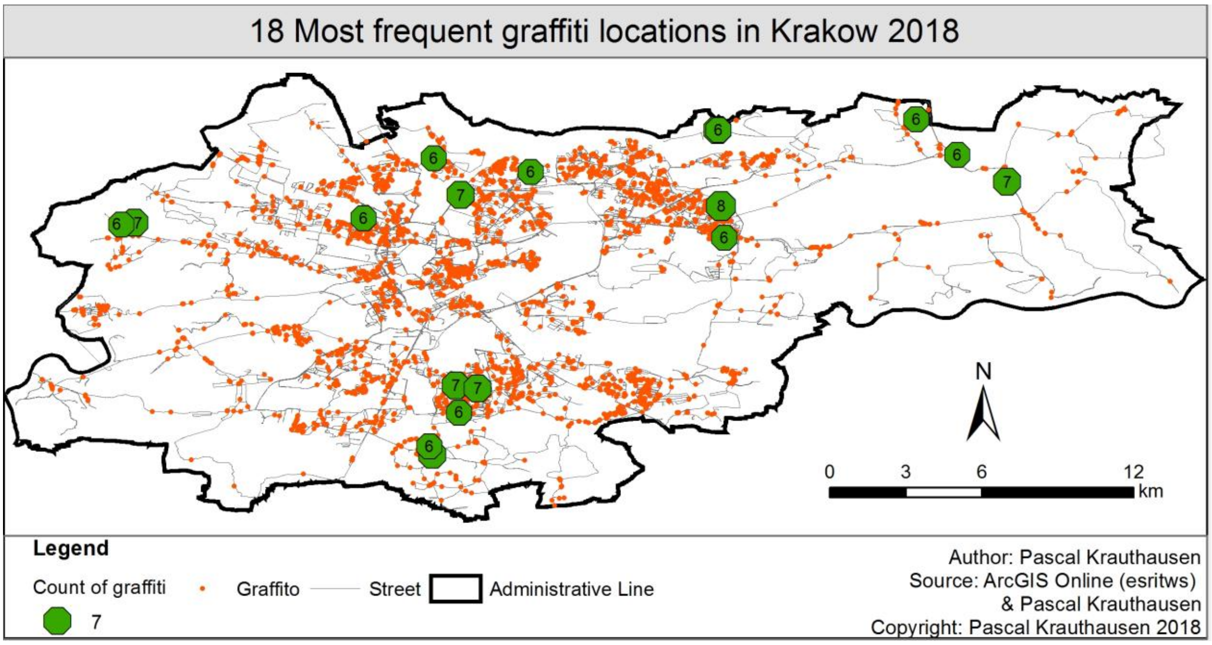



**Figure 24: Most frequent graffiti locations (spatial mode) in Krakow in 2018**

Thus, another technique that focuses on single point incidents within a cluster is the spatial fuzzy mode. The main difference to the spatial mode is that it allows a user defined search radius wherein single incidents are accumulated. Figure 25 depicts the most frequent graffiti locations within a 200 meter search radius inside the city borders of Krakow. A distributional pattern can be identified similar to the overall result of the spatial mode. Concentrations of graffiti are mainly found in northern Krakow with one spatial fuzzy mode located in the southeast. Graffiti of Hutnik Nowa Huta are strongly present in the Nowa Huta region (district 18) in the east, where the only hotspots of this category are shown.

According to the spatial fuzzy mode, a high concentration of graffiti locations can be found around the eastern, western and northern parts of the old town, which is located in district one (see red rectangle Figure 25). The second part of Figure 25 reveals a clear distinction between hotspots of Wisla and Anti Cracovia on the one hand and Cracovia and Anti Wisla graffiti on the other hand. The latter are concentrated in district two, closely to the border to district one. It should be noted that these are the only concentrations of Cracovia graffiti, similar to the Nowa Huta district with high frequencies of Hutnik graffiti. In contrast, the north-western and north-eastern parts of the old town, the third and fifth districts, are dominated by blue and light blue colors, indicating a high frequency of Wisla and Anti Cracovia graffiti. Conflict graffiti are most frequent in the far northwest of the old town, being also the only hotspot for this category according to the spatial fuzzy mode.

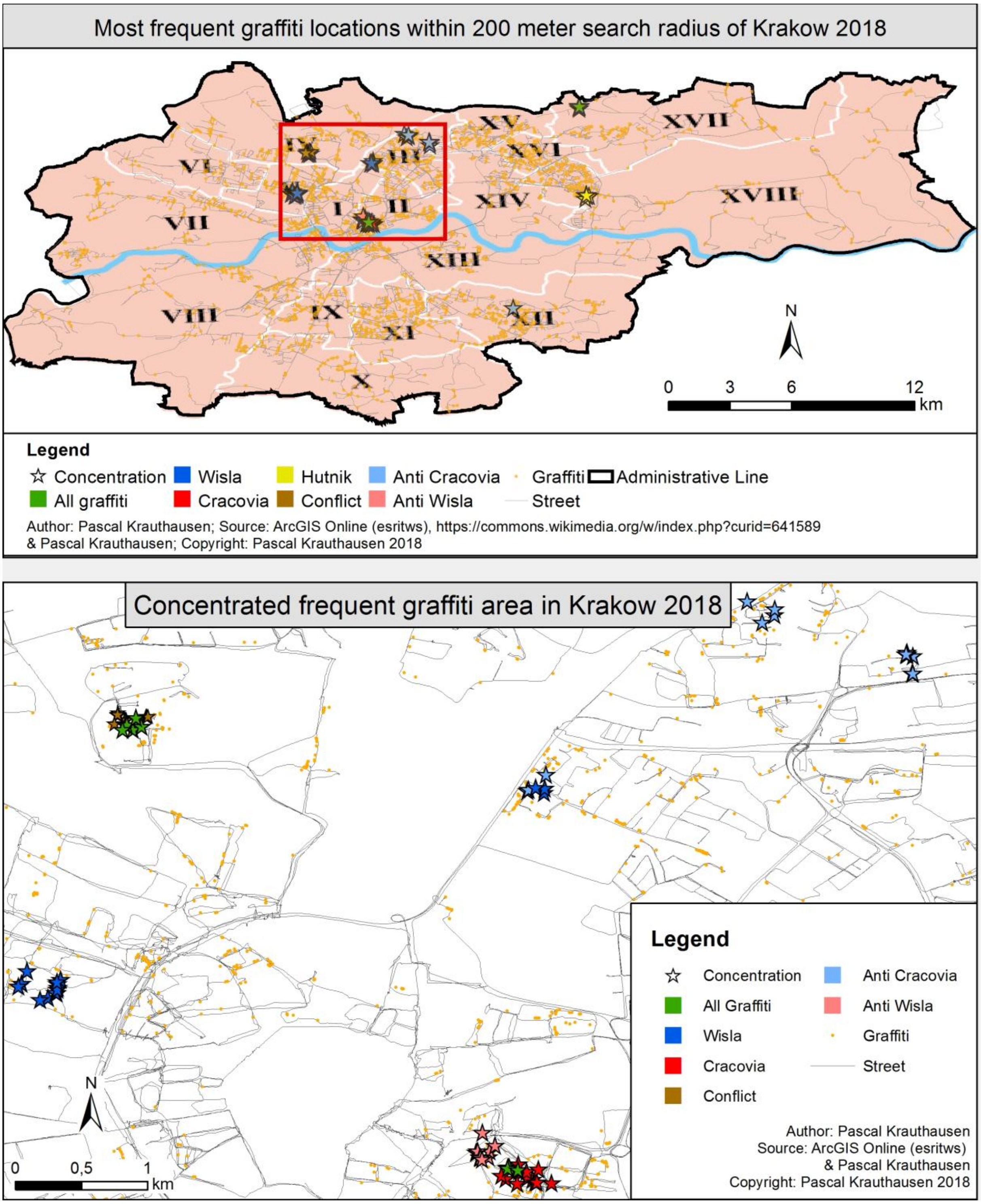



**Figure 25: Spatial fuzzy mode of graffiti locations within a 200 meter search radius in Krakow in 2018**

For a better understanding, the data listed in Table 4 yield the background information for the shown categories in Figure 25. For each category, 15 locations with the highest count of graffiti are taken into account and the five highest counts are displayed in Table 4. Hutnik Nowa Huta graffiti yield the highest count of all categories of graffiti frequency within the 200 meter radius. This result is even more remarkable, when the total number of graffiti is compared, because Cracovia graffiti are found more than three times more often and Wisla graffiti five times more often, than those of Hutnik. This is another indication of comparatively high concentrations of Hutnik graffiti. Cracovia graffiti compared to Wisla graffiti also result in comparatively much higher counts within the 200 meter buffer areas and may lead to the assumption that Wisla graffiti are more widely distributed (i.e., possess a higher spatial variability) whereas Cracovia graffiti are more spatially clustered.

One aspect of the spatial fuzzy mode that has to be considered is the fact that the search radius allows the multiple counting of incidents, because each time a graffito falls inside a search radius around a location it will be counted towards this buffer area. This may exaggerate locations with very high concentrations of incidents and may be the reason, why other spots with only high concentrations are not taken into account. This circumstance is also influenced by the definition of the search radius, which may lead to substantial differences in calculating hotspots. For example, with a 200 meter search radius, all top spatial fuzzy modes occurred within a short distance for Hutnik graffiti.

| **Category** | All Graffiti | Wisla | Cracovia | Hutnik | Anti Cracovia | Anti Wisla | Conflict |
|---|---|---|---|---|---|---|---|
| **Count** | 5098 | 1521 | 1075 | 304 | 608 | 402 | 1154 |
| **1. highest frequency** | 64 | 36 | 43 | 46 | 16 | 13 | 32 |
| **2. highest frequency** | 64 | 34 | 43 | 45 | 15 | 12 | 32 |
| **3. highest frequency** | 64 | 32 | 43 | 45 | 15 | 12 | 30 |
| **4. highest frequency** | 63 | 32 | 42 | 45 | 14 | 11 | 30 |
| **5. highest frequency** | 62 | 29 | 41 | 44 | 14 | 11 | 30 |

**Table 4: Spatial fuzzy mode of graffiti locations within a 200 meter search radius in Krakow in 2018**

Both spatial and spatial fuzzy modes are examples of how to display single point locations that are clustered or define the center of a cluster. Another approach, the nearest neighbor hierarchical (Nnh) clustering, identifies hotspot areas by conceptualizing a certain distribution in space. To begin with, hotspot areas for all graffiti are calculated. As described in Subchapter 3.3.2 Hierarchical Techniques, there are mainly three settings which influence the outcome of the Nnh clustering, which are specified in the following. At first, clusters for all graffiti in Krakow are identified on the basis of a random nearest neighbor distance threshold, with a probability level of $p=0.05$. The minimum number of graffiti that form a cluster is defined by 20 incidents, while each cluster is visualized as an ellipse with 1.5 standard deviations. These properties result in a total of 40 clusters whereas 37 first-order ellipses and three second-order ellipses create hotspot areas displayed in Figure 26. Accordingly, the lion's share of all graffiti is located in the north-eastern part of Krakow. This map also reveals that two clusters of $2^{nd}$-order – indicated by the red rectangle – are forming a belt of concentrated graffiti, which clusters almost one fourth (23.1%) of all collected graffiti, 1,178 graffiti in total. A zoomed-in picture of this "belt" is shown by Figure 27 in which the graffiti belt is formed by extending the two $2^{nd}$-order ellipses by the dashed green line.

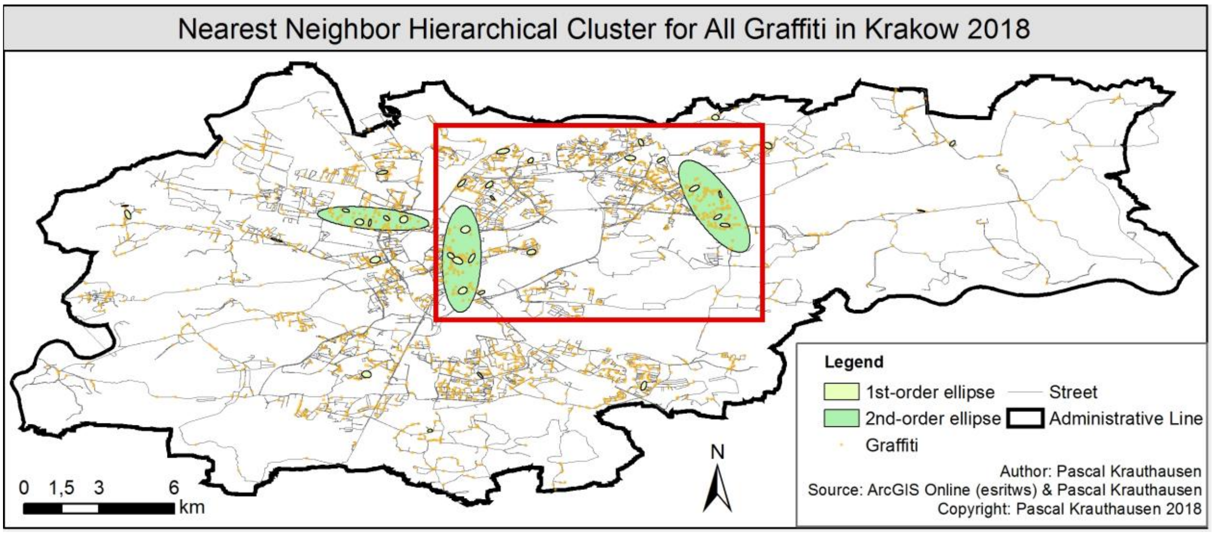



**Figure 26: Nnh cluster all graffiti categories in Krakow in 2018**

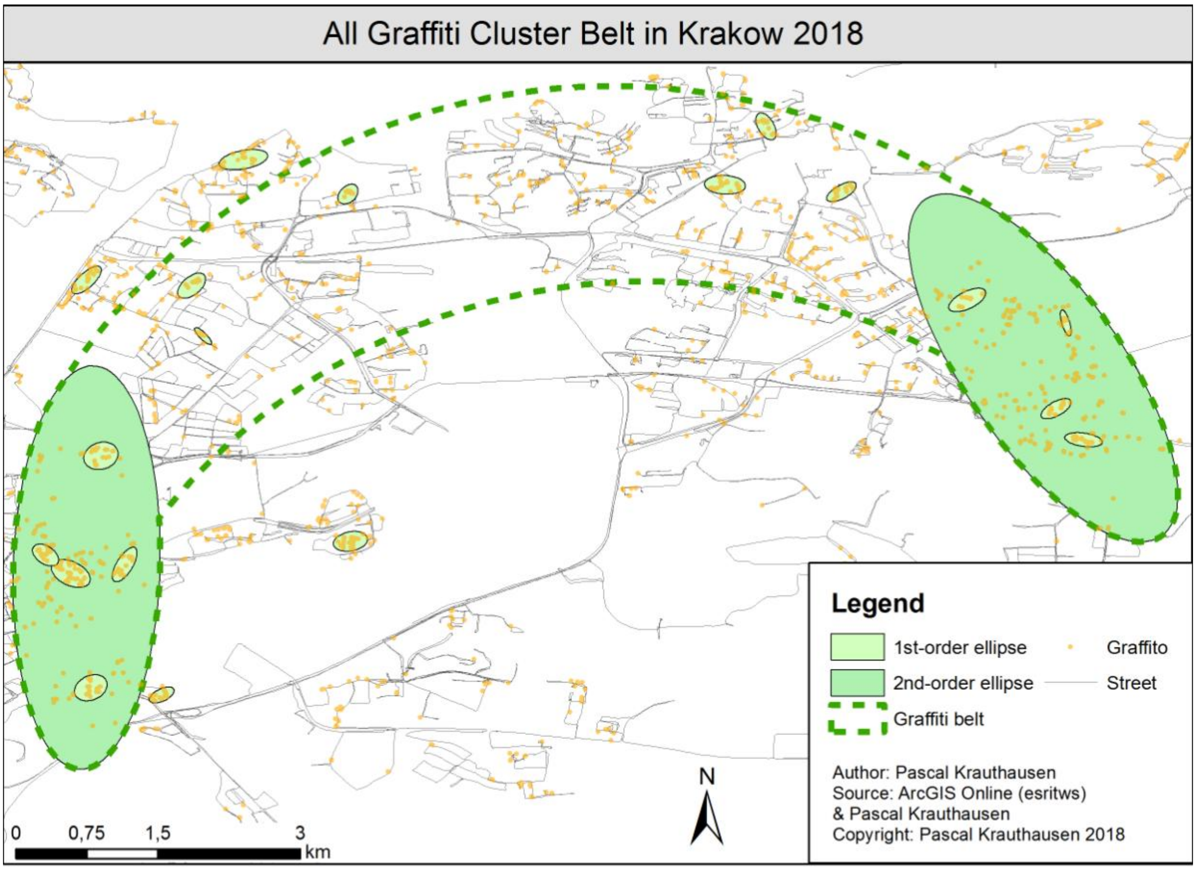



**Figure 27: Nnh cluster belt all graffiti categories in Krakow in 2018**

Moreover, the graffiti cluster belt encircles 1st-order clusters of all graffiti categories, which is shown in Figure 28. The probability level of the random nearest neighbor distance threshold for all categories is defined by p=0.05 and ellipses are displayed with 1.5 standard deviations. The minimum number of incidents that define a cluster varies between the categories. Graffiti that can be allocated to the categories Anti Cracovia, Anti Wisla, and Hutnik have a minimum number of ten graffiti. Those assigned to Wisla, Cracovia, and Conflict, are defined by a minimum of 15 graffiti. In general, results in Figure 28 support results obtained when all graffiti are considered together. For example, the overall tendency of Hutnik graffiti being located mostly in the east, Cracovia graffiti located rather in the south, and those of Wisla located foremost in the northern part of Krakow, can be recognized. Results also found Hutnik graffiti as the most spatially concentrated, which display a high presence inside the boundaries of the belt.

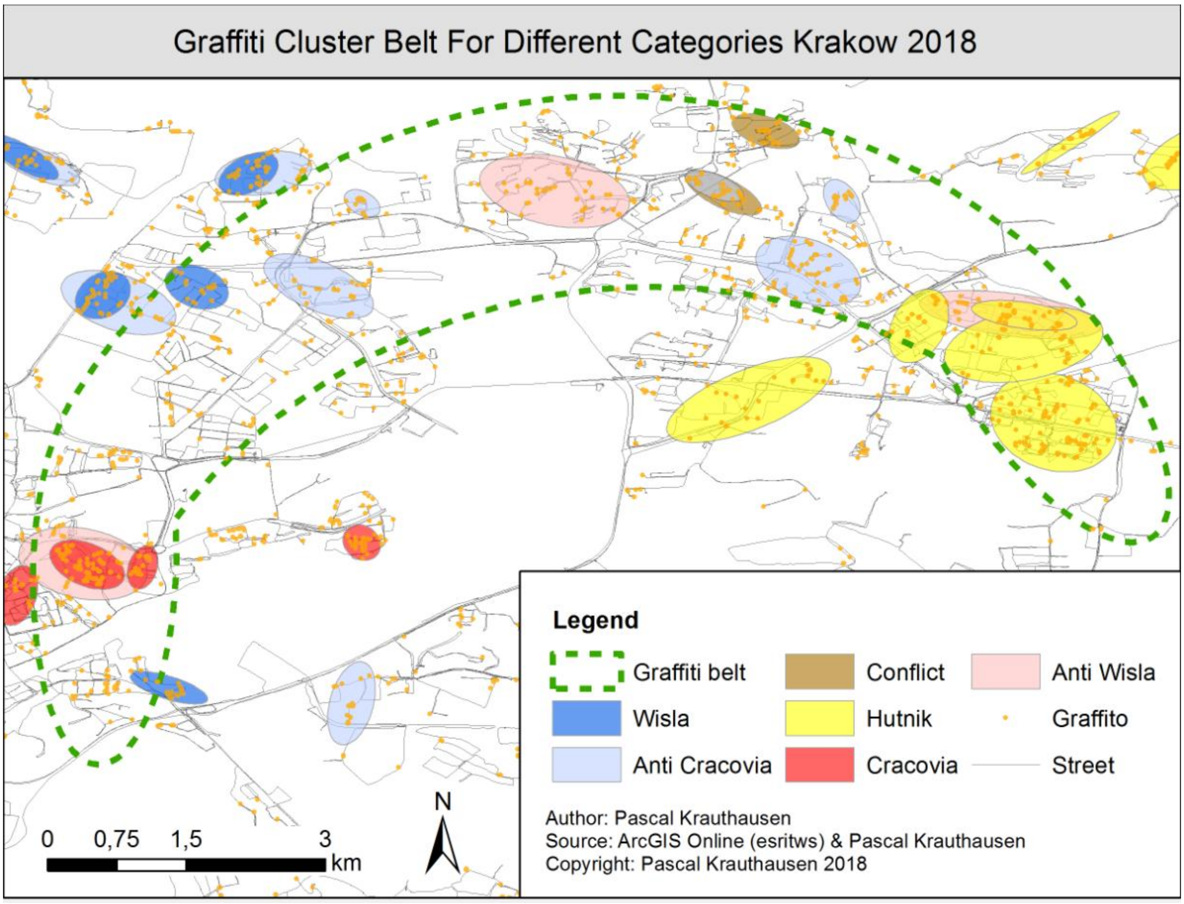



**Figure 28: Graffiti cluster belt for different categories in Krakow in 2018**

The introductory chapter unveiled the heavy rivalry between supporters of Cracovia Krakow and Wisla Krakow and will be analyzed in terms of so called conflict zones next. In this thesis, a conflict zone is described by a high intersection of hotspots of graffiti from two or more different categories, which may implicate such rivalry. Yet, these graffiti do not have to be proved to belong to a certain soccer club or do not have to have any affiliation towards one club. The aversion against one soccer team expressed by more than an average concentration of graffiti is already an indicator for such areas.

Nnh clusters of the graffiti category named ‘conflict’ offer first tendencies towards conflict zones and represent graffiti that are hardly or not at all affirming a distinct team. Figure 29 locates twelve hotspots, which are all first-order ellipses. They occur in different areas of Krakow being slightly more present around the Stare Miasto district, in the south, and in the north-east. Graffiti that are allocated to the “conflict” category consist mostly of disfigured tags, which can be expressed in different ways. For example, by adding prefixes and suffixes, graffitists or the allocated team of the original graffito may be ridiculed or even insulted. In other cases, graffiti are simply overwritten by the other team's initials or colors to show reluctance.

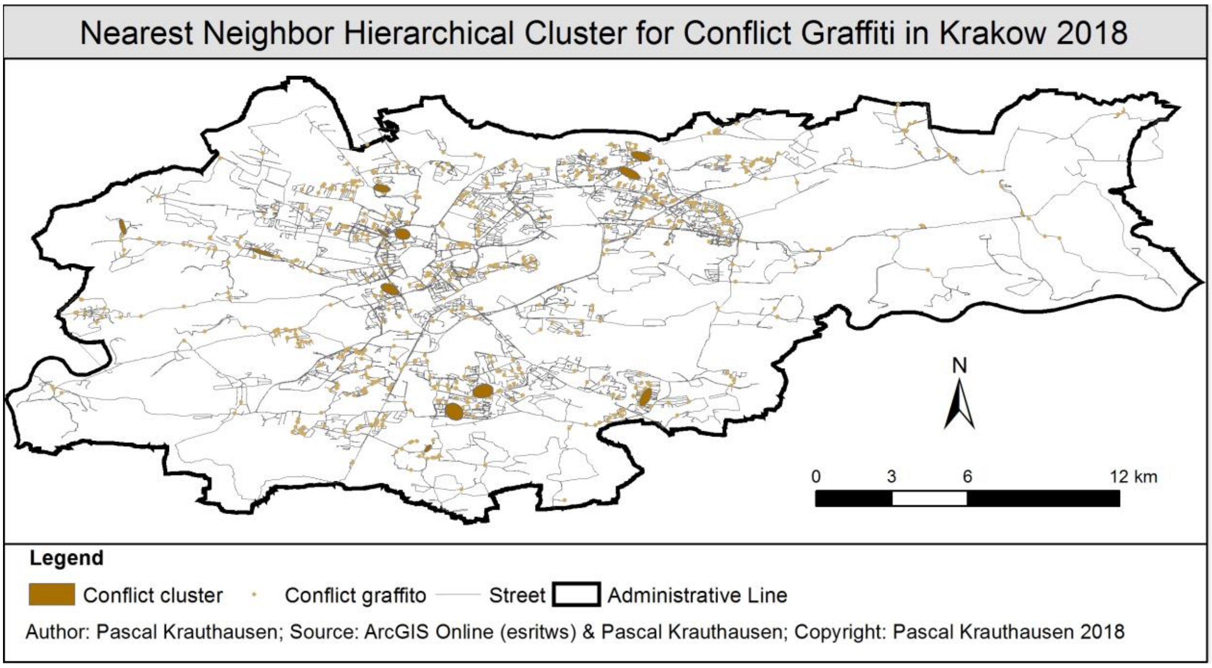



**Figure 29: Nnh for conflict graffiti in Krakow in 2018**

Before selected conflict zones are illustrated, Figure 30 provides an overview of Nnh clusters for different categories. The total amount of all 1st- and 2nd-order clusters is listed in Table 5. Areas that are dominated by Cracovia supporters are demarcated by red shaded ellipses, which are most abundant in the central area of Krakow, as well as, in southern parts. Wisla graffiti are mainly found in northern Krakow, whereas Hutnik graffiti occupy the eastern area of Krakow. However, this map also imparts an overview of conflict zones in Krakow due to overlapping graffiti clusters. Accordingly, two conflict zones are located in the northeast, where clusters of Anti Wisla and Anti Cracovia interfere with Hutnik hotspots. The north, which is a primarily dominated region by Wisla graffiti, demonstrates another three conflict zones, where Wisla and Anti Cracovia graffiti concentrations coincide with their big rival.

| | All graffiti | Wisla | Anti Cracovia | Cracovia | Anti Wisla | Conflict | Hutnik |
|---|---|---|---|---|---|---|---|
| **1st-order count** | 37 | 11 | 12 | 11 | 10 | 12 | 9 |
| **2nd-order count** | 3 | 1 | 1 | 1 | 1 | 0 | 1 |
| **minimum sample size** | 20 | 15 | 10 | 15 | 10 | 15 | 10 |

**Table 5: Count of clusters in Krakow in 2018**

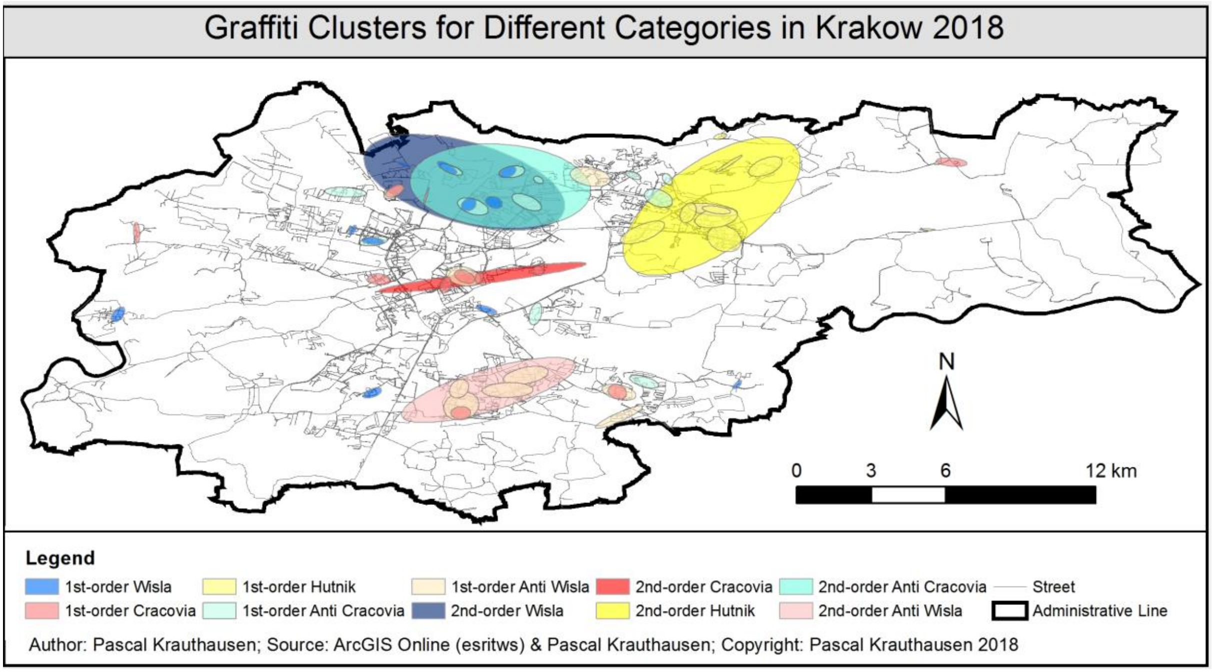



**Figure 30: Nnh clusters for different categories in Krakow in 2018**

Selected conflict zones are displayed next. Figure 31 depicts the rivalry between Cracovia and Wisla by showing graffiti locations in the northern part of Krakow, a primarily dominated area by Wisla graffiti. The map's base layer consists of an Open Street Map, which is helpful for the orientation and the exact position of incidents. There are five categories displayed, including two that can be allocated to either one of both clubs, two that show aversion to each of the two clubs, and some conflict graffiti. The main focus is found in the area, where the 2$^{nd}$-order cluster of Wisla (blue) overlaps with a 1$^{st}$-order ellipse of Cracovia (red), and one 1$^{st}$-order ellipse of Anti Wisla (orange) graffiti, which induces a situation of conflict between both rivaling soccer teams. A total of 70 graffiti are located within a couple of hundred meters, whereas the lion's share is allocated to conflict (33) and Cracovia (20) graffiti. An even greater conflict zone is demonstrated by Figure 32. A total amount of 111 graffiti can be detected in the border area between the 17$^{th}$ and the 18$^{th}$ districts (Nowa Huta), which is dominated by Hutnik graffiti. Both graffiti categories "Hutnik" and "conflict" have the highest counts of graffiti with 37.

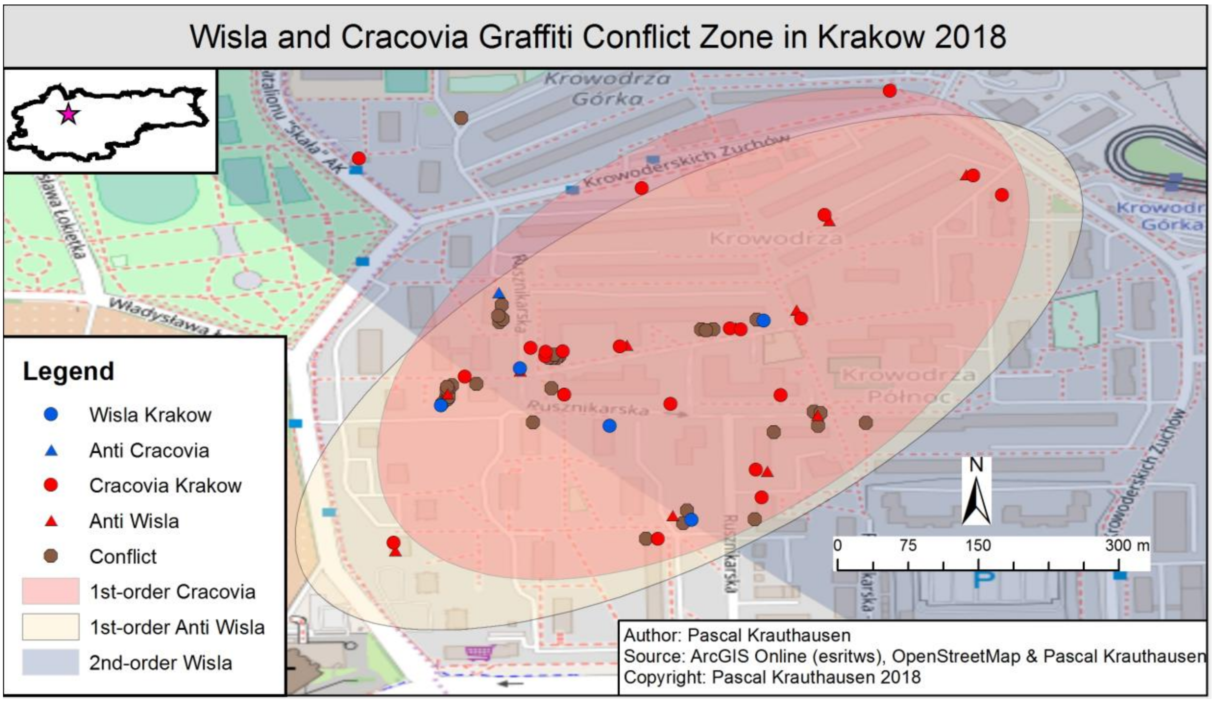



**Figure 31: Cracovia and Wisla conflict zone in Krakow in 2018**

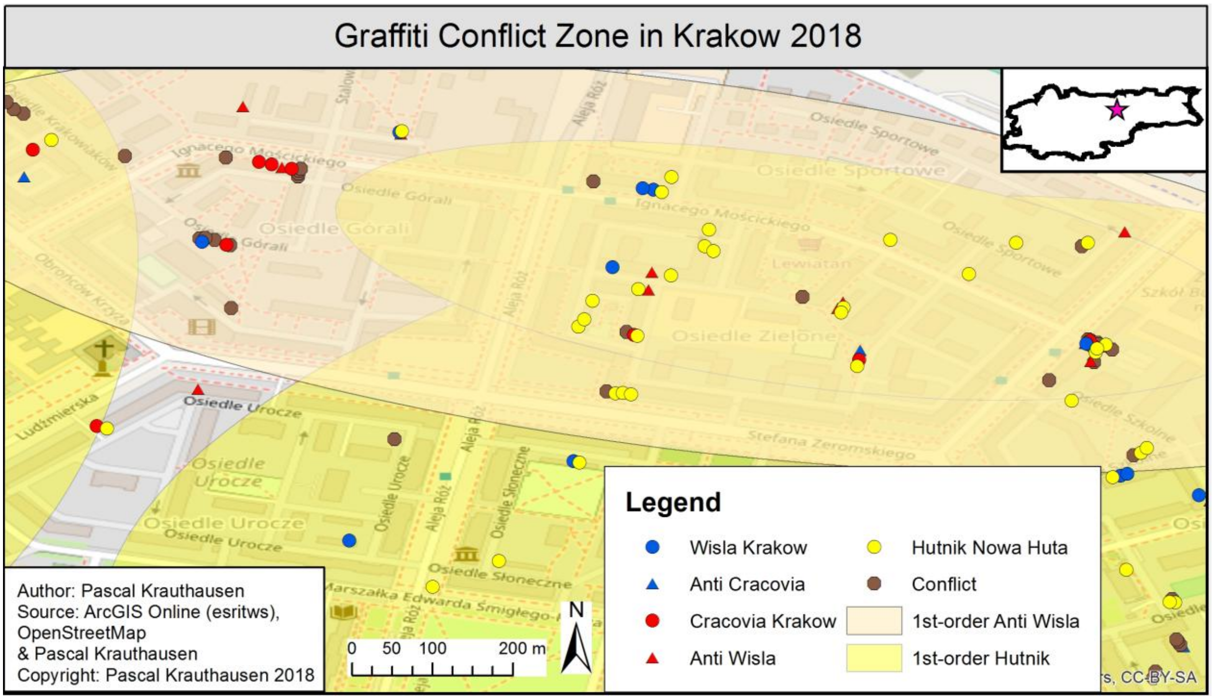



**Figure 32: Graffiti conflict zone in Krakow in 2018**

This chapter verified the existence of graffiti hotspots for different graffiti categories in Krakow in 2018. Therefore, certain areas show tendencies of being dominated by distinct fan sceneries, due to high frequencies of soccer graffiti. Furthermore, some areas are characterized by overlapping hotspots, which may be an indication for conflict zones.

## 4.4 Interpolated Density Maps

Another way of describing the frequency of incidents in the study area is the kernel density interpolation. Its main characteristic is that it generalizes incident locations to the entire study area and not only to ellipses or single points in space. This allows the analyst to interpret the distributional pattern in more detail, because the focus of kernel density maps is not reduced to hotspots or centers of clusters. Consequently, dependent on the use of parameters, the analyst may overcome a loss of information that would be created by selecting certain clusters to identify high frequent places, because other areas with less than the minimum number of incidents would be ignored (cf. LEVINE 2015: 10.1 ff.).

First results concerning density estimates in Krakow are shown in Figure 33. Incidents for all graffiti are interpolated over the whole area by the use of a quartic kernel function. This kernel function uses “a circumscribed circle around the grid cell and weighs near points more than distant points with the fall off being gradual“ (ibid: 10.10). Similar to the normal function, the quartic function weighs events more evenly and tends to smooth the distribution (cf. ibid.). This function will be used for all further kernel density estimation applications. Furthermore, an adaptive bandwidth was chosen, which constantly adjusts the bandwidth’s interval when a minimum number of 100 points is found. The reference grid was generated by CrimeStat and has 400 columns and 151 rows. By applying the kernel density routine, the distance between each of the 60,400 grid cells and each of the 5,098 graffiti incidents was calculated, for each distance the kernel function evaluated, and results summed for each reference cell (cf. ibid.: 10.19).

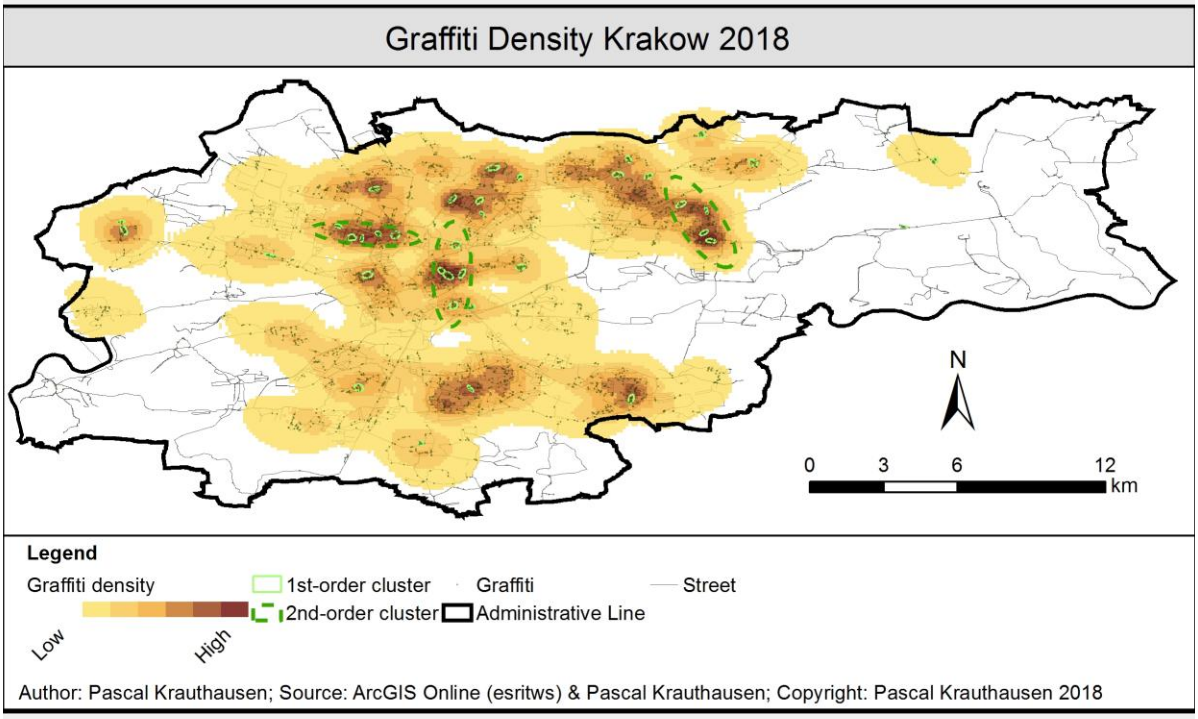



**Figure 33: Graffiti density in Krakow in 2018**

After the calculation in CrimeStat and the import into ArcMap, the density results visualization needed to be adjusted. In the ArcMap document, “Properties – Symbology” is chosen, then the option “Quantities – Graduated Colors”, and, finally, the variable “Z” under the drop down menu “Fields – Value” is chosen. By doing so, each cell is visualized by the corresponding “Z” – value that is included in the attribute table. The “Z”-value was calculated by CrimeStat. Most likely this results in an error message stating that the maximum sample size is reached. This can be solved under “Classify – Sampling” and changing the maximum sample size to a value higher than the amount of grid cells that were calculated by CrimeStat. In this example the maximum sample size is set to 62,000. The default classification method is set to “Natural Breaks (Jenks)”, but the number of classes is increased from five to seven. Differences in density estimates are illustrated by graduated colors, ranging from areas with a high density of graffiti colored in dark brown to areas with low density indicated by no color. Therefore, respective colors are chosen by the “Color Ramp” – option. Finally, the lowest density class is set to “No Color” and outlines of every class are similarly set to “No Color”.

The interpolated density estimation reveals similar patterns as the hot spot methods used before. There exist areas of high density, especially in northern Krakow, which form a similar shape as described by the graffiti belt, previously. To support this assumption the $1^{st}$- and $2^{nd}$-order clusters of all graffiti (green dashed ellipses) are overlaid on the single kernel density estimates. Also, there are three smaller high density peaks in the south and one in the west. The east, according to these kernel density results, is densely populated by graffiti, as well as, the southwest.

Figure 34 shows information about the density of Wisla Krakow graffiti. The only difference concerning the settings is that the minimum sample size of 25 graffiti was set for any adaptive bandwidth interval.  High density areas in this figure appear less dominant, but on the other hand the graffiti are widely spread across the study area in a continuous density, distributed in a similar pattern to the all graffiti densities. Highest graffiti densities are located again in the north.

The Cracovia graffiti density interpolation peaks are especially found in the center of Krakow and in the southern region, which is in compliance with the $1^{st}$- and $2^{nd}$-order clusters (see Figure 35). Whereas, there is no change in the minimum sample size (n=25), the density pattern compared to the Wisla graffiti density shows smaller areas, especially in the north and in the west. Although, the city center is characterized by an increase of densely populated areas, the overall density appears more sparsely.

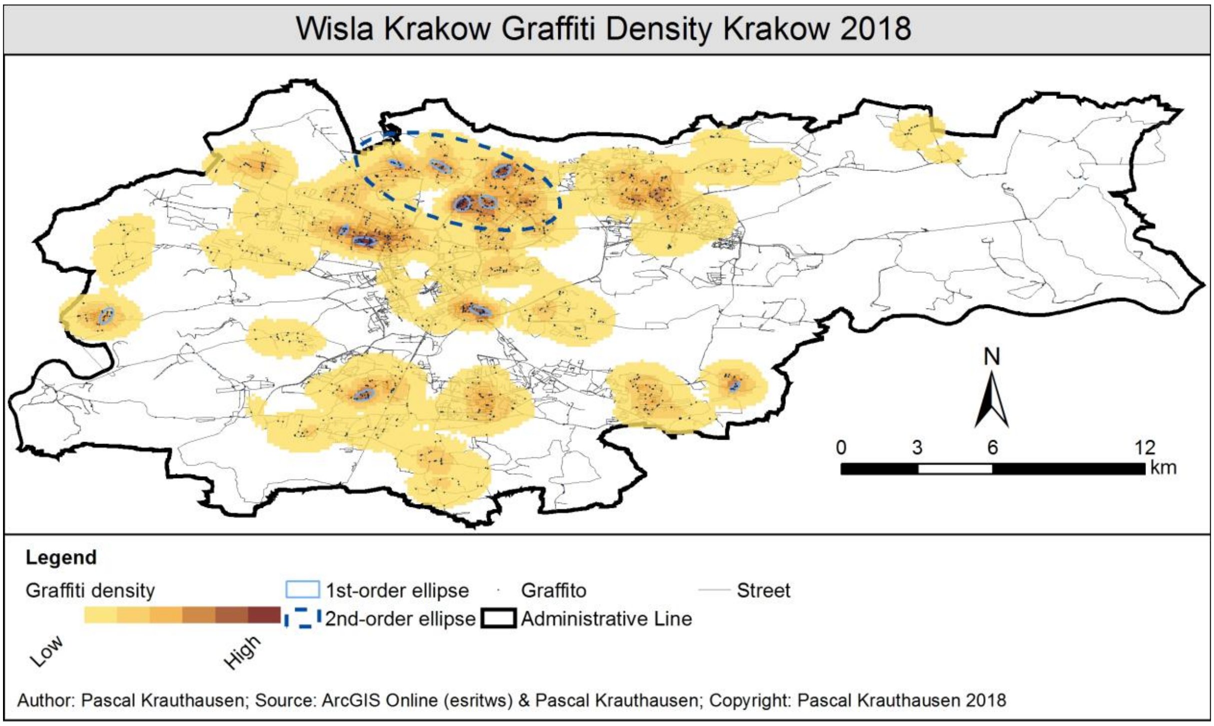



**Figure 34: Wisla graffiti density in Krakow in 2018**

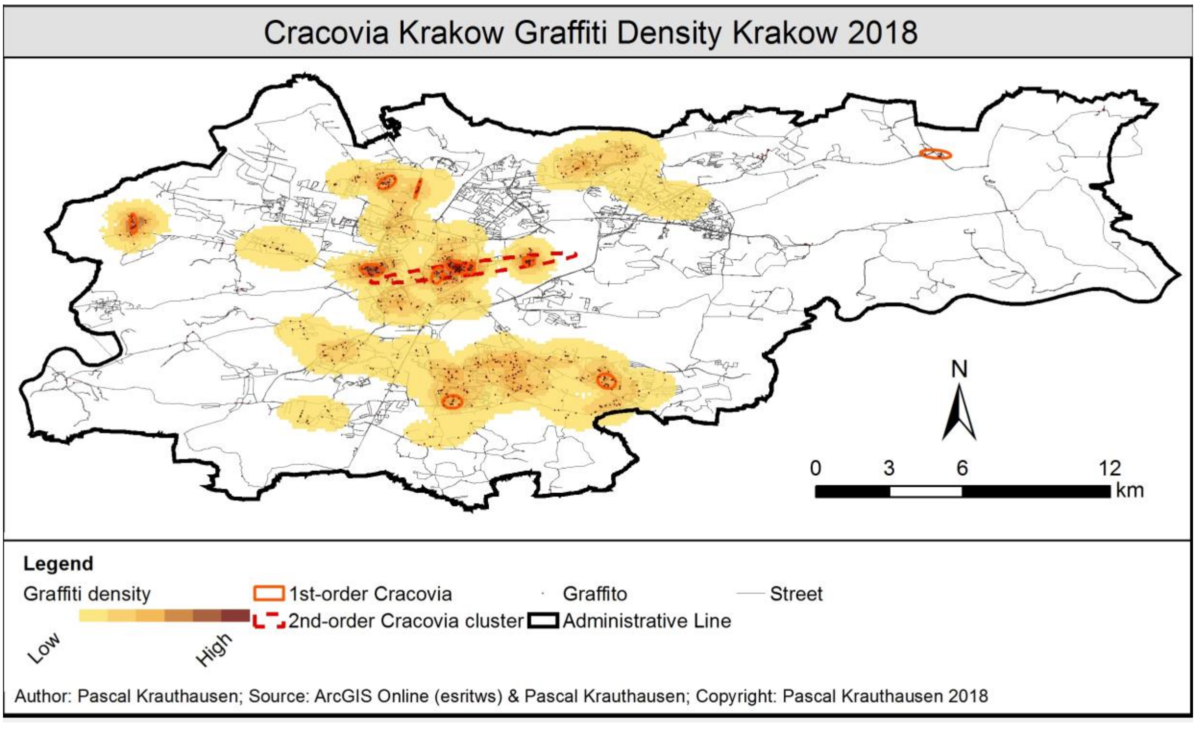



**Figure 35: Cracovia graffiti density in Krakow in 2018**

A more speckled distributional pattern is given by Figure 36, which indicates densities for conflict graffiti and is characterized by a different color range for visualization purposes. In comparison to previous illustrations, no single dominant areas exist that are characterized by high densities, but several smaller hotspots as the 1$^{st}$-order clusters have already previously identified. The same minimum sample size (n=25) as before was applied.

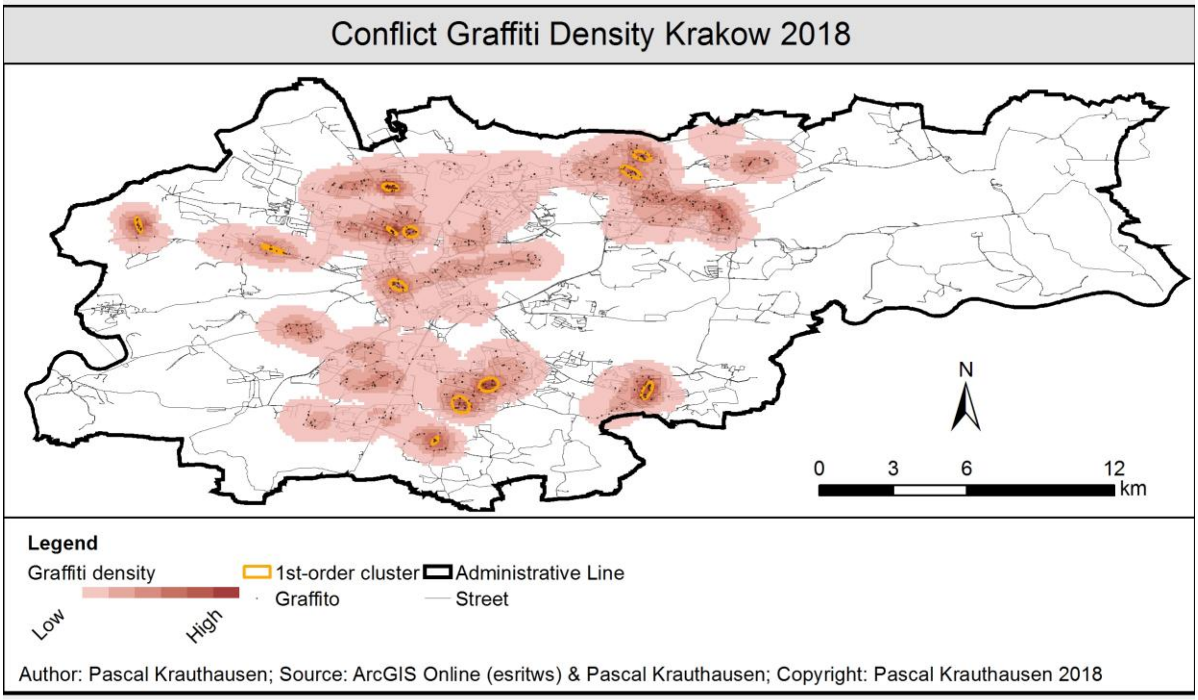



**Figure 36: Conflict graffiti density in Krakow in 2018**

The final kernel density map displays densities for graffiti locations of Hutnik Nowa Huta (see Figure 37). It has the lowest count of graffiti, which is also the reason for reducing the minimum sample size to ten. As a result of the small extent, but yet high density values, density values decrease rapidly. This emphasizes the assumption that Hutnik graffiti are highly clustered in a small part of the study area. The reader of this thesis should be aware that the 2nd-order cluster is based on several 1st-order clusters and does not imply accumulated single incidents. This is important in order to not misinterpret this map, because it only indicates a high concentration of 1st-order clusters without actual referring to the graffiti themselves. Therefore, a great part of this low density area is covered by this higher order cluster, which is, in fact, not densely populated by graffiti.

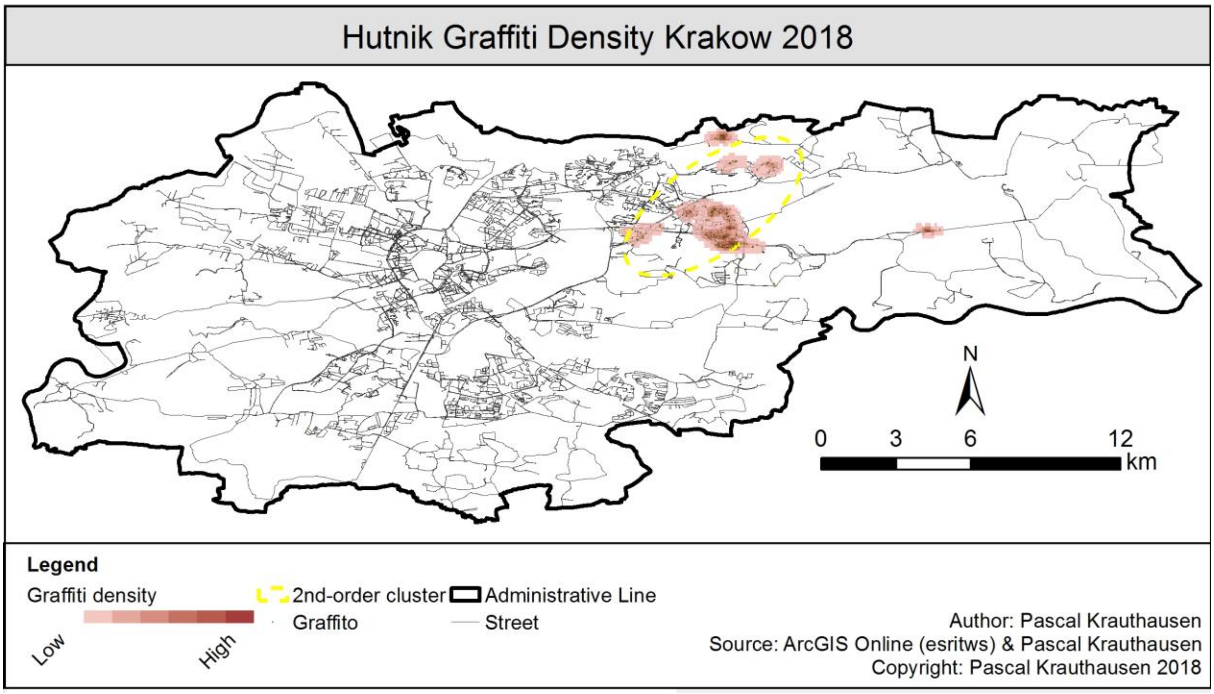



**Figure 37: Hutnik graffiti density in Krakow in 2018**

## 4.5 Comparison of Graffiti Locations between 2016 and 2018

A complete data set of soccer graffiti exists also for the year 2016, which is based on Dr. Trzepacz's research. In order to get additional information about the evolution of soccer-related graffiti in Krakow, both data sets from 2016 and 2018 are compared with each other and analyzed. By doing so, changes in terms of the distributional pattern are developed, which may be helpful for future research in terms of risk modeling. The analyses encompass the same spatial and statistical methods that were applied in the previous subchapters. To begin with, differences between both data sets, as well as, other annotations regarding the data set of 2016 are presented next.

Table 6 lists the counts per graffiti category for both the 2016 and the 2018 data sets. The 2016 data set counts 489 fewer incidents, than the data set of 2018 and except from the Hutnik graffiti, the counts of all other graffiti categories do differ strongly. There are mainly two reasons that explain these differences. First, due to the difference in the overall count of the graffiti, some categories of the 2016 data set need to have less graffiti. The second reason is a different graffiti categorization, especially when graffiti are counted as anti-graffiti, respectively when they are allocated to either Wisla or Cracovia. The original data set of Dr. Trzepacz did not include Anti Wisla or Anti Cracovia categories, but for the purpose of comparison, such categories were invented afterwards. Therefore, categories of Wisla and Cracovia were searched for distinct anti-graffiti and added to the respective category, if the described content of the digitized graffiti allowed it. Despite differences in the overall counts for each graffiti category, there are also similarities to the 2018 graffiti data set. For example, Wisla graffiti are again the most frequent and also Cracovia graffiti show high counts. Anti Cracovia graffiti, which are more likely made by Wisla supporters than by Hutnik supporters, have higher counts compared to Anti Wisla graffiti.

| Data set | Count | Wisla | Cracovia | Hutnik | Conflict | Anti Cracovia | Anti Wisla | Other | Anti Hutnik |
|---|---|---|---|---|---|---|---|---|---|
| **2016** | 4,609 | 1,855 | 1,345 | 314 | 522 | 313 | 174 | 86 | 0 |
| **2018** | 5,098 | 1,521 | 1,075 | 304 | 1,154 | 608 | 402 | 29 | 5 |

**Table 6: Graffiti data sets for Krakow in 2016 and 2018; Data source: Own data & Dr. Piotr Trzepacz**

In terms of the general distributional pattern of the 2016 graffiti, there are no striking differences as Figure 38 illustrates. The different methods of centering the graffiti distribution per category show that most graffiti have their centers slightly east of the Stare Miasto district, similar to those of the 2018 graffiti data, with the exception of Hutnik graffiti, which are located far more east. Wisla's, and respectively Anti Cracovia's graffiti centers are located more to the north, whereas those of Cracovia and Anti Wisla tend to be located more in southern areas. The center of conflict graffiti is located between both rivaling categories.
Similar results to 2018 are also found by depicting standard deviational ellipses of graffiti categories from 2016 (see Figure 39). Accordingly, the graffiti that are widest spread out can be associated with Wisla supporters, whereas Nowa Huta graffiti are strongly spatially clustered, which is indicated by the shortest major axis of all graffiti categories. It is clearly visible that all graffiti categories in 2016 have their main distributions along the major axes of the ellipses, which are oriented almost east-west, following the shape of the city outline.

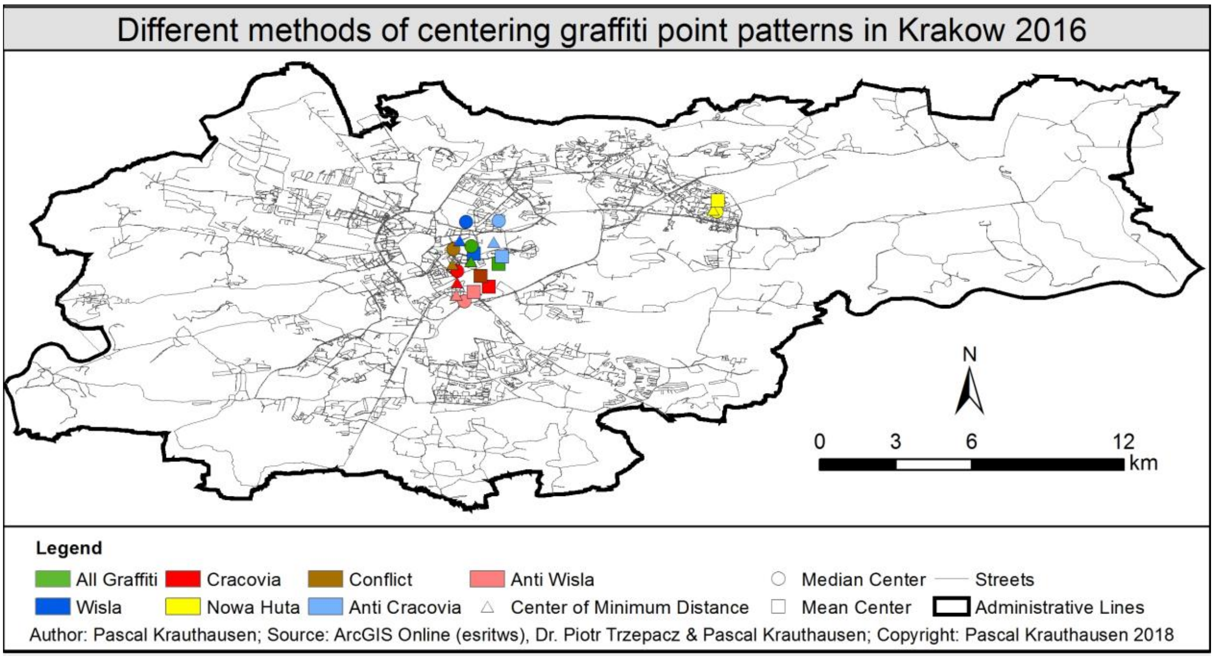



**Figure 38: Centering Methods of Graffiti 2016**

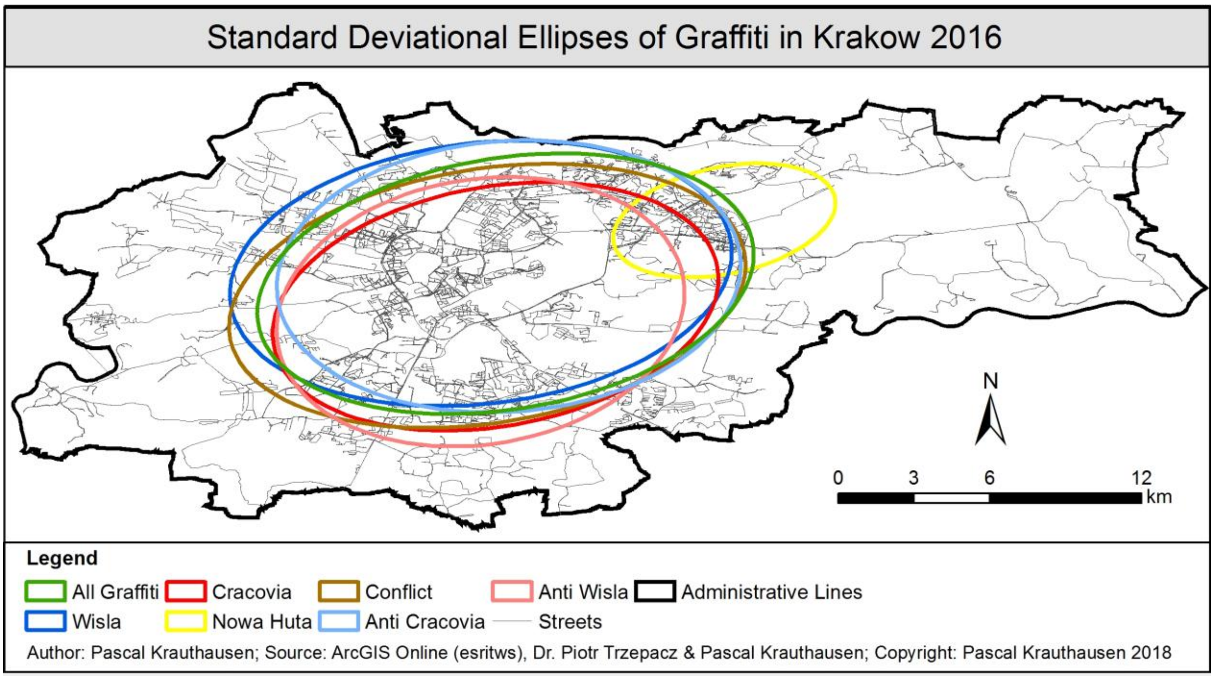



**Figure 39: Standard Deviational Ellipses 2016**

The general information about spatial centers and dispersions of graffiti patterns discussed previously are further supported by Table 7. The NNA for the 2016 graffiti data set indicates that all graffiti locations are spatially concentrated, because all NNI values are less than 1.0. The lowest index is achieved for the "all graffiti" category (0.2788), followed by Cracovia graffiti (0.3043). The highest index is calculated for Anti Cracovia graffiti (0.5189). Graffiti of Hutnik Nowa Huta are also spatially concentrated, but not to the degree as the graffiti data for 2018 (0.1936). Cracovia graffiti have almost the same NNI as Hutnik graffiti, which indicates that both are similarly spatially concentrated. The previously asserted high spatial variability of Cracovia graffiti (compare the standard deviational ellipse in Figure 39) must therefore be augmented by being at the same time highly concentrated. In contrary to Cracovia graffiti, those defined as conflict graffiti tend to be less spatially concentrated as in the 2018 graffiti survey, which is mainly due to a lower graffiti total in 2016 and similar spatial variabilities between the 2016 and 2018 graffiti distributions.

| **Category** | all graffiti | Anti Cracovia | Anti Wisla | conflict | Cracovia | Hutnik | Wisla |
|---|---|---|---|---|---|---|---|
| **Mean nearest neighbor distance (m)** | 43.47 | 291.01 | 362.70 | 178.86 | 83.96 | 124.97 | 80.36 |
| **Mean random distance (m)** | 155.89 | 560.80 | 727.13 | 450.64 | 275.94 | 406.98 | 245.35 |
| **Nearest neighbor index** | 0.28 | 0.52 | 0.50 | 0.40 | 0.30 | 0.31 | 0.33 |
| **Standard error (m)** | 1.20 | 16.57 | 28.81 | 10.31 | 3.93 | 12.01 | 2.98 |
| **Test Statistic (Z)** | -93.66 | -16.28 | -12.65 | -36.36 | -48.81 | -23.49 | -55.41 |
| **p-value (one tail)** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **p-value (two tail)** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Table 7: Nearest neighbor analysis for different graffiti categories in Krakow in 2016; Data source: Dr. Piotr Trzepacz**

The creation of hotspots can be accomplished with the spatial mode, which is illustrated by Figure 40. The sixteen most frequent graffiti locations of all collected graffiti are highlighted by small green octagon symbols, which are labeled with the amount of graffiti at these coordinates. These 16 spatial modes from 2016 possess the same maximum and minimum number of graffiti as were found for the 2018 graffiti data set. The highest count of eight graffiti appears only once, whereas locations with a count of seven are detected five times. Locations with counts of six graffiti occur most frequently, namely ten times. The top spatial modes appear in the south, which is supposed to be dominated by Cracovia and Anti Wisla graffiti. There are also two spatial modes close to the Nowa Huta district, which are dominated by Hutnik Nowa Huta. In comparison to the most frequent graffiti locations in 2018, there are fewer spatial modes in the northern area and no spatial modes in the east or in the west of Krakow. Therefore, this pattern indicates that single locations with highest counts of graffiti are more densely distributed, than in 2018.

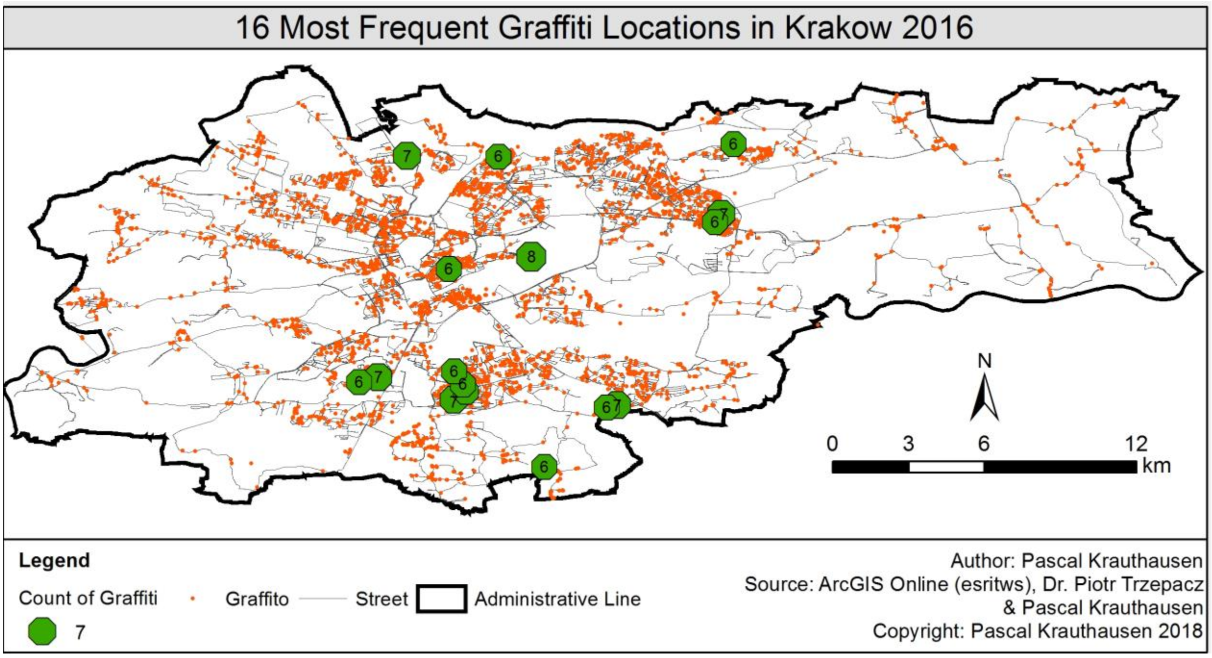



**Figure 40: Most frequent graffiti locations as measured by the spatial mode in Krakow in 2016**

The next method to analyze the data set is the spatial fuzzy mode, which allows the analyst to apply a search radius in order to accumulate single graffiti locations that are spatially close. In this analysis, the same radius (i.e., 200m) as previously selected for the 2018 graffiti data set is applied. The resulting spatial fuzzy mode locations for a 200m search radius for Krakow in 2016 are depicted by Figure 41. Top spatial fuzzy modes are primarily located around the Stare Miasto district and in the north of Krakow, where all categories except “Hutnik” are represented (red rectangle). The latter are – as previous analyses have revealed – located in the Howa Huta district or close to it, which is in accordance to the findings of 2018. Spatial fuzzy mode locations also appear south of Krakow’s center, which was not apparent in the 2018 data set. In order to get a more detailed view on the specific locations of these spatial fuzzy modes, the second map in Figure 41 shows all spatial fuzzy modes inside the red rectangle at a larger scale.

The distinction between hotspots of Wisla and Anti Cracovia on the one hand, and Cracovia and Anti Wisla graffiti on the other, are again recognizable but not as clearly divided into two distinct areas (i.e., north and south) as in 2018. In fact, spatial fuzzy mode locations of Wisla and Anti Cracovia graffiti did not change a lot, but a new hotspot of Anti Wisla graffiti is located in the northwest, which was formerly dominated by conflict graffiti. The spatial concentration of conflict graffiti is located more to the south compared to the 2018 graffiti data set, whereas spatial fuzzy modes for the Cracovia category is very similar to 2018.

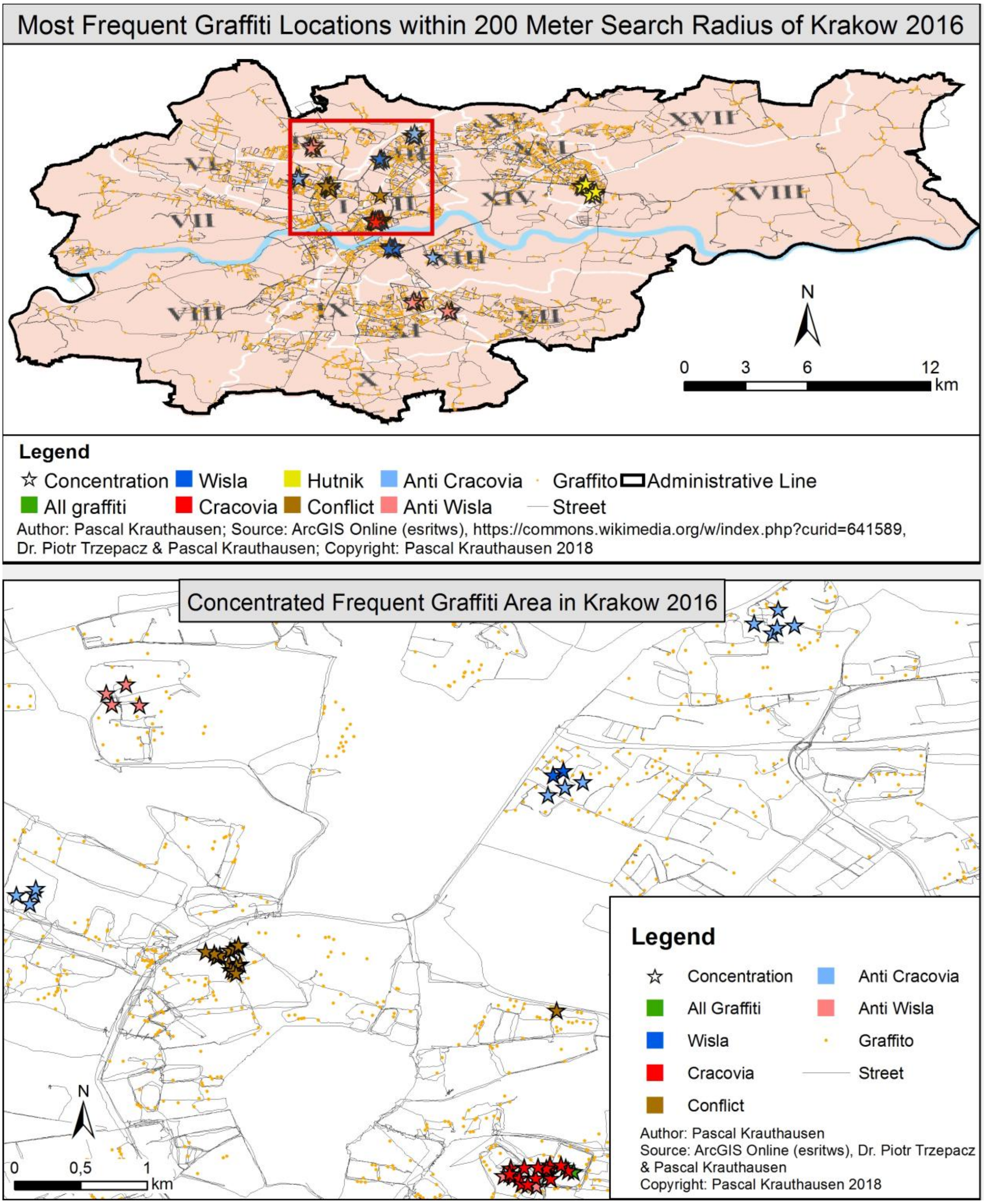



**Figure 41: Spatial fuzzy mode map in Krakow in 2016**

The background data that were used to visualize all spatial fuzzy modes for the 2016 graffiti data set are provided in Table 8. The fifteen highest counts were aggregated to create distinct spatial concentrations for each graffiti category with selected highest graffiti counts listed in this table. Spatial fuzzy modes with highest frequencies fall into the “all graffiti” category, followed by Cracovia, which have both a higher frequency for each spatial fuzzy mode when compared to the 2018 data set. Frequencies of all other categories have increased from 2016 to 2018. Another assumption that was made about the 2018 results was that Cracovia graffiti are more spatially clustered compared to Wisla graffiti due to higher frequencies and a lower overall count of graffiti. In 2016, this finding is even more apparent, since both, overall count and frequencies for Cracovia graffiti are approximately 20 percent higher compared to 2018, but in contrary, overall counts for Wisla graffiti are 19% higher, whereas frequencies are 12.5 percent lower, compared to the 2018 data set. Consequently, Wisla graffiti were spatially more dispersed in 2016 compared to 2018, whereas the distribution pattern of Cracovia graffiti did not change significantly.

| **Category** | All Graffiti | Wisla | Cracovia | Hutnik | Anti Cracovia | Anti Wisla | Conflict |
|---|---|---|---|---|---|---|---|
| **Count** | 4609 | 1855 | 1345 | 314 | 313 | 174 | 522 |
| **Highest frequency** | 68 | 32 | 53 | 30 | 7 | 7 | 17 |
| **2. highest frequency** | 67 | 31 | 52 | 29 | 7 | 7 | 17 |
| **3. highest frequency** | 63 | 30 | 50 | 29 | 7 | 7 | 17 |
| **4. highest frequency** | 62 | 30 | 48 | 28 | 7 | 6 | 17 |
| **5. highest frequency** | 62 | 29 | 47 | 28 | 7 | 6 | 17 |

**Table 8: Spatial fuzzy modes in Krakow in 2016; Data source: Dr. Piotr Trzepacz**

NNHC results for each graffiti category are presented next and such created hotspots for the “all graffiti” category for 2016 are displayed in Figure 42. NNH clusters are based on a random nearest neighbor distance threshold with a probability level of p=0.05. The minimum number of graffiti that forms a cluster is set to 20 graffiti locations. Each cluster is visualized as an ellipse with 1.5 standard deviations. In total, the map displays 14 clusters, including twelve first-order and two second-order ellipses. Results define two distinct areas with graffiti hot spots and both are located close to each other in the center of Krakow around the Stare Miasto district. A coherent formation comparable with the graffiti belt that has been defined in Figure 27 is not as clearly distinguishable with the 2016 graffiti data. However, when combining individual graffiti incidents together with the NNH clusters, then an area with high graffiti occurrences resembles the graffiti belt, as identified with the 2018 data set.

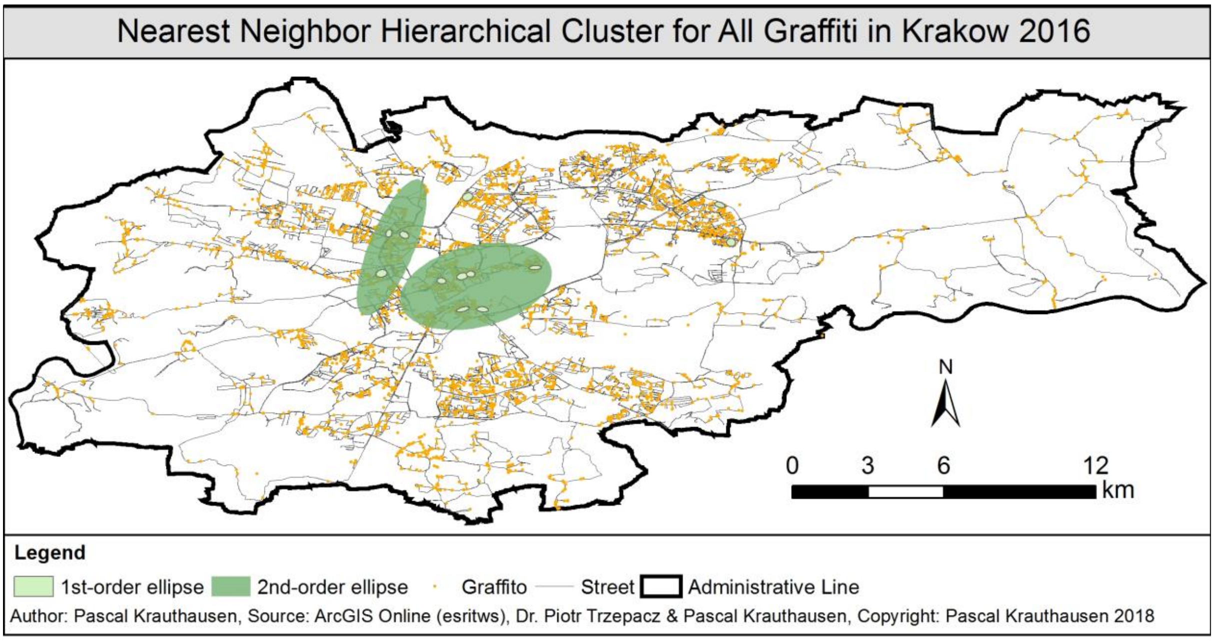



**Figure 42: Nnh cluster for the "all graffiti" category in Krakow in 2016**

To get a first overview of graffiti conflict zones in 2016, Figure 43 depicts clusters for the "conflict graffiti" category. The minimum sample size of graffiti was set to eight. One 2nd-order cluster and five clusters of 1st-order build an area of high concentration in the center of Krakow. In addition, an area south of the center is characterized by six 1st-order clusters and two more clusters are located in the north-east. This pattern is characterized by a wide spatial dispersion, which is similar to the dispersion of conflict graffiti in 2018.

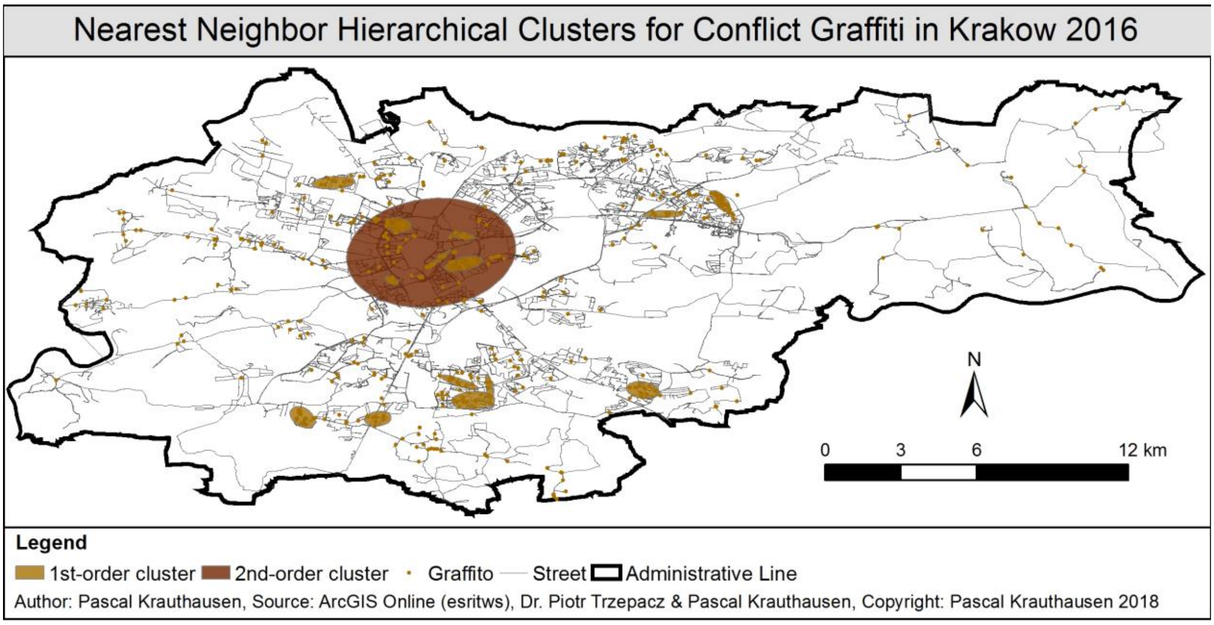



**Figure 43: Nnh for conflict graffiti in Krakow in 2016**

All clusters for different graffiti categories that are created by CrimeStat are summarized by Table 9. In order to compare clusters from both years, parameters were chosen so that the total amount of clusters is about equal for each graffiti category. The only exception constitutes clusters for the “all graffiti” category, which differ greatly. The previously suggested existence of a highly spatially concentrated area of graffiti can be confirmed for the 2016 data, as well, when Figure 44 is examined. There are three major spatial graffiti accumulations, which are leading to this assumption. One 2nd-order cluster of Cracovia graffiti is located slightly south-east of the city center, where also some 1st-order clusters of Wisla and Anti Cracovia graffiti are bordering, indicating a conflict zone. The second big hotspot is located around the Nowa Huta district in the north-east. This hotspot can be allocated to Hutnik graffitists, but it also coincides with smaller Wisla and Anti Cracovia clusters. These two 2nd-order clusters are connected by two second order clusters of Wisla and Anti Cracovia graffiti. In summary, the 2016 graffiti data indicate a similar distribution of dominated graffiti regions in Krakow as the data set of 2018 insofar as Cracovia graffitists are very active in the south, whereas Wisla supporters show most of their affiliation in northern Krakow, and the area dominated by Hutnik graffiti is located in the north-east.

| | All graffiti | Wisla | Anti Cracovia | Cracovia | Anti Wisla | Conflict | Hutnik |
|---|---|---|---|---|---|---|---|
| **1st-order count** | 12 | 15 | 15 | 14 | 9 | 14 | 8 |
| **2nd-order count** | 2 | 1 | 1 | 1 | 0 | 1 | 1 |
| **minimum sample size** | 20 | 15 | 5 | 15 | 5 | 8 | 10 |

**Table 9: Results of NNH clusters in Krakow in 2016; Data source: Dr. Piotr Trzepacz**

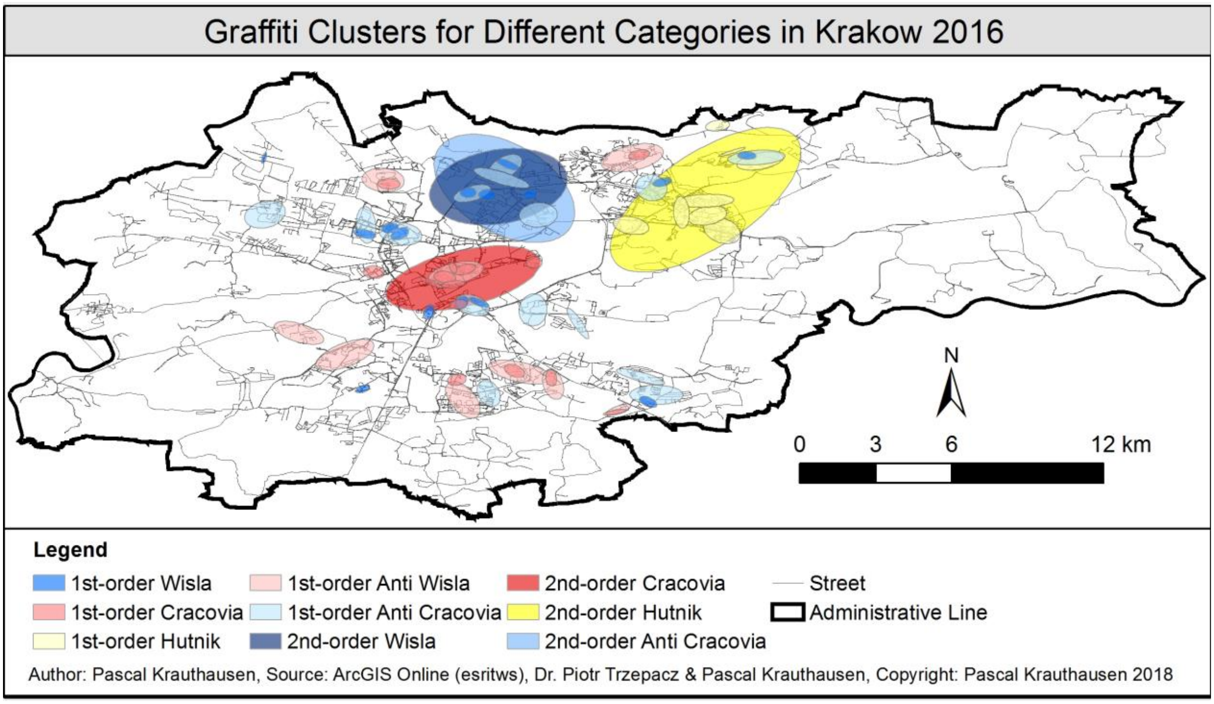



**Figure 44: Nnh clusters for different graffiti categories in Krakow in 2016**

Graffiti densities for different categories in 2016, which are interpolated over the entire study area, are examined next. The quartic function was applied for all kernel density maps, as well as the same reference grid from 2018, which covered Krakow by 60,800 grid cells. Additionally, 1st- and 2nd-order clusters of the respective graffiti category are added. To begin with, Figure 45 shows density estimates for all graffiti, which are depicted by the minimum sample size of 100 incidents. High density areas match with ellipses from the NNH clusters.

However, the kernel density map also reveals additional spatial concentrations in the south, where no clusters are located. Furthermore, the kernel density routine nicely points out the graffiti belt, which is indicated by graduated colors that coalesce in the northeast of the city center. Compared with the 2018 density map, the 2016 map is less stretched and there are no accumulations in the east or in the west.

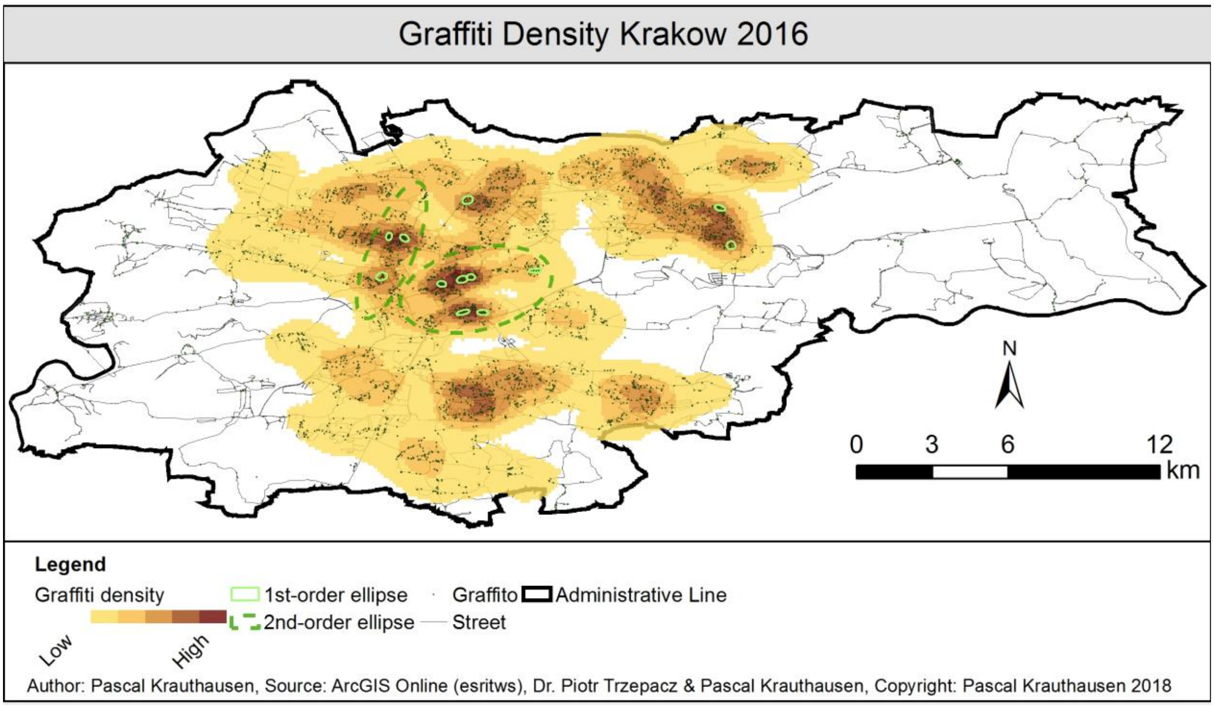



**Figure 45: Overall graffiti density in Krakow in 2016**

For density estimates of Wisla graffiti, which are depicted in Figure 46, the minimum sample size is reduced to 25. The pattern highlights several high density areas with the most distinct being located in the north, which is surrounded by a $2^{nd}$-order cluster. Accordingly, Wisla graffiti are strongly present in different regions and are dispersed almost throughout the entire city. Nevertheless, the spatial pattern appears speckled, due to weakly or low frequented areas in between. Differences to the 2018 density map are not conspicuous, but slightly noticeable in the east, west and in the south, where more low density areas are visible.

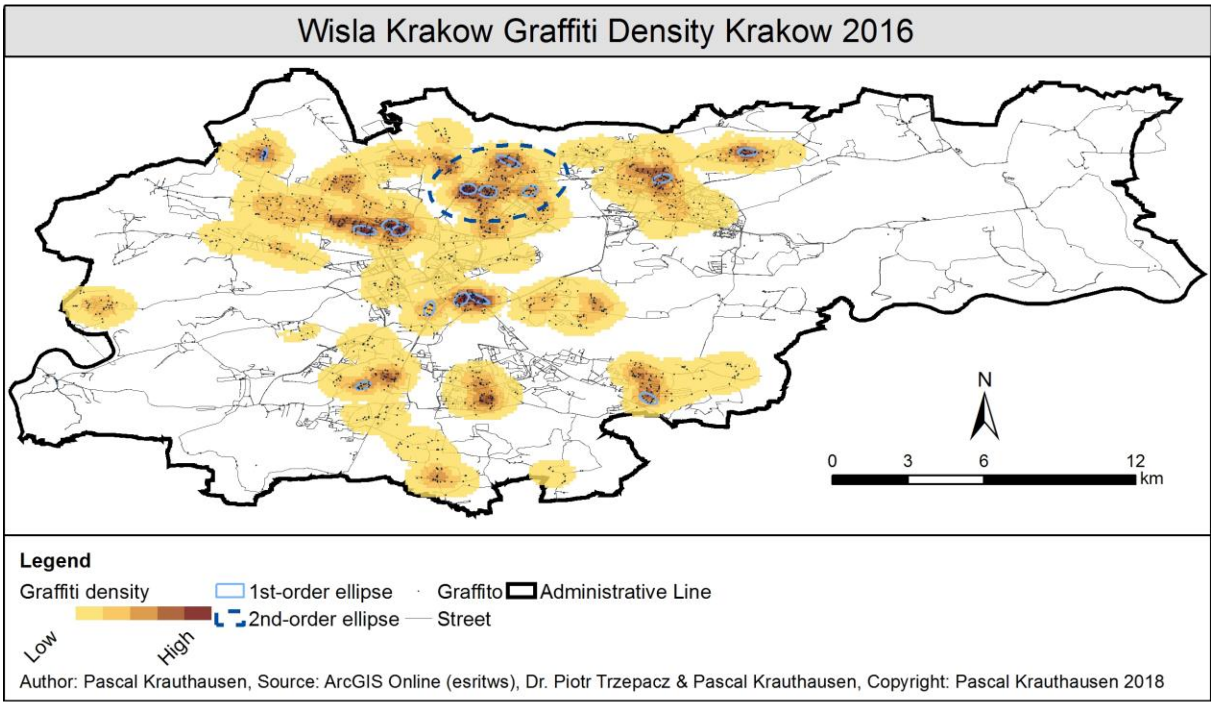



**Figure 46: Wisla graffiti density in Krakow in 2016**

The minimum sample size for Cracovia graffiti density estimates is defined by 25 incidents. Results are illustrated in Figure 47. High graffiti density areas are foremost located in the central area, as well as in the south. Some minor hotspots can be identified in the north and north-east, as well as in the west. The overall extent of density estimates is smaller, despite a bigger count of graffiti locations in comparison to the 2018 data set, which indicates a higher spatial concentration of graffiti.

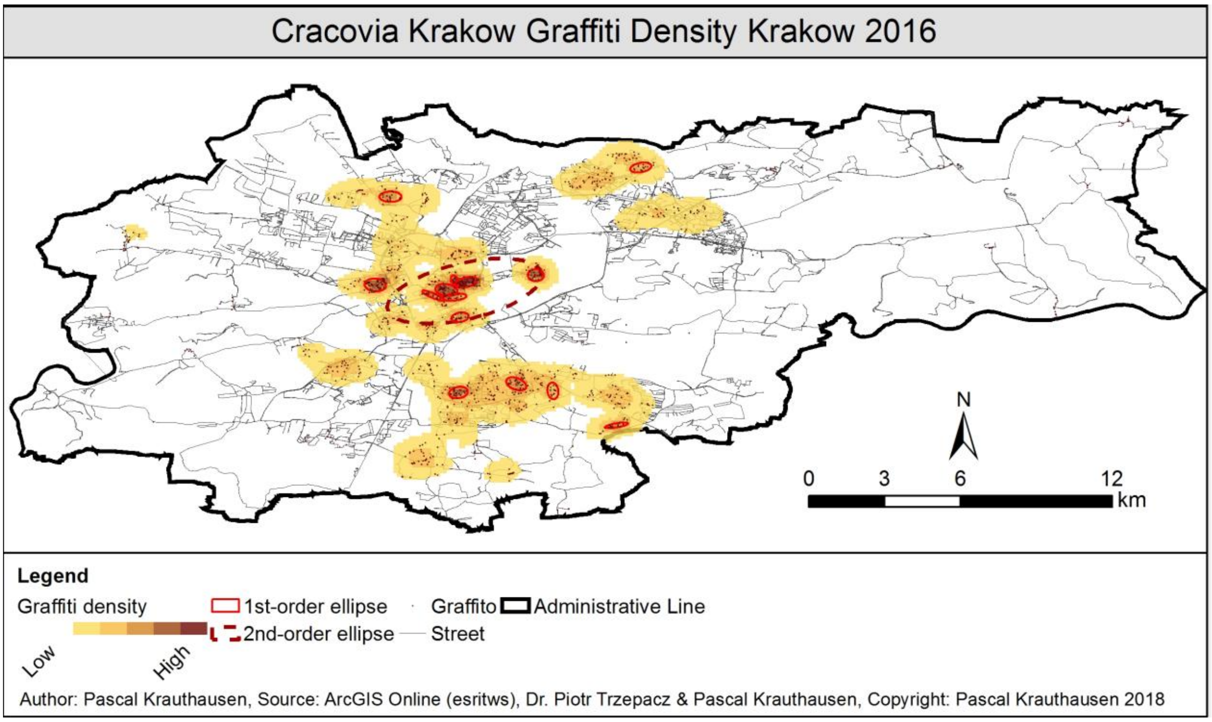



**Figure 47: Cracovia graffiti density in Krakow in 2016**

Overall counts of the "conflict graffiti" category changed the most, when both years are compared with each other (see Figure 48). The minimum sample size chosen for this category is 10 incidents. Similar to density estimates of Wisla graffiti, the spatial pattern of "conflict graffiti" appears speckled, with lower density grid cells being linked together. This kernel density map is substantiated by comparison with the 2018 density map, where only four distinct areas were distinguishable and the biggest hotspot covered a large area of Krakow. In 2016, there are eight (nine, if the very small hotspot in the west is also counted) distinct hotspots, which are all much smaller than the biggest hotspot in 2018.

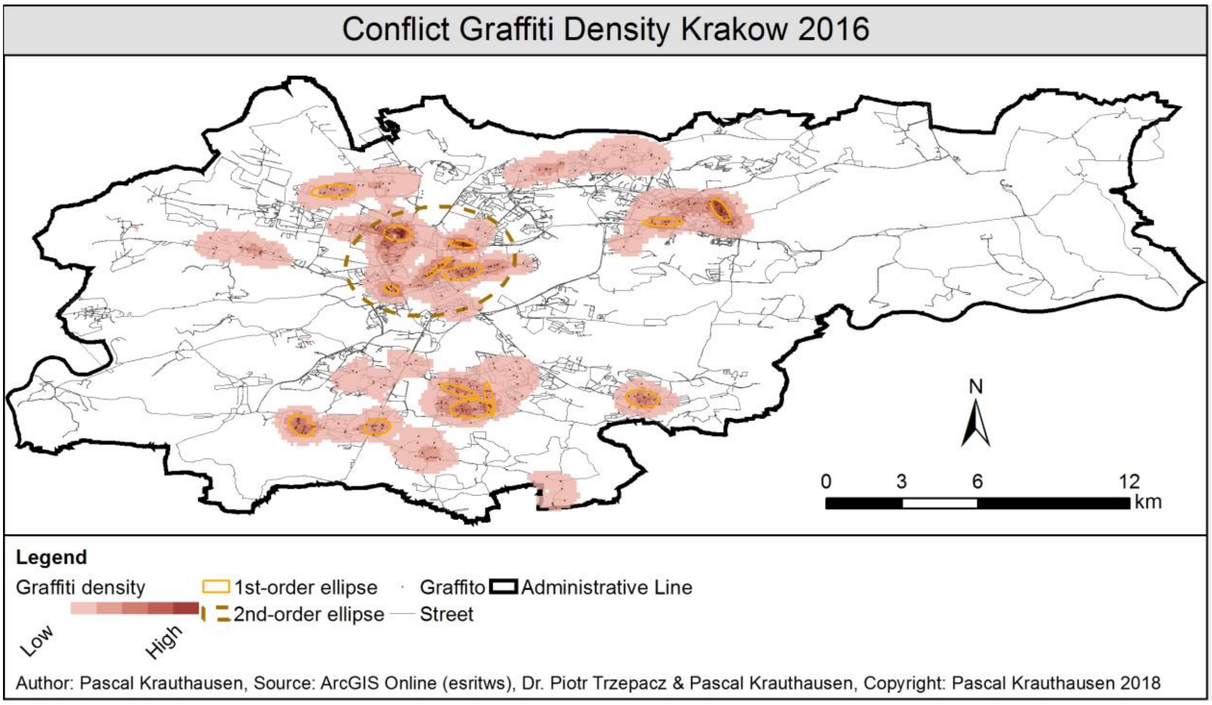



**Figure 48: Conflict graffiti density in Krakow in 2016**

The final map (Figure 49) illustrates density estimates for Hutnik graffiti in 2016. It is noticeable that the pattern barely changed compared to the 2018 pattern. In both years a minimum sample size of 10 was applied and the amount of distinct graffiti density hotspots stayed stable with four unlinked areas.

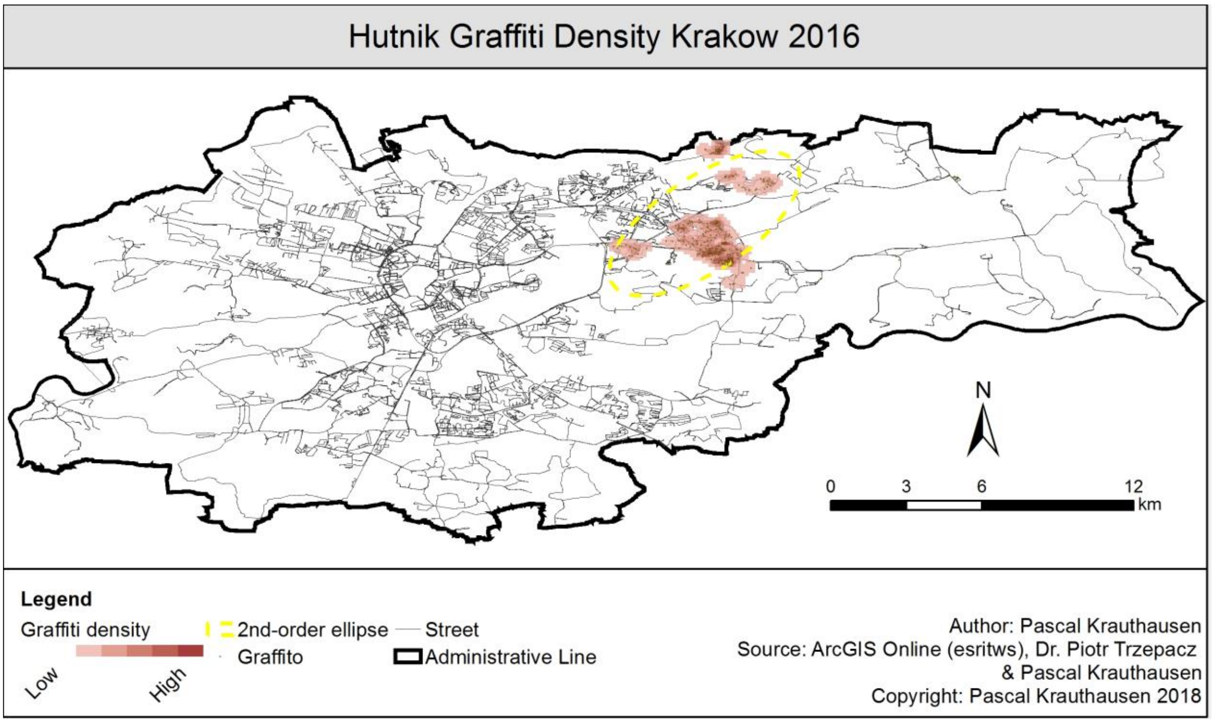



**Figure 49: Hutnik graffiti density in Krakow in 2016**

This subchapter observed the graffiti data from 2016 and highlighted differences and similarities concerning the general distributional pattern and hotspots compared to the 2018 graffiti data set. Besides differences regarding the counts of graffiti for each individual category across Krakow and minor spatial displacements concerning the locations of hotspots, the overall distributional pattern remained steadily between 2016 and 2018. Hence, in 2016, the north of Krakow was already dominated by Wisla graffiti, the south by Cracovia graffiti and the east by Hutnik graffiti, similar to what the analysis of the 2018 graffiti data revealed.

## 4.6 Crimes and Graffiti

In previous subchapters, graffiti for two different years were analyzed regarding both their distinct distributional pattern and their similarities/differences between 2016 and 2018. In the following, it is analyzed whether crime locations spatially correlate with locations of graffiti. For this reason, an open source crime data set from October 2016 until June 2018 that contains geo-referenced crime data is compared with graffiti data for 2018. The data is derived from a publicly accessible webpage, where users are able to report criminal behavior by adding them into a national security threat map (cf. Krajowa Mapa Zagrozen Bezpieczenstwa). These committed crimes can be divided into 5 categories, including acts of vandalism (317 incidents), alcohol consumption in prohibited places (493 incidents), gathering of juveniles engaged in anti-social behavior (52 incidents), homelessness (57 incidents), and begging (48 incidents).

In order to compare both data sets, all committed crimes are combined into one single point shapefile. Next, their 1$^{st}$-order clusters are calculated with a minimum sample size of 20 incidents and a p-value of 0.05 (pink ellipses in Figure 50). Finally, both shapefiles (crime locations and crime clusters) are overlaid on top of the kernel density estimates of all graffiti locations of 2018 and shown in Figure 50. Results show that eleven of the twelve 1st-order crime hotspots are located in areas of at least medium to high graffiti density. One crime outlier is located in the west, where very low graffiti density estimates can be found. Additionally, 1st-order graffiti clusters are illustrated by green ellipses Figure 50, too. There are three hotspots, where 1st-order clusters of both, graffiti and crimes, overlap, and another two instances, where graffiti and crime clusters are spatially close.

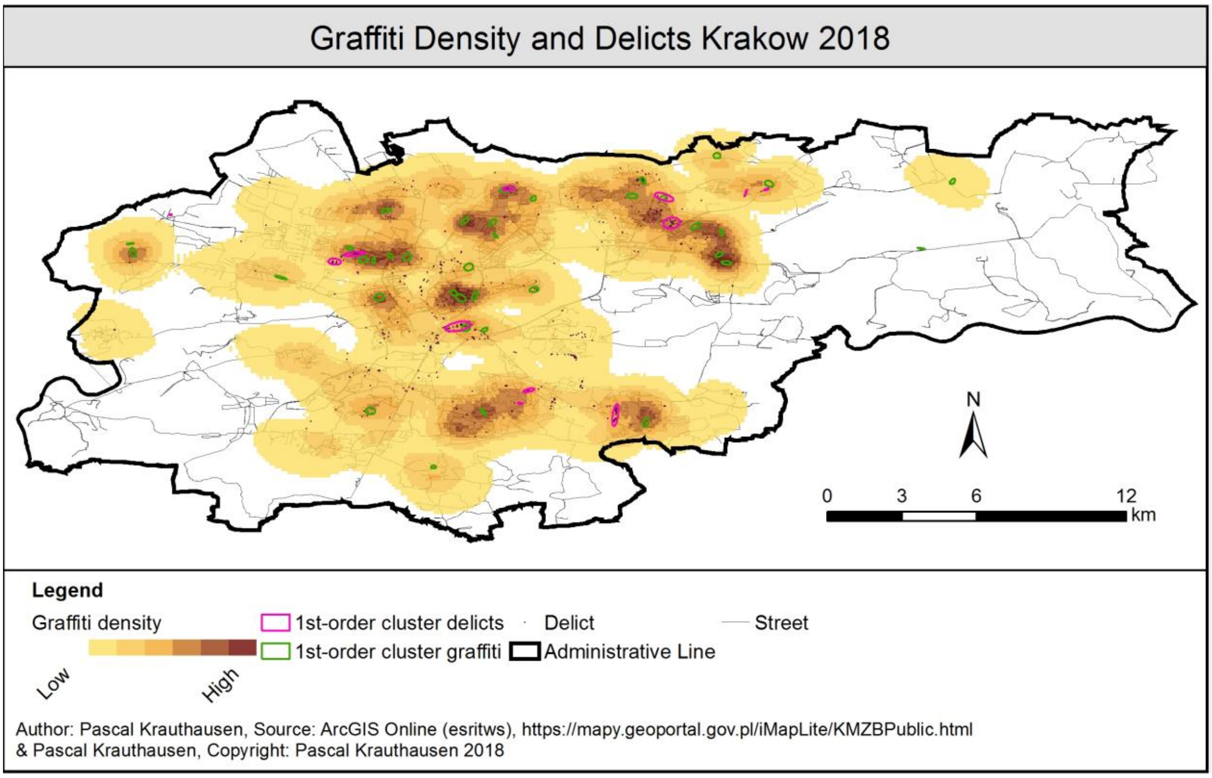



**Figure 50: Spatial distribution of graffiti and delicts in Krakow in 2018**

Figure 51 illustrates the 1st-order cluster with the highest counts of crimes – 87 in total – which intersects with a 1st-order graffiti cluster that counts 53 incidents. For the purpose of orientation, the OpenStreet map layer is used as the base of the map. Most delicts are located around a couple of supermarkets and stores, which are close to a public bus stop and several parking areas. The second highly frequented place is a park located approximately 100 meters to the east. The graffiti are dispersed around the delicts and mostly concentrate around an Aldi supermarket in the southeast. All single crime and graffiti incidents are concentrated within walking distance.

Another example of committed crimes being spatially close to graffiti hotspots is shown in Figure 52. In this figure there are 38 delicts and 61 graffiti locations within a couple of hundred meters. Delicts are again crowded around shopping facilities and encircled by two 1st-order clusters of graffiti. This second example also indicates a pattern of spatial differentiation regarding the location of delicts and graffiti. In both figures, delicts are highly concentrated, whereas the graffiti are more spatially dispersed.

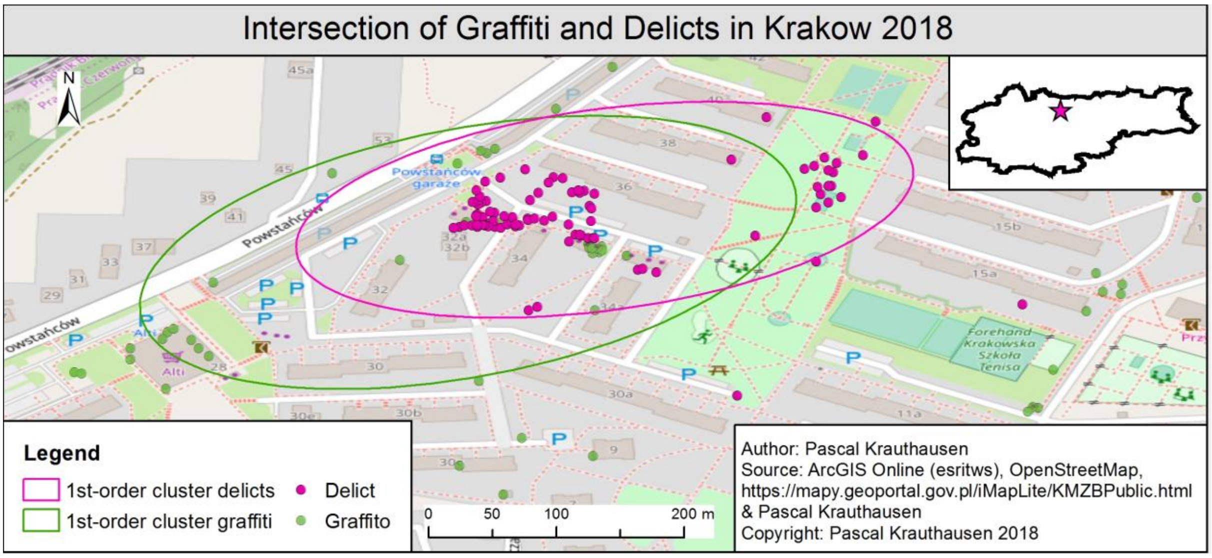



**Figure 51: Intersection of graffiti and delicts in Krakow in 2018**

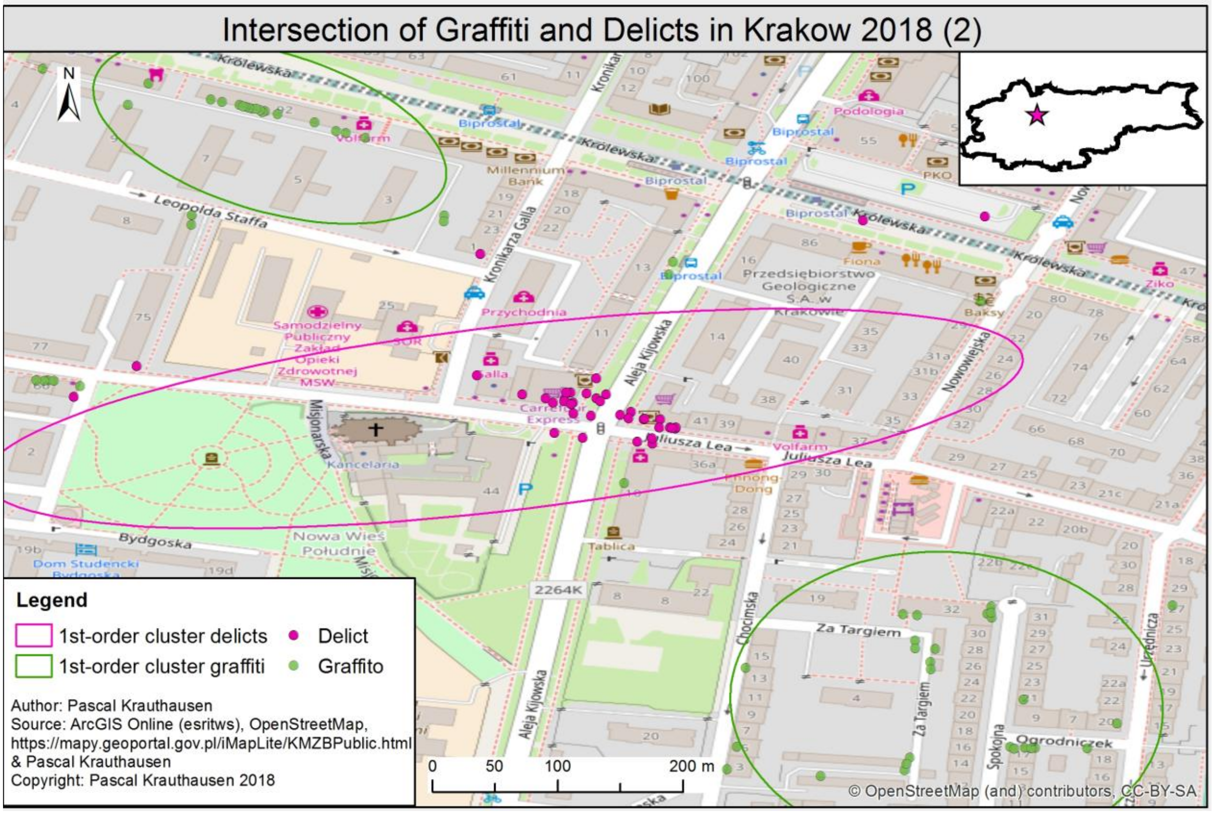



**Figure 52: Intersection of graffiti and delicts in Krakow in 2018 (2)**

The comparison of both data sets revealed first tendencies that criminal behavior and graffiti locations may show a spatial relationship with each other, since eleven of the twelve 1$^{st}$-order clusters of delicts are located in at least medium to high graffiti density areas. Both examples of overlapping clusters are supporting this trend. Further support could be achieved by analyzing alternative crime data that are officially collected by the police.

# 5 Conclusion and Future Research

This chapter summarizes the methodological approaches and main findings, and focuses on answering the research questions. Furthermore, it gives recommendations concerning the conduction of projects, which apply the spatial video acquisition technology and suggests the need for further research in the field of geospatial graffiti analysis.

The main goal of this thesis was to create a “Graffiti-GIS” for the city of Krakow with which soccer-related graffiti data can be stored, modeled, visualized, and analyzed. All data from 2018 were collected by applying the SVAS technology, which was provided by Prof. Dr. Michael Leitner. This technology consisted of several Contour+2 Action Cameras Model 1700 of the company “Contour”, which are able to record video files in HD quality, are equipped with a 170 degree wide angle lens, and a GPS receiver. The latter technology is used for locating the recorded graffiti data on a map in a GIS environment. During each field trip, a car was used as the transport vehicle, where three cameras were mounted, two on each side of the backseat’s windows, as well as one on the front screen. In order to ensure efficient survey trips, the routes had to be planned and adjusted to the driving of a car, because the original routes were provided by Dr. Trzepacz, who conducted a research on soccer-related graffiti in Krakow in 2016 by collecting data on a bicycle. These same routes were covered again in this research. In total, 31 routes inside the city boundary of Krakow were adjusted for the purpose of navigation, which consists of 777 PDF slides. During the 31 surveys, the cameras produced 2,082 GB of video material, which equals an amount of 347 hours of video recording. The videos are stored on hard drives and mini SD cards.

The process of extracting the data from the videos was accomplished with the software program Contour Storyteller, which is also produced from the company Contour. Users are able to process various video formats with this program and generate .gpx-files, which are embedded in the videos, based on the integrated GPS receiver in each camera. Due to different factors that bias the GPS signal of the cameras, the front camera proved to be the most reliable in terms of an accurate survey track. The final records of each route were created in the software ArcMap, which was also applied for visualizing the tracks, as well as the single point incidents of each graffito. Graffiti were digitized from the videos in ArcMap by the help of the VLC media player and the Contour Storyteller application, where the video material was analyzed and the graffiti information visually extracted. In the end, 5,098 single graffiti point features were digitized into a geodatabase, in which different categories of soccer-related graffiti data are stored according to their allocation to one of three soccer clubs in Krakow.

There are, in total, twelve categories of graffiti, whereof five of them were not included into the statistical analyses, but were aggregated with another category in order to increase the sample size. Included into the statistical analysis was a category that counts all graffiti equally. For each major soccer club in Krakow (Wisla Krakow, Cracovia Krakow, Hutnik Nowa Huta) three categories were defined and also statistically analyzed. If a graffito shows aversion against either Cracovia Krakow or Wisla Krakow, it is either counted as Anti Cracovia or Anti Wisla, defining the fifth and sixth categories. The seventh and last category are graffiti that are disfigured or overwritten by other club's supporters and are counted as "Conflict" graffiti. The categories that were not included in the analyses are Anti Hutnik graffiti and graffiti that refer to soccer, but cannot be allocated to or against a certain club, because of their small sample size. In contrast, graffiti of allied soccer clubs were included into the analyses and were added to the category of the respective Krakow soccer team. After every route was surveyed, a distance of 1872.68 kilometers was covered along the streets of Krakow. In comparison to the survey conducted by Dr. Trzepacz in 2016, this research collected roughly 500 more graffiti, but also covered 211 kilometers more of a distance.

Although, the 2018 graffiti data set counts more graffiti compared to 2016, the graffiti inventory is most likely not complete regarding the actual number of graffiti locations along the predefined routes, mainly because of following two reasons: First, some parts of the routes were not accessible by car, since some streets were blocked due to ongoing construction work or barriers, especially around large apartment complexes. Second, every street should be covered from both directions, since no camera is installed at the back window and therefore leads to some blind spots regarding the SVAS technology (e.g. backsides of houses/ garages, etc.).

Concerning the reliability of the SVAS technology, the following recommendations can be formulated for future applications in this field:

Weather conditions are important to take into account, when conducting a survey. Therefore, different kinds of heavy precipitation, e.g. rain, snow, mist, etc., shall be avoided, because they particularly reduce the video quality. The same applies to sunlight conditions. Insufficient light, e.g. during dusk or dawn, not only reduces the visibility while driving, but especially during the video analyzing process. Additionally, the position of the sun can cause cross-fade in the movies. Another unfavorable aspect is cars that park along the street or on parking lots of apartment buildings, because they block the view on building's façades and other locations, where graffiti may be attached to, plus they impede driving between multi-complex buildings. Also, the time commitment for one survey increases during peak traffic hours, mainly in the morning hours between ca. 07:30 am until 09:30 am and in the afternoon from ca. 04:00 pm until 06:00 pm.

To sum up, by applying the SVAS technology with the Contour+2 Action Camera Model 1700 and taking into account the previously stated recommendations, this methodological approach is highly successful for collecting soccer-related graffiti data in Krakow.

After the soccer-related graffiti data were collected and integrated into the GIS environment, statistical analyses with the software CrimeStat IV were applied in order to answer the following research questions:

- What spatial pattern do soccer-related graffiti follow in terms of their distribution?

- Where are spatial clusters of soccer-related graffiti in Krakow, and which fan group from which soccer club can they be assigned to?

- Are there regions, where hotspots of rivaling fan groups overlap, thus create distinct conflict zones?

- Are there changes concerning the distributional pattern and the amount of soccer-related graffiti in Krakow in comparison to 2016?

- Do committed crimes correlate with soccer-related graffiti?

According to the findings, the soccer-related graffiti in the 2018 research are widely spread around Krakow. The only exceptions are Hutnik graffiti, which are highly concentrated in eastern Krakow. All other graffiti categories are centered slightly east of the city center. The lion's share of all graffiti is located in the "graffiti-belt", which clusters almost one fourth of the graffiti locations. This "belt" stretches from the east of the city center to the $18^{th}$ district, called Nowa Huta, in a northerly oriented bow that almost touches the northern perimeter of the city. Additional areas of highly concentrated graffiti are situated north-west of the city center with some minor spots being detectable in the south. The very east and the very west are also densely populated by graffiti. The standard deviational ellipses for each category reveal that Hutnik graffiti have the smallest area of distribution, which already suggests that graffiti of this category are highly clustered. All other graffiti categories have a wide range concerning their distribution. The overall distributional pattern points out that most graffiti classes can be assigned to distinct regions in Krakow, where they are most likely findable. For example, the north is dominated by Wisla graffiti, respectively Anti Cracovia graffiti, whereas in the central and southern areas, it is more likely to identify tags of supporters of Cracovia, respectively tags that disfavor Wisla Krakow. Conflict graffiti are hardly connected with a distinct area. In contrast, Hutnik graffiti exist almost exclusively in eastern Krakow, especially in the $17^{th}$ and $18^{th}$ districts.

A similar distributional pattern is indicated by the nearest neighbor hierarchical cluster analyses (Nnh). Hotspot areas for Hutnik graffiti exist only in the east and north-eastern regions of Krakow. The remaining graffiti categories cluster primarily in the previously denoted areas, but occur as smaller $1^{st}$-order clusters also in areas, which are actually dominated by other opponent fan groups. This led to the assumption of distinct conflict zones, which are characterized by a high concentration of graffiti of two or more categories that are allocated to rivaling fan groups. The greatest conflict zones are detected in the northern and north-eastern parts of Krakow, along the graffiti-belt, where Wisla, Cracovia, and Hutnik graffiti interfere.

A more detailed analysis of distributional patterns enables the kernel density interpolation method, which provides more detailed information about the entire spatial graffiti distribution, compared to the Nnh routine. The latter reduces the graffiti data to single hotspots, whereas kernel density estimates produce contour maps, which generalize single incidents to the entire study area and also reveal information between hotspots. This statistical approach confirms the respective distributional pattern from the Nnh method for each graffiti category, but also highlights areas of medium graffiti density which might be overseen by simply concentrating on hotspots. This additional information pertains to all categories, except Hutnik graffiti, because their graffiti locations are less widely distributed.

Since graffiti data for 2016 were also available, a comparison concerning the evolution of graffiti distribution during this two years period was part of this research, too. The overall counts of graffiti in both data sets differ, insofar as a total of 489 more graffiti were collected in 2018. Despite significant differences in the total of all graffiti and in most categories, separately – Hutnik graffiti differ only by 10 incidents – the overall distribution pattern did not change by much. For example, Wisla graffiti of are still the majority in northern Krakow, Cracovia graffiti are most likely to be spot in central Krakow and in the south, and Hutnik graffiti are highly concentrated in the north-eastern districts. However, as the fuzzy mode statistics show, the category with highest frequencies of graffiti in distinct locations changed from Cracovia in 2016 to Hutnik graffiti in 2018. This leads to the assumption that the concentration of Hutnik graffiti has increased in the last two years, while at the same time it has decreased for Cracovia graffiti. Wisla graffiti concentrations are relatively stable. For both years, the Wisla graffiti category posses the highest total of single incidents per category. Moreover, the graffiti belt is recognizable in 2016, too, but not as clearly distinguishable as in 2018, according to the Nnh of all graffiti. Nevertheless, when individual clusters for each category are observed, the graffiti belt comes out more clearly. Hence, for both years, northern Krakow is the dominant region of graffiti in general.

One aspect of this thesis is to examine whether committed crimes correlate with soccer-related graffiti. Therefore, a data set with point shapefiles that locates different crime types in Krakow was compared with the graffiti data of 2018. These 967 reported crimes are not official police data. They were collected from a publicly accessible webpage that allows the report of crimes ranging from drinking alcohol in prohibited places to general anti-social behavior and other minor offenses. The findings are that eleven out of twelve 1$^{st}$-order clusters of crimes overlap with at least medium high kernel density estimates for graffiti. Moreover, three of these 1$^{st}$-order crime clusters overlap with 1$^{st}$-order clusters of graffiti and two other crime clusters are spatially close (within 100 meters) to another three graffiti clusters.

In order to get a more detailed confirmation of the correlation between criminal behavior and the making of graffiti, a collaboration with the police could be expedient, because official crime data may be more reliable. Also the amount of committed crime data would need to be larger, if the findings shall be statistical significant, regarding a possible correlation between crime and graffiti.

There are plenty of possible further research options, which could be applied to the 2018 collected graffiti data set. One of these options is presented next. During the video analyses process, some distinctive graffiti were spotted that were depicted in a similar style. One consists of the two letters “TS”, which is most likely made by a graffitist (or several graffitists) that supports Wisla Krakow, because it is the abbreviation for „towarzystwo sportowe”, in English „sports association”, which is often used as a synonym for the Wisla Krakow soccer-club (TRZEPACZ 2018: 336). The other depicts an „h”, which is often used as an abbreviation for hooligans and may be used by any supporter of a soccer team (ibid.: 143). Both graffiti are common in Krakow, but they often differ in their style of drawing. The assumption is that certain graffitists try to illustrate their tag in a characteristic manner that can be identified, when the tag is observed explicitly. If several graffiti indicate similar characteristics, they can possibly be ascribed to one and the same person. Therefore, a geographical search pattern of a graffitist could be analyzed, which aims on labeling crime areas and tries to understand “the probable spatial behavior of the offender within the context of the locations” (LEVINE 2015: 13.11). This routine is named “Geographic Profiling” and is a helpful tool for investigating criminal behavior in space.

## References

**BAIRD J.A. and TAYLOR Claire (Ed.) (2011):** Ancient Graffiti in Context. – New York.

**Bleacher Report (2008)**: Wisla Krakow Vs MKS Cracovia: The Holy War; http://bleacherreport.com/articles/60684-wisla-krakow-vs-mks-cracovia-the-holy-war (Retrieved: November 22, 2017).

**Blickfang Ultra (2008)**: Ultra. Eine Subkultur?! – In: Blickfang Ultra 2 (8), 46-51.

**CARDAIS S. A. and BOISSEVAIN J. (2011)**: Around the Bloc: Krakow Gets Tough on Graffiti, Chechen Poet Slain in Moscow. – In: Transitions Online 11 (22), 29-31; https://www-ceeol-com.uaccess.univie.ac.at/search/viewpdf?id=147485 (Retrieved: November 22, 2017).

**CURTIS A., MILLS J. W., KENNEDY B., FOTHERINGHAM S. and MCCARTHY T. (2007)**: Understanding the Geography of Post-Traumatic Stress: An Academic Justification for Using a Spatial Video Acquisition System in the Response to Hurricane Katrina. – In: Journal of Contingencies and Crisis Management 15 (4), 208 – 219; DOI: 10.1111/j.1468-5973.2007.00522.x.

**ECK John E., CHAINEY Spencer, CAMERON James G., LEITNER Michael and WILSON Ronald E. (Ed.) (2005)**: Mapping Crime: Understanding Hot Spots. – Washington; https://www.ncjrs.gov/pdffiles1/nij/209393.pdf (Retrieved: September 4,2017).

**GUS (Główny Urząd Statystyczny) (Ed.) (2016)**: Population. Size and structure and vital statistics in Poland by territorial division in 2016. Statistical information and elaborations. – Warsaw; http://stat.gov.pl/download/gfx/portalinformacyjny/en/defaultaktualnosci/3286/3/21/1/size_and_structure_of_population_and_vital_statistics_in_pl_by_terri_as_of_31_dec_2016.pdf (Retrieved: November 22, 2017).

**GRÜN A. (2016)**: Ultras und Graffiti – Ein Aufeinandertreffen zweier Subkulturen. –In: DUTTLER G. and HAIGIS B. (Ed.): Ultras. Eine Fankultur im Spannungsfeld unterschiedlicher Subkulturen. – Bielefeld. (= Kulturen der Gesellschaft 17), 157-172; https://www-degruyter-com.uaccess.univie.ac.at/viewbooktoc/product/467531 (Retrieved: November 9, 2017).

**GUTHRIE R. Dale (2005)**: The Nature of Paleolithic Art. – Chicago; https://books.google.at/books?hl=de&lr=&id=3u6JNwMyMCEC&oi=fnd&pg=PA113&dq=The+nature+of+paleolithic+art&ots=JPmVQmYhTu&sig=BTo-T92EK_NAZVFvwjyxyc3uA6o&redir_esc=y#v=onepage&q=graffiti&f=false (Retrieved: October 23, 2017).

**GYAN D. (2017)**: In Krakow, arch rivals separated by a narrow field; https://soccerinnyc.com/2017/08/25/in-krakow-arch-rivals-separated-by-a-narrow-field/ (Retrieved: November 22, 2017).

**HAWORTH B., BRUCE E. and IVESON K. (2013)**: Spatio-temporal analysis of graffiti occurrence in an inner-city urban environment. –In: Applied Geography 38, 53-63; http://dx.doi.org/10.1016/j.apgeog.2012.10.002.

**HALSEY M. and YOUNG A. (2002)**: The Meanings of Graffiti and Municipal Administration. –In: The Australien and New Zealand Journal of Criminology 35(2), 165–186; http://journals.sagepub.com.uaccess.univie.ac.at/doi/pdf/10.1375/acri.35.2.165 (Retrieved: October 30, 2017).

**LEVINE N. (2015)**: CrimeStat: A Spatial Statistics Program for the Analysis of Crime Incident Locations (v 4.02). – Ned Levine & Associates, Houston, Texas, and the National Institute of Justice, Washington, D.C. August.

**LEITNER M. (n.y.)**: Introduction to Hot Spot Analysis. Crime Analysis & Modeling with CrimeStat IV. – Department of Geoinformatics – Z GIS, Salzburg.

**LOMBARD K.-J. (2012)**: Art crimes: The Governance of Hip Hop Graffiti. –In: Journal for Cultural Research 17(3), 255–278; http://dx.doi.org/10.1080/14797585.2012.752160.

**LUKAC S. (2014)**: When writing turns savage: Contextualizing anti-Semitic graffiti on the streets of Krakow and Budapest. – Master’s Thesis, Central European University, Budapest; http://www.etd.ceu.hu/2014/lukac_stanislav.pdf (Retrieved: November 23, 2017).

**Magiczny Kraków (2016)**: Public information bulletin of the city of Kraków; http://www.krakow.pl/english/visit_krakow/197929,artykul,about_krakow.html (Retrieved: November 20, 2017).

**MANN C. (2009)**: The world’s most violent football rivalries; http://sportslens.com/most-violent-football-rivalries/36725/ (Retrieved: November 22, 2017).

**McGIRR D. (2017):** Policing the Krakow Derby – ‘The Holy War’. Święta Wojna, - Derby Krakowa; http://krakowexpats.pl/safety/policing-the-krakow-derby-the-holy-war/ (Retrieved: November 22, 2017).

**MEGLER V., BANIS D. and CHANG H. (2014)**: Spatial analysis of graffiti in San Francisco. –In: Applied Geography 54, 63–73; https://doi.org/10.1016/j.apgeog.2014.06.031.

**MONTOYA L. (2003)**: Geo-data acquisition through mobile GIS and digital video: an urban disaster management perspective. –In: Environmental Modelling & Software 18, 869–876; DOI: 10.1016/S1364-8152(03)00105-1.

**MORGAN A. and LOUIS E. (2009)**: Key issues in graffiti. –In: Australian Institute of Criminology: Research in Practice – Summary paper (6);

http://www.aic.gov.au/media_library/publications/rip/rip06/rip06.pdf (Retrieved: September 11, 2017).

**Oxford Dictionary (n.d.)**: Definition according to Oxford Dictionaries; http://www.oxforddictionaries.com/definition/english/graffiti (Retrieved: September 2, 2017).

**SAGL G. (2008)**: Evaluation of Geospatial Video Data Acquisition: A Case Study in New Orleans, Louisiana. – Diploma Thesis, Fachhochschule Kärnten, Villach.

**SCHNEIDER T. A. (2018)**: Guideline to digitize Geodata using ArcGIS Software Package and Spatial Video Technology. – Carinthia University of Applied Sciences, Klagenfurt.

**SERKAN G. and GÜLSEN Y. (2006)**: Understanding graffiti in the built environment: The case in Ankara, Türkiye. –In: 42nd ISoCaRP Congress 2006; http://www.isocarp.net/Data/case_studies/724.pdf (Retrieved: September 15, 2017).

**SOMMEREY M. (2010)**: Die Jugendkultur der Ultras. Zur Entstehung einer neuen Generation von Fußballfans. – Stuttgart.

**STOWERS G.C. (1997)**: Graffiti Art: An Essay Concerning the Recognition of Some Forms of Graffiti as Art; https://www.graffiti.org/faq/stowers.html (Retrieved: September 11, 2017).

**TRZEPACZ P. (2018)**: Polish-English vocabulary of the football graffiti content in Krakow – Urban vocabulary of Cracow 2018. – Krakow.

**VANDERWEEN G. and VAN EIJK G. (2015)**: Criminal but Beautiful: A Study on Graffiti and the Role of Value Judgments and Context in Perceiving Disorder. – In: European Journal on Criminal Policy and Research 22 (1), 107–125; online first September 10, 2015, http://dx.doi.org/10.1007/s10610-015-9288-4.

**WACLAWEK A. (2012):** Graffiti und Street Art. – Berlin.

**WEISEL D. L. (2002)**: Graffiti. –In: Office of Community Oriented Policing Services – U.S. Department of Justice: Problem-oriented guides for police series (9); http://www.popcenter.org/problems/pdfs/Graffiti.pdf (Retrieved: September 13, 2017).

**WILSON J. Q. and KELLING G. L. (1982)**: Broken Windows – The police and neighborhood safety. –In: The Atlantic Online; https://www.theatlantic.com/magazine/archive/1982/03/broken-windows/304465/ (Retrieved: September 11, 2017).

## Internet Sources

**ArcGIS Pro Mean Center:** https://pro.arcgis.com/de/pro-app/tool-reference/spatial-statistics/h-how-mean-center-spatial-statistics-works.htm (last received: 17.10.2018)

**ArcGIS Pro Median Center:** https://pro.arcgis.com/de/pro-app/tool-reference/spatial-statistics/h-how-median-center-spatial-statistics-works.htm (last received: 17.10.2018)

**ArcGIS Resources I:** http://resources.arcgis.com/de/help/getting-started/articles/026n00000014000000.htm (last received: 17.10.2018)

**ArcGIS Resources II:** https://resources.arcgis.com/en/help/main/10.2/index.html#/How_Directional_Distribution_Standard_Deviational_Ellipse_works/005p0000001q000000/ (last received: 17.10.2018)

**Contour Manual:** http://help.contour.com/customer/portal/topics/103657 (last received: 04.10.2018)

**Contour Store:** https://store.contour.com/products/contour-2 (last received: 04.10.2018)

**Google Support:** https://support.google.com/mymaps/answer/3024836?hl=de&ref_topic=3024924 (last received: 04.10.2018)

**Google Maps:** https://maps.google.com (last received: 16.08.2018)

**Google MyMaps:** https://www.google.com/mymaps (last received: 04.06.2018)

**Krajowa Mapa Zagrozen Bezpieczenstwa:** https://mapy.geoportal.gov.pl/iMapLite/KMZBPublic.html (last received: 10.07.2018)

**Magiczny Krakow**: https://www.krakow.pl/english/ (last received: 17.08.2018)

**OpenStreetMap**: https://www.openstreetmap.org/ (last received: 17.10.2018)

**Runtastic**: https://www.runtastic.com/en/about (last received: 04.10.2018)

**Wikimedia**: https://commons.wikimedia.org/w/index.php?curid=641589 (last received: 17.10.2018)

# Appendix I: Import of .kml Files into Google MyMaps

Given below is the explanation of how .kml files are imported into a personal Google MyMaps account (all figures are screenshots taken personally during the workflow):

To use Google MyMaps (https://www.google.com/mymaps) it is required to have a Google account. When logged into the personal Google MyMaps account, a new map can be created by the "+CREATE A NEW MAP" button (cf. Figure 53).

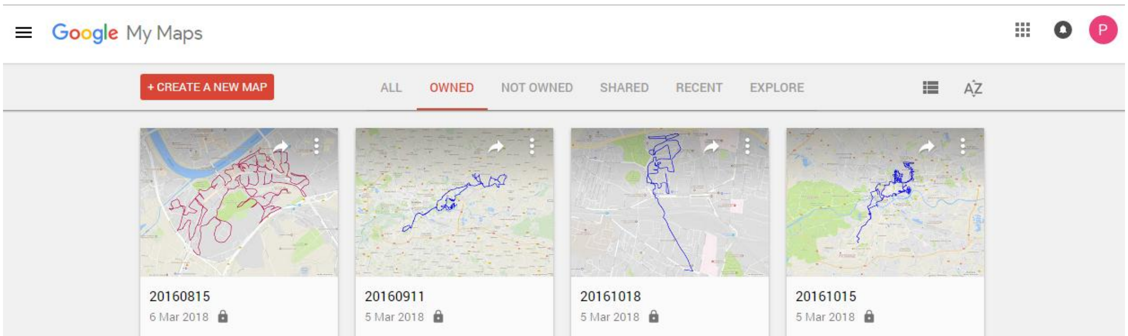



**Figure 53: Accessing a new map**

To add a new layer to a map the "Import" button is used (cf. Figure 54).

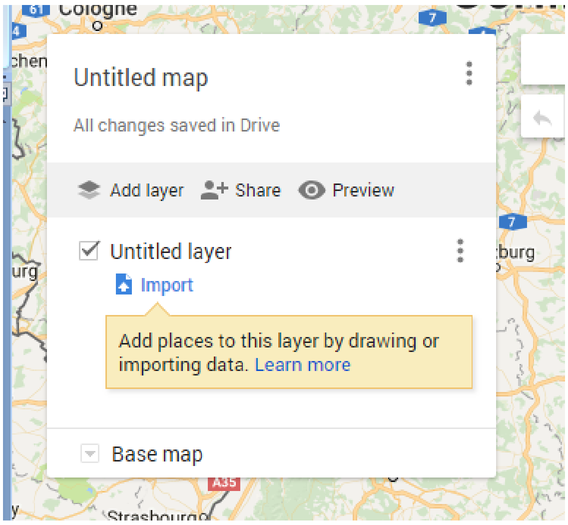



**Figure 54: Adding a layer to a map**

The following window is a drag and drop field, where different file formats can be placed and integrated into the map. In this case the .kml-file is chosen either by drag and drop or by navigating to the folder where the file is stored on the computer (cf. Figure 55).

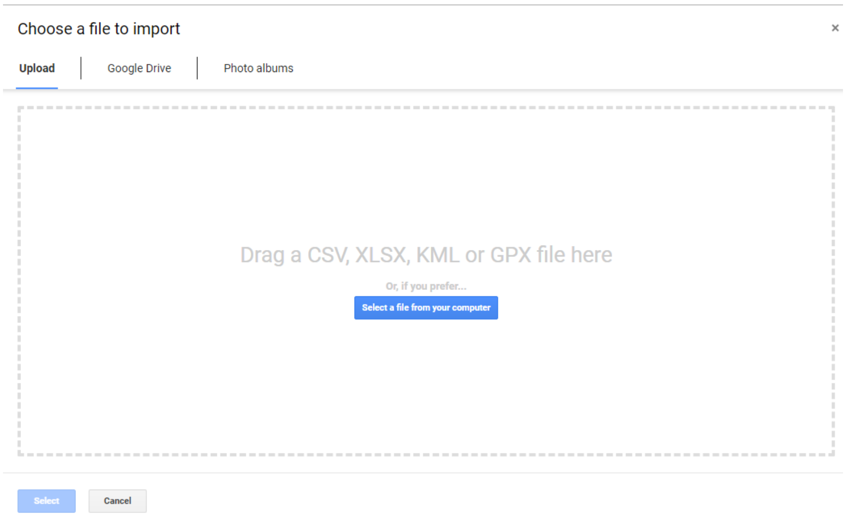



**Figure 55: Choosing a file window**

If the process was successful, the map will be saved directly to the personal Google Drive account and displayed in the Google Maps environment (cf. Figure 56).

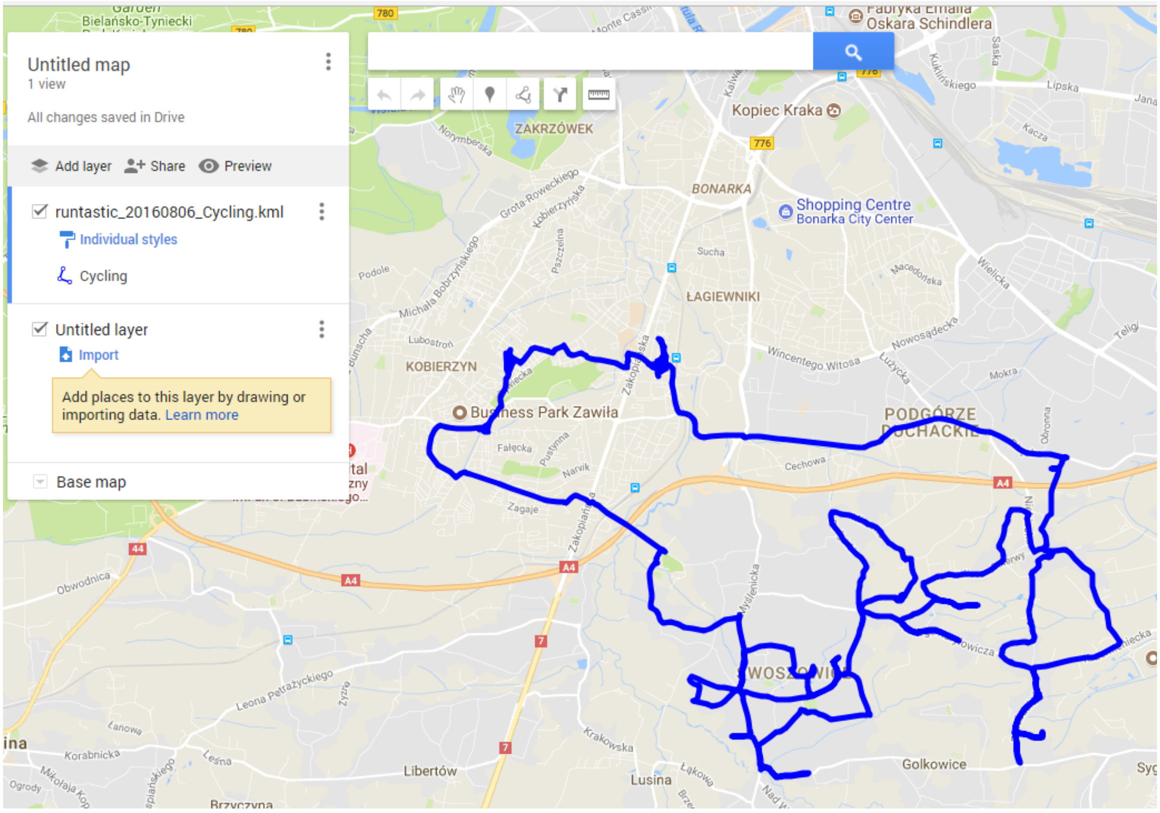
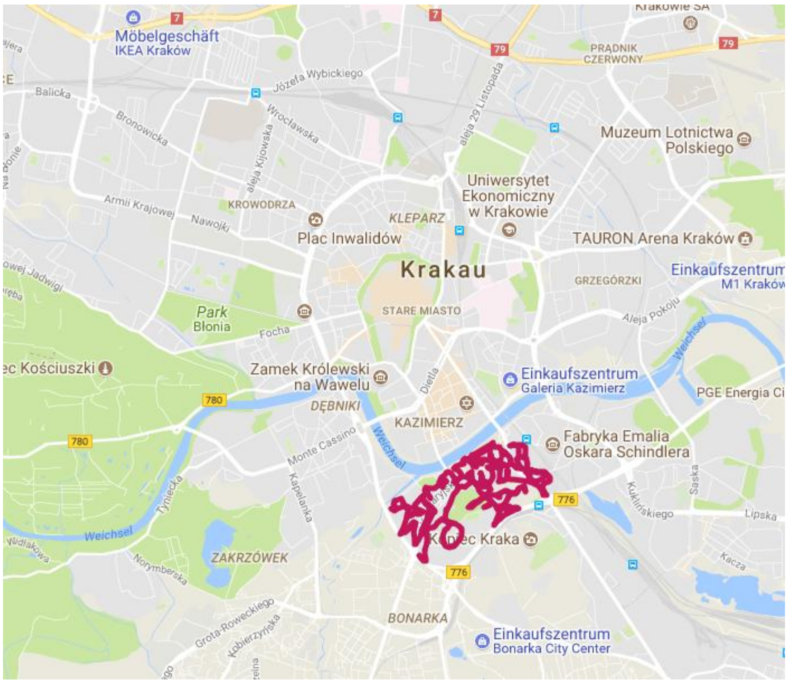



**Figure 56: Final track in MyMaps**

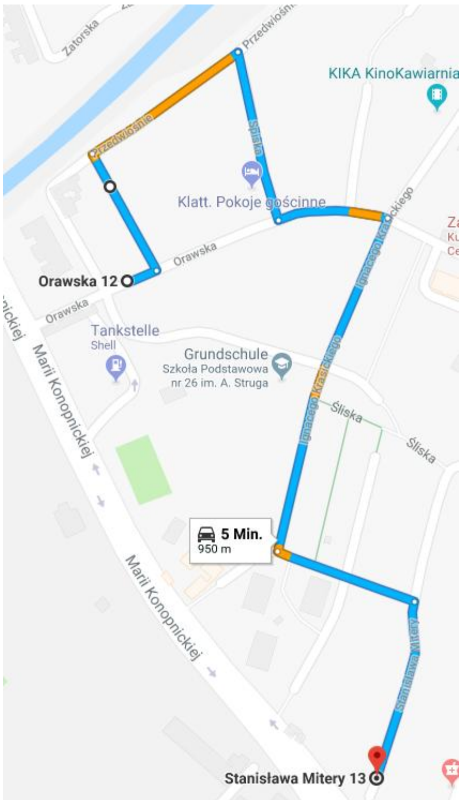
More information can be accessed by the support service of Google (Google Support).

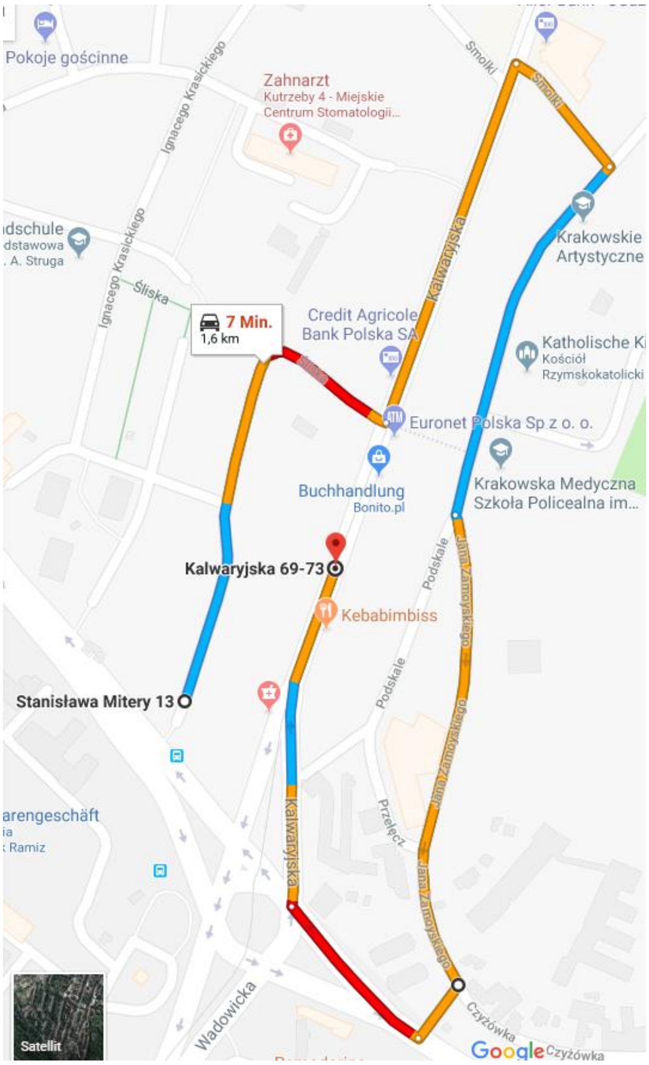
# Appendix II: Sample Route 20160815

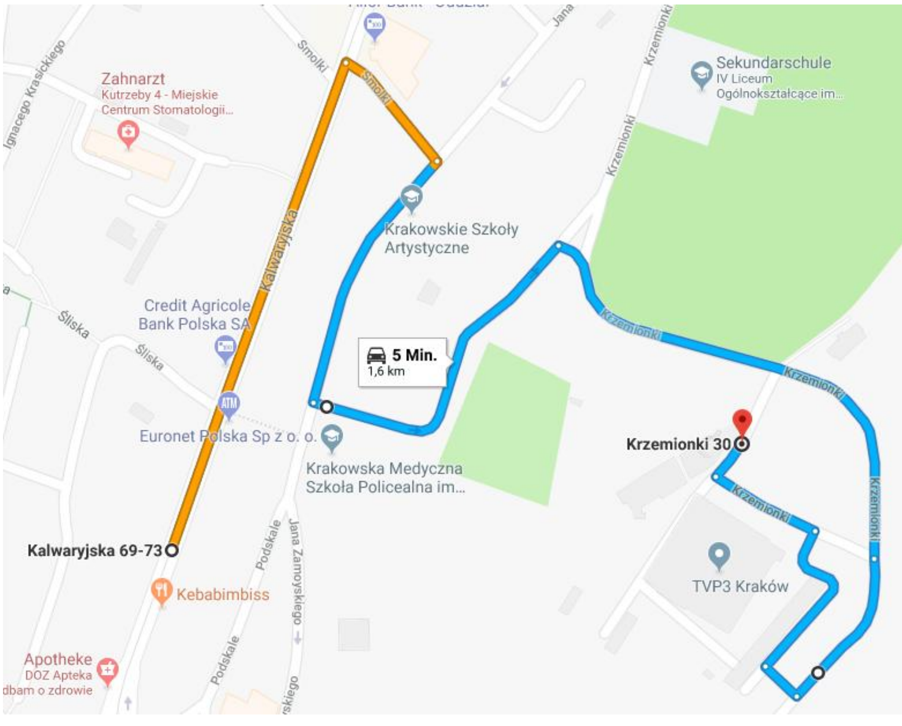
Overview of route 20160815:

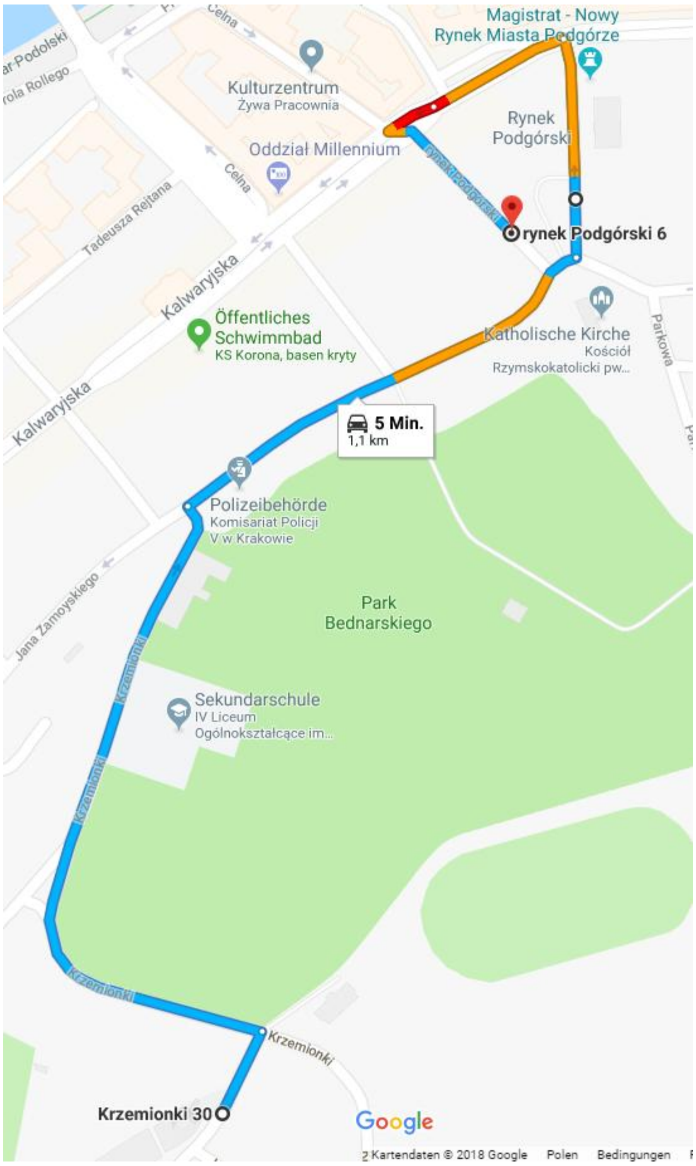


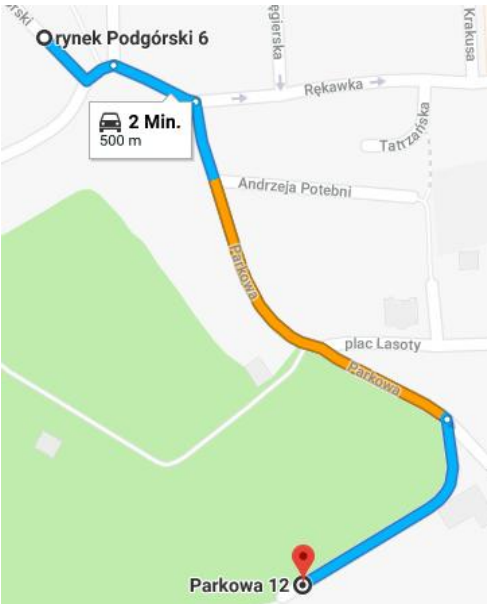

Start: Orawska 12, Kraków

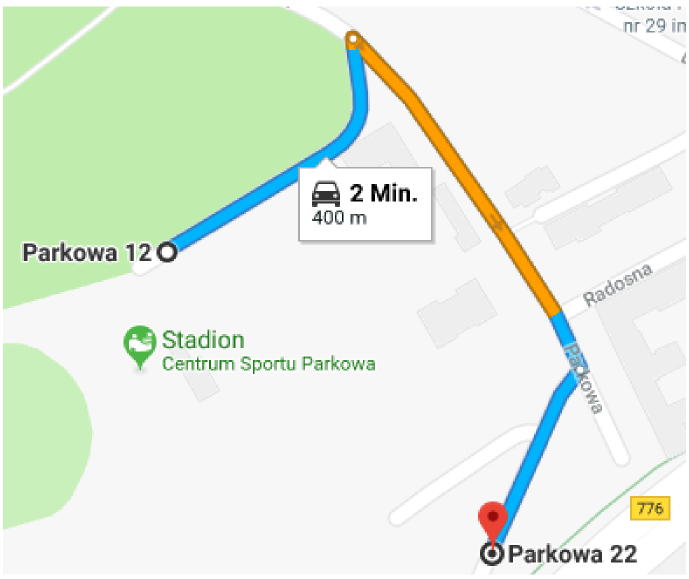


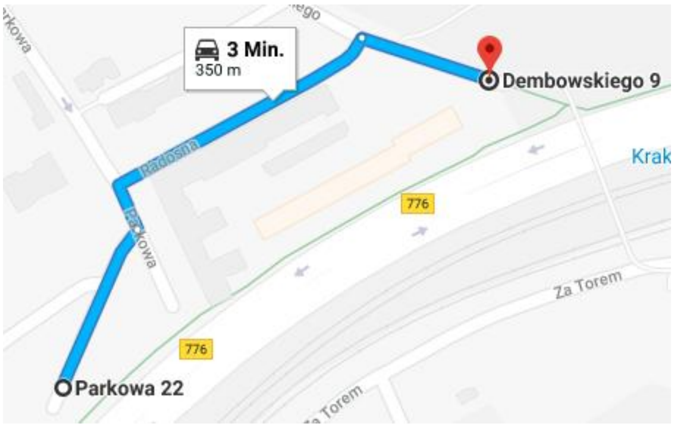

Pokoje gościnne
Zahnarzt
Kutrzeby 4 - Miejskie Centrum Stomatologii...
Smolki
Krakowskie Artystyczne
Kalwaryjska
7 Min.
1,6 km
Credit Agricole Bank Polska SA
Katholische Ki
Kościół Rzymskokatolicki
Euronet Polska Sp z o. o.
Buchhandlung
Bonito.pl
Krakowska Medyczna Szkoła Policealna im...
Kalwaryjska 69-73
Kebabimbiss
Stanisława Mitery 13
Podskale
Jana Zamoyskiego
Przełęcz
Wadowicka
Czyżówka
Satellit
Google

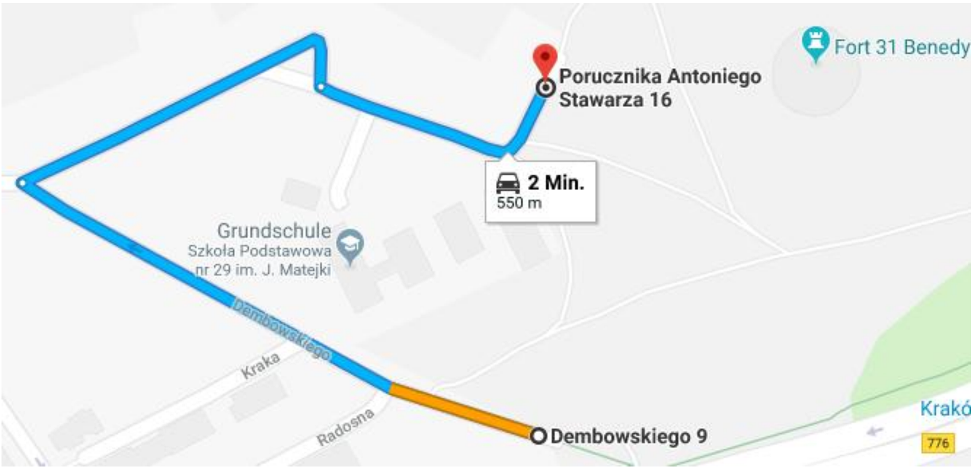

Zahnarzt
Kutrzeby 4 - Miejskie Centrum Stomatologii...
Smolki
Sekundarschule
IV Liceum Ogólnokształcące im...
Krzemionki
Krakowskie Szkoły Artystyczne
Credit Agricole Bank Polska SA
Kalwaryjska
Śliska
5 Min.
1,6 km
Euronet Polska Sp z o. o.
Krakowska Medyczna Szkoła Policealna im...
Krzemionki 30
Kalwaryjska 69-73
Kebabimbiss
TVP3 Kraków
Apotheke
DOZ Apteka
Podskale
Jana Zamoyskiego


Magistrat - Nowy
Rynek Miasta Podgórze
Kulturzentrum
Żywa Pracownia
Oddział Millennium
Rynek
Podgórski
rynek Podgórski 6
Kalwaryjska
Öffentliches
Schwimmbad
KS Korona, basen kryty
Katholische Kirche
Kościół
Rzymskokatolicki pw...
5 Min.
1,1 km
Polizeibehörde
Komisariat Policji
V w Krakowie
Park
Bednarskiego
Sekundarschule
IV Liceum
Ogólnokształcące im...
Krzemionki
Krzemionki 30
Google
Kartendaten © 2018 Google
Polen
Bedingungen


rynek Podgórski 6
Rękawka
2 Min.
500 m
Andrzeja Potebni
Parkowa
plac Lasoty
Parkowa 12


2 Min.
400 m
Parkowa 12
Radosna
Stadion
Centrum Sportu Parkowa
776
Parkowa 22

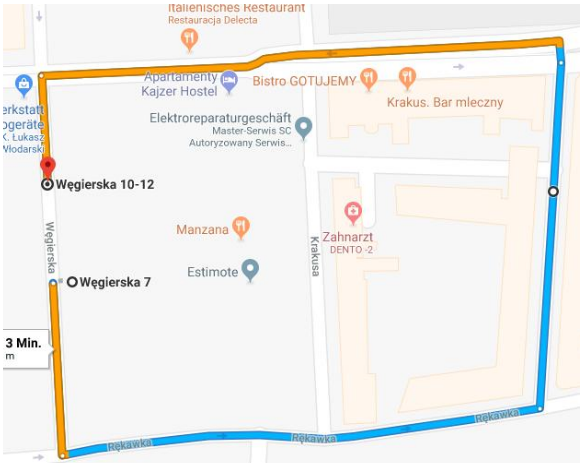

3 Min.
350 m
Dembowskiego 9
Radosna
Parkowa
776
Za Torem
Parkowa 22

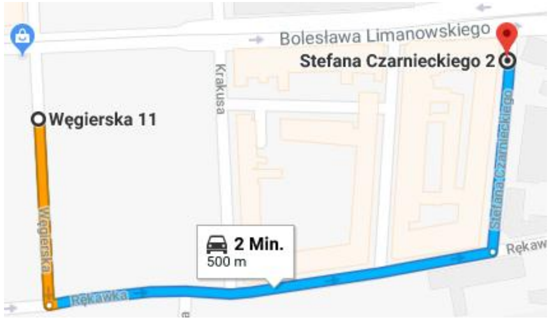

Fort 31 Benedy
Porucznika Antoniego Stawarza 16
2 Min.
550 m
Grundschule
Szkoła Podstawowa nr 29 im. J. Matejki
Dembowskiego
Kraka
Radosna
Dembowskiego 9
Krakó
776

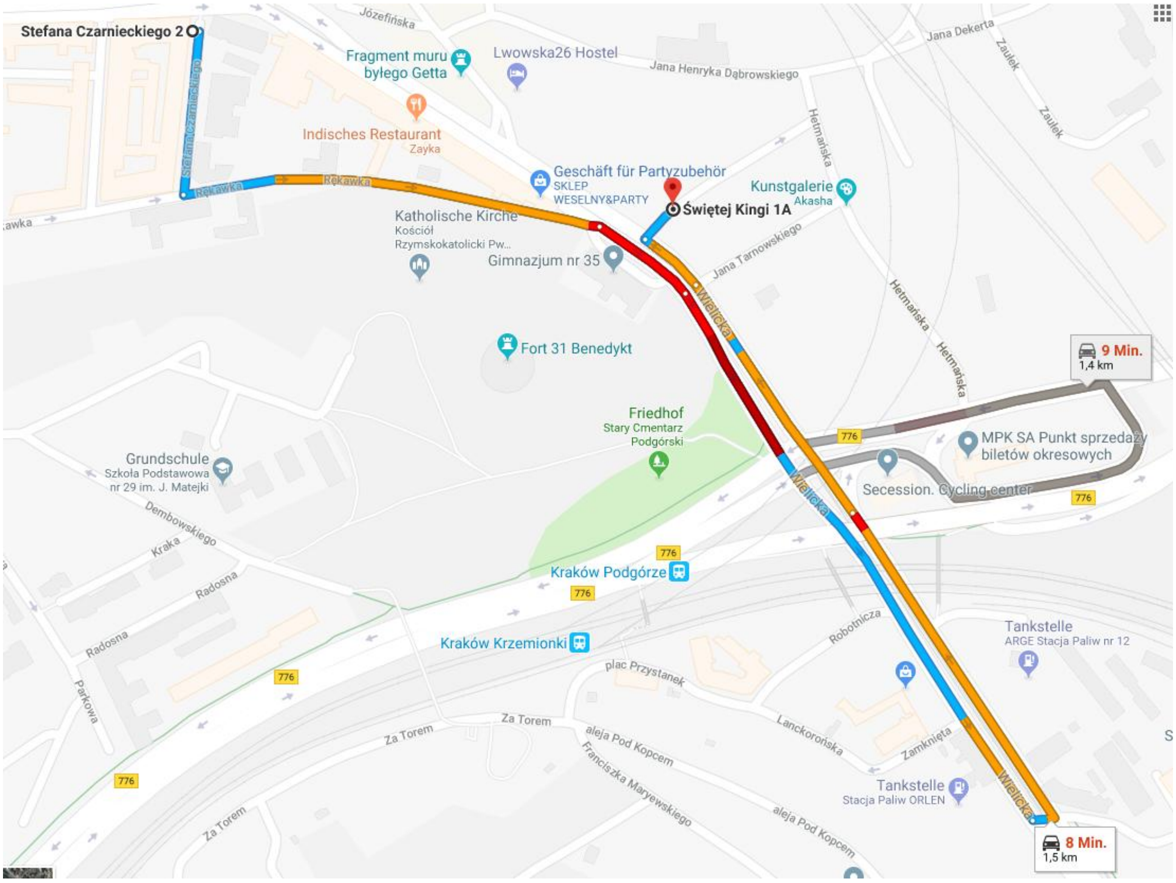

2 Min.
450 m
Tatrzańska 4
Porucznika Antoniego Stawarza 16
plac Lasoty
Parkowa
Grundschule
Szkoła Podstawowa

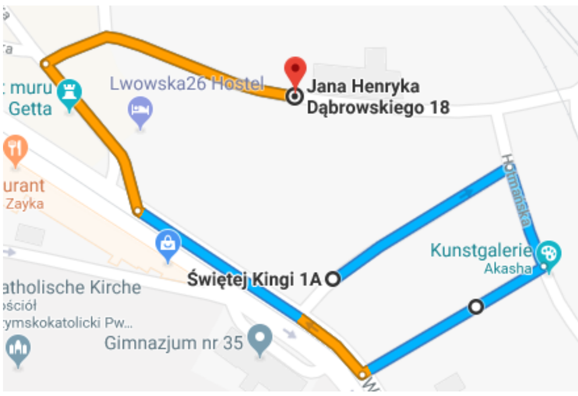

Andrzeja Potebni
Andrzeja Potebni 8-10
Parkowa
Tatrzańska 4
1 Min.


Bolesława Li
Krakusa
Manzana
Węgierska 7
4 Min.
650 m
Rękawka
Parkowa
Andrzeja Potebni
Andrzeja Potebni 8-10

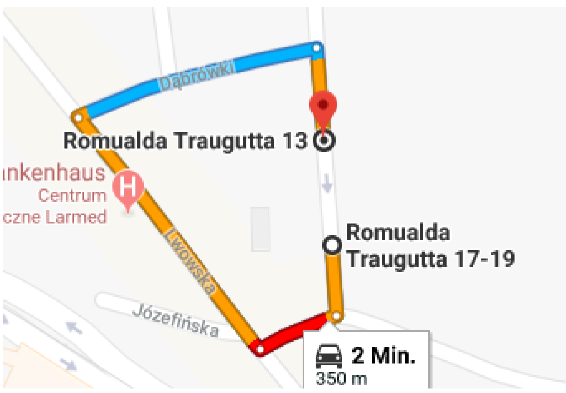

Apartamenty
Kajzer Hostel
Bistro GOTUJEMY
Krakus. Bar mleczny
Elektroreparaturgeschäft
Master-Serwis SC
Autoryzowany Serwis...
Węgierska 10-12
Manzana
Zahnarzt
DENTO -2
Węgierska 7
Estimote
Węgierska
Krakusa
3 Min.
Rękawka


Bolesława Limanowskiego
Stefana Czarnieckiego 2
Węgierska 11
Krakusa
Węgierska
2 Min.
500 m
Rękawka


Stefana Czarnieckiego 2
Józefińska
Fragment muru
byłego Getta
Lwowska26 Hostel
Jana Henryka Dąbrowskiego
Jana Dekerta
Indisches Restaurant
Zayka
Geschäft für Partyzubehör
SKLEP
WESELNY&PARTY
Kunstgalerie
Akasha
Świętej Kingi 1A
Rękawka
Katholische Kirche
Kościół
Rzymskokatolicki Pw...
Gimnazjum nr 35
Jana Tarnowskiego
Hetmańska
Wielicka
Fort 31 Benedykt
9 Min.
1,4 km
Friedhof
Stary Cmentarz
Podgórski
MPK SA Punkt sprzedaży
biletów okresowych
Secession. Cycling center
Grundschule
Szkoła Podstawowa
nr 29 im. J. Matejki
Dembowskiego
Kraka
Radosna
776
Kraków Podgórze
Kraków Krzemionki
Robotnicza
Tankstelle
ARGE Stacja Paliw nr 12
Parkowa
Za Torem
plac Przystanek
aleja Pod Kopcem
Franciszka Maryewskiego
Lanckorońska
Zamknięta
Tankstelle
Stacja Paliw ORLEN
8 Min.
1,5 km

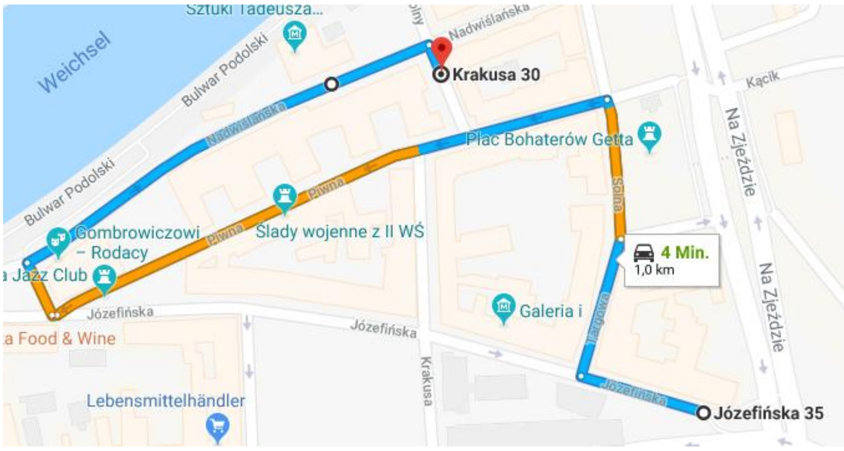

Lwowska26 Hostel
Jana Henryka
Dąbrowskiego 18
Zayka
Kunstgalerie
Akasha
Hetmańska
Świętej Kingi 1A
Gimnazjum nr 35


Kącik
Lipowa
Lipowa
Kulturzentrum
Centrum Szkła i
Dąbrówki
Romualda Traugutta
Romualda
Traugutta 17-19
Lwowska
Józefińska
Fragment muru
byłego Getta
Lwowska26 Hostel
Jana Henryka
Dąbrowskiego 18
Hetmańska
Indisches Restaurant
Zayka
Rękawka
6 Min.
1,2 km
Kunstgalerie
Akasha
Gimnazjum nr 35

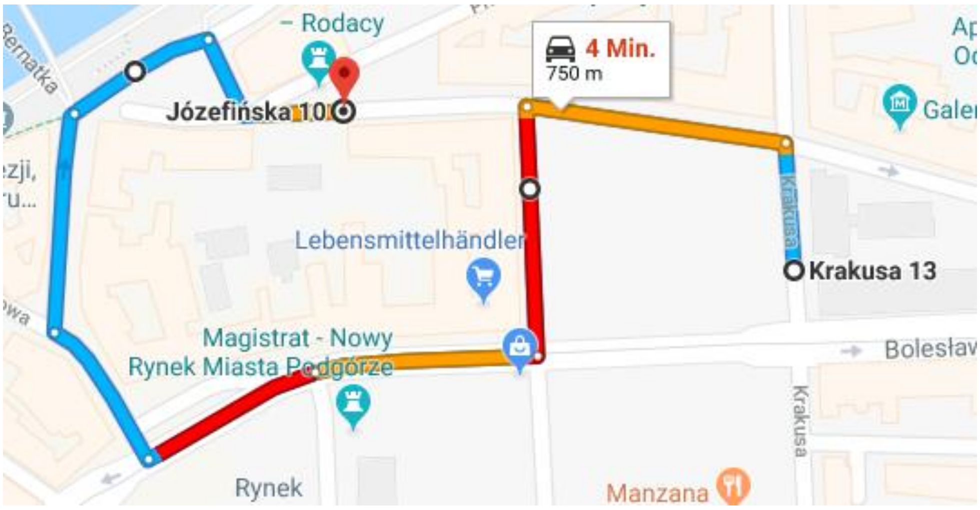

Dąbrówki
Romualda Traugutta 13
Centrum
Lwowska
Romualda
Traugutta 17-19
Józefińska
2 Min.
350 m

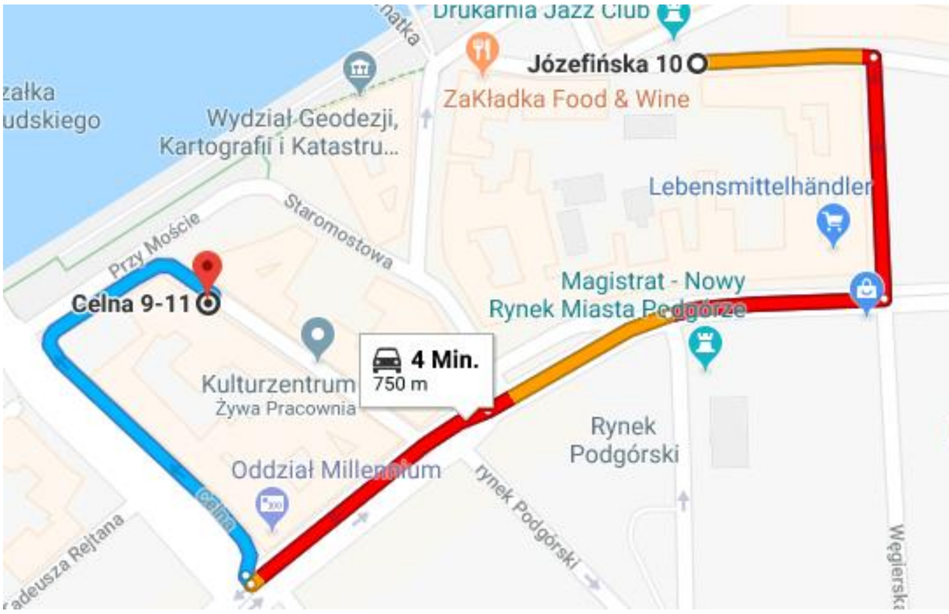

Kącik 1-3
Kącik
Na Zjeździe
Na Zjeździe
3 Min.
550 m
Romualda Traugutta
Dąbrówki
Romualda Traugutta 13
Krankenhaus
Centrum
Medyczne Larmed
Lwowska
Józefińska

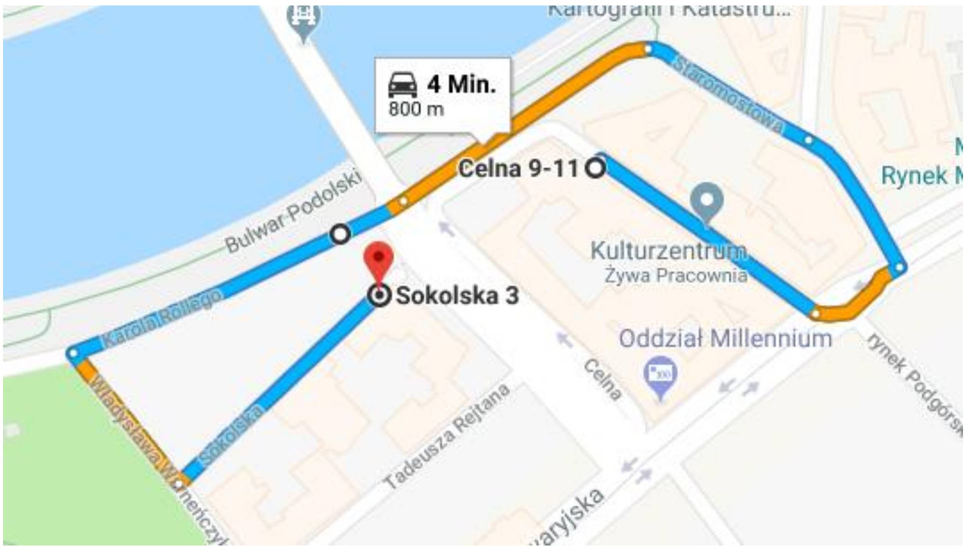

Weichsel
Bulwar Podolski
Solna
Na Zjeździe
3 Min.
950 m
Kącik 1-3
Plac Bohaterów Getta
Apteka pod Orłem. Oddział Muzeum...
Galeria i
Józefińska 35
Bolesława Limanowskiego
7 Min.

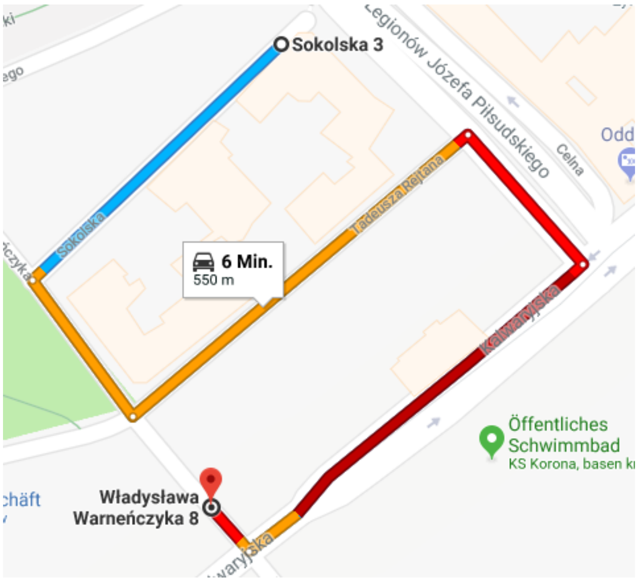

Weichsel
Bulwar Podolski
Krakusa 30
Plac Bohaterów Getta
Gombrowiczowi – Rodacy
Ślady wojenne z II WŚ
4 Min.
1,0 km
Galeria i
Józefińska
Lebensmittelhändler
Józefińska 35

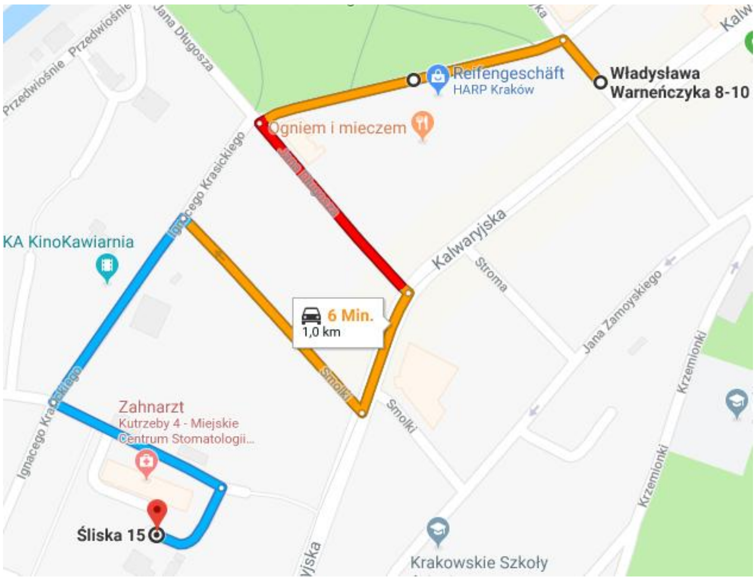

Krakusa 30
Plac Bohaterów Getta
Na Zjeździe
6 Min.
800 m
Apteka pod Orłem. Oddział Muzeum...
Galeria i
Józefińska
Krakusa 13
Bolesława Limanowskiego

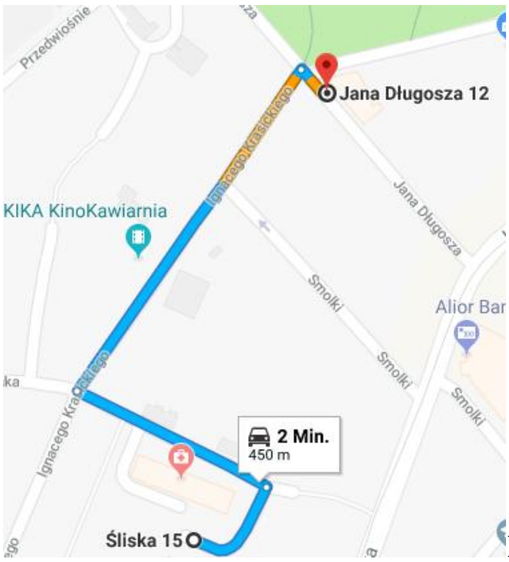

Rodacy
4 Min.
750 m
Józefińska 10
Krakusa 13
Lebensmittelhändler
Magistrat - Nowy
Rynek Miasta Podgórze
Krakusa
Rynek
Manzana


Drukarnia Jazz Club
Józefińska 10
ZaKładka Food & Wine
Wydział Geodezji,
Kartografii i Katastru...
Lebensmittelhändler
Staromostowa
Przy Moście
Magistrat - Nowy
Rynek Miasta Podgórze
Celna 9-11
4 Min.
750 m
Kulturzentrum
Żywa Pracownia
Rynek
Podgórski
Oddział Millennium
rynek Podgórski
Celna


4 Min.
800 m
Staromostowa
Celna 9-11
Bulwar Podolski
Sokolska 3
Kulturzentrum
Żywa Pracownia
Karola Rollego
Oddział Millennium
Celna
Sokolska
Tadeusza Rejtana


Sokolska 3
Legionów Józefa Piłsudskiego
Celna
Sokolska
Tadeusza Rejtana
6 Min.
550 m
Kalwaryjska
Öffentliches
Schwimmbad
Władysława
Warneńczyka 8


Jana Długosza
Reifengeschäft
HARP Kraków
Władysława
Warneńczyka 8-10
Ogniem i mieczem
Ignacego Krasickiego
KA KinoKawiarnia
Kalwaryjska
Stroma
6 Min.
1,0 km
Jana Zamoyskiego
Krzemionki
Smolki
Zahnarzt
Kutrzeby 4 - Miejskie
Centrum Stomatologii...
Śliska 15
Krakowskie Szkoły


Przedwiośnie
Jana Długosza 12
Ignacego Krasickiego
KIKA KinoKawiarnia
Jana Długosza
Smolki
Alior Bar
2 Min.
450 m
Śliska 15

End of route!

# Appendix III: Embedding Data from Contour Storyteller into ArcGIS

In this Appendix it is explained how to process .mp4 video material with GPS data in Contour Storyteller and to embed a track into ArcMap:

Videos are imported into Contour Storyteller by the function "Import Movie" (Figure 57).

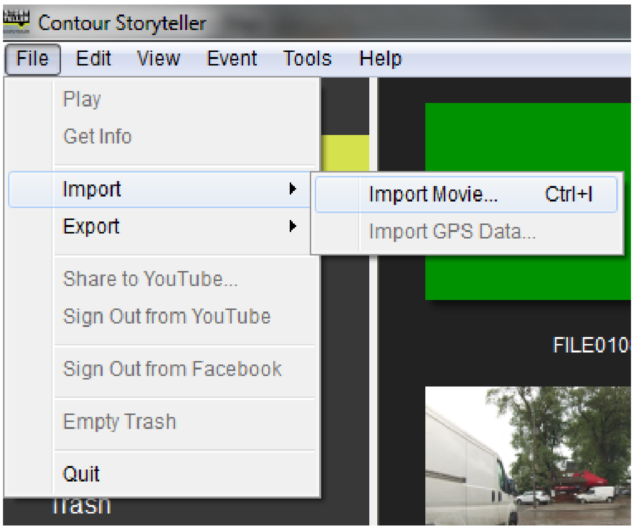



**Figure 57: Importing a movie file into the Contour Storyteller application**

In the following window a .mp4 file can be selected and integrated (Figure 58).

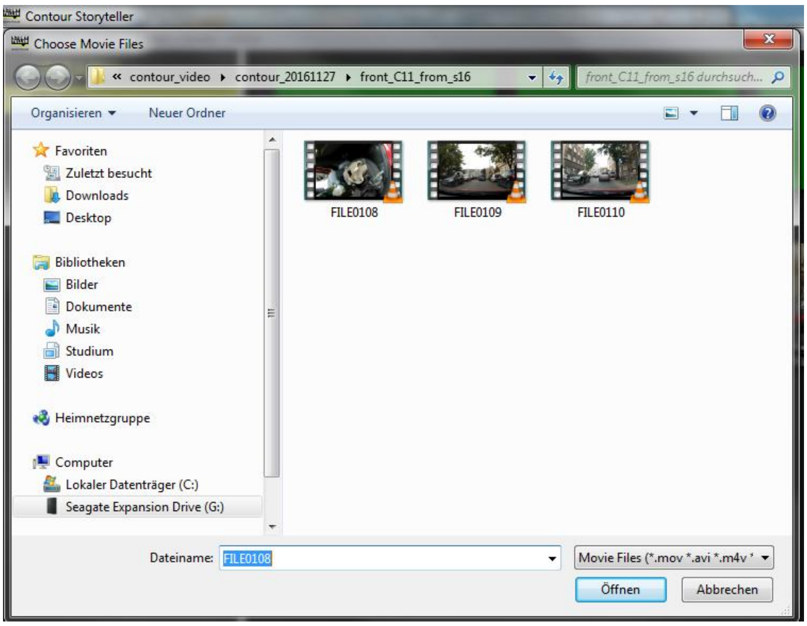



**Figure 58: Choosing a file to import into Contour Storyteller**

Embedded GPS data can be exported from videos by using the "Export GPS data" function (FFigure 59). It is important to have the chosen file (yellow frame around the file) selected before opening the function.

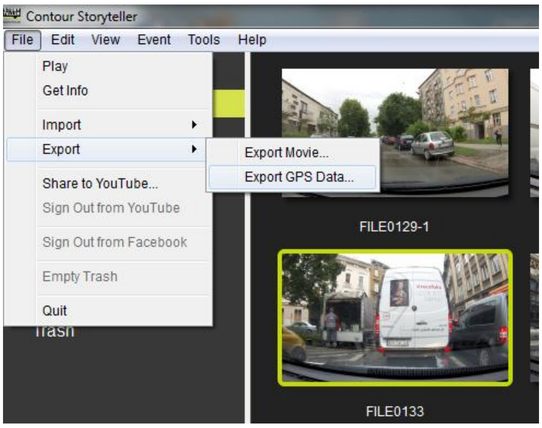



**Figure 59: Export GPS data function in Contour Storyteller**

The following window is opened to choose a location where to store the GPS data (Figure 60). With the "Browse" button it is possible to navigate to the requested location on the computer.

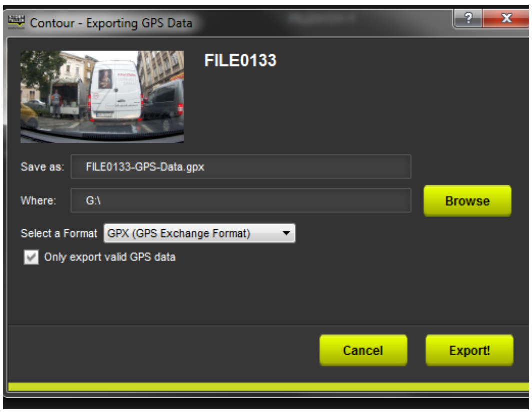



**Figure 60: Exporting GPS Data window**

The user has now a .gpx file, which can be integrated into a GIS. It is not possible to simply drag and drop a file into ArcMap. Therefore, the .gpx file has to be imported into the software by the function "GPX to Features" (Figure 61).

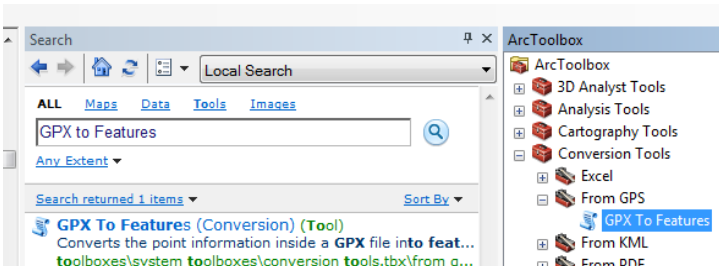



**Figure 61: Accessing "GPX to Features"- tool**

In the following window the input GPX file as well as the output Feature Class needs to be selected (Figure 62).

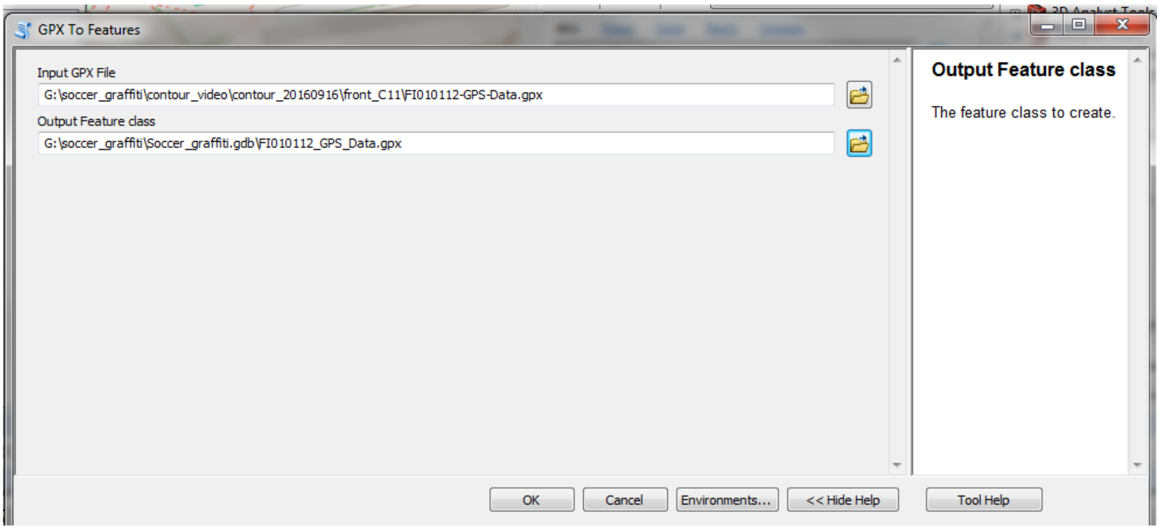



**Figure 62: Tool "GPX to Features" window**

When the tool executes successfully, a similar point shapefile and attribute table, as shown in Figure 63, is derived.

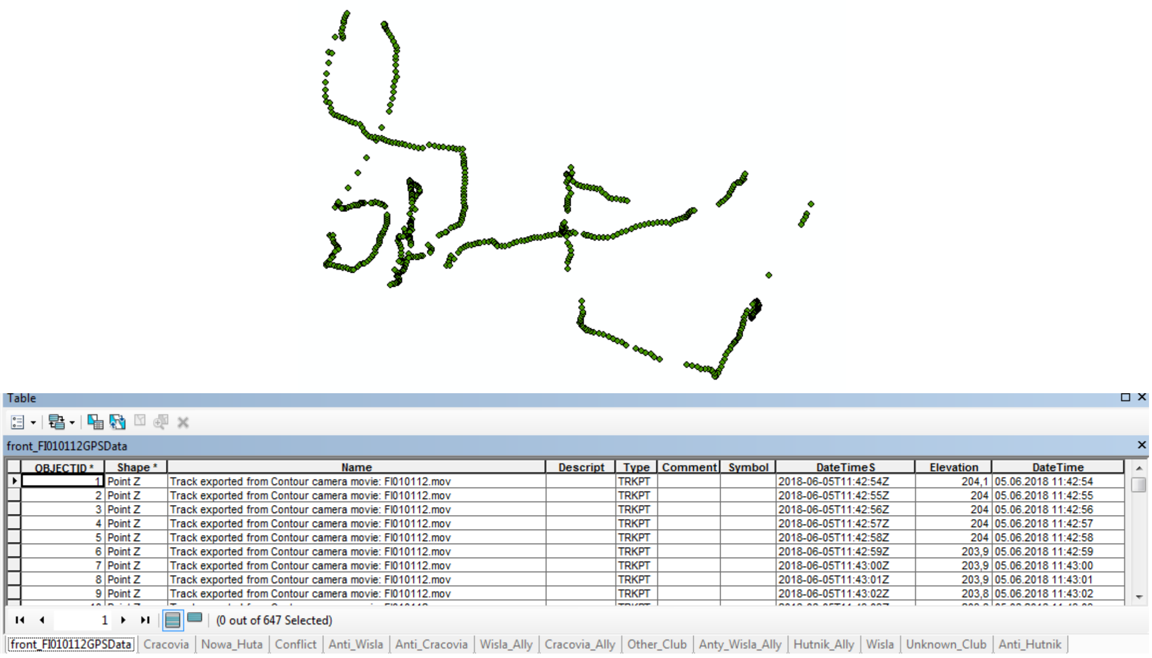



**Figure 63: Example of exported GPS data and its attribute table**

The final step is to convert the point shapefile into a line shapefile, which can be achieved by the tool “Points to Line”. Next to the input and output features the “DateTime” option should be selected in the dropdown menu of the “Sort Field” option, because it sorts “the points that are used for the calculation according to their generation time, if the point shapefile contains an accurate time and/or date column” (Figure 64) (SCHNEIDER 2018: 7).

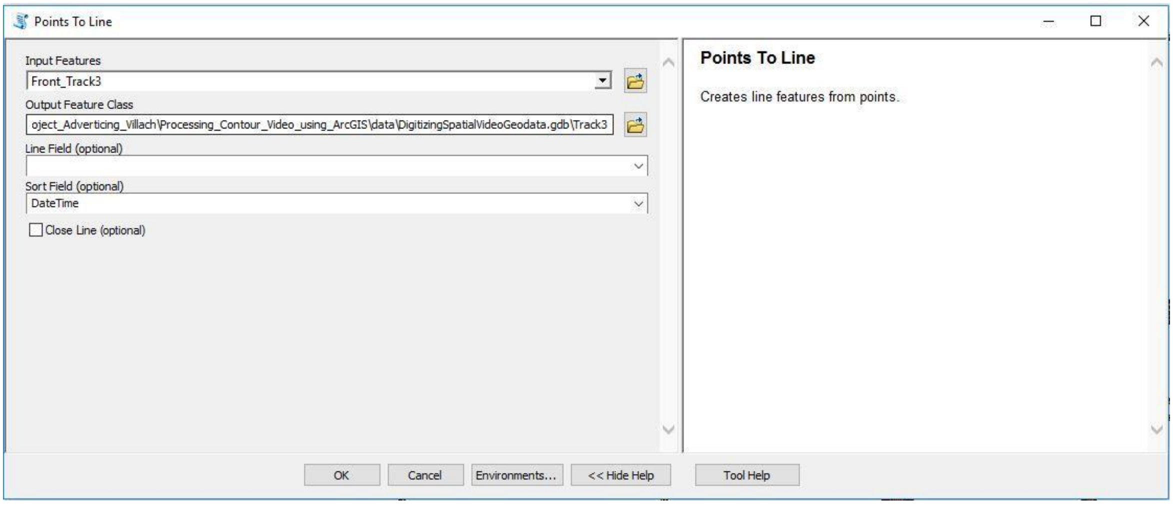



**Figure 64: Tool-window "Point To Line"; Source: SCHNEIDER 2018: 7**

The final track is visualized in Figure 65.

**Figure 65: Example of the final track**

For better orientation a basemap can be added to ArcMap (Figure 66).

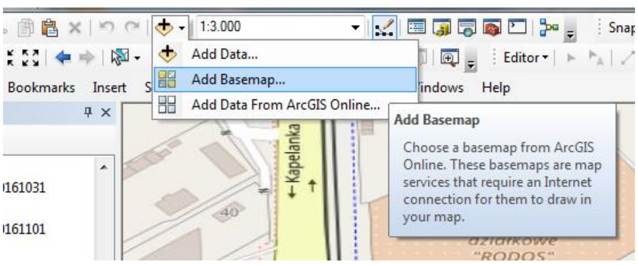



**Figure 66: Adding a basemap to ArcMap**

**Statutory Declaration**

Herewith I affirm,

- That this master thesis is entirely my own work and that I have not used any other sources than those indicated.
- That this master thesis was not submitted as an examination paper before.
- That this master thesis is identical with the version evaluated by the supervisor.

**Eidesstattliche Erklärung**

Hiermit versichere ich,

- dass ich die Masterarbeit selbstständig verfasst, andere als die angegebenen Quellen und Hilfsmittel nicht benutzt und mich auch sonst keiner unerlaubten Hilfe bedient habe,
- dass ich dieses Masterarbeitsthema bisher weder im In- noch im Ausland in irgendeiner Form als Prüfungsarbeit vorgelegt habe
- und dass diese Arbeit mit der vom Begutachter beurteilten Arbeit übereinstimmt.

Wien, Oktober 2018 Unterschrift