Surveillance and Subjectivity: A GIS-Based Study of Fear of Crime and CCTV Distribution

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Abstract: Crime is an ever-present aspect of daily life, encompassing both physical and virtual forms. How individuals perceive the fear of physical crime is inherently subjective, influenced by factors such as time, location, personal attitudes, behaviors, and individual personality. The increasing adoption of digital technologies, particularly the widespread deployment of Closed-Circuit Television (CCTV) cameras in various commercial and public settings, has brought into front their usage in crime detection and in enhancing physical safety in urban spaces. The present research introduces a novel geoinformatics-based methodology designed to quantitatively assess the subjective perception of safety among people in urban areas. The assessment and monitoring of the fear of crime have a long-standing history and are invaluable tools for law enforcement. The quantitative analysis identified a correlation between the spatial location of security cameras and urban areas that people perceive as dangerous.

Keywords: CCTV; crime geography; fear of crime; perceived sense of safety and security

1 Introduction

Crime and fear of crime have always been part of human life and human behavior. Crimes themselves vary widely, from minor offences like pick-pocketing and theft to severe acts such as kidnapping and manslaughter [1]. The present research specifically focuses on the perception of physical crime in physical urban areas and explores whether a tool like CCTV can help reduce that perceived fear of crime when it is installed.

Geoinformatics has developed rapidly recently, leading to its application in an expanding array of visualization fields. One promising area of its application is the study of the fear of crime. Evidence of public concern regarding crime-related issues is prevalent in many locations. Therefore, the primary objective of the present

research is to investigate the key spatial characteristics of urban residents' subjective perception of security within Székesfehérvár (the ninth largest city in Hungary), Furthermore, the study aims to explore whether the strategic deployment of CCTV cameras could help improve the perception of safety in areas previously identified with a high perceived human fear of crime.

The present research introduces a novel approach within the Hungarian context, as there have been limited studies that measure subjective perceptions of safety using geographic information tools. Furthermore, the study of the relationship between subjective safety and security perceptions and CCTV cameras is unique. The research proposes that there is a potential association between newly installed CCTV cameras in urban areas with high rate of crime detection and lower perceived fear of crime.

The paper is structured as follows. After the presentation of the research methodology, the concept of fear of crime is discussed with a condensed literature review presented, and the role of CCTV cameras in crime prevention and its role in mass surveillance will be discussed. The next section presents the results of the survey on the fear of crime in Székesfehérvár and draws conclusion how mass surveillance and CCTV cameras can improve safety and reduce the fear of crime feeling of humans in urban areas.

2 Fear of Crime – Literature Review

Many factors in society can cause people to fear, and a significant one is the fear of crime. This concept of fear of crime was first defined by Ferraro and La Grange in 1987 [2] as a negative emotional manifestation that most likely induces fear and anxiety in people. More simply, the fear of crime is a psychological and emotional response, like anxiety or worry, about the possibility of being harmed by a criminal act [3]. Given this conceptual definition, there are generally two approaches to look at it: the fear of crime itself, and the perceived risk of crime as being a potential victim of crime [4].

Individuals who perceive risk of fear in their lives are often not solely afraid of crime itself, but also of victimization [5]. The degree of anxiety can be strongly influenced by information disseminated through the media. Specifically, in areas with less crime-related content in newspapers and online media platforms, people tend to report a higher sense of security. This phenomenon is largely attributed to increased confidence, as individuals lack information that might suggest they are potential victims of crime [6]. The demand for crime-related information gained significant momentum in the 1970s, which consequently led to the emergence of a new discipline, victimology [7]. This field is dedicated to the study of victims of sexual and violent crime, with justice, and the typical behaviors of offenders.

Some research shows contradicting results. While on the one hand, research in the US and Germany has shown that victims of violent crime are more likely to get over what has happened than those who have suffered property damage [8], [9], [10]. However, the fear of victimization is not only related to the severity of the crime suffered, but also to the victim's standard of living. On the contrary, personal experience, for example a history of victimization or repeated victimization, can increase anxiety in people. Victims of crime often experience symptoms of post-traumatic stress syndrome (PTSS) and rape trauma syndrome (RTS), which improve only slowly over time and significantly impair their quality of life [11]. The following symptoms with a negative impact on the rest of the victims' lives are observed among trauma survivors: they avoid going out after dark, they dare to go out during the day only with an escort, they try to make their environment safe by various means [12].

According to Korinek, fear of crime is:

- an abstract concept, a certain anxiety meaning a general level where social fears are subsumed into a larger whole, e.g. war, unemployment, environmental pollution.
- a specific term, which refers to an individual and is a fear linked to the place where they live. In this category, the media plays a significant role, presenting both real and latent crime. In the case of a small municipality, for example, rumor also plays a significant role [13].

2.1 Mapping the Fear of Crime

In Hungary, the systematic analysis of crime was adopted by law enforcement roughly two decades later than in Western Europe. The primary reason for this delay was the unavailability of adequate technical tools within the country. In addition, the public in Hungary has historically been, and largely remains, skeptical and suspicious of this methodology, despite its demonstrated effectiveness in various parts of the world for decades.

The first official mention of crime analysis and mapping in Hungary was made in Act XXXIV of 1994 (Police Act) [14], which described the effectiveness of the new system. The regulations, which had already formulated the most important working procedures and concepts, were published in 2001 (the Crime Analysis Regulations of the Police of the Republic of Hungary) [15].

The maps produced with data from crime analysis belong to the group of thematic maps. A map is a scaled-down, generalized model of natural social phenomena, objects and processes on Earth or other celestial bodies [16]. According to their content, maps can be divided into two major groups. The first group includes the thematic maps mentioned above, which show the spatial distribution of data that can be related to the earth's surface, such as natural and social phenomena. The other

large group of maps is the group of general geographic maps, which describe the surface of celestial bodies in terms of general orientation. These maps can be either topographic or cartographic, depending on the level of detail, i.e. the scale of their representation.

Thematic mapping has been an integral part of human life for at least 1500 years. However, the earliest surviving map, or a direct copy thereof, dates back to the Roman Empire [17]. Thanks to the rapid development of various scientific disciplines, maps that show the basics of modern cartography could be produced as early as the 19th Century, which was also the beginning of rudimentary crime mapping, where scientists began to look for relationships between geographical location and crime rates. During this period, the most significant researcher in the field of various crime statistics was the French-born lawyer, André Michel Guerry. His seminal contribution is widely recognized as his 'Essay on the Moral Statistics of France' [18]. In his scholarly work, he noted that violence against property tended to be higher in the north of the country, while violence against the person was higher in the south. A few decades prior, a notable tool in police practice was the use of the so-called 'pin maps'. On these paper maps, the locations of murders and robberies were marked with pins and plotted on corkboards. While the original 'pin map' method is largely outdated, it is now being used in digital format in the United States. However, Hungary has not yet fully adopted this digital transition yet.

A major benefit of digital maps over traditional paper maps is that their immediate daily readiness. Additionally, paper maps demand considerable extra effort for archiving. Crime maps should also possess mobile capabilities. In this regards the Robotzsaru (NEO) Integrated Case Management and Case Processing System used by the Hungarian police can be of great help [19]. With the advent of personal computers, a system has been developed in the United States, with data provided by the Crime Mapping Research Center, founded in 1997 [17]. A new initiative in Greece, the Intelligence-Led Policing also integrates such new technologies in their practices [20]. Such maps can also used in other areas such as detecting visual pollution with the help of eye tracking [21].

In the field of domestic crime mapping a few experts who contributed to the development of the field and its application in law enforcement is worth mentioning. Erdősi was the first to propose the inclusion of geospatial information in crime analysis [22]. One of the authors of the paper, Pődör continued Erdősi's ideas and presented some practical applications with results that can be used in domestic crime prevention [23], [24]. Furthermore, Mátyás [25] a researcher at the National University of Public Service conducts research in criminal geography. Fuzzy extension of mapping crime has also been tested in Hungary [26], while the use of mapping can be traced in visualization of semantic proximity in the work by Kumargazhanova et al. [27].

Below, some of the principal types of maps that are recommended for use in crime mapping will be examined. Single-type thematic maps are rare in criminology, usually map types are mixed, a combination of maps is applied [28].

- Dot maps are the most commonly used type, displaying information as a point. Their density and size indicate the degree of concentration.
- Chorochromatic maps use color to express the differences in quality.
- Isoline maps are used to display not only temperature, precipitation, barometric pressure or terrain at the same elevation, but also crime data.
- Choropleth maps use statistical data to map the available information. It provides a spatial representation of the differences of relative quantities
- Diagram maps try to make statistical data more understandable by means of diagrams and are, therefore, also excellent for crime mapping.
- Pictogram map: uses symbols to present information in a clear way. The Robotzsaru system is also based on this method.[17], [29].

3 The Role of CCTV in Crime Prevention

Thanks to leaps and bounds in technology, anyone can now easily access a wide range of image capture equipment. However, we need to be aware of data protection issues related to image and video recording and we must be aware that these activities may infringe personal and property rights. The same principle applies to urban CCTV systems. However, in their informational campaigns regarding CCTVs, municipalities often exclusively emphasize the positive effects role of these systems in crime prevention. Nevertheless, these systems generally enjoy public support and foster confidence in the authorities.

The results of empirical studies on CCTVs are not uniform and the effectiveness of crime prevention is still unclear. For example, although some studies have concluded that CCTVs are effective in preventing crime [30], [31], [32], [33], others have found that crime rates were reduced more in the control area than in the test area with deployed CCTVs [34]. Studies have concluded that the presence of a CCTV, depending on the area of installation, did not result in crime reduction in residential areas, but was effective in preventing crime in parking lots and other relatively enclosed areas [35]. In addition, depending on the type of crime, some studies have shown that CCTVs were effective in preventing property crimes such as theft and robbery [31], [33].

In addition to crime prevention, CCTVs have also been proposed and installed to reduce the fear of crime in communities [36]. A number of studies have been conducted to test the effectiveness of CCTV on the fear of crime [37]. Research has shown that over 70% of residents reported a reduction in fear of crime after CCTV

installation [38], [39]. Other studies have confirmed that CCTV was not effective in preventing crime, but was effective in reducing fear of crime and increased the perception of safety [38], [40], [41]. In contrast, other studies reported that CCTV was not effective in reducing fear of crime [42] or increasing the perception of safety [43].

Three major stakeholders are identified among those involved in the operation of CCTVs, namely the state, the market and the public. The state tries to reinforce the sense of security by installing CCTV cameras. The market is interested because of the revenue from the sale of equipment, as if the state decides to expand, the various camera manufacturers can sell more equipment and use the revenue to develop new equipment, which can then generate additional revenue. Finally, we should not forget the public, who are the ones who support the expansion of such a system in the hope of a safe and secure living and working environment, but who also expect in return the tax paid to be used for the right purposes by the state [44].

3.1 The Beginning of Space Monitoring

The camera system that monitors our lives was already in the imagination of the writer Orwell in 1948, when he put the plots of his famous novel 1984 at the service of the Thought Police: 'With the development of television, and the technical advance which made it possible to receive and transmit simultaneously on the same instrument, private life came to an end Every citizen, or at least every citizen important enough to be worth watching, could be kept for twenty-four hours a day under the eyes of the police and in the sound of official propaganda, with all other channels of communication closed.' [44], [45, p. 214].

The first CCTV cameras were installed in 1942 to study the launch of the German wonder weapon (V-2) [46]. Subsequently, banks and shopping centers were equipped with security cameras. As time went by, electronic surveillance systems were more readily accepted by society and the era of digital mass surveillance started [47]. As Lazányi states [48] there is significant advancement in surveillance methods that significantly contribute to crime prevention. It is to emphasize that mass surveillance is often regarded as a necessary evil in order to create safety and security and to maintain stability [49], which is probably since the 1990s, more attacks have been stopped and perpetrators identified thanks to electronic devices. The technological advancement and the gradual acceptance of surveillance is now considered a fundamental dimension of modern societies, called the Surveillance Society by Lyon [50]. In Hungary, five CCTV cameras were first installed in November 1997 in the fifth district of the capital, Budapest, which is now, in an upgraded form, the mainstay of the modern metropolitan network [44].

Based on the literature review the following hypothesis was formulated:

H1: There is a potential association between newly installed CCTV cameras in urban areas with high rate of crime detection and lower perceived fear of crime.

The hypothesis is tested in the ninth largest city in Hungary in Székesfehérvár, and because of the surveying mode and technique, the survey can be repeated in any other cities and settlements.

4 Research Methodology

The research employed a quantitative survey method after the novel method of geoinformatics had been identified [51]. The survey used the web-based interface previously employed by Jakobi and Pődör [52] for data collection. On this specific platform, respondents were asked to encircle the areas with different colors where they feel safe or unsafe, that is they could identify the areas they consider safe or frightening. In this way participants drew polygons on the map. The accuracy of the processed results is greatly influenced by the precision of the participants, specifically how accurately each polygon was drawn. To a large extent precision also depends on the time invested in filling in the polygons. The map was part of a questionnaire which included questions on gender, age, and the form of transportation they typically use.

Data collection was done through the above detailed questionnaire, partly online and partly through structured personal interviews in the streets of Székesfehérvár. Therefore, partly purposive, partly convenient sampling methods were applied, which did not result in a representative sample, however, could reach people, who actually live and move in Székesfehérvár, and has experience in the city and have a general knowledge of the location of CCTV cameras. The questionnaire was anonymous and by filling in the questionnaire the participants gave their consent as well. The availability of the questionnaire was advertised on social media platforms, and in both years, approximately 100 participants responded.

The processing methodology was the same as the one previously presented in Jakobi & Pődör [52]. According to this method, a grid was placed over the overlapping polygons obtained from the questionnaire responses, with each grid cell measuring 100x100 meters. Using geographic information system (GIS) software, the number of overlapping polygons under each cell for both the unsafe and safe labels were calculated. Then, using the union of the resulting layers, the number of labels for each cell – negative for unsafe labels and positive for safe labels – resulting in a global evaluation for each cell in both years were added up. Afterwards, the cells where surveillance cameras were already installed in 2022 were filtered out. As the last step, the values obtained for these specific cells in both 2016 and 2022 were evaluated and compared.

The information received was used to create a spatial database, from which the authors produced spatial analyses and mapped maps to identify areas that people perceive as dangerous. In addition, the authors investigated correlations between

locations of security cameras and the areas identified by participants. All spatial data was processed by ArcGIS Pro software version 3.3.0.

5 Results and Findings

When these polygons are analyzed, some differences in the data collected at two separate times can be spotted. However, for the most part, the results remain nearly identical.

5.1 Demographic Profile

A total of 159 individuals participated in the survey in 2016, whereas 66 responses were collected in 2022 (Table I), which can be attributable to the longer data collection period in 2016 (three months), compared to the one-month period in 2022. In the 2016 survey, the proportion of female respondents was generally higher compared to males, and both yearly surveys were characterized by a higher proportion of young men (39.06% in 2016 and 31.58% in 2022). Younger generations rather responded to the questions (between 60 and 75% of participants, males and females came from the age range of 18 to 50).

Table 1
Demographic overview of the Respondents

Age	**2016**			**2022**		
	Female	**Male**	**F/M**	**Female**	**Male**	**F/M**
18-20	5	9	0.56	4	5	0.80
21-30	21	25	0.84	6	12	0.50
31-40	21	17	1.24	5	5	1.00
41-50	26	6	4.33	7	6	1.17
51-60	19	5	3.80	3	6	0.50
61 and older	3	2	1.50	3	3	1.00
Total	95	64	1.48	28	38	0.74

In both surveys, the number of pedestrians was the largest 44.65% and 46.97%), highlighting the importance of CCTV cameras in shaping perceptions of safety (Table II).

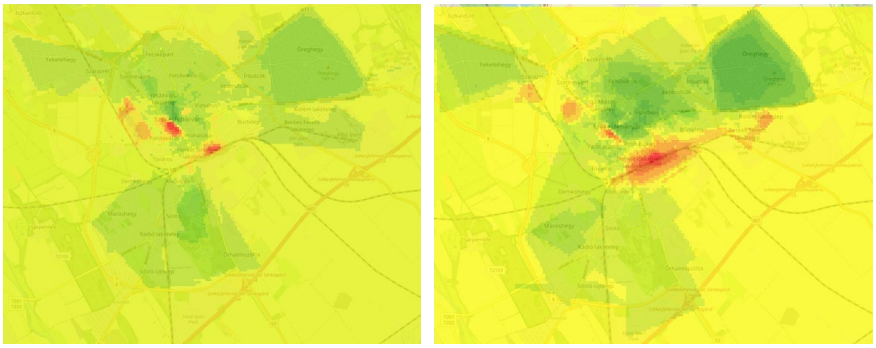
Table 2
Distribution of respondents by mode of transport

Mode of transport	**distribution of the respondents (%)**	
	2016	***2023***
car	31.45	30.30

bicycle	8.81	12.12
public transport	15.09	10.61
foot	44.65	46.97

5.2 The Emergence of Fear of Crime

Both maps (Figure 1) compiled based on the collected data from 2016 and 2022 show safe (green) and dangerous (red) areas.



2016 **2022**

Figure 1
Perceived safe and dangerous areas based on data collected in the first round of surveying in 2016 and in 2022, the differences in each pixel (100*100m) (source: edited by the authors)

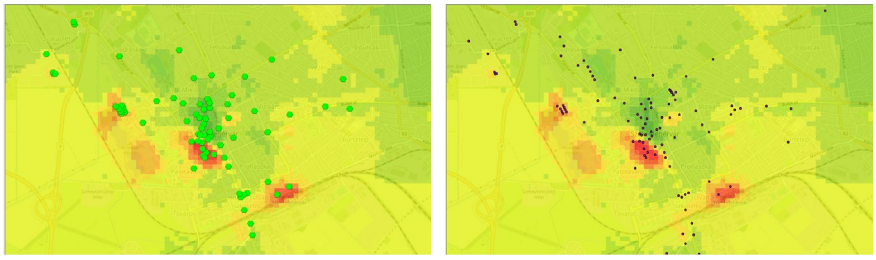
Based on the survey responses, the participants found the same areas dangerous in 2016 and in 2022. The intensity and spatial spread of the red color were notably greater in 2022. This suggests an increase in the perceived less safe areas within the specific city (Székesfehérvár). To determine the overall evaluation for each cell, a negative value was assigned if it was labeled as frightening and a positive number was assigned if it was labeled as safe.

Based on the maps and the respondents' opinions, four main areas are considered hazardous. The first main area is the railway station and its surroundings (Peace Square), the second main area includes a plaza area (the Alba Plaza) and the square (the Palotai kapu square) in front, the bus station (Piac Square) and a park (Petőfi Park) opposite. The third main area is a neighborhood where a certain type of segregation can be identified. This neighborhood is Mura Street, where social rented housing is located. The fourth main area is the neighborhood (Hübner András Street and Gánts Pál Street), where also social rented housing units are typical. In addition, it can be stated that smaller to larger districts are predominantly characterized by dangerous markings. These areas are a row of garages (Tóvárosi housing estate), the area around a department store (Skála), and the housing area of workers (part of the Köfém housing estate) nearer the industrial park.

5.2.1 Safe Areas and Zones

Further examination of the maps (Figures 1) shows that the suburban areas of the city, i.e., Feketehegy-Szárazrét, Öreghegy, Maroshegy and Felsőváros can be considered safe areas. They also include the Historic Downtown, the Water City residential area and the Guard Hills, as well as the Sóstó and the Radio Park.

Take into account the presence of surveillance cameras (Figures 2) as well, it can be said that an increase in their number does not necessarily expand the size of safe areas nor do new areas entirely deemed dangerous emerge. Instead, the primary effect is an increase in the number of polygons within already identified areas, thereby intensifying the perceived level of safety or danger in those existing locations. It can be attributed to a loss of trust among the public, and the higher number of CCTV cameras triggers a reverse effect. People may believe that CCTV cameras have been installed precisely because the number of crimes in that area has justified their presence.



2016 **2022**

Figure 2
Location of CCTV cameras in 2016 and 2022

Figure 3 shows the results map extractions with the number of installed cameras in 2016 and in 2022.

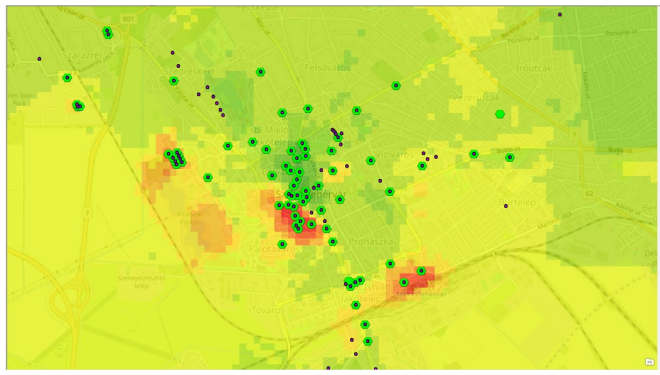


Figure 3
Location of cameras in 2016 and 2022

The grid cells where there is a minimum one CCTV located are visualized. The coloring refers to the respondents' global evaluation: green indicates a predominantly positive evaluation, while red signifies a predominantly negative evaluation. The grid cells are numbered from 1-101. The map also shows the intensity of CCTV cameras in the specific area. Green colored symbols indicate cameras in 2016, and black colored symbols indicate cameras in 2022, overlaid on the surface depicting the global evaluations of the respondents in 2016.

It is also necessary to look at the figures themselves that is to look at a distribution chart based on the camera pixel values. It can therefore be observed that in certain locations, the number of areas designated as dangerous has remained unchanged. The likely reason is that the perception of safety has not changed. On the other hand, there are locations where the situation has improved drastically with CCTV cameras installed. The differences in the rating of safe and unsafe areas in 2016 and 2022 were calculated, and the global evaluation of the respondents for each grid cell where a CCTV can be found for the years 2016 and 2022 was conducted (Figure 4).

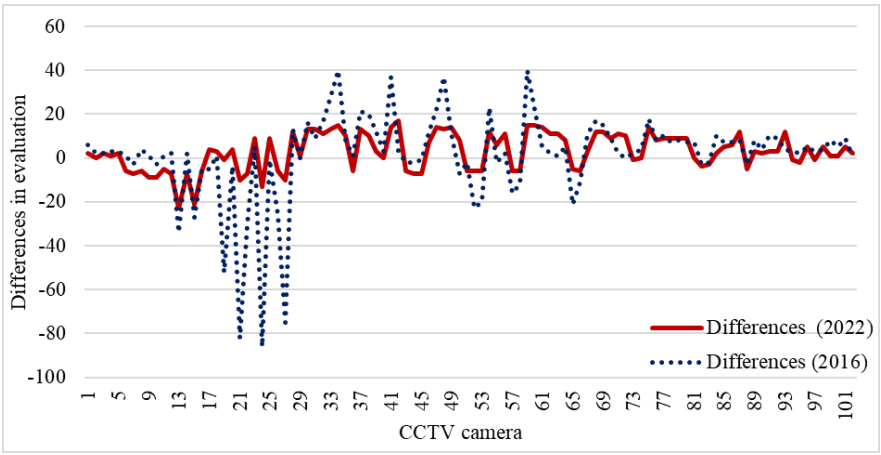


Figure 4
Global evaluation of the respondents for each cell where a CCTV can be found for the years 2016 and 2022

It is clearly visible, for example, in the grid cells containing CCTVs numbered between 18 and 28, located near the bus station on the map in Figure 5. At this particular location there has been no significant increase in the number of surveillance devices. However, the perception of crime has slightly decreased.

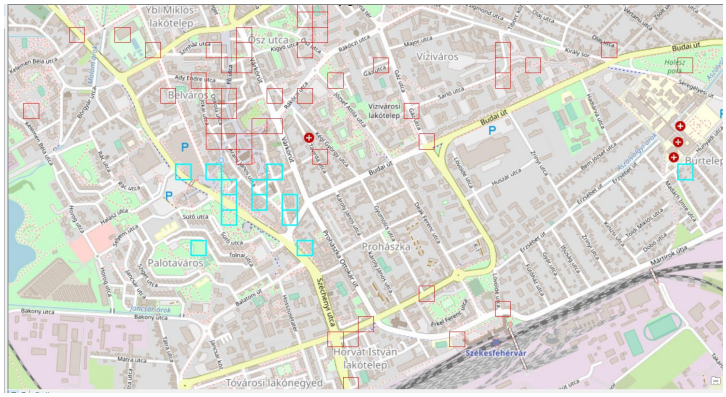


Figure 5
Camera pixels where CCTV cameras have led to significant improvements

The diagram in Figure 6 shows a relatively similar trend in the other parts of the city. In the area with CCTVs indexed 30-60, the number of polygons drawn by the respondents is higher as more respondents mark these grid cells safe in 2022.

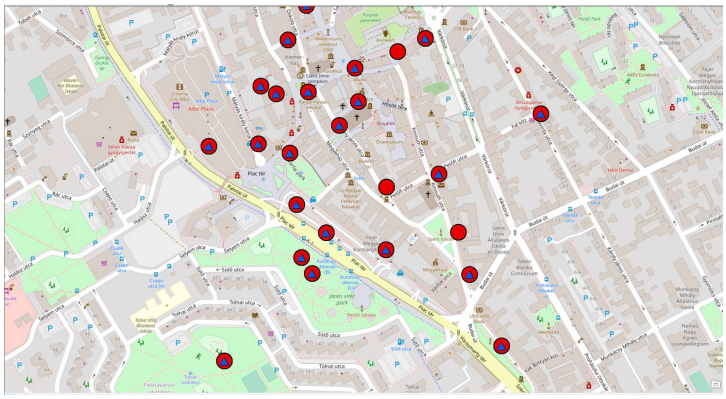


Figure 6
Surveillance cameras around the bus station

A combined map is presented in Figure 7, where CCTV cameras have led to significant improvements by 2022. Green depicts the best evaluation, while red color means the worst. A limitation of this study is the inconsistency in participant demographics and sample size between the 2016 and 2022 data collections. Specifically, the cohorts were not longitudinal, meaning the same individuals did not participate in both survey administrations. Consequently, direct comparisons between the two years must be interpreted with caution. To mitigate this issue and enhance the robustness of the statistical analysis, a bootstrapping method was employed.

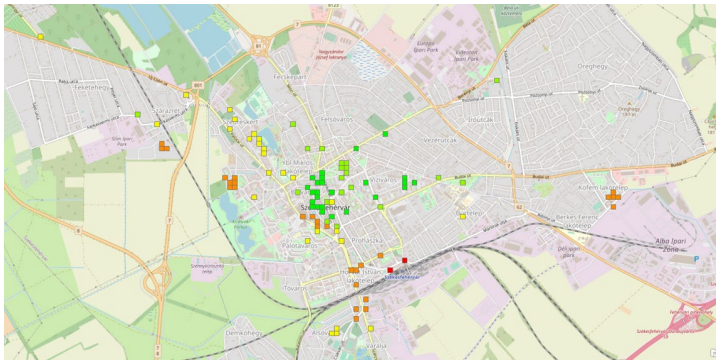


Figure 7
Camera pixels where CCTV cameras have led to significant improvements in 2022

Independent t-test helped to evaluate the comparison of the results in 2016 and 2022. As no equal variance could be justified, the test version assuming unequal variances were applied. In total, no significant increase in perceived safety could be detected in the areas where CCTV cameras are installed ($p>0.05$), but areas with different changes could be found. Cameras numbers 18-28 are newly installed cameras, which were installed after the evaluation of the results in 2016. In these locations, the perception of safety increased noticeably ($p=0.012$), i.e. the perception of fear of crime significantly decreased. Changes to the worse – increased fear of crime – could be detected in the locations of the CCTV cameras numbered 30-60, where cameras were already installed in 2016, but this negative change did not prove significant ($p>0.05$). The perceived fear of crime slightly increased but still inhabitants feel safe in these areas. The difference could be attributed to the different participants in the observed periods. As CCTV cameras were installed in the areas where a higher rate of crime was detected (based on police data), consequently, the hypothesis is supported with the results and therefore it can be concluded that CCTV camera installation strengthens the positive effect on perceived safety.

Discussion and Conclusion

Based on the research results, it can be concluded that the installation of CCTV cameras has reduced the sense of fear in the observed area for a substantial majority of the population (over 70%). A significant relationship was found between perceived fear of crime and the newly installed surveillance cameras in areas previously considered dangerous ($p<0.05$). In the observed area already equipped with surveillance cameras, there was no significant change in the perceived fear of crime. The results are partially aligned with the findings of other studies, where it was found that CCTV cameras did not substantially reduce crime, but significantly improved the public's perception of safety [53]. Furthermore, it aligns with a study's results that CCTV cameras had no positive effect at all on reducing crime or improving the aforementioned sense of security [37], [54]. It also shows that CCTV

cameras have a different effect on women and men. Women are less affected by these devices, while men experience a significant reduction in fear of crime [37].

The study examined the possible relationship between fear of crime and geospatial information. In the literature review, the most important concepts and possible methods of representing crime on maps were introduced. Subsequently, the social context of crime and criminality in relation to segregation was explored. The authors presented the neighborhoods of Székesfehérvár as the sample area studied. In addition, the solutions for spatial surveillance, the relationship between spatial information technology and crime prevention, and the relationship between the information obtained from the evaluation and spatial surveillance cameras were examined.

The research has its limitations as different people participated in the survey in 2016 and 2022, which can cause certain bias, however, due to the similar nature of results, they could be compared. The method applied can be generalized and future research will include further surveys in other smaller and larger cities, and rural areas in order to map inhabitants' perceived fear of crime and to help policy makers and the police with CCTV camera usage and mass surveillance.

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