PREDICTIVE ACCIDENT FORECASTING SOFTWARE IN HUNGARY AND SERBIA

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Abstract. *This paper examines predictive software tools developed in Hungary and Serbia for forecasting traffic accidents. Using artificial intelligence and statistical analysis, these systems aim to identify high-risk locations and reduce accident rates. The Serbian ANN1 and ANN2 models use neural networks to predict accident numbers and severity, while Hungary's Sopianae software integrates historical data with lunar and weather factors. These predictive technologies are particularly valuable in regions where traditional traffic safety methods have proven insufficient, and where law enforcement resources are limited. Both systems enhance preventive policing and support traffic safety planning. By analyzing temporal and spatial accident patterns, authorities can deploy patrol units more effectively and proactively reduce risks. The study evaluates the potential of predictive analytics to support the EU's long-term road safety goals. Results highlight the importance of data-driven decision-making and the need for international cooperation in preventing traffic accidents. Additionally, the paper explores the origins of predictive policing in Hungary, predating well-known American initiatives, and presents preliminary results from the Sopianae system's application in Pécs. By promoting innovation and cross-border collaboration, these tools may significantly contribute to reducing fatalities and improving public safety, especially in Central and Eastern Europe, where predictive solutions remain underutilized.*

Keywords*: predictive policing, traffic, Serbia, Hungary, accident*

1. INTRODUCTION

Most people have witnessed a traffic accident or have even been involved in one themselves. In most cases, accidents result in property damage only, without personal injury. However, thousands of serious and fatal traffic accidents occur each year in most European countries. If we were to sum up the total damage caused by these accidents, the final amount would be measured in billions of euros. In the case of an accident, one typically considers the damage to the vehicles, which is usually covered by insurance – if one exists. However, in many cases, infrastructure such as lampposts and other public property is also damaged, and the state bears the cost of repair. Injured individuals are often unable to work and may require long-term hospital care, which again results in significant expenses paid by the state (Mohammed, 2023: 70). Additionally, road closures caused by accidents usually lead to traffic delays that last for hours, forcing drivers to

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take detours, which entails extra costs. When someone dies in a traffic accident, it is a tremendous loss – not only financially but also morally – for society as a whole.

With the above, the authors aim to illustrate that preventing traffic accidents is a shared societal interest that concerns everyone. This is why traffic safety systems must operate as efficiently as possible (Sugiyanto – Santi, 2017: 110).

Predictive policing has the potential to emerge as one of the most significant domains in the 21st century due to several compelling reasons. Firstly, the advancement of data technology in the 21st century has led to an exponential increase in the volume and quality of data available. This proliferation of data, coupled with the development of sophisticated analytical tools, enables law enforcement agencies to make more accurate and effective predictions regarding the locations and times of potential criminal activities. Secondly, the evolution of machine learning and artificial intelligence technologies has enhanced the capability of predictive systems to recognize complex patterns and make precise forecasts. This technological progress aids law enforcement in the optimal allocation of resources and the preemption of criminal activities. Thirdly, the capability for real-time data analysis provided by modern technologies allows law enforcement to respond immediately to changing conditions and crime patterns. This responsiveness increases operational efficiency and reduces reaction times. Fourthly, predictive policing facilitates the optimization of police resources by focusing on the likely locations and times of criminal activities. This targeted approach minimizes unnecessary patrols and increases police presence in areas with the greatest need, thereby enhancing overall effectiveness. Fifthly, the societal impact of reducing crime and enhancing safety cannot be overstated. Safer environments improve the quality of life, attract investments, and foster economic growth, thereby benefiting communities at large. Lastly, continuous innovation and technological development promise to make predictive systems even more accurate and effective in the future. This ongoing evolution suggests that predictive policing will have an increasingly significant impact on crime prevention and public safety efforts. In summary, the combination of technological advancements, data analytics, and the potential for significant societal benefits positions predictive policing as a potentially pivotal area in the fight against crime and the enhancement of public safety in the 21st century (Farkas – Sallai, 2021: 275).

2. WHAT DOES PREDICTIVE POLICING MEAN?

At first glance, the question posed in the title may seem simple, and one might be tempted to provide a straightforward, definition-like answer. The most frequently cited interpretation is the one by Perry, which states the following:

"Predictive policing is the application of analytical techniques – particularly quantitative techniques – to identify likely targets for police intervention and prevent crime or solve past crimes by making statistical predictions." (Perry, W. L. et al. 2013: 15.) Its very interesting that the predictive system was introduced in the prison system as well, called predictive tool for reintegration of inmates (Czenczer, 2009: 8).

There is, however, a notable limitation in the above definition. When Perry and his co-authors first formulated the concept of predictive policing, they primarily focused on forecasting crimes and identifying potential offenders. At that time, they did not yet consider that predictive methods could also be applied to non-criminal public safety issues, such as forecasting traffic accidents. While the core elements of Perry's definition remain valid over a decade later, they require an update to reflect new fields of application.

This conceptual gap was addressed by Szabolcs Mátyás, who, in a forthcoming 2025 textbook on predictive policing, proposed the following expanded definition (the book had not yet been published at the time of writing this paper):

"A GIS application based on mathematical and statistical principles that – also enabling the application of artificial intelligence – predicts the expected location and time of crimes, as well as the possible range of victims and perpetrators, based on past crime data, with a certain percentage of error; predictive forecasting also can predict the expected location, time and type of traffic accidents." (Mátyás in press)

This revised definition explicitly broadens the scope of predictive forecasting beyond crime, recognizing that traffic accidents – as spatio-temporal events with identifiable patterns – can also be predicted using similar methodologies. Thus, predictive policing is no longer limited to crime prevention but is evolving into a wider, more versatile tool in public safety management.

Reducing the number of road traffic accidents is a key factor in evaluating the efficiency of police organizations; therefore, a predictive approach is particularly emphasized in this context (Tihanyi – Vári, 2025: 121).

3. SOME THOUGHTS ON THE ORIGINS OF PREDICTIVE POLICING

When we look at predictive policing historical sources written in English and other languages, they almost always "lead” the reader to the United States (Perry et al., 2013; Szikinger, 2016). These sources claim that the American retail giant Walmart noticed that weather changes (e.g., rainy, sunny, dry) influenced the types of food and other goods people bought. A clear correlation was found between rainy weather and the sale of rubber boots and umbrellas. However, it was more challenging to find a connection between the weather and the sales of Strawberry Pop-Tarts. This iconic sweet treat became the first product whose demand was successfully forecasted — specifically when more or less of it would be purchased. Once this prediction proved effective, the logic followed: if it is possible to predict when people will buy more Strawberry Pop-Tarts, then perhaps it is also possible to predict when and where crimes will occur. This marked the inception of the PredPol software (although it wasn’t initially called that, and it has since ceased operation).

This is the story that appears in almost every academic article about predictive policing. However, the reality is different. The first functional predictive software was developed in Hungary. In 2004, it was created by Ferenc Traub, a police officer at the Budapest Police Headquarters, who developed the software in his spare time. In the early 2000s, car theft was a significant problem in Hungary (Mátyás, 2017a: 500). In District III, where Ferenc Traub worked, numerous vehicles were stolen every week (Mátyás, 2017b: 220). At the time, the police lacked proper equipment and had too few officers, making it impossible for them to combat this wave of crime successfully. Thanks to the software, the number of vehicle thefts dropped. The program was capable of predicting five types of crimes. It was used for many years and proved highly effective. District III is also home to the Sziget Festival grounds – Europe’s largest open-air festival. For several years in a row, there were instances where no crimes occurred in the streets surrounding the festival (Traub, 2004: 6; Traub, 2005: 4; Molnár, 2016: 6).

The software was introduced to other countries by foreign police officers visiting the area during the Sziget Festival. It was taken to Germany, France, the Czech Republic, Poland, and the Netherlands. However, there is no available information on whether it was used in those countries.

Eventually, the use of the software was discontinued. Partly because Ferenc Traub retired and his deputy left the police force. Additionally, in the second half of the 2000s, crime rates began to decline rapidly nationwide, resulting in a lack of sufficient data for the software to operate effectively. For any predictive software to function accurately, it requires a substantial amount of historical data.

Based on the above, it is clear that the origins of predictive policing should not be credited to the Americans but rather to Hungary's Ferenc Traub, who created such software as early as 2004.

4. THE IMPORTANCE OF PREDICTIVE ANALYTICS IN TRAFFIC ACCIDENT PREVENTION

Accurate forecasting and thorough risk analysis are crucial tools in preventing traffic accidents. Predictive analytics can, within a certain margin of error, anticipate the likelihood of accidents and identify the contributing risk factors. This technology enables authorities to generate forecasts that serve as a foundation for preventive measures, such as increased patrol presence, warning systems, or optimized road maintenance. Forecasting accidents is particularly crucial in countries where transport infrastructure is underdeveloped, and the economic impact of accidents is especially severe (Kaliraja et al., 2022: 1784).

In both Hungary and Serbia, traffic accidents pose a significant public safety issue. The number of serious and fatal accidents in both countries remains above the European average. While this study does not seek to explore all the underlying causes in-depth, factors such as aging vehicles, poor road conditions, and aggressive driving behavior – commonly observed in both nations – are worth noting. As motorization increases and more vehicles fill the roads, traditional accident prevention strategies are proving insufficient. Thus, both Serbia and Hungary have been seeking new approaches to reduce accident rates (Szabó – Bíró, 2024: 12).

In many countries, predictive algorithms are already in use for traffic accident forecasting. However, such methods remain relatively rare in Central and Southeastern Europe. This study presents a scientific experiment conducted in Serbia and Hungary, aiming to demonstrate how predictive software could contribute to a decrease in serious and fatal road accidents. The paper references predictive algorithms applied in both countries. Still, it focuses more specifically on the Hungarian solution since only one prior study has been published about it in a foreign language.

5. THE VISION OF THE EUROPEAN UNION

"2. SAFE MOBILITY: Putting safety first

Safety is fundamental to any transport system; it must always be the top priority. As mobility continues to grow and is radically transformed by digitisation, decarbonisation and innovation, the opportunities to further improve safety performance must be seized.

They undertook to set a target of halving the number of serious injuries in the EU by 2030, compared to the 2020 baseline.

Road safety in the EU has improved significantly in recent decades, thanks to actions at the EU, national, regional, and local levels. Between 2001 and 2010, the number of road fatalities in the EU decreased by 43 percent, and between 2010 and 2017, by another 20 percent. Nonetheless, 25,300 people still lost their lives on EU roads in 2017, equivalent to some 70 lives lost per day, and about 135,000 people were seriously injured, including a large percentage of pedestrians, cyclists, and motorcyclists. These figures represent an unacceptable humanitarian and social cost. In monetary terms, the annual cost of road fatalities and serious injuries has been estimated to exceed EUR 120 billion, equivalent to approximately 1 percent of GDP.[1]

The EU's long-term goal will remain moving as close as possible to zero fatalities in road transport by 2050 ("Vision Zero"). The same should be achieved for serious injuries. The EU will also pursue new interim targets to reduce the number of road deaths by 50 per cent between 2020 and 2030 as well as to reduce the number of serious injuries by 50 per cent in the same period (using the new common definition of serious injury agreed with all Member States)." (European Commission 2018)

According to official European Union documents, traffic accidents cause significant social and economic damage in all member states, resulting in annual losses of several billion euros. Although Serbia is not an EU member state, the principles outlined by the EU are still relevant, as it is in the fundamental interest of every country to reduce the number of traffic accidents – particularly those resulting in serious injuries or fatalities.

The European Commission's 2018 policy document outlines highly ambitious goals: by 2030, the number of road fatalities is expected to be halved compared to 2020, and by 2050, the EU aims to achieve zero road deaths. The authors of this paper argue that these goals are unrealistic. Based on current statistical trends, it is unlikely that the number of fatalities will be halved by 2030, and it is even more improbable that zero road deaths will be achieved by 2050. The available data do not support the EU's "vision." Nevertheless, efforts to reduce traffic accidents remain essential. Every possible tool should be utilized to get as close as possible to these targets, even if they may not be fully attainable. One such tool is the use of predictive algorithms, which can support more effective prevention and decision-making in traffic safety management (European Commission 2018).

6. NEIGHBORING COUNTRIES, SIMILAR PROBLEMS

Serbia and Hungary differ from one another in many respects; however, they share several common characteristics, particularly in terms of road safety. In this study, the authors briefly outline the most relevant similarities that affect traffic accident patterns in both countries.

As shown in Table 1, there is no significant difference in the overall size or population of the two countries. Yet in 2024, Serbia – despite having a smaller population – recorded a higher number of personal injury accidents (Serbia: 18,574; Hungary: 14,678) and fatal road accidents (Serbia: 498 fatalities; Hungary: 446 fatalities) than Hungary. When calculating these figures per one million inhabitants, the difference becomes even more pronounced. The rate of personal injury accidents in Serbia is almost

[1] Although from a criminal law perspective these acts are not classified as road traffic accidents, it is nevertheless important to note that in 2016, a new form of terrorist tactic emerged in Europe: the Vehicle-Ramming Attack. In contrast to typical road traffic incidents, which are generally the result of negligence, these attacks are characterized by intentional conduct. According to the provisions of the Criminal Code, such acts fulfil the statutory definition of terrorism, yet they are perpetrated on public roads using vehicles, and result in fatal outcomes (Vajda, 2017: 180; Vajda, 2022: 22).

twice that of Hungary (2814.2 vs. 1589.9). In contrast, the frequency of fatal accidents is over 1.5 times higher in Serbia compared to Hungary (75.5 vs. 46.5). Furthermore, the proportion of serious road accidents is approximately 20% lower in Hungary compared to Serbia (URL 1, 2).

Table 1. Main traffic statistical indicators of Serbia and Hungary (Source: URL 1, 2, 3, 4)

	Hungary	Serbia
Area (km²)	93,000	77,474
population (million people) (2024)	9,6	6,6
Personal injury accidents (cases) (1 million people) (2024)	14,687 (1589,9)	18,574 (2814,2)
Fatal accidents (number of deaths) (1 million persons) (2024)	446 (46,5)	498 (75,5)
Number of serious traffic accidents (cases) (1 million people)	4143 (431,6)	3524 (534,0)
average age of vehicles (year)	16,2	17

Hungarian traffic safety indicators are significantly better compared to those of Serbia; however, when measured against the EU average, Hungary still ranks among the worst-performing countries. The underlying causes of these high values are often similar. In many cases, poor road quality (Ürmösné, 2024: 150) is directly linked to the occurrence of accidents. In both countries, a considerable proportion of roads need renovation. The average age of vehicles is another important contributing factor. In both Serbia and Hungary, the average vehicle age exceeds the EU average of 12.5 years, which increases the risk of accidents, as older vehicles are typically less equipped with modern safety features. Another significant risk factor is aggressive driving behavior. Although it is difficult to quantify and objectively measure the aggressiveness of driving styles in a particular country, it is widely acknowledged that drivers in Balkan countries tend to drive more dynamically and assertively. In Hungary, notable differences in driving behavior can be observed between the eastern and western regions of the country (URL 3, 4).

6.1. The Serbian ANN1 and ANN2 Models

The Serbian software is based on artificial neural networks (ANN). It was developed to reduce the number of traffic accidents and to support transportation planning, particularly on newly constructed road sections. The software predicts the number of traffic accidents as well as the severity of their consequences, including fatalities, injuries, and property damage. Two separate models were created: ANN1 and ANN2. The ANN1 model is designed for two-lane roads (non-motorways), whereas ANN2 is designed explicitly for motorways (Gatarić et al., 2023: 3).

The software relies on several indicators that contribute to its predictive capability. These include road length, terrain type, road width, average daily traffic volume, and speed limit. The research was conducted in two countries: Serbia and Bosnia and Herzegovina (Republika Srpska).

The two models focus on different predictive goals. The ANN1 model forecasts the number of accidents, while ANN2 predicts not only the number of accidents but also the number of fatalities, serious injuries, and property damage cases. To ensure model accuracy, more than 100,000 different configurations were tested. Both models are capable of predicting accidents and their severity with high precision. Additionally, they can identify road segments that are considered particularly hazardous. One of the most critical questions in predictive modeling is determining which indicators are most relevant for forecasting accidents or crimes and what weight each of these indicators holds in the prediction. Since not all factors contribute equally, their relative importance must be analyzed. In this particular software, road length was found to be the most influential indicator (Gatarić et al., 2023: 7).

The software is useful not only for law enforcement but also for traffic authorities. The model can be applied to both existing and planned roads. For newly constructed roads, where no historical accident data is yet available, the model's predictions are especially valuable. In such cases, forecasts are generated based on expected traffic volumes and road geometry.

According to the developers, the model is effective in both urban and non-urban environments. Furthermore, its applicability is not limited to Serbia and Bosnia and Herzegovina; it can also be implemented in other countries. The developers emphasize the model's efficiency and potential cost savings, highlighting its usefulness in supporting transportation policy decisions (Gatarić et al., 2023: 11).

6.2. The Hungarian Sopianae software[2]

The Sopianae software was developed to forecast traffic accidents in Hungary, with the primary goal of enhancing the efficiency of police operations. Developed by teachers at Ludovika University of Public Service (Budapest), the system was created in response to a noticeable decline in traditional crimes, such as burglaries and thefts, while traffic accidents remain a significant public safety issue. The National Media and Infocommunications Authority funded the project, and testing has been conducted by the Pécs Police Department using real accident data.

Technically, Sopianae consists of a Microsoft SQL-based database and a Windows Form application written in C#. The software operates independently and offline without relying on external systems or networks. Forecasts are based on the statistical analysis of previous traffic accident data, including the date, time, location, accident type, weather conditions, and a unique factor: the phase of the Moon. Developers included lunar phases because studies suggest a correlation between full moons and behavioral or physiological changes that may increase the risk of accidents.

Sopianae includes eight core features: accident registration, daily forecast, action plan, statistical analysis, patrol zone guide, backup function, data editor, and exit. The accident registration interface uses codes from the Hungarian Central Statistical Office, ensuring standardized input for causes, vehicle types, and outcomes. The daily forecast function supports patrol planning by identifying high-risk streets and providing printable suggestions for deployment. The action plan module focuses on weekly patterns, determining the days with the highest accident risk and allocating resources accordingly.

Commanders can generate and edit Word documents summarizing action plans, including assigned officers and vehicles. The statistical function allows monthly comparisons by police unit or district, with data visualized through clear graphs and charts. The patrol guide helps determine jurisdictional boundaries, supporting file

[2] This chapter is based on the summary of – in press – book chapter titled **"The Sopianae Software"** by Szabolcs Mátyás and Zita Traub.

management and administrative processes. The backup module ensures that recorded data is regularly saved to avoid losses, and the editor allows for live updates to data, such as adding new streets or updating accident causes.

Although Sopianae was developed as a prototype for the city of Pécs, its flexible architecture allows it to be adapted to other areas. It could be used in border policing, urban traffic control, or even criminal investigations, provided that the data models are customized to fit the specific context. The primary objective of the software is to facilitate predictive policing, support data-driven decision-making, and prevent traffic accidents through proactive interventions. In this regard, Sopianae serves not only as a data tool but as a complete decision-support system. It demonstrates how modern technology and predictive analytics can directly contribute to public safety.

6.2.1. Results so far

This subsection provides a brief overview of the results achieved using the Sopianae software at the Pécs Police Department. The term "results" should be used cautiously in the context of predictive policing, as any reported success can be easily challenged. The difficulty lies in proving whether a decrease in accidents (or crimes) was truly the result of predictive forecasting. According to the authors, growing resistance to predictive software is mainly due to concerns among civil rights advocates that crime-predicting algorithms are discriminatory. As a result, many cities have ceased using such software. In addition, civil rights groups have demanded to know the algorithms behind these systems. Since these are considered trade secrets and development companies often refuse to disclose them, many have questioned the effectiveness of these programs.

It must be acknowledged that demonstrating precise effectiveness is indeed difficult. For example, if a city reports ten fewer robberies than the previous year, one might argue that this reduction would have occurred even without the use of predictive software. To resolve this debate, ideally, one would need two identical cities – with the same people, buildings, roads, and so on – one using the software and the other not. At the end of the year, the crime rates could be compared. Naturally, this is impossible because a city exists only once.

A valid question arises: how can we verify that predictive forecasting works and is effective? One approach is to compare the figures to those from the previous year. If the numbers decline, it is a good sign, although some may argue the decrease would have occurred anyway. Year-to-year fluctuations in crime and accident rates are not uncommon. Therefore, it is not enough to consider a drop in numbers alone. It is worth examining whether surrounding municipalities also saw a decline in incidents. If not – and only the city using the predictive software saw improvement – then it is reasonable to assume the software played a role. If this pattern repeats over several years, consistently showing reductions only in the location using the system, there can be little doubt that the software is working effectively.

In the case of Sopianae, less than one year of data is available, as the software was officially launched on November 30, 2024. However, it had already been operating for one month, providing forecasts that were used to plan patrol routes. Based on data from this short period, five fewer people died within the jurisdiction of the Pécs Police Department compared to the previous year, and six fewer people were seriously injured in traffic accidents (according to oral communication from Károly Böröcz). These results are extremely promising and are encouraging for the software developers. The figures for surrounding municipalities were not as favorable, although these other towns in

Baranya County are generally smaller and tend to experience different types of accidents. According to the authors, the software needs at least two years of data to produce the most accurate predictions. After that period, it will be worthwhile to compare the results from Pécs to those of other large Hungarian cities to draw meaningful conclusions.

The software's creators believe the initial results are promising, but the test period must be completed to confirm this. Only then will it become clear which indicators have strong predictive value? Some indicators may need to be removed, while others may need to be added, and the weighting of certain variables may require adjustment.

7. SUMMARY

Road traffic accidents continue to cause significant social and economic losses worldwide, making their prevention a shared public priority. In both Hungary and Serbia, the number of severe and fatal traffic accidents consistently exceeds the EU average, highlighting the need for new, innovative solutions. This study presents two predictive software systems designed to forecast accidents and support law enforcement and transportation policy. The Serbian ANN1 and ANN2 models, based on artificial neural networks, are capable of predicting accident frequency and severity, as well as identifying high-risk road sections. Hungary's Sopianae software analyzes historical accident data, factoring in weather conditions, lunar phases, and temporal patterns. Both systems aim to enable more efficient resource allocation and more targeted preventive actions. The European Union's long-term objective—halving road fatalities by 2030 and achieving zero deaths by 2050—is deemed unrealistic by the authors, yet serves as a guiding vision. Predictive algorithms can contribute to this goal, especially in countries with less developed infrastructure or aging vehicle fleets. The featured software tools can be beneficial not only to police departments but also to municipalities and transportation planners. The article highlights the importance of data-driven decision-making in traffic safety and advocates for enhanced international cooperation in predictive analytics and accident prevention strategies.

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