CRIMINOLOGICAL FOUNDATIONS FOR INTRODUCING DIGITAL TECHNOLOGIES AND ARTIFICIAL INTELLIGENCE IN ENSURING TRANSPORT SAFETY

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Abstract: The rapid development of digital technologies is fundamentally changing approaches to road traffic safety and the prevention of transport-related offences. Automated video surveillance, photo-radar systems, intelligent traffic cameras, electronic fine systems, and artificial intelligence-based analytical tools increasingly form an integral part of modern road-safety management. Their criminological significance lies not simply in recording violations but in changing the probability of detection, increasing the certainty of sanctions, identifying dangerous behavioural patterns, and enabling preventive intervention before a serious traffic offence occurs. This study examines the criminological foundations of introducing digital technologies and artificial intelligence elements into the transport-safety system, with particular attention to audio-video recording, photo-radar monitoring, automated fine mechanisms, and predictive analytics. Statistical, criminological, comparative-legal, systemic, and analytical methods were employed. The results indicate that digitalisation can strengthen the principle of inevitability of liability and reduce opportunities for selective enforcement, while its preventive effect depends on the quality of technological infrastructure, institutional coordination, legal certainty, and public acceptance. The study proposes a risk-oriented digital prevention model in which automated detection is combined with criminological analysis, targeted supervision, and evidence-based preventive measures.

Keywords: transport safety, road traffic offences, digital technologies, artificial intelligence, video surveillance, photo-radar, automated fines, criminological prevention, predictive analytics, traffic enforcement.

INTRODUCTION

Road traffic safety has traditionally been approached through legislation, police supervision, driver education, engineering measures, and sanctions for violations. However, the increasing intensity of road transport has made purely conventional forms of supervision less capable of providing continuous and comprehensive control over road-user behaviour. Digital technologies offer a fundamentally different possibility by enabling traffic violations to be detected automatically, recorded electronically, processed rapidly, and linked to the relevant vehicle or driver.

The criminological importance of this transformation is particularly significant. A traffic rule has a preventive function only when road users perceive a realistic probability that its violation will be detected and followed by an appropriate legal response. Consequently, the effectiveness of enforcement depends not exclusively on the severity of punishment but also on the certainty, speed, consistency, and transparency of detection. Recent developments in artificial intelligence have expanded this potential. Modern computer-vision systems can analyse traffic flows, identify prohibited manoeuvres, recognise licence plates, detect speeding and lane violations, and assist in identifying potentially dangerous driving patterns. The resulting information can be used not only for punishment

but also for criminological forecasting and preventive management. For Uzbekistan, this issue is particularly relevant because the volume of road transport continues to grow. Official statistical data indicate that road passenger transportation increased from 6,292.7 million passenger trips in 2023 to 6,642.3 million in 2024 and 7,586.0 million in 2025. During the same period, the country recorded 9,364 road traffic accidents in 2024 and 9,226 in 2025. These figures demonstrate that the development of transport infrastructure and mobility must be accompanied by increasingly sophisticated mechanisms of road-safety control.

PURPOSE AND OBJECTIVES

The purpose of this study is to identify the criminological foundations of digital and artificial intelligence-based technologies in preventing transport-related offences and improving road safety.

The research objectives are to:

1. examine the criminological role of automated traffic monitoring;
2. assess the preventive significance of audio-video recording and photo-radar systems;
3. analyse the relationship between automated fines and the inevitability of liability;
4. determine the potential of artificial intelligence for criminological forecasting;
5. develop recommendations for an integrated digital prevention mechanism.

RESEARCH METHODOLOGY

The study applies criminological, statistical, comparative-legal, systemic, and analytical methods. Statistical analysis is used to assess changes in road traffic accidents and transport activity. The criminological approach identifies behavioural and institutional factors that contribute to traffic offending. Comparative analysis is used to examine developments in Uzbekistan and selected CIS countries. A systemic approach is applied to examine digital surveillance as part of a broader prevention mechanism rather than as an isolated technological instrument. Particular attention is given to the relationship between detection, identification, administrative processing, sanctions, repeated offending, and subsequent preventive intervention. The study also considers the criminological implications of artificial intelligence. AI is treated not as a replacement for legal decision-making but as an analytical instrument capable of processing large volumes of traffic data and identifying patterns that may remain invisible through conventional supervision.

RESULTS

1. Digital monitoring as a criminological prevention instrument

The introduction of automated monitoring changes the traditional structure of traffic enforcement. Under conventional police supervision, detection depends heavily on the physical presence of an officer and the ability to observe a violation at a particular moment. Automated systems, by contrast, can operate continuously and record violations independently of the immediate presence of an enforcement officer. This creates an important criminological effect: the perceived probability of detection increases. A driver who understands that speeding, prohibited manoeuvres, red-light violations, or other offences may be automatically recorded is more likely to modify behaviour before committing the violation. Therefore, the preventive value of digital surveillance should not be

measured only by the number of fines issued. A more important indicator is whether the presence of automated monitoring changes driver behaviour and reduces repeated violations.

2. Audio-video recording and photo-radar systems

Audio-video recording systems provide evidentiary documentation of traffic violations and potentially serious incidents. Their value is particularly high where disputes arise regarding the circumstances of an offence. Photo-radar systems have a different but complementary function. They continuously monitor vehicle speed and automatically identify cases in which established limits are exceeded. The combination of speed measurement, licence-plate recognition, time registration, and location data creates a reliable evidentiary chain. From a criminological perspective, the important feature of these technologies is their impersonal nature. When the detection process is automated, opportunities for selective enforcement, informal interference, or inconsistent treatment of drivers may be reduced. However, automation itself does not guarantee effectiveness. Incorrect identification, technical failures, poor road-sign visibility, inadequate calibration, or weak procedures for challenging an erroneous decision may undermine public confidence in the system.

3. The criminological effect of automated fines

An automated fine system represents the final stage of the digital enforcement chain. Its preventive effectiveness depends on whether detection is followed by a timely and legally valid sanction.

The basic criminological mechanism can be expressed as:

violation → automatic detection → identification → notification → sanction → behavioural correction.

If one of these stages consistently fails, the preventive effect of the entire system is weakened.

For this reason, the introduction of digital enforcement should be accompanied by systematic analysis of repeated offences. A driver who receives multiple penalties for similar violations should not simply accumulate fines; the pattern itself should become a basis for differentiated preventive measures within the limits of the law.

4. Artificial intelligence and criminological forecasting

The greatest potential of artificial intelligence lies not in replacing traffic officers but in processing large-scale information more rapidly and identifying behavioural patterns.

An AI-based analytical system could theoretically integrate:

- repeated traffic violations;
- speeding frequency;
- dangerous manoeuvres;
- accident history;
- driving-right restrictions;

- time and location patterns;
- vehicle characteristics;
- repeated violations in high-risk road sections.

The resulting analytical profile could help authorities identify locations, periods, and behavioural patterns associated with elevated transport risk. For example, if repeated violations are concentrated at particular intersections during specific hours, resources can be redirected toward those locations. Similarly, if a particular behavioural pattern repeatedly precedes serious incidents, preventive measures can be introduced before the situation escalates. This represents a transition from reactive enforcement to predictive prevention.

5. Digital technologies and regional criminological differences

The effectiveness of digital monitoring may differ considerably between regions. Uzbekistan's 2025 statistical data demonstrate substantial regional differences in the number of recorded road traffic accidents: for example, 538 accidents were registered in Kashkadarya Region, 630 in Andijan Region, 470 in the Republic of Karakalpakstan, and 310 in Bukhara Region. Such differences should not automatically be interpreted as differences in criminality. Population size, traffic intensity, road infrastructure, vehicle ownership, urbanisation, and reporting practices can all influence the figures. Nevertheless, regional data can be used for risk-based allocation of preventive resources. Regions and road sections demonstrating consistently elevated risks may receive priority for automated monitoring, infrastructure improvement, traffic reorganisation, and targeted police supervision.

DISCUSSION

The findings demonstrate that digital technologies are gradually changing the criminological foundations of transport-safety enforcement by increasing the continuity and objectivity of traffic control. Automated video and photo-radar systems reduce dependence on the physical presence of enforcement officers and consequently increase the probability that dangerous behaviour will be detected. From a criminological perspective, this is important because the certainty of detection often has a stronger preventive effect than simply increasing the severity of punishment. Automated fine systems can strengthen this effect when violations are processed quickly, consistently, and transparently. At the same time, excessive reliance on fines may produce a formal enforcement model in which the same driver repeatedly pays penalties without any meaningful change in behaviour. Artificial intelligence provides an opportunity to overcome this limitation by identifying repeated violations and behavioural patterns rather than treating each offence as an isolated event. The use of predictive analytics can also improve the allocation of police resources by identifying high-risk roads, time periods, intersections, and behavioural patterns. However, algorithmic forecasting must not be confused with proof of guilt, since a predicted risk represents a probability and cannot by itself establish criminal responsibility. Therefore, AI systems should support—not replace—human and legal decision-making. Their effectiveness also depends on data quality, system reliability, cybersecurity, transparency, and the possibility of challenging incorrect automated decisions. In this context, the most promising model is a combination of automated detection, criminological analysis, targeted prevention, and continuous evaluation of outcomes. Thus, digitalisation should be regarded not merely as a technical modernisation of traffic control but as a transformation of the institutional mechanism for preventing transport-related crime.

CRIMINOLOGICAL MODEL OF DIGITAL PREVENTION

The results allow the development of an integrated five-stage model:

Stage 1 — Digital detection.
Cameras, photo-radar systems, sensors, and other devices continuously record traffic behaviour.

Stage 2 — Automated identification.
The system identifies the vehicle and links the recorded violation with the relevant electronic information.

Stage 3 — Criminological analysis.
Repeated violations and behavioural patterns are analysed to determine the level of preventive risk.

Stage 4 — Differentiated intervention.
Depending on the legally established risk indicators, authorities may apply warnings, educational programmes, intensified monitoring, administrative measures, or other lawful preventive mechanisms.

Stage 5 — Continuous evaluation.
The system evaluates whether the intervention reduces repeated violations and adjusts preventive measures accordingly.

This model transforms digital infrastructure from a simple "camera–fine" system into a "detection–analysis–prevention" system.

PRACTICAL RECOMMENDATIONS

1. Develop an integrated national digital platform connecting traffic cameras, photo-radar systems, driver records, and administrative violation databases.
2. Introduce criminological analysis of repeated traffic violations rather than evaluating offences exclusively as isolated events.
3. Use AI-assisted analytics to identify high-risk road sections and periods of increased traffic danger.
4. Establish objective criteria for identifying drivers who require intensified preventive intervention.
5. Improve the technical calibration and regular verification of automated monitoring equipment.
6. Ensure transparent procedures for reviewing and challenging incorrect automated decisions.
7. Develop regional road-safety risk maps based on statistical and behavioural data.
8. Combine automated enforcement with road engineering, driver education, and targeted police prevention.
9. Introduce regular independent assessments of the actual preventive effect of digital enforcement.
10. Establish strict legal and ethical safeguards governing the use of artificial intelligence in transport-safety management.

CONCLUSION

The introduction of digital technologies and artificial intelligence into transport-safety management represents an important development in modern criminological prevention. Automated video surveillance, photo-radar systems, electronic fines, and intelligent analytical tools can increase the probability of detecting violations and strengthen the practical implementation of the inevitability of liability. However, technological expansion should not be reduced to increasing the number of cameras or penalties. The real criminological value of digitalisation lies in its ability to identify behavioural patterns, detect repeated offending, forecast areas of elevated risk, and support targeted preventive intervention. For Uzbekistan, the growing intensity of road transport makes this transition particularly relevant. The most effective approach is therefore an integrated model in which digital detection, artificial intelligence, statistical analysis, law enforcement, road engineering, and preventive education operate as interconnected elements. The ultimate objective should be not the maximisation of penalties but the reduction of dangerous behaviour and serious road traffic consequences. In this sense, digital technologies should be evaluated according to their capacity to change behaviour, prevent repeated violations, and improve overall transport safety.

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