
**Investigative Frontiers Integration of
Science Transforming Criminal
Investigation**

Year: 2026

Intuition to Innovation: The Scientific Evolution of Criminal Investigation

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Abstract

The nature of criminal investigation has changed in a drastic way from the intuitive approach to scientifically oriented investigative techniques. This review addresses the history of criminal investigation through a focus on the beginnings of scientific investigation, the development of forensic science, the interdisciplinary nature of the field, and new technological advances. The principles of forensic science, the application of the scientific method, and the role of evidence-based inquiry in making crime investigations more reliable and objective are discussed. It also emphasizes the evolution of investigative methods over the years from traditional investigative methods to current forensic science methods and the use of standardized quality assurance procedures. The review also explores the interplay of forensic science and criminology, psychology, behavioral profiling, and data science, highlighting the ways that interdisciplinary strategies enhance the accuracy of investigations and judicial assessment. In addition, new advancements like artificial intelligence, machine learning, extended reality, blockchain, biometrics, and predictive analytics are explored as they can transform the field of crime scene investigation and evidence analysis. While these technologies offer some ethical, privacy, and legal issues, they are still improving the effectiveness, transparency, and credibility of modern criminal justice systems. The review underscores the scientific progress of criminal investigation and underscores the need for innovation to be coupled with evidence-based practices to enhance the justice system.

¹ ISBN No. - 978-93-7640-081-2

Keywords: *Criminal Investigation; Forensic Science; Evidence-Based Inquiry; Interdisciplinary Investigation; Emerging Forensic Technologies.*

1 Introduction

The term Intuition to Innovation embodies the incredible shift from a primarily human judgement and experience-based criminal investigation to one that is based on scientific evidence and technological innovation. Historically investigators used their intuition, observational skills, confessions, and logical thinking to determine who to suspect and to reconstruct a crime. While these methods helped solve many crimes, they were prone to cognitive bias, faulty recollections, false confessions, and could not be substantiated or validated with objective evidence. The advent of scientific evidence has revolutionized this approach, moving away from subjective assumptions to systematic observation, empirical confirmation, and the repeatability of analytical methods, in order to enhance the fairness and reliability of criminal investigations.²

Innovation in criminal investigation is the ongoing incorporation of new scientific findings, Forensic techniques and advanced technologies into the investigative process. Forensic science is a blend of biology, chemistry, physics, medicine, computer science and engineering that works with physical and digital evidence to make precise analyses. Technological advances like DNA Profiling, trace evidence analysis, forensic toxicology, digital forensics, artificial intelligence (AI), biometric identification and 3-D crime scene reconstruction have improved investigators' capacity to identify perpetrators, reconstruct a crime scene and draw factual inferences about crime evidence and its connection to a criminal activity. More recent systematic reviews also confirm the effectiveness of these technologies in streamlining investigations and making them more precise and based on evidence.³

The shift from intuition to innovation has not taken away the role of the investigator, but has enhanced the investigative decision-making process by incorporating investigative skills and scientifically sound evidence. Modern crime investigation has evolved into an interdisciplinary effort which combines forensic science, criminology, psychology, behavioural science and data analysis in investigating a wide range of crime types including cybercrime, terrorism, financial fraud and transnational organised crime. This cooperative approach allows investigators to

² Bakhtiar, H. S. (2024). The Evolution of Scientific Evidence Theory in Criminal Law: A Transformative Insight. *Media Iuris*, 7(2), 221–240. <https://doi.org/10.20473/mi.v7i2.51095>

³ Chango, X., Flor-unda, O., Gil-jim, P., & Gómez-Moreno, H. (2024). Technology in Forensic Sciences: Innovation and Precision. *Technologies*. <https://doi.org/10.3390/technologies12080120>

better understand the evidence, identify criminal trends and assist in crime prevention activities, while maintaining scientific standards. Meanwhile, advancements in technology have created new challenges to the reliability of evidence, privacy concerns, transparency of algorithms, and ethical responsibility, which necessitates ongoing enhancements to forensic norms and investigative practices.⁴

In this context, this review will discuss the scientific development of criminal investigations from intuition-based investigative methods to innovation-based forensic investigations. It covers the principles of scientific criminal investigation, the development of the forensic fields, inter-disciplinary aspects and the new technologies that are revolutionizing contemporary criminal justice. The review also suggests that the scientific understanding, technological progress and interdisciplinary cooperation have all contributed to making modern criminal investigations more accurate, credible and effective.

2 Foundations of Scientific Criminal Investigation

The basic principle of scientific criminal investigation is the application of scientific principles and methods in the identification, collection, preservation, examination, and interpretation of evidence for legal purposes. The scientific method of investigating crime is different from the traditional investigative approach, which was more dependent on eyewitness evidence, on confessions and on the investigator's intuition to reconstruct the criminal events and determine the actual perpetrator. It combines a variety of forensic disciplines, such as forensic biology, chemistry, toxicology, ballistics, anthropology and digital forensics, to build a factual connection between suspects, witnesses and crime scenes. One of the basic principles of forensic examination is Locard's Exchange Principle, which holds that contact leaves material behind; trace evidence is vital to understanding criminal events. In addition, the scientific processing of physical and digital evidence, from its recognition, documentation, collection, preservation and laboratory analysis, guarantees the accuracy, integrity and admissibility of the forensic results presented in judicial proceedings. Scientific criminal investigation has become an indispensable basis of modern criminal justice, which can improve the objectivity and reduce the investigative

⁴ Devlin, C., Morelato, M., & Baechler, S. (2024). Forensic intelligence: Expanding the potential of forensic document examination. *WIREs Forensic Science*, 6. <https://doi.org/10.1002/wfs2.1528>

bias to a certain extent, and thus has become the basis for effective law enforcement and fair judgment.⁵

A. Principles of Forensic Science

The principles of Forensic Science set out a scientific framework for the collection, examination and interpretation of evidence in Criminal Investigations. Such principles guarantee the objectivity, reliability, and the legal admissibility of forensic conclusions. Important principles include the Law of Individuality (all objects and living beings have unique characteristics), the Law of the Exchange Principle (every contact leaves a trace), the Principle of Comparison (what evidence is compared with suitable reference samples), and the Principle of Probability (associations between evidence and reference samples are evaluated on the basis of scientific evidence). These are the principles that allow forensic scientists to reconstruct incidents of crime and can help to serve justice.⁶

B. Scientific Method in Criminal Investigations

The scientific method is a systematic and objective approach to criminal investigations that involves the collection, analysis, and interpretation of evidence. It allows investigators to generate hypotheses, analyze physical and electronic evidence, and corroborate the results with scientific testing and replication. This method reduces cognitive bias and increases the reliability of the forensic conclusions, and makes them subject to judicial scrutiny. Combining knowledge and information from biology, chemistry, physics, and toxicology, investigators can be able to reconstruct the events of a crime and establish facts between the evidence, victims and suspects. As a result, the credibility and effectiveness of modern forensic investigations is enhanced by the scientific method.⁷

C. Role of Evidence-Based Inquiry

Evidence-based inquiry is a basic tool of scientific crime solving and one of the most important aspects is that it is based on objective, verifiable, and scientifically valid evidence not on

⁵ Haziri, F. (2026). The Role of Forensic Science in Modern Criminal Investigations: Scientific Foundations, Challenges, and Future Directions. *International Journal of Forensic Science and Criminal Investigation (IJFSCI)*. <https://doi.org/10.54026/IJFSCI/1007>

⁶ Pyrih, I., & Shynkarenko, I. (2018). Principles of Forensic Science. *Theory and Practice of Forensic Science and Criminalistics*, 18, 221–230. <https://doi.org/10.32353/khrife.2018.24>

⁷ Nagwanshi, B. K., Kosariya, S. S., Bhagat, P., Kujur, K., Thakur, V. S., & Tiwari, S. (2025). The Role of the Scientific Method in Forensic Crime Scene Investigation: A Vehicular Homicide Case Study. *Saudi Journal of Biomedical Research*, 293–297. <https://doi.org/https://doi.org/10.36348/sjbr.2025.v10i09.001>

intuition or assumptions. The systematic gathering, preservation, analysis and interpretation of physical, biological, digital and testimonial evidence to either reconstruct the events of a crime or to make investigative decisions. This process improves investigation accuracy, transparency, and credibility, and it minimizes the potential for bias and misconceptions. The effective implementation of evidence-based inquiry also demands a connection between investigators and forensic scientists and between investigators and the prosecution, in order to get the evidence assessed and presented in court.⁸



Finger print



DNA profiling



Evidence Analysis

Figure 1: Evidence-Based Inquiry⁹

3 Evolution of Forensic Science in Criminal Investigation

Forensic Science has changed the approach of criminal investigations from being strictly observational and intuitive to a scientific endeavor using objective evidence and scientifically accepted methods of analysis. Improvements in the biological, chemical, physical and digital sciences have made it possible for investigators to accurately and reliably identify, collect, preserve, and interpret evidence. In today's digital age, Forensic science combines various fields to help solve crimes and aid in court decisions, including toxicology, fingerprint analysis, trace, DNA analysis and digital evidence. Simultaneously, the credibility and admissibility of forensic evidence has been enhanced under the application of standardised procedures, laboratory

⁸ Visser, C., Markus, A., Poot, C. de, Kop, N., & Weggeman, M. (2024). Sensemaking and evidence in criminal investigations of organised crime: A literature review. *International Journal of Police Science & Management*, 26(1), 37–52. <https://doi.org/10.1177/14613557231196377>

⁹ Chatterjee, S. (2024). The Evolution of Crime Scene Investigation: A 21st Century Perspective. *Journal of University of Shanghai for Science and Technology*, 26(10), 54–77.

accreditation and quality management systems, making forensic science an essential part of the modern criminal justice system.¹⁰

A. Historical Transition from Intuition-Based to Scientific Investigation

In the past, criminal investigations were heavily dependent on the use of witnesses, confessions and investigators' subjective opinion that was often subject to human error and cognitive bias. The evolution of forensic science brought a scientific approach using the analysis of physical evidence, scientific testing and repeatable procedures. Locard's Exchange Principle was the first to be recognized that every contact leaves a trace, which forms the basis for the science of trace evidence and crime scene reconstruction. This transition introduced a new paradigm of criminal investigations which began to move towards evidence-based decision making, increasing the reliability of investigative outcomes and judicial confidence in the validity of forensic evidence.¹¹

B. Development of Modern Forensic Disciplines

The advent of specialization in forensic science, such as forensic DNA analysis, latent fingerprint examination, forensic toxicology, digital forensics, forensic anthropology, and multimedia evidence analysis, has grown significantly. The use of new techniques developed in molecular biology, analytical instrumentation and computer science have improved the ability to identify suspects, reconstruct crime scenes and analyse complex evidence with increasing accuracy. Digital evidence has become one of the most rapidly expanding forensic fields as it is used in criminal activities and they use computers, mobile phones, cloud systems and networked devices. These advancements have expanded the breadth of forensic investigation and enhanced the scientific approach to criminal investigations.¹²

C. Standardization and Quality Assurance in Forensic Practice

As an increasing amount of forensic evidence is relied upon, the need for standardisation and quality assurance in forensic practice is becoming more significant. International standards like ISO/IEC 17025 provide criteria for the competence of the laboratory, method validation,

¹⁰ Doyle, S. (2020). A review of the current quality standards framework supporting forensic science: Risks and opportunities. *WIREs Forensic Science*, 2(3), e1365. <https://doi.org/https://doi.org/10.1002/wfs2.1365>

¹¹ Reedy, P. (2023). Forensic Science International : Synergy Interpol review of digital evidence for 2019 – 2022. *Forensic Science International: Synergy*, 6, 100313. <https://doi.org/10.1016/j.fsisyn.2022.100313>

¹² Page, H., Horsman, G., Sarna, A., & Foster, J. (2019). A review of quality procedures in the UK forensic sciences: What can the field of digital forensics learn? *Science & Justice*, 59(1), 83–92. <https://doi.org/https://doi.org/10.1016/j.scijus.2018.09.006>

qualification of personnel, calibration of equipment and quality management systems for the production of reliable and reproducible results. The integrity and admissibility of forensic evidence is further strengthened by accreditation, peer review, proficiency testing and documented chain-of-custody procedures.¹³ The ongoing process of quality improvement reduces the likelihood of analytical error to reduce the risk of compromising public confidence in the role of forensic science within the justice systems and to ensure a fair allocation of justice.

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4 Interdisciplinary Approaches in Criminal Investigation

The interdisciplinary nature of modern criminal investigation is aimed at coping with the increasing complexity of crime by combining forensic science and criminology, psychology and behavioral science, and data science. The modern offences such as cybercrime, organised crime, terror and financial frauds demand the expertise of several disciplines in order to evidence and validate the information collected in a satisfactory manner. The forensic science gives scientific proof of physical and digital evidence and criminology teaches the patterns of crime and the behavior of its agents. While psychology can aid in offender profiling and investigative interviewing, data science can help investigators navigate and comprehend vast amounts of data, uncover hidden connections and patterns, and forecast criminal trends. This collaborative model improves the quality of investigations, facilitates evidence-based decision making and boosts judicial outcomes. Recent technological developments, as highlighted by Chatterjee (2024), have revolutionized the field of CSI, including digital forensics, artificial intelligence, and real-time data analytics, which have enhanced the accuracy and speed of evidence interpretation.¹⁵ The same way, Sheoran (2025) emphasizes how the multi-disciplinary approach has become essential to reliable investigations and the effective administration of justice.¹⁶

¹³ Doyle, S. (2020). A review of the current quality standards framework supporting forensic science: Risks and opportunities. *WIREs Forensic Science*, 2(3), e1365. <https://doi.org/https://doi.org/10.1002/wfs2.1365>

¹⁴ Page, H., Horsman, G., Sarna, A., & Foster, J. (2019). A review of quality procedures in the UK forensic sciences: What can the field of digital forensics learn? *Science & Justice*, 59(1), 83–92. <https://doi.org/https://doi.org/10.1016/j.scijus.2018.09.006>

¹⁵ Chatterjee, S. (2024). The Evolution of Crime Scene Investigation: A 21st Century Perspective. *Journal of University of Shanghai for Science and Technology*, 26(10), 54–77.

¹⁶ Sheoran, M. (2025). The Critical Role of Forensic Evidence in Modern Criminal Investigations. *International Journal of Law Management & Humanities*, 8(2), 2105–2133. <https://doi.org/https://doi.org/10.1000/IJLMH.119303>

A. Integration of Forensic Science and Criminology

Forensic science and criminology integration offer a well-rounded perspective on scientifically and socially oriented aspects of crime. Forensic science involves identifying, preserving, examining, and interpreting physical and digital evidence, while criminology deals with the causes, frequency, motivations and prevention of crime. Application of these disciplines together allows investigators to not only identify offenders through scientific evidence, but to understand the nature of crime and environmental factors that affect crime. This interdisciplinary partnership boosts investigative approach, strengthens crime prevention policies and supports judicial decision making. Recent research has highlighted that scientific evidence such as DNA Profiling, Fingerprint Examination, and Digital Forensics have enhanced investigative reliability, and criminological theories help to interpret offender behavior and crime trends.¹⁷

B. Psychological and Behavioral Profiling

The procedure of psychological and behavioral profiling has gained significance in investigations, especially in cases of serial offences, violent crimes, and sexual assaults, as well as in the investigation of terrorism. Investigators can generate behavioral profiles of crime scene characteristics, victim selection, modus operandi, and offender interactions, which can be useful in narrowing the identification of suspects and help direct investigative efforts. Psychological profiling also helps to understand the offender's motive, personality characteristics, and patterns of criminal behaviour, which can complement forensic evidence. While behavioral profiling does not yield a definitive answer on identification, it can be a useful investigative tool and complement interview tactics, threat assessment, and threat evaluation. Combining psychology with forensic science leads to more complete criminal investigations by combining behavior interpretation with scientifically sound evidence, which enhances the efficiency of the investigation.¹⁸

C. Data Science and Data Analytics

In the era of big data, data science and data analytics have become game-changers in modern-day criminal investigation, capable of handling vast amounts of structured and unstructured data

¹⁷ Sheoran, M. (2025). The Critical Role of Forensic Evidence in Modern Criminal Investigations. *International Journal of Law Management & Humanities*, 8(2), 2105–2133.
<https://doi.org/https://doi.org/10.1000/IJLMH.119303>

¹⁸ Chatterjee, S. (2024). The Evolution of Crime Scene Investigation: A 21st Century Perspective. *Journal of University of Shanghai for Science and Technology*, 26(10), 54–77.

efficiently and effectively. Machine learning, artificial intelligence, predictive analytics, network analysis, and digital forensics are among the techniques now being used by investigators to find patterns in crime, uncover fraud, review communication logs, and piece together crimes. These technologies help evidence-based policing by aiding in proactively preventing crime, allocating resources, and making rapid decisions in the investigation process. Moreover, digital forensic analysis of computers, smartphone, cloud platforms and communication networks is essential in the fight against cybercrime and organized criminal activities. While privacy, data security, and algorithmic bias concerns have risen, responsible use of technologies based on data remains a means to improve investigative accuracy and public safety.

Table 1: Interdisciplinary Approaches in Criminal Investigation

Author(s) & Year	Interdisciplinary Focus	Key Findings	Relevance to Criminal Investigation
1 ¹⁹	Forensic Science and Criminal Justice	DNA analysis, fingerprinting, and digital forensics improve investigative accuracy and reliability.	Strengthens evidence-based investigations and supports fair judicial outcomes.
2 ²⁰	Forensic Science, Medicine, and Law	Forensic science integrates medical, biological, and legal knowledge to examine evidence.	Enhances collaboration between scientific experts and legal authorities.
3 ²¹	Digital Forensics and Technology	Modern technologies improve forensic analysis and case resolution but require training and resources.	Highlights the growing role of digital tools in criminal investigations.

¹⁹ Sheoran, M. (2025). The Critical Role of Forensic Evidence in Modern Criminal Investigations. *International Journal of Law Management & Humanities*, 8(2), 2105–2133.
<https://doi.org/https://doi.org/10.10000/IJLMH.119303>

²⁰ Patil, P., & Angadi, S. S. (2024). Role of Forensic Science In Criminal Investigation: Admissibility In India. *Journal of Emerging Technologies and Innovative Research*, 11(2), 388–398.

²¹ Bajen, D. R., Borja, M. R. S., Bangga-an, R. J. E., & Bandolos, I. P. (2026). The Evolving Landscape of Criminal Investigation: Exploring the Impact and Efficiency of Modern Technology in Forensic Analysis and Digital Investigations. *International Journal for Multidisciplinary Research*, 8(2), 1–14.

4 ²²	Scientific Evidence and Legal Studies	Scientific evidence, including DNA and cyber forensics, offers greater objectivity than eyewitness testimony.	Improves accuracy, fairness, and reliability in criminal justice decisions.
Comparative Insight	Forensic Science, Technology, and Law	Interdisciplinary approaches combine scientific methods, technology, and legal frameworks.	Essential for investigating complex crimes and delivering effective justice.

5 Emerging Innovations in the criminal investigation

Criminal investigations are undergoing significant changes with the emergence of new technologies and innovations that enhance the accuracy, efficiency, and objectivity of forensic processes. Artificial Intelligence (AI), machine learning, extended reality (XR), blockchain technology, biometrics, cloud forensics, and predictive analytics are increasingly being integrated into investigative workflows to aid in the collection and reconstruction of evidence, digital evidence analysis, and to assist with investigative decision making.²³ The use of AI can enable quick analysis of vast amounts of data, uncovering hidden connections and automating the classification of evidence, and blockchain technology can enhance the security and traceability of digital evidence by managing the chain of custody.²⁴ Moreover, XR technologies, such as virtual reality (VR), augmented reality (AR), and mixed reality (MR), have become new tools for three-dimensional crime scene reconstruction, forensic training, and courtroom visualization, allowing investigators to maintain and analyze crime scenes without any alteration of physical evidence.²⁵ While recent systematic reviews suggest that XR technologies

²² Bakhtiar, H. S. (2024). The Evolution of Scientific Evidence Theory in Criminal Law: A Transformative Insight. *Media Iuris*, 7(2), 221–240. <https://doi.org/10.20473/mi.v7i2.51095>

²³ Chango, X., Flor-unda, O., Bustos-estrella, A., Gil-jiménez, P., & Gómez-moreno, H. (2025). Extended Reality Technologies: Transforming the Future of Crime Scene Investigation. *Technologies*, 13(315), 1–32. <https://doi.org/https://doi.org/10.3390/technologies13080315>

²⁴ Singh, S. (2026). The Evolution of Forensic Science in Crime Solving: From Traditional Methods to Artificial Intelligence. *Journal of Forensic Science and Medicine*, 12, 11–14. https://doi.org/10.4103/jfsm.jfsm_81_25

²⁵ Dino, M. J., Balbin, P. T., Villafuerte, C. M. R., Magat-Pangilinan, M. S., David, J., Tee, P. A., Samante, L., Acena, V., Salinas, M., Daquioag, E., & Lazaro, B. (2025). Extended reality in

can enhance collaboration, interpretation of evidence, and investigative efficiency, issues concerning implementation costs, technical issues, ethical concerns, privacy protection, and legal admissibility of virtual evidence must be taken into account. Researchers call for uniform protocols, validation studies and interdisciplinary cooperation to ensure the proper implementation of these new technologies into contemporary criminal justice systems.

6 Conclusion

With the development of criminal investigation from a practice based on intuition to a scientific methodology, criminal justice administration has undergone fundamental changes. Forensic science has transformed the way that investigations are conducted, replacing subjective investigative methods with objective evidence-based methods which will increase the accuracy, reliability, and legal admissibility of investigations. Scientific evidence has become more credible, with scientific methods, standard laboratory practices and quality assurance systems improving the reliability of scientific evidence and reducing investigative error. In addition, interdisciplinary cooperation between forensic scientists, criminologists, psychologists, behavioral experts and data analysts has increased the capacity for the more holistic and data-based investigation of increasingly complex crimes. Artificial Intelligence, Machine Learning, Extended Reality, Blockchain Technology, Digital Forensics, and Predictive Analytics are the next evolution of science in criminal investigation, aiding in swift evidence analysis, reconstruction of crimes, and decision-making. However, the effective implementation of these innovations requires the establishment of ethical guidelines, legal frameworks, and protocols for privacy, transparency, and compliance, while ongoing professional development is essential. Hence, future criminal investigations should be made to accord with the principles of scientific investigation, technological innovations, and multi-disciplinary team work to secure justice that is accurate, fair and efficient.

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