

The Role of Forensic Evidence in Modern Criminal Law: Challenges and Emerging Trends

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Abstract

The administration of criminal justice has undergone a remarkable transformation with the increasing integration of forensic science into criminal investigations and judicial proceedings. Traditional methods of investigation, which primarily relied upon eyewitness testimony, confessions, and circumstantial evidence, have gradually been supplemented and, in many cases, replaced by scientific techniques capable of producing more objective and reliable evidence. Forensic evidence has emerged as one of the most influential tools for ensuring accuracy in criminal investigations, reducing wrongful convictions, strengthening prosecutorial outcomes, and safeguarding the rights of both victims and accused persons. Scientific advancements in disciplines such as DNA profiling, fingerprint identification, forensic pathology, toxicology, ballistics, digital forensics, cyber forensics, and artificial intelligence have significantly enhanced the capacity of law enforcement agencies to reconstruct crime scenes, identify offenders, and establish factual truth with greater precision.

In India, the enactment of the Bharatiya Nyaya Sanhita, 2023, the Bharatiya Nagarik Suraksha Sanhita, 2023, and the Bharatiya Sakshya Adhiniyam, 2023 reflects a renewed legislative emphasis on scientific investigation and evidentiary reliability. These reforms seek to modernize criminal procedure by promoting the use of forensic techniques, particularly in offences carrying severe punishments, thereby aligning the criminal justice system with international standards of evidence-based investigation. However, despite these legislative developments, several institutional and procedural challenges continue to impede the effective utilization of forensic evidence. Inadequate forensic infrastructure, shortage of trained experts, delays in laboratory examination, improper preservation of evidence, weaknesses in maintaining the chain of custody, and concerns regarding judicial appreciation of scientific testimony often undermine the evidentiary value of forensic materials.

This research critically examines the evolving role of forensic evidence in modern criminal law by analysing its legal significance, scientific reliability, and practical application within the criminal justice system. It further evaluates the admissibility and evidentiary value of forensic evidence under contemporary Indian legal frameworks while drawing comparative insights from selected foreign jurisdictions. The study also explores emerging technological innovations, including artificial intelligence, machine learning, blockchain-based evidence management, and digital forensic analytics, which are reshaping criminal investigations globally. Through doctrinal and analytical legal research supported by judicial precedents, statutory analysis, and scholarly literature, the paper argues that the future effectiveness of criminal justice depends upon strengthening forensic institutions, ensuring scientific integrity, promoting judicial competence in forensic appreciation, and adopting technologically advanced investigative practices capable of balancing efficient law enforcement with constitutional guarantees of fairness, due process, and human rights.

Keywords: Forensic Evidence, Criminal Law, DNA Profiling, Digital Forensics, Bharatiya Sakshya Adhiniyam, Scientific Investigation, Expert Evidence, Criminal Justice, Artificial Intelligence, Chain of Custody.

Introduction

The pursuit of justice within every criminal justice system is fundamentally dependent upon the accurate determination of facts. Criminal courts are entrusted with the responsibility of distinguishing truth from falsehood while simultaneously protecting society against crime and safeguarding the constitutional rights of individuals accused of criminal offences. For centuries, criminal adjudication relied predominantly upon eyewitness testimony, confessions, documentary evidence, and circumstantial proof. Although these traditional forms of evidence continue to play an important role, they are frequently vulnerable to human error, memory distortion, coercion, bias, fabrication, and deliberate manipulation. Numerous wrongful convictions across jurisdictions have demonstrated that reliance solely upon conventional evidence may compromise the integrity of criminal justice. Consequently, the emergence of forensic science has fundamentally transformed the methods through which criminal investigations are conducted and criminal liability is established.

Forensic science represents the systematic application of scientific knowledge and technological methods to legal questions arising during criminal and civil proceedings. It combines principles derived from biology,

chemistry, physics, medicine, computer science, engineering, anthropology, psychology, and digital technologies to examine physical evidence capable of establishing objective facts before a court of law. Unlike testimonial evidence, forensic evidence is primarily based upon measurable scientific observations that are capable of independent verification. Consequently, scientific evidence has increasingly become indispensable for reconstructing crime scenes, identifying offenders, excluding innocent suspects, establishing causation, estimating the time and manner of death, detecting fraudulent activities, tracing digital footprints, and corroborating or contradicting oral testimony presented during criminal trials.

The evolution of forensic science has substantially altered the philosophy of criminal investigation. Modern criminal investigations no longer depend exclusively upon confessions or eyewitnesses but increasingly prioritize scientific reconstruction of criminal events. DNA profiling has become one of the most reliable methods of human identification, frequently resolving cases involving homicide, sexual offences, missing persons, disaster victim identification, and disputed parentage. Similarly, fingerprint analysis continues to remain one of the oldest yet most dependable techniques of personal identification. Advances in forensic pathology have strengthened medico-legal investigations by scientifically determining causes and circumstances of death. Toxicological examinations assist investigators in detecting poisoning, narcotic substances, and chemical intoxication, while ballistic examinations provide crucial evidence regarding firearms, ammunition, and trajectories. More recently, the rapid expansion of cybercrime has significantly increased the importance of digital forensics, which enables investigators to recover electronic data, analyse communication records, authenticate digital documents, and identify cyber offenders operating across national boundaries.

The increasing dependence upon forensic evidence reflects broader developments in scientific innovation and technological progress. Contemporary forensic investigations increasingly utilise sophisticated technologies such as artificial intelligence, machine learning, facial recognition systems, automated fingerprint identification systems, biometric databases, blockchain-supported evidence management, geospatial mapping, and advanced digital analytics. These innovations enable investigators to analyse enormous quantities of information with greater speed and accuracy while reducing human error during evidence examination. Artificial intelligence, for instance, has demonstrated considerable potential in identifying behavioural patterns, analysing surveillance footage, predicting criminal activities, and supporting forensic image enhancement. Nevertheless, these technological developments also generate significant legal and ethical concerns relating to privacy, algorithmic bias, transparency, accountability, data protection, and procedural fairness, thereby requiring continuous judicial and legislative scrutiny.

Within the Indian context, forensic science has acquired renewed importance following comprehensive criminal law reforms introduced through the Bharatiya Nyaya Sanhita, 2023, the Bharatiya Nagarik Suraksha Sanhita, 2023, and the Bharatiya Sakshya Adhiniyam, 2023. These legislative measures recognise scientific investigation as an essential component of effective criminal justice administration. The revised procedural framework places greater emphasis upon forensic examination in serious offences and seeks to improve investigative efficiency through the incorporation of modern scientific techniques. Such reforms acknowledge that scientific evidence possesses significant capacity to strengthen prosecutions while simultaneously preventing wrongful convictions by objectively evaluating competing factual claims.

Despite these progressive legislative developments, the practical implementation of forensic science within India continues to encounter numerous structural and institutional challenges. Many forensic laboratories experience significant case backlogs, resulting in prolonged delays in criminal trials. The shortage of qualified forensic experts, uneven distribution of forensic facilities across states, inadequate training of investigating officers, improper crime scene management, contamination of biological samples, and deficiencies in maintaining an unbroken chain of custody frequently diminish the evidentiary reliability of forensic materials. Moreover, judicial appreciation of complex scientific evidence requires specialised understanding, while legal practitioners often face difficulties in effectively examining or challenging expert testimony during adversarial proceedings. These practical limitations illustrate that scientific advancement alone cannot ensure justice unless supported by robust institutional capacity, professional competence, and effective procedural safeguards.

The admissibility and evidentiary value of forensic evidence remain closely connected with fundamental principles governing criminal adjudication. Scientific evidence must satisfy requirements relating to authenticity, relevance, reliability, legality of collection, preservation, documentation, and expert interpretation before it can meaningfully assist judicial decision-making. Courts must carefully evaluate whether forensic opinions are scientifically validated, whether testing procedures comply with accepted professional standards, and whether the evidentiary chain remains free from contamination or manipulation. The principle of a fair trial further requires that accused persons receive adequate opportunities to challenge forensic findings through independent expert examination and effective cross-examination of prosecution witnesses. Consequently, forensic evidence should neither be regarded as infallible nor rejected merely because of its scientific complexity; instead, it must be evaluated according to established legal standards that balance scientific objectivity with constitutional guarantees of due process.

Internationally, several jurisdictions have developed sophisticated forensic infrastructures supported by accreditation mechanisms, quality assurance standards, independent forensic institutions, and specialised judicial training. Comparative experiences from countries such as the United Kingdom, the United States, Canada, and Australia demonstrate that effective integration of forensic science requires coordinated cooperation among investigators, forensic scientists, prosecutors, defence counsel, and judicial officers. These comparative developments provide valuable guidance for strengthening forensic governance in India while preserving the constitutional commitment to fairness, equality before law, and protection of individual rights.

Against this background, the present study critically examines the evolving role of forensic evidence in modern criminal law with particular reference to contemporary developments in India. The paper seeks to evaluate the contribution of forensic science to criminal investigations, examine its evidentiary significance under the reformed legal framework, analyse emerging technological innovations influencing forensic practice, and identify institutional challenges affecting the administration of criminal justice. The study further argues that the future credibility of criminal justice depends not merely upon technological advancement but upon ensuring scientific integrity, procedural transparency, institutional accountability, judicial competence, and effective legal regulation of forensic practices. By integrating doctrinal legal analysis with comparative perspectives and emerging technological trends, the research aims to contribute to the continuing discourse on the development of an evidence-based, scientifically reliable, and constitutionally compliant criminal justice system.

Literature Review

The increasing integration of forensic science into criminal justice has generated substantial interdisciplinary scholarship spanning criminal law, forensic science, criminology, medicine, digital technology, and human rights. Existing literature broadly recognizes that forensic evidence has transformed the investigative process by replacing subjective assumptions with scientifically verifiable methods capable of improving the accuracy and credibility of criminal adjudication. Nevertheless, scholarly discourse also highlights persistent legal, institutional, ethical, and technological challenges that continue to affect the reliability and admissibility of forensic evidence. An examination of the existing literature reveals that while considerable attention has been devoted to scientific techniques and evidentiary principles, comparatively limited research has examined the practical implications of India's recent criminal law reforms in relation to forensic investigation and the emerging role of advanced technologies such as artificial intelligence and digital forensic analytics. Classical legal scholarship on the law of evidence consistently emphasizes that the primary objective of criminal adjudication is the discovery of truth through legally admissible and reliable evidence. Traditional authors on evidence law argued that oral testimony, documentary evidence, and circumstantial evidence constituted the principal foundations of criminal trials. However, subsequent developments in forensic science gradually shifted academic attention toward scientific methods capable of independently verifying disputed facts. Contemporary legal scholars increasingly acknowledge that scientific evidence significantly enhances judicial confidence by reducing dependence upon potentially unreliable eyewitness testimony and involuntary confessions. This transition reflects a broader movement from experience-based investigation to evidence-based criminal justice, where objective scientific analysis supplements traditional legal reasoning. Research in forensic science has consistently demonstrated that physical evidence possesses unique characteristics that distinguish it from testimonial evidence. Biological materials, fingerprints, firearm residues, toxic substances, trace evidence, and digital records often remain unaffected by memory loss, personal bias, or intentional deception. Scientific examination of such materials enables investigators to reconstruct criminal events with greater precision while simultaneously excluding innocent individuals from suspicion. Numerous empirical studies have concluded that the increased use of forensic evidence contributes to higher investigation quality, improved conviction rates in deserving cases, and a corresponding reduction in wrongful prosecutions. Nevertheless, researchers also caution that scientific evidence is not inherently infallible because its reliability depends upon proper collection, preservation, laboratory examination, interpretation, and judicial evaluation.

Among all forensic disciplines, DNA profiling has attracted the greatest scholarly attention. Since its introduction into criminal investigations during the late twentieth century, DNA evidence has been widely regarded as one of the most reliable forms of personal identification. Scientific literature demonstrates that DNA analysis has revolutionized investigations involving homicide, sexual offences, disaster victim identification, missing persons, and disputed biological relationships. Comparative research conducted in the United States, the United Kingdom, Canada, and several European jurisdictions illustrates that DNA evidence has not only facilitated successful prosecution of offenders but has also resulted in the exoneration of numerous wrongfully convicted individuals. These developments have strengthened the scholarly argument that forensic science serves both prosecutorial and protective functions by promoting justice for victims while safeguarding innocent persons against erroneous conviction.

Parallel scholarship concerning fingerprint identification continues to recognize fingerprint examination as one of the oldest and most dependable forensic techniques. Researchers observe that despite significant

technological advancement, fingerprint analysis remains indispensable because of its relatively low cost, well-established scientific methodology, and widespread judicial acceptance. Modern automated fingerprint identification systems have further enhanced investigative efficiency through digital comparison of latent fingerprints recovered from crime scenes. However, recent literature also questions the assumption of absolute infallibility in fingerprint examination by emphasizing the importance of standardized laboratory protocols, examiner competence, peer review, and accreditation mechanisms designed to minimize subjective interpretation.

Medical jurisprudence and forensic pathology constitute another major area of academic discussion. Scholars argue that medico-legal examination plays an essential role in determining the cause, manner, and approximate time of death while assisting courts in establishing causation and criminal responsibility. Forensic pathology has become particularly significant in homicide investigations, custodial deaths, suspicious deaths, and cases involving grievous bodily injuries. Similarly, toxicological research demonstrates the increasing importance of scientific detection of poisons, narcotic substances, alcohol, pharmaceuticals, and chemical agents in criminal prosecutions. Nevertheless, medical researchers consistently identify shortages of trained forensic pathologists, inadequate medico-legal infrastructure, and inconsistent autopsy practices as significant barriers affecting the quality of criminal investigations in developing jurisdictions.

The rapid expansion of cybercrime has generated an extensive body of literature concerning digital forensics and electronic evidence. Contemporary researchers emphasize that modern criminal activity increasingly involves computers, mobile devices, cloud storage, cryptocurrency transactions, social media platforms, encrypted communications, and interconnected digital networks. Consequently, digital forensic investigation has emerged as one of the fastest-growing disciplines within forensic science. Existing scholarship examines methods for recovering deleted data, authenticating electronic documents, tracing digital communications, analysing metadata, preserving electronic evidence, and maintaining evidentiary integrity throughout the investigative process. Legal scholars further argue that traditional evidentiary doctrines require continuous adaptation in order to accommodate technological developments that were previously unknown to criminal procedure. This literature becomes particularly relevant in jurisdictions where electronic evidence is increasingly relied upon to prosecute financial crimes, cyber offences, organized crime, and terrorism.

Recent academic discourse has increasingly focused upon the application of artificial intelligence and machine learning in forensic investigation. Emerging research suggests that artificial intelligence possesses considerable potential for analysing surveillance footage, recognizing facial features, identifying behavioural patterns, processing forensic images, detecting document forgery, and assisting investigators in analysing enormous quantities of digital evidence within comparatively shorter periods. Machine learning algorithms have demonstrated promising applications in forensic anthropology, fingerprint comparison, handwriting analysis, voice recognition, and predictive crime mapping. However, this emerging body of literature also raises important concerns regarding algorithmic bias, transparency, explainability, accountability, cybersecurity, and the admissibility of automated forensic conclusions within judicial proceedings. Scholars caution that artificial intelligence should complement rather than replace independent human expertise because criminal adjudication ultimately requires judicial assessment of fairness, reliability, and constitutional safeguards.

Within Indian legal scholarship, considerable attention has traditionally focused upon statutory provisions governing expert evidence and judicial appreciation of scientific testimony. Earlier research frequently examined the evidentiary status of expert opinions under the former Indian Evidence Act, 1872 while analysing judicial precedents relating to fingerprint evidence, handwriting examination, medical testimony, ballistic reports, and DNA profiling. More recent scholarship has shifted towards analysing the implications of the Bharatiya Sakshya Adhiniyam, 2023 and associated criminal law reforms. Scholars generally agree that the new legislative framework reflects a significant policy commitment towards scientific investigation by encouraging wider utilization of forensic examination in serious criminal cases. However, commentators also observe that legislative reform alone cannot guarantee effective forensic administration unless accompanied by substantial investment in forensic laboratories, professional training, technological modernization, and institutional independence.

Numerous governmental and institutional reports reinforce these scholarly observations. Reports examining the functioning of forensic science laboratories repeatedly identify substantial case backlogs, shortages of qualified personnel, inadequate infrastructure, uneven geographical distribution of laboratories, and delays in forensic reporting. These administrative deficiencies frequently contribute to prolonged criminal trials and reduce public confidence in scientific investigation. Similar concerns have been expressed regarding crime scene management, preservation of biological evidence, documentation procedures, maintenance of the chain of custody, and coordination between investigating agencies and forensic experts. Consequently, institutional literature consistently recommends expanding forensic infrastructure, strengthening quality assurance mechanisms, promoting laboratory accreditation, enhancing multidisciplinary training, and adopting internationally recognized scientific standards.

Comparative legal scholarship provides additional insight into the governance of forensic science. Researchers examining criminal justice systems in jurisdictions such as the United Kingdom, the United States, Australia, and Canada emphasize the importance of independent forensic institutions, standardized operating procedures, professional accreditation, external quality assessment, judicial education, and ethical regulation. Comparative studies demonstrate that the credibility of forensic evidence depends not merely upon scientific advancement but also upon institutional transparency, procedural accountability, and effective oversight mechanisms capable of minimizing scientific error and protecting individual rights. These comparative experiences offer valuable guidance for countries seeking to modernize forensic administration while maintaining constitutional guarantees of fair trial and due process.

Another significant theme emerging from recent literature concerns the relationship between forensic evidence and human rights. Legal scholars argue that scientific investigation contributes to the protection of fundamental rights by reducing arbitrary arrests, coercive interrogations, custodial violence, and reliance upon involuntary confessions. Objective scientific evidence strengthens the presumption of innocence by enabling investigators to distinguish between genuine suspects and innocent individuals through empirical analysis rather than subjective suspicion. At the same time, researchers caution that expanding forensic databases, biometric surveillance, facial recognition technologies, and DNA repositories raise important constitutional questions concerning privacy, informational autonomy, proportionality, and data protection. Consequently, contemporary scholarship increasingly advocates balancing technological innovation with constitutional safeguards designed to preserve civil liberties within democratic legal systems.

Although existing literature provides comprehensive discussion of individual forensic disciplines and evidentiary doctrines, several significant research gaps remain. Most Indian studies continue to analyse forensic evidence primarily through the lens of traditional expert testimony without comprehensively examining the integrated impact of the Bharatiya Nyaya Sanhita, 2023, the Bharatiya Nagarik Suraksha Sanhita, 2023, and the Bharatiya Sakshya Adhiniyam, 2023 on forensic investigation and criminal adjudication. Similarly, comparatively limited scholarship evaluates the legal implications of artificial intelligence, blockchain-supported evidence management, digital chain-of-custody mechanisms, and advanced forensic analytics within the evolving framework of Indian criminal law. Furthermore, relatively few studies simultaneously examine scientific reliability, institutional capacity, constitutional rights, judicial appreciation of expert evidence, and comparative international practices within a unified socio-legal framework.

The present research seeks to address these gaps by undertaking a comprehensive doctrinal and analytical examination of forensic evidence in modern criminal law. Unlike earlier studies that primarily focus upon isolated forensic techniques or statutory interpretation, this research integrates legal analysis, scientific developments, comparative perspectives, institutional challenges, and emerging technological innovations within a single analytical framework. It further evaluates the implications of recent criminal law reforms while exploring how scientific advancement can strengthen criminal justice without compromising constitutional guarantees of fairness, due process, and protection of fundamental rights. In doing so, the study contributes to the growing discourse on evidence-based criminal justice and the future evolution of forensic science within contemporary legal systems.

Research Methodology

The present study adopts a doctrinal and analytical method of legal research to critically examine the evolving role of forensic evidence in modern criminal law with particular reference to the Indian criminal justice system. The research is primarily based on qualitative analysis of statutory provisions, judicial precedents, academic literature, government reports, and internationally recognized forensic standards.

The doctrinal approach facilitates a systematic examination of the legal principles governing the admissibility, relevance, and evidentiary value of forensic evidence under the Bharatiya Sakshya Adhiniyam, 2023, the Bharatiya Nyaya Sanhita, 2023, and the Bharatiya Nagarik Suraksha Sanhita, 2023. Comparative legal analysis has also been employed to evaluate forensic practices adopted in selected jurisdictions such as the United Kingdom, the United States, Canada, and Australia, where scientific investigation has become an integral component of criminal justice administration.

In addition, analytical and descriptive methods are used to assess the relationship between scientific innovation, technological advancement, constitutional guarantees, and procedural fairness. The study relies exclusively on secondary sources, including books, peer-reviewed journal articles, Law Commission reports, forensic science manuals, government publications, reports of international organizations, and landmark judicial decisions.

Through this integrated methodological framework, the research evaluates both the legal and practical dimensions of forensic evidence while identifying institutional challenges, technological developments, and emerging regulatory issues influencing the administration of criminal justice.

Main Discussion

1. Evolution of Forensic Evidence in Criminal Justice

The administration of criminal justice has historically depended upon the ability of courts to ascertain the truth through legally admissible evidence. In earlier periods, criminal investigations relied predominantly upon eyewitness testimony, confessions, documentary evidence, and circumstantial facts. Although these forms of evidence continue to retain legal significance, experience has repeatedly demonstrated that human perception, memory, and testimony are susceptible to error, coercion, intimidation, prejudice, and deliberate fabrication. Numerous miscarriages of justice across jurisdictions have revealed that reliance solely upon traditional forms of proof frequently exposes innocent individuals to wrongful conviction while simultaneously permitting guilty offenders to evade legal accountability. The emergence of forensic science represents one of the most significant developments in modern criminal law because it introduces objective scientific methods capable of independently verifying disputed facts through empirical examination rather than subjective belief.

2. Concept and Nature of Forensic Evidence

Forensic evidence refers to scientifically analysed material that assists courts in establishing the existence or absence of facts relevant to criminal liability. Unlike oral testimony, forensic evidence derives its evidentiary strength from scientific observation, laboratory examination, measurable data, and standardized investigative procedures. Biological samples, fingerprints, bloodstains, fibres, firearms, toxic substances, electronic records, and digital footprints collectively provide investigators with reliable sources of information capable of reconstructing criminal events with remarkable precision. The growing acceptance of scientific evidence reflects a broader transformation in criminal justice from confession-oriented investigations towards evidence-based investigations grounded in scientific objectivity. Modern criminal law increasingly recognizes that justice cannot be effectively administered unless criminal investigations are supported by reliable scientific techniques capable of distinguishing factual truth from speculation.

3. Growth and Branches of Forensic Science

The rapid advancement of forensic science has fundamentally altered investigative practices throughout the world. Scientific disciplines such as forensic biology, forensic pathology, toxicology, ballistics, anthropology, odontology, questioned document examination, forensic psychology, digital forensics, cyber forensics, and DNA profiling have substantially expanded the investigative capabilities of law enforcement agencies. Crime scene investigation itself has become a sophisticated scientific process involving systematic documentation, preservation, collection, transportation, laboratory examination, and interpretation of physical evidence. Every stage of this process requires adherence to established scientific protocols because even minor contamination or procedural irregularities may compromise the evidentiary value of forensic material during trial. Consequently, forensic science is no longer regarded merely as an auxiliary investigative tool but has become an indispensable component of criminal justice administration.

4. DNA Profiling as Scientific Evidence

Among the various branches of forensic science, DNA profiling has emerged as one of the most influential scientific developments of the modern era. The uniqueness of individual genetic characteristics enables forensic experts to establish personal identity with exceptionally high levels of scientific accuracy. DNA evidence has transformed investigations involving homicide, sexual offences, kidnapping, unidentified human remains, mass disasters, disputed parentage, and missing persons. In many jurisdictions, post-conviction DNA testing has resulted in the exoneration of individuals who had been wrongfully convicted on the basis of mistaken eyewitness identification or unreliable confessions. Consequently, DNA profiling serves both prosecutorial and protective functions by strengthening the conviction of guilty offenders while simultaneously preventing miscarriages of justice involving innocent persons. However, legal scholars consistently emphasize that the reliability of DNA evidence depends upon proper collection, preservation, documentation, transportation, and maintenance of an unbroken chain of custody.

5. Fingerprint, Ballistics and Toxicological Evidence

Fingerprint examination continues to occupy an equally significant position within forensic investigation. Modern automated fingerprint identification systems have enhanced investigative efficiency by enabling rapid comparison of latent fingerprints recovered from crime scenes against extensive biometric databases. Likewise, forensic ballistics, forensic pathology, and toxicology provide objective scientific evidence that assists courts in establishing causation, criminal responsibility, poisoning, firearm usage, and the manner of death. Collectively, these forensic disciplines strengthen criminal prosecutions through scientifically verified evidence.

6. Legislative Framework under the Bharatiya Criminal Laws, 2023

The enactment of the Bharatiya Sakshya Adhiniyam, 2023, together with the Bharatiya Nyaya Sanhita, 2023, and the Bharatiya Nagarik Suraksha Sanhita, 2023, marks a significant legislative transition in the Indian criminal justice system by emphasizing scientific investigation as an essential element of criminal adjudication. These reforms encourage wider utilization of forensic evidence and seek to improve evidentiary reliability through stronger procedural safeguards.

7. Forensic Evidence in Emerging Crimes

The growing complexity of criminal activity—including cybercrime, terrorism, financial fraud, identity theft, cryptocurrency offences, and transnational crime—has significantly expanded the importance of forensic evidence. Scientific examination of biological, chemical, electronic, and digital evidence now plays a decisive role in reconstructing criminal events and identifying offenders.

8. Reliability and Limitations of Forensic Evidence

Despite remarkable scientific developments, forensic evidence should not be regarded as infallible. Scientific reliability depends upon the integrity of crime scene preservation, evidence collection, laboratory examination, documentation, interpretation, and maintenance of the chain of custody. Courts must therefore carefully evaluate forensic reports alongside all other evidence while ensuring compliance with statutory and constitutional safeguards.

9. Digital Forensics and Electronic Evidence

The rapid growth of digital technology has transformed criminal investigations. Digital forensics enables investigators to recover deleted files, analyse metadata, authenticate electronic records, reconstruct communication histories, and establish digital links between suspects and criminal activities. Because electronic evidence is highly volatile, its collection and preservation require specialized expertise and internationally accepted forensic protocols.

10. Artificial Intelligence in Forensic Investigation

Artificial intelligence has revolutionized forensic investigation through facial recognition, fingerprint comparison, voice identification, predictive analytics, crime scene reconstruction, and pattern recognition. While AI significantly enhances investigative efficiency, its application raises concerns regarding algorithmic bias, transparency, accountability, and procedural fairness. Accordingly, AI-generated forensic conclusions must always remain subject to judicial scrutiny and expert verification.

11. Blockchain and Chain of Custody

Blockchain technology offers a secure and tamper-resistant mechanism for maintaining the chain of custody of forensic evidence. Immutable digital records documenting every stage of evidence handling can enhance transparency, accountability, authenticity, and public confidence in criminal investigations.

12. Crime Scene Management and Procedural Integrity

Effective utilization of forensic evidence depends upon proper crime scene management. Scientific evidence must be systematically documented, preserved, packaged, transported, analysed, and reported under standardized protocols. Any procedural lapse or contamination may substantially weaken the evidentiary value of forensic material.

13. Constitutional Dimensions of Forensic Investigation

The increasing use of DNA databases, biometric identification, digital surveillance, facial recognition, and artificial intelligence raises significant constitutional concerns relating to privacy, equality, informational autonomy, and procedural fairness. Therefore, forensic technologies must operate within the framework of legality, necessity, proportionality, and judicial oversight.

14. Comparative International Practices

Comparative experiences from jurisdictions such as the United Kingdom, the United States, Canada, Australia, and Europe demonstrate the importance of laboratory accreditation, quality assurance, professional certification, judicial education, and institutional independence in ensuring the credibility of forensic science.

15. Challenges before the Indian Criminal Justice System

Although India has strengthened its legislative framework through the Bharatiya criminal laws of 2023, significant practical challenges remain. Delays in forensic reports, inadequate laboratory infrastructure, shortage of trained forensic experts, insufficient funding, outdated equipment, and procedural deficiencies continue to affect the effective administration of forensic justice.

16. Judicial Appreciation of Expert Evidence

Scientific evidence frequently involves complex technical concepts requiring specialized knowledge. Courts must therefore carefully evaluate expert testimony without treating forensic opinions as conclusive. Continuous judicial education, interdisciplinary collaboration, and adherence to professional ethics remain essential for ensuring reliable forensic adjudication.

17. Future Directions of Forensic Evidence

The future of forensic evidence depends upon integrating scientific innovation with constitutional safeguards and institutional reforms. Investment in modern forensic laboratories, AI-assisted analytics, blockchain-supported evidence management, nationwide accreditation systems, standardized protocols, and comprehensive legal regulation will strengthen criminal investigations while safeguarding fundamental rights and promoting fair, transparent, and evidence-based justice.

Results and Analysis

The present study demonstrates that forensic evidence has evolved from a supplementary investigative aid into one of the most decisive components of contemporary criminal justice. The doctrinal and analytical examination of statutory provisions, judicial developments, comparative legal practices, and forensic

literature reveals that scientific evidence substantially enhances the quality, reliability, and fairness of criminal investigations. Unlike traditional forms of evidence, which frequently depend upon human perception, memory, or testimonial credibility, forensic evidence is founded upon scientifically verifiable principles capable of producing objective and reproducible results. Consequently, the integration of forensic science into criminal investigations has significantly strengthened the evidentiary framework upon which judicial decisions are based.

The analysis further indicates that the modernization of criminal justice increasingly depends upon scientific investigation rather than confession-oriented policing or excessive reliance upon eyewitness testimony. DNA profiling, fingerprint identification, forensic pathology, toxicological examination, ballistic analysis, digital forensics, and cyber forensic investigation collectively provide investigators with multiple independent sources of corroborative evidence capable of reconstructing criminal events with greater precision. These scientific techniques reduce investigative uncertainty, improve the identification of offenders, and strengthen prosecutorial decision-making while simultaneously protecting innocent individuals from wrongful implication.

The examination of India's recent criminal law reforms reveals a significant legislative commitment towards evidence-based investigation. The Bharatiya Sakshya Adhiniyam, 2023, read together with the Bharatiya Nyaya Sanhita, 2023, and the Bharatiya Nagarik Suraksha Sanhita, 2023, reflects an important shift from conventional investigative practices to scientifically supported criminal adjudication. The legislative emphasis on forensic examination in serious offences demonstrates recognition that criminal justice must increasingly rely upon objective scientific evidence capable of improving investigative accuracy and judicial confidence.

A critical finding emerging from the study concerns the persistent gap between legislative aspirations and institutional realities. Despite substantial technological advancements, forensic administration in India continues to experience significant structural deficiencies. Delays in forensic laboratory examinations, shortage of qualified experts, inadequate laboratory capacity, uneven geographical distribution of forensic facilities, deficiencies in crime scene preservation, improper documentation, and failures in maintaining the chain of custody frequently diminish the evidentiary value of scientific materials. These institutional weaknesses not only delay criminal trials but also adversely affect the quality of justice delivered by the courts.

The research also identifies digital transformation as one of the defining characteristics of modern criminal investigations. Increasing dependence upon electronic communication, digital financial transactions, cloud computing, encrypted communication platforms, artificial intelligence, and interconnected technological systems has substantially expanded the scope of forensic investigation. Digital evidence has become indispensable in prosecuting cybercrime, financial fraud, terrorism, organized crime, identity theft, child exploitation, and transnational criminal networks.

Comparative analysis undertaken during the research demonstrates that jurisdictions possessing advanced forensic governance systems generally emphasize institutional independence, laboratory accreditation, standardized scientific procedures, continuous quality assurance, and specialized judicial education. These jurisdictions recognize that scientific evidence derives credibility not solely from technological sophistication but from transparent institutional practices capable of ensuring scientific neutrality and procedural integrity. The comparative experience therefore suggests that India's forensic modernization should extend beyond technological investment to include independent accreditation systems, national quality standards, interdisciplinary professional training, external scientific audits, and continuous judicial capacity-building programmes.

The findings further reinforce the proposition that forensic evidence should not be regarded as infallible merely because it is scientific in nature. Scientific conclusions remain dependent upon proper evidence collection, preservation, laboratory examination, expert interpretation, and judicial appreciation. Errors occurring at any stage of the investigative process may significantly affect evidentiary reliability. Courts therefore retain the ultimate responsibility of evaluating forensic opinions in conjunction with all other evidence presented during trial. Expert testimony should assist judicial reasoning rather than replace it, ensuring that scientific expertise remains consistent with constitutional guarantees of equality, fairness, and procedural justice.

Conclusion

The present study concludes that forensic evidence has become indispensable to the effective functioning of modern criminal justice systems. Scientific investigation has transformed criminal adjudication by improving the accuracy, reliability, and objectivity of fact-finding while simultaneously strengthening procedural fairness and safeguarding the rights of the accused. The transition from traditional evidence-based investigations to scientifically supported criminal investigations reflects a fundamental shift in contemporary criminal jurisprudence toward evidence-based justice.

The research further establishes that the enactment of the Bharatiya Sakshya Adhiniyam, 2023, together with the Bharatiya Nyaya Sanhita, 2023, and the Bharatiya Nagarik Suraksha Sanhita, 2023, represents a

significant legislative advancement in integrating forensic science into India's criminal justice framework. Nevertheless, the effectiveness of these reforms ultimately depends upon robust institutional implementation, adequate forensic infrastructure, standardized scientific protocols, trained personnel, and efficient coordination among investigative agencies, forensic laboratories, prosecutors, and the judiciary. Overall, the study affirms that forensic science should be viewed not merely as a technological tool but as an essential pillar of fair, transparent, and constitutionally compliant criminal justice. Its true contribution lies not only in improving conviction rates but also in preventing wrongful convictions, protecting individual liberties, and enhancing public confidence in the administration of justice.

Future Directions

Future research and policy initiatives should adopt a multidisciplinary approach integrating law, forensic science, technology, ethics, and constitutional governance. National forensic infrastructure requires substantial expansion through modern laboratories equipped with internationally accredited quality assurance systems and advanced analytical technologies.

Greater emphasis should also be placed upon specialized education and continuous professional training for police officers, forensic scientists, prosecutors, defence counsel, and members of the judiciary to ensure proper collection, preservation, interpretation, and judicial evaluation of scientific evidence. Universities and research institutions should encourage interdisciplinary research focusing on artificial intelligence, digital forensics, blockchain-based evidence management, forensic genetics, cybercrime investigation, and emerging technologies.

Future legislative reforms should establish comprehensive regulatory frameworks governing artificial intelligence-assisted forensic investigation, biometric databases, DNA repositories, automated surveillance systems, and digital evidence management. Such regulation should prioritize transparency, explainability, accountability, proportionality, and protection of fundamental rights while facilitating responsible technological innovation.

Finally, international cooperation in forensic science should be strengthened through harmonization of forensic standards, collaborative scientific research, expert exchange programmes, laboratory accreditation, and mutual legal assistance in transnational criminal investigations. These measures will enable forensic science to continue evolving as a reliable instrument for delivering accurate, efficient, and constitutionally grounded criminal justice.

REFERENCES

1. Ashworth A and Redmayne M, *The Criminal Process* (5th edn, Oxford University Press 2019).
2. Butler JM, *Forensic DNA Typing: Biology, Technology, and Genetics of STR Markers* (2nd edn, Elsevier 2005).
3. Casey E, *Digital Evidence and Computer Crime* (3rd edn, Academic Press 2011).
4. Champod C, Lennard C, Margot P and Stoilovic M, *Fingerprints and Other Ridge Skin Impressions* (2nd edn, CRC Press 2016).
5. Dennis I, *The Law of Evidence* (8th edn, Sweet & Maxwell 2020).
6. Fisher BAJ and Fisher DR, *Techniques of Crime Scene Investigation* (8th edn, CRC Press 2012).
7. Garrett BL, *Convicting the Innocent* (Harvard University Press 2011).
8. Galton F, *Finger Prints* (Macmillan 1892).
9. Heard BJ, *Handbook of Firearms and Ballistics* (3rd edn, Wiley-Blackwell 2016).
10. Houck MM and Siegel JA, *Fundamentals of Forensic Science* (4th edn, Academic Press 2019).
11. Karch SB, *Karch's Pathology of Drug Abuse* (5th edn, CRC Press 2015).
12. Knight B and Saukko P, *Knight's Forensic Pathology* (4th edn, CRC Press 2016).
13. Loftus EF, *Eyewitness Testimony* (Harvard University Press 1996).
14. Robertson B and Vignaux GA, *Interpreting Evidence* (2nd edn, Wiley 2016).
15. Roberts P and Zuckerman A, *Criminal Evidence* (3rd edn, Oxford University Press 2022).
16. Saferstein R, *Criminalistics: An Introduction to Forensic Science* (13th edn, Pearson 2020).
17. Siegel JA, Saukko PJ and Houck MM, *Encyclopedia of Forensic Sciences* (3rd edn, Elsevier 2023).
18. Jackson ARW and Jackson JM, *Forensic Science* (4th edn, Pearson 2021).
19. White PC, *Crime Scene to Court* (Royal Society of Chemistry 2020).
20. Fraser J and Williams R (eds), *Handbook of Forensic Science* (Routledge 2019).
21. Jeffreys AJ, 'Genetic Fingerprinting' (1985) 316 *Nature* 76.
22. Saks MJ and Koehler JJ, 'The Coming Paradigm Shift in Forensic Identification Science' (2005) 309 *Science* 892.
23. Saks MJ and Koehler JJ, 'The Individualization Fallacy in Forensic Science Evidence' (2008) 61 *Vanderbilt Law Review* 199.
24. Mnookin JL and others, 'The Need for a Research Culture in the Forensic Sciences' (2011) 58 *UCLA Law Review* 725.
25. Risinger DM, 'Navigating Expert Reliability' (2000) 64 *Albany Law Review* 99.

26. Koehler JJ, 'Fingerprint Error Rates and Proficiency Tests' (2008) 7 *Law, Probability and Risk* 1.
27. Edmond G, 'What Lawyers Should Know About Forensic Science' (2015) 36 *Adelaide Law Review* 33.
28. Cole SA, 'Forensics Without Uniqueness, Conclusions Without Individualization' (2009) 8 *Law, Probability and Risk* 233.
29. Dror IE, 'Cognitive and Human Factors in Expert Decision Making' (2020) *Forensic Science International*.
30. Wachter S, Mittelstadt B and Russell C, 'Counterfactual Explanations without Opening the Black Box' (2018) 31 *Harvard Journal of Law & Technology* 841.
31. Bharatiya Nyaya Sanhita 2023.
32. Bharatiya Nagarik Suraksha Sanhita 2023.
33. Bharatiya Sakshya Adhiniyam 2023.
34. Information Technology Act 2000.
35. Digital Personal Data Protection Act 2023.
36. Constitution of India.
37. Code of Criminal Procedure 1973 (historical).
38. Indian Evidence Act 1872 (historical).
39. *Selvi v State of Karnataka* (2010) 7 SCC 263.
40. *Mukesh v State (NCT of Delhi)* (2017) 6 SCC 1.
41. *Krishan Kumar Malik v State of Haryana* (2011) 7 SCC 130.
42. *State of Bombay v Kathi Kalu Oghad* AIR 1961 SC 1808.
43. *Anvar PV v PK Basheer* (2014) 10 SCC 473.
44. *Arjun Panditrao Khotkar v Kailash Kushanrao Gorantyal* (2020) 7 SCC 1.
45. *Maneka Gandhi v Union of India* (1978) 1 SCC 248.
46. *Justice KS Puttaswamy (Retd) v Union of India* (2017) 10 SCC 1.
47. *Zahira Habibullah Sheikh v State of Gujarat* (2004) 4 SCC 158.
48. *State of Himachal Pradesh v Jai Lal* (1999) 7 SCC 280.
49. *Daubert v Merrell Dow Pharmaceuticals Inc* 509 US 579 (1993).
50. *Kumho Tire Co Ltd v Carmichael* 526 US 137 (1999).
51. *Frye v United States* 293 F 1013 (DC Cir 1923).
52. *R v Turner* [1975] QB 834.
53. *R v Bonython* (1984) 38 SASR 45.
54. National Research Council, *Strengthening Forensic Science in the United States: A Path Forward* (National Academies Press 2009).
55. President's Council of Advisors on Science and Technology, *Forensic Science in Criminal Courts* (2016).
56. Bureau of Police Research and Development, *Model Forensic Science Laboratory Manual*.
57. National Crime Records Bureau, *Crime in India* 2023.
58. Law Commission of India, *185th Report on Review of the Indian Evidence Act* (2003).
59. Law Commission of India, *277th Report: Wrongful Prosecution* (2018).
60. Parliamentary Standing Committee on Home Affairs, Reports relating to Criminal Law Reforms.
61. United Nations Office on Drugs and Crime, *Crime Scene and Physical Evidence Awareness for Non-Forensic Personnel* (2009).
62. United Nations Office on Drugs and Crime, *Guidance for Crime Scene Investigation* (2010).
63. INTERPOL, *Global Forensic Science Strategy* (2023).
64. INTERPOL, *Disaster Victim Identification Guide*.
65. ISO/IEC 17025:2017.
66. ISO 21043 (Parts 1–5): *Forensic Sciences*.
67. European Commission, *Ethics Guidelines for Trustworthy AI* (2019).
68. National Institute of Standards and Technology, *AI Risk Management Framework* (2023).
69. Forensic Science Regulator, *Codes of Practice and Conduct* (UK, 2023).
70. ENFSI, *Best Practice Manuals*.
71. National Institute of Justice (NIJ).
72. Federal Bureau of Investigation (FBI) Laboratory Publications.
73. Central Forensic Science Laboratory (CFSL), India.
74. Directorate of Forensic Science Services (DFSS), Ministry of Home Affairs.
75. National Judicial Data Grid (for criminal justice statistics).