

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

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# **Securing the Truth: Scientific Principles and Practices in Crime Scene Management**

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### **Abstract**

Crime scene management is the scientific basis of criminal investigation where the truth is determined by systematically gathering, documenting, preserving, analysing, and interpreting evidence. The integrity of the crime scene procedures and adherence to scientifically proven principles are crucial to the reliability of forensic findings and judicial outcomes. This review focuses on the concept and goals of crime scene management and highlights the scientific principles involved with forensics, such as Locard's Exchange Principle, individuality, progressive change, scientific analysis and objectivity. It also addresses the standardized procedures used in the evaluation of a crime scene, evidence identification, evidence collection and preservation, chain of custody, crime scene laboratory examination, and reconstructing criminal events. The review also examines how forensic evidence analysis is used to reconstruct a criminal incident and the potential of new technologies like 3D documentation, artificial intelligence, drones, digital forensics and geospatial systems in contemporary investigations. This review highlights the scientific soundness of crime scene management, which enhances the accuracy of investigations, maintains evidence integrity, and contributes to the fair and just administration of justice by combining theory with methodology and technology. Implementing these scientific practices is still critical to the truth and to increasing confidence in forensic science and criminal justice systems.

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## **1 Introduction**

Securing the truth is the fundamental objective of every criminal investigation, and the crime scene serves as the primary source from which objective facts are established. A crime scene is not just the place where a crime has happened but a scientific environment that encompasses physical, biological, chemical and digital evidence that together can be used to recreate the events. The dependability of any forensic investigation is dependent upon the handling of the crime scene from its discovery to when all evidence has been recorded, retrieved, preserved, and submitted for scientific analysis. The integrity of judicial proceedings may be compromised by even small errors made at any point during this process, and result in evidence becoming contaminated, critical information being lost, or the evidence being misunderstood.<sup>2</sup>

Forensic science has come a long way, moving from an observational process to a systematic scientific discipline, with well-defined principles and evidence-based procedures. Modern investigations combine the forensic biology, chemistry, toxicology, digital forensics, engineering, pathology and crime scene reconstruction disciplines to ensure that all items of evidence are studied scientifically.<sup>3</sup> A multidisciplinary approach increases the reliability, validity and admissibility of forensic results, and limits the possible subjective interpretation and investigative bias. Additionally, the use of new technologies, such as 3-D documentation of crime scenes, artificial intelligence, advanced imaging systems and automated evidence analysis, has greatly enhanced the ability to identify, preserve and analyze forensic evidence.<sup>4</sup>

This review paper discusses mechanisms, scientific principles, and practices that are the basis for effective crime scene management, and how they each contribute to obtaining the truth during the investigative process. It explores the scientific principles underlying the conduct of a crime scene investigation, the methods used to identify and preserve evidence, the role of forensic sciences in interpreting evidence in a crime investigation, and the adoption of new

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<sup>2</sup> H. S. Ohal, P. P. Karale, H. S. Aphale, R. D. Patil, and A. V. Pawar, "Reconstructing the Truth: Innovative Techniques in Crime Scene Reconstruction," IEEE Xplore, pp. 320–327, 2025, doi: 10.1109/ACCESS65134.2025.11135643.

<sup>3</sup> R. A. Wickenheiser, "Proactive crime scene response optimizes crime investigation," Forensic Sci. Int. Synerg., vol. 6, p. 100325, 2023, doi: 10.1016/j.fsisyn.2023.100325.

<sup>4</sup> M. Esposito, F. Sessa, G. Cocimano, P. Zuccarello, S. Roccuzzo, and M. Salerno, "Advances in Technologies in Crime Scene Investigation," diagnostics, vol. 13, pp. 1–9, 2023, doi: <https://doi.org/10.3390/diagnostics13203169>.

technology to improve the accuracy of the investigation process. This review combines aspects of up-to-date scientific facts and best professional practice to emphasise the paramount importance of retaining evidence integrity and scientific rigour to ensure that crime scene investigation can reliably assist in the administration of justice.

## **2 Concept and Objectives of Crime Scene Management**

Crime scene management is a systematic and scientifically controlled method that includes identification, protection, documentation, examination, collection, preservation and the transfer of evidence from a scene of a criminal event. It is the backbone of forensic investigation because the quality of evidence obtained at the crime scene directly affects the accuracy of the forensic analysis later on in the investigation and the judgment made by the court. Crime scene management is not just a single investigative activity but an organized and coordinated effort by law enforcement personnel, medical professionals, forensic scientists, and crime scene investigators that ensures that each piece of evidence is treated in a scientific and legal manner. The multi-disciplinary approach ensures that evidence is not lost, contaminated or misunderstood and that scene authenticity and evidential value are preserved.<sup>5</sup>

The main goal of crime scene management is to obtain the truth by preserving the original condition of the crime scene and by recovering reliable evidence that will objectively reconstruct the sequence of events. A successful outcome will require immediate scene security to deter any unauthorized entry, careful documentation using photos, video, sketches and notes, a systematic process that will identify and gather physical and biological evidence, and the proper collection, packaging, labeling, and chain of custody of evidence. An equally important goal is to make sure that everything done in an investigation is scientifically defensible, legally admissible, and can be reproduced in the forensic context and during court proceedings. Good crime scene management also helps identify victims and suspects, makes connections between people, objects, and places, and enhances the accurate reconstruction of criminal events. The field of forensic science is constantly evolving, developing a scientific approach to crime scene management, moving beyond the traditional methods of gathering evidence and focusing on precision, objectivity, quality assurance and interdisciplinary collaboration. Together, these

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<sup>5</sup> M. Ghanem, "Initial Response at Crime Scenes and Prioritization of Efforts," in Crime Scene Management within Forensic science, 2021. doi: [https://doi.org/10.1007/978-981-16-4091-9\\_1](https://doi.org/10.1007/978-981-16-4091-9_1).

goals enhance the credibility of criminal investigations and help to ensure fair and effective justice administration.<sup>6</sup>

### 3 Scientific Principles in Crime Scene Management

Scientific principles form the theoretical basis of crime scene management and serve as the basis for all stages of the forensic process. These principles will create a logical and evidence-based approach to recognising, preserving, analysing and interpreting evidence and reduce the risk of bias and procedural errors. These applications will guarantee scientific reliability, legal admissibility and a true reconstruction of the criminal events.<sup>7</sup> The most fundamental principles governing crime scene management are discussed below.

1. **Locard's Exchange Principle:** This principle was proposed by Edmond Locard which says that “every contact leaves a trace”. People that come into contact with a crime scene are going to leave there some sort of trace behind that can consist of fingerprints, DNA, fibres, hair, soil particles or other trace evidence. This principle is the scientific basis for drawing connections between suspects, victims, objects and crime scenes.<sup>8</sup>
2. **Principle of Individuality:** The principle of individuality is that each object, person or material has its own specific attributes that set it apart from other objects, people or materials. Fingerprints, DNA profiles, tool marks, handwriting and firearm markings provide unique characteristics that allow forensic experts to identify or distinguish evidence with a high degree of scientific certainty.
3. **Principle of Progressive Change:** According to this principle, all crime scenes are constantly changing because of the environment, biological activity, human activity, and time. This means that scene security, documentation and evidence preservation must be done immediately to avoid the destruction or degradation of any useful forensic information.
4. **Principle of Analysis:** In scientific investigations, all the evidence must be analyzed with validated forensic techniques in a controlled laboratory setting. Standardised analytical processes and procedures guarantee that conclusions are accurate,

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<sup>6</sup> D. V. Chauhan, “Crime Scene Management: Principles, Practices, and Contemporary Challenges in Forensic Investigation,” *WebLog J. Forensic Sci. Criminol.*, pp. 1–2, 2026, doi: <https://doi.org/10.5281/zenodo.19313851>.

<sup>7</sup> A. S, “DNA PROFILING AND CRIME SCENE MANAGEMENT: A SCIENTIFIC APPROACH TO CRIMINAL INVESTIGATION,” *INDIAN J. Leg. Rev.*, vol. 6, no. 9, pp. 802–816, 2026.

<sup>8</sup> D. Mummery, “Life & Times Every contact leaves a trace,” *BJGP Life*, p. 2021, 2021, doi: DOI: <https://doi.org/10.3399/bjgp21X717569>.

reproducible and based on objective scientific information and not assumptions or speculation.

5. **Principle of Objectivity and Scientific Validation:** Observable facts and scientifically valid investigative techniques must be used in crime scene investigations without any bias. Personal bias or assumption should be avoided by investigators and evidence only interpreted based on empirical evidence. The use of scientific validation methods, such as standardized techniques and protocols for quality assurance and peer-reviewed forensic practices, increases the credibility of the investigative process and its results, and enhances their acceptance in judicial proceedings.<sup>9</sup>

#### 4 Scientific Practices in Crime Scene Management

Scientific Practices in Crime Scene Management are the application of the principles of science to crime scenes in a manner that uses a standardized procedure to maintain integrity of the evidence and assist in accurate criminal investigation. These practices ensure that the investigation is conducted in a systematic way, with minimal contamination, loss of evidence, and legal admissibility.<sup>10</sup> In order to accomplish forensic analysis and crime reconstruction, the following scientific practices must be carried out in a coordinated manner.

1. **Initial Crime Scene Assessment:** The investigation starts with a preliminary assessment and the identification of potential hazards, the nature of the incident and the setting of scene boundaries and then developing an appropriate investigative strategy.
2. **Crime Scene Security and Isolation:** Access is immediately controlled by restricting access to unauthorized areas with physical barriers and controlled access points. This practice prevents contamination or disturbance of evidence, and maintains the original condition of the scene.
3. **Systematic Crime Scene Documentation:** Investigators take photographs, video recordings, sketches, measurements and detailed notes of the scene in a search to ensure that evidence has been preserved accurately for further analysis before it is disturbed.<sup>11</sup>

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<sup>9</sup> A. P. Winburn and C. M. J. Clemmons, "Objectivity is a myth that harms the practice and diversity of forensic science," *Forensic Sci. Int. Synerg.*, vol. 3, pp. 3–6, 2021, doi: <https://doi.org/10.1016/j.fsisyn.2021.100196>.

<sup>10</sup> S. Çetin, "Evidence Collection, Analysis, and Interpretation in Criminal Investigations," 2025, doi: [10.13140/RG.2.2.20797.32484](https://doi.org/10.13140/RG.2.2.20797.32484).

<sup>11</sup> A. K. Gautam et al., "Systematic Perspectives to Proceeding a Scene of Crime: An Overview," *J. Clin. Forensic Sci.*, vol. 1, no. 1, pp. 9–14, 2023, doi: DOI: [10.21088/jcfs.3107.6874.1123.1](https://doi.org/10.21088/jcfs.3107.6874.1123.1).

4. **Scientific Evidence Recognition:** Investigators employ scientific search techniques and forensic knowledge to systematically collect physical, biological, trace, impression and digital evidence, thus leaving no relevant evidence uncollected.
5. **Evidence Collection Techniques:** Evidence is gathered through the validated forensic process and by utilizing specific equipment that is suitable for the type of evidence collected, thus ensuring the physical and biological integrity of the evidence throughout the forensic investigation process.<sup>12</sup>
6. **Evidence Packaging and Preservation:** This involves each item being individually packaged, properly labelled, sealed, and kept under suitable environmental conditions to prevent degradation, contamination or accidental damage.
7. **Chain of Custody Management:** All evidence transfer, evidence handling, storage and evidence examination is properly documented to provide an unbroken chain of evidence to ensure traceability, authenticity, and admissibility.<sup>13</sup>
8. **Laboratory Submission and Scientific Examination:** Collected evidence is sent to certified forensic laboratories, where valid methods of analysis, such as DNA profiling, fingerprinting, toxicology, and trace evidence analysis are used to derive scientifically valid findings.
9. **Crime Scene Reconstruction and Reporting:** The last practice includes the combination of observations collected at the scene of the crime and laboratory results to form a complete objective case history of the events. The conclusions are conveyed in detailed scientific reports, which clearly and accurately reflect the forensic results and evidence in the judicial process.<sup>14</sup>

## 5 Forensic Evidence Analysis and Crime Scene Reconstruction

Forensic evidence analysis and crime scene reconstruction represent the highest forms of scientific crime scene management, and it is the final step in the process of converting collected evidence into objective information that helps to explain the events of a crime. Evidence collection captures the physical evidence of a crime while forensic analysis scientifically

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<sup>12</sup> M. A. Daibes et al., “Knowledge about crime scenes and evidence management among emergency medical team professionals,” *BMC Emerg. Med.*, vol. 25, no. 75, 2025, doi: <https://doi.org/10.1186/s12873-025-01230-y>.

<sup>13</sup> T. D. Anna et al., “The Chain of Custody in the Era of Modern Forensics: From the Classic Procedures for Gathering Evidence to the New Challenges Related to Digital Data,” *healthcare*, vol. 11, no. 634, 2023, doi: <https://doi.org/10.3390/healthcare11050634>.

<sup>14</sup> M. S. Balbudhe, B. S. K. Shetty, N. A. Kumar, D. Singh, and A. I. Sherekar, “Crime scene reconstruction: a scoping review,” *Egypt. J. Forensic Sci.*, vol. 15, no. 79, 2025, doi: <https://doi.org/10.1186/s41935-025-00495-5>.

analyzes the materials to establish their origin, significance and relationship to the crime. This process brings together the skills and knowledge from many different aspects of forensic science such as forensic biology, chemistry, toxicology, fingerprint examination, firearm identification, trace evidence analysis, pathology and digital forensics. The scientific contribution of each discipline is different and when all of these different pieces of information are interpreted together, they will give a complete picture of the crime.<sup>15</sup>

Crime scene reconstruction is an investigative process that utilizes crime scene evidence, crime scene documentation, evidence laboratory analysis and crime scene observations in a systematic manner to determine the sequence of events leading up to, during and after the offence.<sup>16</sup> Bloodstain pattern analysis, trajectory analysis, injury interpretation, footwear and tyre impressions, DNA and digital evidence are scientifically interpreted to find interactions between the victims, suspects, weapons and the environment. The reliability of the reconstruction is based on the quality and integrity of evidence, on the use of validated analytical techniques, and on the objective interpretation of the evidence without cognitive bias. Forensic reconstruction does not begin with assumptions but begins with hypotheses that are evaluated by the available scientific evidence until the most probable explanation is reached. The precision and visualisation of reconstructed crime scenes have been improved with recent developments in three-dimensional laser scanning, artificial intelligence, geospatial technologies and computer-based reconstruction models. Forensic evidence analysis and crime scene reconstruction thus improve the accuracy of an investigation, and offer scientific evidence that helps investigators, forensic specialists and courts achieve the truth and fair administration of justice.<sup>17</sup>

## **6 Technological Innovations in Crime Scene Management**

Technology has revolutionized the field of crime scene investigation, enhancing the efficiency, precision, and reliability of investigations. The tools that investigators use for investigation are often supplemented by cutting edge technologies which allow investigators to document a crime scene more thoroughly, pick up evidence that they may not have noticed before, and conduct scientific analysis with greater accuracy. These innovations have led to improvements in the

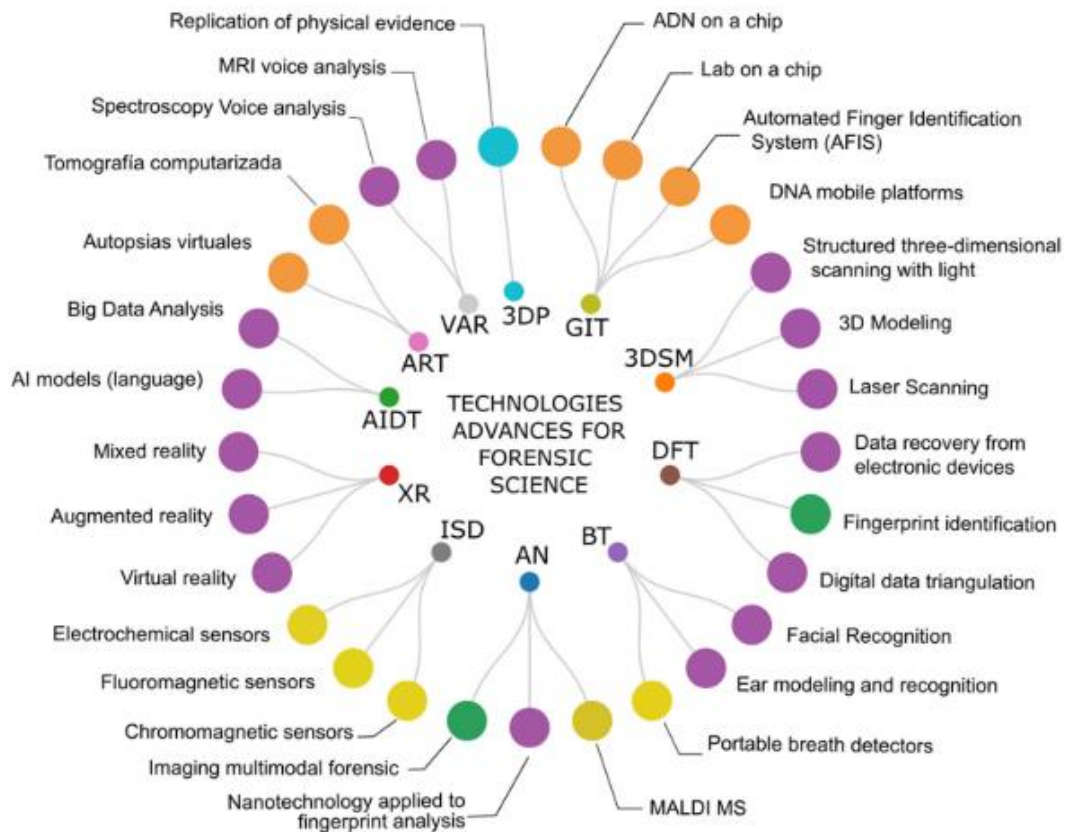
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<sup>15</sup> M. Nicho, M. Alblooki, S. AlMutiwei, C. D. McDermott, and O. Ilesanmi, "A Crime Scene Reconstruction for Digital Forensic Analysis," *Int. J. Digit. Crime Forensics*, vol. 15, no. 1, 2023, doi: <https://doi.org/10.4018/IJDCF.327358>.

<sup>16</sup> V. Venkatesh, V. Kn, K. Pankaj, and M. Sharma, "Reconstruction of Crime Scene: Reveals the Truth at Railway Track," *Crimson Publ. Wings to Res.*, vol. 5, no. 4, pp. 424–427, 2021, doi: 10.31031/FSAR.2021.05.000621.

<sup>17</sup> M. A. Maneli and O. E. Isafiade, "3D Forensic Crime Scene Reconstruction involving Immersive Technology: A Systematic Literature Review," *IEEE Access*, 2022, doi: 10.1109/ACCESS.2022.3199437.

ability of forensic practitioners to keep evidence intact, to reconstruct a crime scene, and to produce objective findings that will assist in judicial decision making. This has led to the current method of crime scene management being a multi-disciplinary process using technology and digital tools that incorporate traditional forensic principles.<sup>18</sup>



*Figure 4: Technological advances by type and contribution to forensic sciences.<sup>19</sup>*

One of the most recent advancements is the use of 3D laser scanning and photo-grammetry to generate very accurate virtual models of crime scenes for detailed examination and virtual

<sup>18</sup> X. Chango, O. Flor-unda, P. Gil-jim, and H. Gómez-Moreno, "Technology in Forensic Sciences: Innovation and Precision," *Technologies*, 2024, doi: <https://doi.org/10.3390/technologies12080120>.

<sup>19</sup> X. Chango, O. Flor-unda, P. Gil-jim, and H. Gómez-Moreno, "Technology in Forensic Sciences: Innovation and Precision," *Technologies*, 2024, doi: <https://doi.org/10.3390/technologies12080120>

reconstruction.<sup>20</sup> Unmanned aerial vehicles (drones), high resolution imaging systems, alternate light sources and hyperspectral imaging help to document large or inaccessible crime scenes and aid in the identification of latent fingerprints, biological stains and trace evidence. The use of artificial intelligence and machine learning algorithms is growing in the analysis of complex forensic data, pattern recognition, facial recognition and digital evidence interpretation. Geographic information systems (GIS), global positioning systems (GPS) and advanced crime mapping technologies also assist in spatial analysis and event reconstruction.<sup>21</sup> With the rise of electronic evidence in a wide range of electronic devices, cloud storage, and network systems, digital forensic tools have broadened the scope of modern investigations. While these innovations significantly enhance the effectiveness of investigations and the accuracy of scientific results, their effective application requires the use of methodologies that are validated and standardized, constant professional training, and respect for legal and ethical guidelines. As a result, technological advancements have become an essential part of the scientific search for truth in the field of crime scene management, and have bolstered the credibility and effectiveness of forensic investigations.

## **7 Conclusion**

Criminal investigations have become a field of science and at its heart is crime scene management. The adoption of the well-known scientific principles and standardized investigative practices helps ensure that evidence can be accurately preserved, analysed and interpreted in an objective and legally reliable way. This review focuses on the ability to effectively manage a crime scene beyond evidence collection, through systematic documentation, contamination control, maintaining a chain of custody, forensic lab examination, and the reconstruction of a criminal event. Principles like the Locard's Exchange Principle, individuality, progressive change etc. with scientific objectivity give a solid theoretical basis for the generation of credible forensic findings. Additionally, advancements in technology have improved the precision and efficiency of modern crime scene investigations, such as 3D documentation, artificial intelligence, digital forensics, and powerful analytical tools. While these improvements have been made, proper crime scene management still relies on following established protocols, teamwork, ongoing professional development, and quality assurance. With the ongoing evolution of forensic science, combining new technologies with

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<sup>20</sup> M. Esposito, F. Sessa, G. Cocimano, P. Zuccarello, S. Roccuzzo, and M. Salerno, "Advances in Technologies in Crime Scene Investigation," *diagnostics*, vol. 13, pp. 1–9, 2023, doi: <https://doi.org/10.3390/diagnostics13203169>.

<sup>21</sup> M. Dağlar and U. Argun, "Crime Mapping and Geographical Information Systems in Crime Analysis," *Int. J. Hum. Sci.*, vol. 13, no. 1, 2016, doi: 10.14687/ijhs.v13i1.3736.

traditional scientific techniques will further enhance the ability to obtain truth. Finally, scientifically sound C.S.M. will help in improving the investigation results and help in the fair, transparent, and efficient administration of justice while increasing the public's confidence in forensic science.

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