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Phone : +91 73059 14348 - info@iledu.in / Chairman@iledu.in

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ADVANCED TECHNIQUES IN TRACK EVIDENCE

AUTHOR - J.PIRAVIN ANSARI* & MR. SUJITH KUMAR**

* STUDENTS AT SCHOOL OF EXCELLENCE IN LAW (SOEL), THE TAMILNADU DR. AMBEDKAR LAW UNIVERSITY

** PROFESSOR AT CRIME AND FORENSIC LAW DEPARTMENT, SCHOOL OF EXCELLENCE IN LAW (SOEL), THE TAMILNADU DR. AMBEDKAR LAW UNIVERSITY

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Chapter I – Introduction, Research Framework, and Review of Literature

1.1 Introduction

Track evidence refers to impressions left by footwear, bare feet, tires, or other contact surfaces at a crime scene. These impressions may be visible, latent, or plastic and are considered an important form of circumstantial forensic evidence. Track evidence assists investigators in reconstructing crime scenes, understanding movement patterns, establishing the presence or absence of individuals, and corroborating other forensic and testimonial evidence[1352].

With advancements in forensic science, traditional methods of track evidence collection and analysis have been supplemented and, in some cases, replaced by technologically advanced techniques such as 3D photogrammetry, laser scanning, LiDAR, and artificial intelligence-based footwear identification systems. These developments necessitate a structured academic inquiry into their scientific reliability, legal admissibility, and practical applicability[1353].

[1352] Saferstein, Richard, *Criminalistics: An Introduction to Forensic Science*, 12th ed., Pearson Education, 2018, pp. 162–165.
[1353] Galanakis, G., "A Study of 3D Digitisation Modalities for Crime Scene Investigation," *Applied Sciences*, Vol. 11, MDPI, 2021

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1.2 Aim and objectives of the Study

The primary aim of this research is to examine advanced techniques used in track evidence analysis critically and to evaluate their forensic reliability and legal admissibility within the Indian criminal justice system[1354].

The specific objectives of the study are:

1. To examine the concept and significance of track evidence in criminal investigations.
2. To analyse traditional methods of track evidence collection and their limitations.
3. To study advanced technological techniques used in track evidence analysis.
4. To evaluate the legal admissibility and evidentiary value of track evidence in India.
5. To identify challenges in the application of advanced techniques and suggest suitable reforms.

1.3 Review of Literature

Various forensic scholars and international forensic bodies have emphasized the importance of scientific rigor in tracking evidence analysis. Earlier studies focused primarily on photographic documentation and casting methods, highlighting issues of distortion and subjectivity. Recent literature reflects a shift toward digital documentation, 3D modelling, and automated footwear databases, emphasizing objectivity and reproducibility[1355].

International research demonstrates that 3D photogrammetry and laser scanning improve the accuracy of impression analysis. Studies on artificial intelligence-based footwear identification suggest improved efficiency in database searches, although concerns regarding validation and explainability persist. Legal literature highlights judicial caution toward forensic evidence lacking standardized methodology, reinforcing the need for transparent and validated techniques[1356].

1.4 Research Problem

Despite technological advancements, track evidence continues to face skepticism in courts due to concerns relating to subjectivity, lack of standardization, limited validation, and improper documentation. In the Indian criminal justice system, there is insufficient clarity regarding the evidentiary value and admissibility of advanced track evidence techniques. The research problem addressed in this study is the gap between scientific advancement in track evidence analysis and its effective legal acceptance and utilization.

1.5 Research Questions

The study seeks to answer the following research questions:

1. What is the forensic significance of track evidence in criminal investigations?
2. What are the limitations of traditional track evidence techniques?
3. How do advanced techniques enhance the accuracy and reliability of track evidence analysis?
4. What is the legal position regarding the admissibility of track evidence in India?
5. What measures are required to strengthen the use of advanced track evidence techniques in courts?

1.6 Hypothesis

The study is based on the following hypotheses:

- Advanced scientific techniques significantly improve the reliability and evidentiary value of track evidence.
- Proper standardization and validation of advanced track evidence techniques

[1354] National Research Council, *Strengthening Forensic Science in the United States: A Path Forward*, National Academies Press, 2009
[1355] Bodziak, William J., *Footwear Impression Evidence: Detection, Recovery and Examination*, 2nd ed., CRC Press, 2017.
[1356] Ujvári, Z. et al., "A Consistent Methodology for Forensic Photogrammetry," *Forensic Science International*, Vol. 334, Elsevier, 2023.

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can increase judicial confidence and admissibility.

1.7 Research Methodology

The research adopts a **doctrinal and analytical methodology**. Primary sources include statutes, constitutional provisions, and judicial decisions related to forensic and expert evidence. Secondary sources comprise textbooks, research articles, forensic science journals, reports of forensic institutions, and international guidelines. Comparative analysis is undertaken where necessary to understand global best practices.

1.8 Scope and Limitations of the Study

Scope:
The study focuses on footwear and tire impression evidence and examines advanced analytical techniques relevant to criminal investigations, with particular reference to the Indian legal system.

Limitations:

- The study is doctrinal in nature and does not involve empirical or laboratory-based experimentation.
- Limited Indian case law directly addressing advanced track evidence techniques restricts judicial analysis.
- Rapid technological developments may render some techniques discussed subject to further evolution.

1.9 Scheme of the Study

The research is divided into five chapters:

- **Chapter I** deals with the introduction, research framework, and review of literature.
- **Chapter II** examines traditional methods of tracking evidence and their limitations.
- **Chapter III** analyses advanced techniques in track evidence analysis.
- **Chapter IV** discusses legal admissibility and judicial perspectives in India.
- **Chapter V** presents challenges, recommendations, and conclusions.

Chapter II – Traditional Methods and Their Limitations

2.1 Conventional Methods of Track Evidence Collection

Historically, track evidence was documented through:

- Visual observation and sketching
- 2D photography with measurement scales
- Casting using plaster of Paris or dental stone
- Electrostatic dust lifting for dry surfaces[1357]

These methods formed the backbone of early forensic practice and are still relevant in resource-constrained settings.

2.2 Limitations of Traditional Techniques

Despite their usefulness, traditional techniques suffer from several drawbacks:

- **Loss of detail:** Fine ridge patterns and depth information are often lost in 2D photography.
- **Environmental vulnerability:** Weather, foot traffic, and substrate instability can quickly degrade impressions[1358].
- **Subjectivity:** Manual comparison relies heavily on examiner experience, increasing the risk of cognitive bias.
- **Reproducibility issues:** Once an impression is cast or lifted, re-examination is limited.

2.3 Judicial Concerns

Courts have increasingly questioned forensic methods that lack scientific validation and

[1357] Bodziak, William J., *Footwear Impression Evidence: Detection, Recovery and Examination*, 2nd ed., CRC Press, 2017, pp. 45–52.
[1358] Dror, I.E., "Cognitive Bias in Forensic Science," *Journal of Forensic Sciences*, Vol. 58, 2013.

standardized procedures[1359]. In India, forensic evidence unsupported by corroboration has been viewed with caution, emphasizing the need for technologically robust and transparent methods[1360].

Chapter III – Advanced Techniques in Track Evidence Analysis

3.1 3D Photogrammetry

3D photogrammetry uses multiple overlapping photographs to generate a three-dimensional digital model of an object. This method captures depth, contour, and minute surface details, allowing virtual re-examination without disturbing the original evidence[1361]. It is cost-effective and highly suitable for uneven or soft substrates.

3.2 3D Laser Scanning and LiDAR

Laser scanners and LiDAR technology actively measure distances using light pulses to create precise 3D representations of impressions and entire crime scenes[1362]. These techniques are particularly useful in documenting large scenes with multiple impressions and enable accurate reconstruction for investigative and courtroom purposes[1363].

3.3 Chemical and Physical Enhancement Techniques

Advanced chemical reagents, physical powders, and gelatin or silicone lifters enhance latent impressions on hard or textured surfaces[1364]. Modern practice emphasizes combining enhancement with prior digital documentation to preserve evidentiary integrity.

3.4 Automated Footwear Databases and Artificial Intelligence

Computer-assisted footwear identification systems and machine learning algorithms assist in searching large databases of outsole patterns. These systems reduce manual workload and help prioritize potential matches, though final conclusions remain examiner-driven[1365].

3.5 Quantitative and Probabilistic Approaches

Modern forensic science increasingly favors probabilistic evaluation over categorical conclusions[1366]. Likelihood ratios and statistical models provide transparent measures of evidential strength, aligning track evidence analysis with contemporary forensic standards.

Chapter IV – Legal Admissibility and Judicial Perspective in India

4.1 Track Evidence as Expert Evidence

Under Indian criminal jurisprudence, track evidence is treated as expert evidence and must satisfy standards of relevance, reliability, and procedural fairness[1367]. Courts examine the qualifications of the expert, the methodology used, and the chain of custody.

4.2 Compulsion to Provide Footprint or Footwear Samples

The Supreme Court has clarified that directing an accused to provide fingerprints, footprints, or footwear impressions does not violate Article 20(3) of the Constitution, as such evidence is physical in nature and not testimonial[1368]. However, refusal to cooperate cannot by itself form the basis of conviction.

4.3 Evidentiary Value and Corroboration

Indian courts generally treat track evidence as corroborative rather than conclusive[1369]. Convictions based solely on track evidence

[1359] Saks, M.J. & Koehler, J.J., "The Coming Paradigm Shift in Forensic Identification Science," *Science*, Vol. 309, 2005.
[1360] *State of U.P. v. Sunil*, (2017) 4 SCC 393.
[1361] Ujvári, Z. et al., "A Consistent Methodology for Forensic Photogrammetry," *Forensic Science International*, Vol. 334, Elsevier, 2023.
[1362] Rüther, H., et al., "Terrestrial Laser Scanning for Forensic Applications," *Journal of Forensic Sciences*, Vol. 54, 2009.
[1363] Buck, U. et al., "3D Documentation and Reconstruction of Crime Scenes," *Forensic Science International*, Vol. 222, 2012.
[1364] Bodziak, William J., *Footwear Impression Evidence: Detection, Recovery and Examination*, 2nd ed., CRC Press, 2017.
[1365] Champod, C. et al., *Forensic Science Reform: Scientific and Legal Perspectives*, Wiley-Blackwell, 2017.
[1366] Saks, M.J. & Koehler, J.J., "The Coming Paradigm Shift in Forensic Identification Science," *Science*, Vol. 309, 2005.
[1367] Section 45, Indian Evidence Act, 1872; see also Bharatiya Sakshya Adhiniyam, 2023 (expert evidence provisions).
[1368] *State of Uttar Pradesh v. Sunil*, (2017) 4 SCC 393.
[1369] *Magan Bihari Lal v. State of Punjab*, (1977) 2 SCC 210.

without independent corroboration are rare, reflecting judicial caution toward forensic evidence that lacks comprehensive validation.

4.4 Challenges in Admissibility of Advanced Techniques

The use of AI, 3D modeling, and digital reconstruction raises issues of transparency, validation, and explainability[1370]. Courts may demand disclosure of algorithms, error rates, and standard operating procedures before accepting such evidence.

Chapter V – Challenges, Recommendations, and Conclusion

5.1 Scientific and Practical Challenges

- Distortion due to substrate conditions
- Partial or degraded impressions
- Examiner bias and lack of blind verification
- Limited validation of AI-based tools
- Inadequate training and infrastructure in developing jurisdictions

5.2 Recommendations

- Adoption of standardized protocols for digital capture and analysis
- Mandatory validation and accreditation of forensic laboratories
- Training of investigators, prosecutors, and judges in advanced forensic techniques
- Development of national footwear and track evidence databases in India
- Clear judicial guidelines for admitting technologically advanced forensic evidence

5.3 Conclusion

Advanced techniques have significantly enhanced the scientific value of track evidence by improving accuracy, objectivity, and reproducibility. While these developments hold immense potential for criminal justice, their effectiveness depends on proper validation, ethical use, and judicial oversight. A balanced integration of technology and legal safeguards is essential to ensure that track evidence contributes meaningfully to fair trials and reliable convictions.

5.4 References

Books

1. Saferstein, Richard, *Criminalistics: An Introduction to Forensic Science*, 12th ed., Pearson Education, New York, 2018.
2. Bodziak, William J., *Footwear Impression Evidence: Detection, Recovery and Examination*, 2nd ed., CRC Press, Boca Raton, 2017.
3. Houck, Max M. & Siegel, Jay A., *Fundamentals of Forensic Science*, 3rd ed., Academic Press, London, 2015.
4. Champod, Christophe, Evett, Ian W. & Jackson, Graham, *Forensic Science Reform: Scientific and Legal Perspectives*, Wiley-Blackwell, Oxford, 2017.
5. Robertson, Bernard & Vignaux, G.A., *Interpreting Evidence: Evaluating Forensic Science in the Courtroom*, Wiley, Chichester, 1995.
6. Cole, Simon A., *Suspect Identities: A History of Fingerprinting and Criminal Identification*, Harvard University Press, Cambridge, 2001.

Journals & Research Articles

7. Galanakis, Georgios, "A Study of 3D Digitisation Modalities for Crime Scene Investigation," *Applied Sciences*, Vol. 11, MDPI, 2021.
8. Ujvári, Zoltán et al., "A Consistent Methodology for Forensic Photogrammetry," *Forensic Science International*, Vol. 334, Elsevier, 2023.

[1370] Edmond, Gary, "Forensic Science Evidence and the Conditions for Rational Evaluation," *Melbourne University Law Review*, Vol. 39, 2015.

9. Baiker-Sørensen, M., "INTERPOL Review of Shoe and Tool Marks 2016–2019," *Forensic Science International: Synergy*, Vol. 2, Elsevier, 2020.
10. Saks, Michael J. & Koehler, Jonathan J., "The Coming Paradigm Shift in Forensic Identification Science," *Science*, Vol. 309, 2005.
11. Edmond, Gary, "Forensic Science Evidence and the Conditions for Rational Evaluation," *Melbourne University Law Review*, Vol. 39, 2015.

Reports & Guidelines

12. National Research Council, *Strengthening Forensic Science in the United States: A Path Forward*, National Academies Press, Washington D.C., 2009.
13. SWGTREAD, *Guide for the Forensic Documentation and Photography of Footwear and Tire Impressions*, National Institute of Standards and Technology (NIST), 2006.
14. INTERPOL, *Review of Shoe and Tool Mark Evidence*, INTERPOL Forensic Science Review Series, Lyon, 2020.
15. UK Home Office, *Forensic Science Strategy*, Government of the United Kingdom, 2016.

Indian Legal Sources

16. *State of Uttar Pradesh v. Sunil*, (2017) 4 SCC 393.
17. *Ritesh Sinha v. State of Uttar Pradesh*, (2019) 8 SCC 1.
18. Bharatiya Sakshya Adhiniyam, 2023.
19. Constitution of India, Article 20(3).

Research Methodology Sources

20. Jain, M.P., *Legal Research and Methodology*, 8th ed., LexisNexis, New Delhi, 2016.
21. Kothari, C.R., *Research Methodology: Methods and Techniques*, 2nd ed., New Age International, New Delhi, 2004.