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ROLE OF FORENSIC SCIENCE IN ENSURING EQUITABLE ACCESS TO JUSTICE: A CRITICAL ANALYSIS

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Abstract: *The paper explores the vital role that forensic science plays in advancing fair access to justice while examining the structural issues that frequently stand in the way of its democratic potential. The use of forensic science usually reflects and occasionally perpetuates societal injustices, even though it ostensibly provides objective, scientific evidence that cuts across socioeconomic and demographic divides. According to the research, economically disadvantaged rural areas and well-funded metropolitan jurisdictions differ significantly in terms of resource allocation, quality requirements, and access to knowledge. These differences show up in several ways, including the restricted availability of forensic testing for public defenders, differences in laboratory quality standards, and geographic limitations on obtaining specialised knowledge. The paper highlights important structural changes that are required to overcome these disparities, such as requiring defence forensic services to have financing sources, standardising laboratory procedures, and introducing mobile forensic capabilities. The study also highlights how crucial educational programs and technical advancements are to closing the gaps in service delivery that currently exist. Legislative measures, institutional changes, and technology developments are all included in the suggested remedies, underscoring the necessity of a thorough reform strategy. The results indicate that in addition to significant investments in infrastructure and human capital development, politicians, practitioners, and communities must remain committed to transforming forensic science into an effective tool for equal justice. This study concludes that although forensic science has a lot of promise to advance justice equity, achieving this potential would necessitate tackling underlying structural injustices via concerted reform initiatives.*

Keywords: *Forensic Science, Equitable Access to Justice, Criminal Justice Disparities, Access to Forensic Services, Justice System Reform*

INTRODUCTION

Forensic science is a fundamental component of evidence-based investigation and prosecution in the contemporary criminal justice system. Its development from crude fingerprinting methods to advanced DNA analysis and digital forensics has completely changed the way that justice is sought and administered. Forensic DNA profiling is utilised in courts to resolve complicated criminal and civil issues, including maternity disputes, child snatching, sexual offences, kidnapping, and rape-murder, immigration, etc.[1] But because forensic science and equal justice have a complicated and multidimensional connection, it is important to carefully consider both its revolutionary potential and inherent limitations. In a system that has always been beset by subjective biases and injustices, the application of scientific approaches to criminal investigations offers impartiality. From conventional criminalistics and toxicology to more recent areas like digital forensics and forensic anthropology, forensic science covers a wide range of subjects. Every subject offers distinct techniques and methods that have the ability to level the playing field in criminal prosecutions by providing evidence-based insights that cut beyond racial, cultural, and socioeconomic divides.

However, fair access to justice is not ensured by the sheer presence of forensic skills. With all of its inherent inequities and systemic injustices, forensic science is incorporated into the legal system within pre-existing societal frameworks. The quality of analysis, findings interpretation, and availability to forensic resources all affect whether forensic science promotes equality or, ironically, perpetuates current structural injustices. The dual character of forensic science in the legal system is examined in this critical

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[1] Dinesh Singh and Sufiya Ahmed, 'Forensic DNA profiling in Criminal Investigation: A Comparative Analysis of U.K., U.S.A. and India,' (2021) XIII (4) Philosophical Readings 2340, <https://www.researchgate.net/publication/365790531_Forensic_DNA_profiling_in_Criminal_Investigation_A_Comparative_Analysis_of_U > accessed on 5 November 2024.

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examination, which acknowledges the institutional, structural, and practical limitations that may restrict its equalising influence while also examining the discipline's ability to advance equality through objective evidence. By comprehending these relationships, we may more effectively handle the potential and difficulties of using forensic science to build a more just legal system that benefits everyone in society.

THE DEMOCRATIC PROMISE OF FORENSIC EVIDENCE

The democratic promise of forensic science lies in its fundamental principle of scientific objectivity and its potential to transcend traditional barriers to justice. Forensic science functions according to accepted scientific principles, which are independent of the defendant's history, social standing, or demographic traits, in contrast to subjective types of evidence. Forensic evidence's scientific basis demonstrates its democratic potential through a number of crucial mechanisms:

A. *Objective Methodology and Universal Standards*

Forensic science is based on empirical procedures that can be repeated and validated in several laboratories and jurisdictions. Stakeholders in forensic science must be reassured that the field is adhering to accepted standards so that they can assess if the findings are accurate, trustworthy, or significant given the circumstances of the case they are working on.[2] This standardisation implies that DNA analysis, ballistics testing, and toxicity screening should produce consistent results regardless of where or who does them. The scientific method emphasises repeatability and peer review, which offers a framework where evidence may be judged based on merit rather than the qualifications or authority of those presenting it. Forensic science relies on strong scientific technique across disciplines and jurisdictions. This method necessitates rigorous hypothesis testing, controlled experiments, and data-driven findings that can be independently validated. Each forensic analysis must adhere to established methods that reduce subjective interpretation and increase reliability. The scientific process guarantees that findings are founded on factual data rather than personal opinion, resulting in a standardised framework for forensic analysis that is consistent independent of the laboratory or analyst involved. This neutrality is particularly critical in criminal justice environments, where analytical findings can profoundly affect case results and individual liberty.

To guarantee consistent evidence gathering, processing, and interpretation across jurisdictions, forensic science depends on universal standards. Standard operating procedures, or SOPs, are revised often to take into account best practices and new developments in technology. To ensure constant analytical quality, standardisation involves procedures for various forms of evidence, quality control techniques, and proficiency testing. Forensic dependability is further reinforced by quality assurance systems that include blind quality control samples, external audits, and recurring proficiency assessments. To guarantee analytical precision, laboratories must uphold accreditation and validate statistical methods. This all-encompassing strategy ensures reliable forensic evidence, supporting fairness in the legal system and scientific reliability everywhere.

Before being used, forensic processes must undergo a thorough validation process. While verification ensures ongoing analytical accuracy, validation ensures that processes are reliable, acceptable for their intended use, and scientifically sound. This process involves determining appropriate applications, estimating error rates, and evaluating approach limits. To support open scientific practice and enable critical analysis of forensic evidence, validation studies must be recorded and made accessible for review. Frequent technique validation helps identify any new flaws or limitations and guarantees continued reliability.

B. *Transparency and Verifiability*

The democratic nature of forensic evidence is further supported by its transparency and verifiability. In many respects, openness and transparency further the goals by offering vital details about the reliability of the studies supporting scientific practice and the

[2] John Lentini, 'Forensic Science Standards: Where They Come From and How They Are Used' (2009) 1 (1) Forensic Science Policy and Management 10, DOI: http://dx.doi.org/10.1080/19409040802596315 <https://www.researchgate.net/publication/233448599_Forensic_Science_Standards_Where_They_Come_From_and_How_They_Are_Used> accessed on 6 November 2024.

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competence of the examiner.[3] In contrast to circumstantial evidence or eyewitness accounts, forensic results should be focussed on the followings to avoid wrongful convictions:

1. All analytical processes, including detailed protocols, reagent preparations, and quality control methods, must be meticulously documented by forensic labs. Transparency and scientific validity in forensic analysis are promoted by this meticulous record-keeping, which guarantees repeatability of results and permits in-depth evaluation of techniques by other specialists.
2. Physical evidence is kept available for further analysis by methodical documenting using photography and appropriate evidence preservation procedures. This procedure preserves the integrity of the evidence for possible future study utilising cutting-edge technology or techniques, permits independent verification of conclusions, and supports appeals procedures.
3. The capacity of impartial specialists to examine and validate forensic results is an essential defence against prejudice and mistakes. Experts with the necessary training may review unprocessed data, analysis methods, and findings, adding another level of scientific scrutiny to forensic evidence's credibility.
4. Scientific results must be subject to peer review and recognised methodology. This involves having the capacity to repeat tests, confirm findings using different methods, and rigorously examine conclusions to make sure forensic evidence satisfies recognised scientific norms.
5. Evidence must be accessible for re-examination using enhanced techniques and new technology as forensic science develops. Justice may be served through improved analytical skills and cases can profit from scientific advancements thanks to this continuous review possibility.

C. *Evidence Preservation and Post-Conviction Review*

The preservation and easy retrieval of specimens from cases that have been decided or that remain unresolved benefits every individual involved in the criminal justice system.[4] The Innocence Project and similar organisations have demonstrated that preserved forensic evidence, particularly DNA, can be a powerful tool for justice long after initial convictions. Prolonged forensic evidence preservation enables post-conviction review and appeals, which is a crucial defence against erroneous convictions. This factor is particularly significant for marginalised populations that have historically had higher rates of unjust convictions.

Proper evidence preservation necessitates sophisticated storage methods that can keep evidence intact for long periods of time. To avoid biological, chemical, and physical evidence degradation, storage facilities must maintain environmental parameters such as temperature, humidity, and light exposure. Each evidence type necessitates unique storage protocols, such as biological evidence need refrigeration or freezing, digital evidence needs safe electronic storage with regular backups, and physical evidence must be protected from contamination and deterioration. Storage facilities must keep extensive environmental monitoring records and perform frequent quality inspections to verify that preservation conditions stay within defined ranges. These standards demand considerable investment in infrastructure and continual maintenance to guarantee evidence stays viable for future examination.

Maintaining comprehensive documentation systems is crucial for preserving and accessing evidence over time. These systems must monitor all aspects of evidence storage, such as location, handling history, and condition evaluations. Modern tracking systems use barcode or RFID technology to preserve precise chain of custody records and allow for speedy evidence placement and retrieval. The documentation must contain thorough images, condition reports, and environmental monitoring data. This information is critical during post-conviction proceedings, because issues concerning evidence processing and preservation may influence case results. Regular audits of documentation systems guarantee that records are accurate and thorough.

[3] Carlos Miguel Ibaviosa and Jason M. Chin, 'Beyond CSI: Calibrating public beliefs about the reliability of forensic science through openness and transparency' (2022) Science & Justice., DOI: https://doi.org/10.31222/osf.io/tvcm6 < https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4037367 > accessed on 7 November 2024.

[4] NISTIR 7928, 'The Biological Evidence Preservation Handbook: Best Practices for Evidence Handlers,' DOI: http://dx.doi.org/10.6028/NIST.IR.7928 < https://www.nist.gov/system/files/documents/forensics/NIST-IR-7928.pdf > accessed on 7 November 2024.

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Protocols must regulate access to preserved material during post-conviction review. These guidelines strike a compromise between ensuring evidence accessible and protecting integrity and chain of custody. Access procedures must include authorisation verification, examination documentation, and evidence handling oversight. Protocols should cover both defence and prosecution access rights, providing fair treatment while protecting evidence. This includes techniques for independent testing and analysis that are authorised by courts or competent authorities.
Technological advancements present possibilities and problems for preserving and reviewing evidence. Digital storage systems must be updated on a regular basis to avoid obsolescence and ensure data integrity. Converting physical documents to digital versions necessitates rigorous validation and backup methods. New analytical techniques may necessitate particular preservation strategies to guarantee that evidence is suitable for future examination. Regular evaluation of technical capabilities ensures that preservation procedures stay current and effective for anticipated future analytical demands.

D. Scientific Advancement and Equal Application

Stakeholders in the field have really called for forensic science tests to be carried out by qualified professionals using established standards at approved facilities.[5] Its continuous advancement creates fresh opportunities for justice for individuals from all walks of life. Advancements in fields like:

1. Modern DNA analysis tools, such as probabilistic genotyping and low-copy number analysis, can produce more reliable results from smaller or damaged samples. These developments assist all cases equally, regardless of jurisdiction or resource availability, by providing more solid evidence for both prosecution and defence when effectively applied across laboratories.
2. Digital forensic technologies now provide complicated data recovery and analysis across several devices and platforms. When appropriately deployed, these capabilities enable jurisdictions of all sizes to efficiently analyse digital evidence, guaranteeing that technology evidence may be adequately evaluated regardless of case location or resources.
3. Improved chemical analysis techniques, such as mass spectrometry and chromatography, can accurately identify and quantify substances. These advancements improve the credibility of evidence analysis in all situations, promoting fair justice with more exact scientific results.
4. Artificial intelligence and machine learning enhance the accuracy of traditional forensic comparisons. These technologies can standardise analysis across jurisdictions, decreasing subjective bias and providing more uniform results independent of laboratory location.
5. Automated systems for evidence processing and analysis can standardise practices across laboratories. This automation maintains uniform quality and minimises processing time, making advanced forensic capabilities more available to all jurisdictions regardless of size and resources.

These developments provide new opportunities for both prosecution and defence, and they may be utilised equally to situations irrespective of the social or economic standing of the subject.

E. Chain of Custody and Documentation

The most crucial and significant procedure for recording evidence is the "chain of custody," which in criminal and civil law refers to the sequence in which the evidence was handled during a case's investigation.[6] When a chain of custody is needed to demonstrate the legitimacy of the artefact or its unaltered state, it is vital to ascertain the beginning and end of the chain.[7] The strict guidelines for upholding the chain of custody and appropriate paperwork when handling forensic evidence give another degree

[5] American Bar Association, House of Delegates, Resolution of August 9 and 10, 2004, page 5 <https://www.nacdl.org/getattachment/ff7ea91a-f7d7-494c-8243-8e7a6a3316a5/aba-adopts-statement-of-best-practices-for-promoting-the-accuracy-of-eyewitness-identification-procedures-august-2004.pdf > accessed on 8 November 2024.
[6] Robert Longley, 'What Is Chain of Custody? Definition and Examples.' ThoughtCo., (2022) https://www.thoughtco.com/chain-of-custody-4589132 accessed on 10 November 2024.
[7] Tommaso D'Anna, Maria Puntarello, Giovanni Cannella, Giovanni Scalzo, Roberto Buscemi, Stefania Zerbo, Antonina Argo, '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,' (2023) 11(5) Healthcare 634. DOI: https://doi.org/10.3390/healthcare11050634 <https://pmc.ncbi.nlm.nih.gov/articles/PMC10000967/#B1-healthcare-11-00634 > accessed on 10 November 2024.

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of democratic security. These guidelines guarantee that:

1. Maintaining evidence integrity necessitates meticulous documenting of its possession, storage conditions, and handling. Every transmission must include timestamps, handler identification, and purpose. Continuous monitoring guarantees that the evidence is untampered and legally acceptable. Proper processes retain authenticity, ensure trustworthiness in judicial proceedings, and maintain the chain of custody.
2. Standardised protocols determine how evidence is collected, processed, transported, and kept. These protocols specify the criteria for distinct forms of evidence, environmental conditions, and preservation techniques. Consistently applying these criteria maintains evidence quality, regardless of jurisdiction or handling facility.
3. Document all interactions with evidence, including descriptions, photos, collecting techniques, and storage conditions. Records must be current, comprehensive, and stored in secure systems. This extensive documentation promotes evidence dependability and facilitates effective evaluation.
4. Records in the chain of custody must be available to authorised individuals while being secure. Digital tracking devices allow for the real-time monitoring of evidence location and status. This accessibility promotes openness while maintaining evidence integrity through restricted access and extensive audit records.
5. Clear accountability processes necessitate authorisations for evidence access and management. Every encounter must be reasonable, recorded, and verifiable. Regular audits assure compliance with handling guidelines, preserving evidence integrity through systematic supervision and responsibility tracking.

Further bolstering the democratic promise of forensic science, this methodical approach to evidence management helps avoid manipulation or selective application of forensic procedures.

LEADING CASES ON FORENSIC SCIENCE

F. Leading Cases at Global Level

1. R v. Pitchfork[8]: The Colin Pitchfork case was a watershed moment in UK criminal investigations, since it was the first time DNA profiling was used to arrest a killer. Pitchfork raped and killed two schoolgirls, Lynda Mann (1983) and Dawn Ashworth (1986), in Leicestershire. Initially, an innocent guy was suspected, but Pitchfork was arrested after convincing a coworker to do the DNA test on his behalf. The fraud was revealed, and Pitchfork's DNA matched the crime scenes through semen, blood and saliva samples. He was condemned to life in 1988. His conviction transformed forensic science by establishing DNA profiling as an effective investigative technique.[9]

2. Frye v. United States[10]: The decision of this case established an important legal precedent for the acceptance of scientific evidence in US courts. James Alphonso Frye was found guilty of second-degree murder, and his defence attempted to bring evidence from a systolic blood pressure deception test (an early lie detector). The court dismissed this evidence, stating that scientific methodologies must be "generally accepted" by the relevant scientific community in order to be admitted. This "Frye Standard" became a fundamental criterion for expert testimony in courts, affecting the appraisal of forensic and scientific evidence until it was amended by the Daubert standard in 1993.[11]

3. Williams v. The State[12]: The Wayne Williams case concerned the infamous Atlanta Child Murders, in which at least 28 African American children, teenagers, and young adults were slain between 1979 and 1981. Williams was first found guilty of the murders of Jimmy Ray Payne and Nathaniel Cater and sentenced to two life terms. His appeal claimed, among other things, that the state's presentation of evidence connected to 10 additional suspected killings was inappropriate and prejudicial. The Georgia Supreme Court upheld the conviction, ruling that the state's evidence was admissible under the requirement that it served to establish a pattern or modus operandi tying Williams to the offences. According to the majority ruling, the evidence from ten further killings was admissible since it showed a pattern that was in line with Williams' method of operation in the

[8] (2009) EWCA Crim 963
[9] R v. Pitchfork < https://www.casemine.com/judgement/uk/5b46f2042c94e0775e7f062f > accessed on 13 November 2024.
[10] 293 F. 1013 (D.C. Cir. 1923)
[11] Frye v. United States < https://www.casebriefs.com/blog/law/evidence/evidence-keyed-to-fisher/lay-opinions-and-expert-testimony/frye-v-u-s/ > accessed on 14 November 2024.
[12] 251 Ga. 749, 804 (16) (312 SE2d 40) (1983).

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alleged murders. In order to deduce a systematic strategy by Williams in committing these murders, the court carefully examined the commonalities between the instances, including victim characteristics, disposal techniques, and tangible evidence like fibres and dog hairs. The court also considered Williams' procedural objections to due process and the validity of expert testimony, concluding that these were inconsequential given the weight of the evidence as a whole. His case had a tremendous influence on forensic fibre analysis in investigations.[13]

4. Bundy V. Florida[14]: The Ted Bundy case saw the end of one of America's most prominent serial murderers. Bundy, a charismatic law student, was apprehended in Florida after fleeing from custody. In January 1978, he viciously murdered two women at Florida State University's Chi Omega sorority before abducting and killing 12-year-old Kimberly Leach. His trial was significant, as it was the first nationally televised trial in the United States. Bundy represented himself and exploited media attention, but was found guilty based on physical evidence, including bite marks. He was sentenced to death and hanged in 1989 after confessing to more than 30 killings in different states.[15]

5. State of Tennessee v. Paul Ware[16]: In 1994, Paul Ware was charged in Tennessee with the rape and murder of four-year-old Lindsey Green. The case was remarkable because it was the first in the United States to use mitochondrial DNA (mtDNA) evidence in court.[17] Investigators discovered a little red hair in the victim's neck and others on a bed at the crime scene. The mtDNA recovered from these hairs matched those collected from Ware but not from the victim, supporting the prosecution's case. Despite the defense's claim that another person was to blame, Ware was convicted in 1996 of first-degree felony murder and two counts of child rape, getting a life sentence without parole plus extra consecutive sentences.[18]

G. *Leading Cases in India*

1. Dharam Deo Yadav v. State of UP[19]: Diana Clare Routley, 22, a tourist from New Zealand, went missing in Varanasi, India, in 1997. She was last seen with Dharam Deo Yadav, a local guide. Following her father's allegation, officials apprehended Yadav, who confessed to Diana's murder and led police to her buried body. Forensic analysis, including DNA testing, established her identity. Yadav was condemned to death after being found guilty of murder in 2006. In 2014, the Supreme Court of India affirmed the judgement but modified the death sentence to life in jail without the possibility of release.[20]

2. Selvi v. State of Karnataka[21]: Selvi case was a significant decision by India's Supreme Court on the legitimacy of involuntary scientific tests such as narco-analysis, polygraph, and brain mapping in criminal investigations. The Court decided that compelling an accused person to take such tests violated Article 20(3) of the Indian Constitution, which safeguards against self-incrimination. It ruled that these tests could only be carried out with the individual's permission and sufficient precautions. The ruling upheld human rights and due process by emphasizing that involuntary remarks made during such tests were inadmissible as evidence in court.[22]

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[13] Williams v. The State : Establishing Standards for Admissibility of Correlative Crimes Evidence in Georgia <https://www.casemine.com/commentary/us/williams-v.-the-state:-establishing-standards-for-admissibility-of-correlative-crimes-evidence-in-georgia/view#:~:text=The%20State%2C%20251%20Ga.%20749%20%281983%29%2C%20adjudicated%20by,correlative%20crimes%20evidence%20in%20the%20state%E2%80%99s%20judicial%20proceedings.> accessed on 15 November 2024.

[14] 479 U.S. 894 (1986)

[15] Bundy V. Florida, 479 U.S. 894 (1986) < https://supreme.justia.com/cases/federal/us/479/894/ > accessed on 16 November 2024.

[16] C.C.A. No. 03C01-9705-CR-00164, 1999 WL 233592

[17] C. Leland Davis, 'Mitochondrial DNA: State of Tennessee v. Paul Ware,' Case Report <https://www.promega.com/~/media/Files/Resources/Profiles%20In%20DNA/103/Mitochondrial%20DNA%20State%20of%20Tennessee%20v%20Paul%20Ware.ashx > accessed on 17 November 2024.

[18] State v. Ware < https://casetext.com/case/state-v-ware-86 > accessed on 17 November 2024.

[19] (2014) 5 SCC 509

[20] Department of Forensic Science and Criminal Investigation, Dharam Deo Yadav vs the State of U.P. <https://forensic.legaldesire.com/2021/06/04/dharam-deo-yadav-vs-the-state-of-u-p/ > accessed on 18 November 2024.

[21] AIR 2010 SC 1974

[22] Law Bhoomi, Selvi v State of Karnataka (2010) < https://lawbhoomi.com/selvi-v-state-of-karnataka/ > accessed on 19 November 2024.

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3. Ritesh Sinha v. State of UP[23]: In Ritesh Sinha case the Supreme Court of India considered whether ordering an accused person to produce a voice sample breaches Article 20(3)'s constitutional guarantee against self-incrimination. Ritesh Sinha was suspected of fraud, and detectives wanted a voice sample to match to recorded conversations. He disputed this, citing self-incrimination issues. The Court decided that delivering a voice sample does not constitute testimonial coercion since it is similar to tangible evidence such as fingerprints or handwriting, which are non-testimonial. Thus, requiring an accused to give a voice sample does not violate Article 20(3).[24]

4. Rohit Shekhar v. Narayan Dutt Tiwari[25]: This case was a landmark paternity case in India. Rohit Shekhar sued elderly politician Narayan Dutt Tiwari, claiming to be his biological son. Tiwari originally rejected the charges, but after a lengthy legal struggle, the Delhi High Court ordered a DNA test to validate Shekhar's claim. The case established a precedent for paternity laws and the right to identification. Tiwari openly acknowledged Shekhar's paternity in 2014. The case raised concerns about privacy, personal identification, and the legal significance of DNA evidence in paternity disputes.[26]

5. Santosh Kumar Singh vs. State Through CBI[27]: *This case emphasizes the importance of DNA evidence in sexual assault cases. Santosh Kumar Singh was acquitted in 1999 for the rape and murder of Priyadarshini Mattoo owing to a lack of direct evidence. The CBI's appeal was based on forensic results, including DNA evidence tying Singh to the crime. In 2006, the Delhi High Court convicted him, emphasizing the importance of DNA in verifying circumstantial evidence. In 2010, the Supreme Court affirmed his life sentence. The case highlighted the importance of DNA in sexual assault proceedings, assuring scientific neutrality in the delivery of justice.*[28]

CURRENT CHALLENGES AND DISPARITIES

The area of forensic science has a number of problems, including the possibility of human mistake, sample contamination, and constant scrutiny and criticism.[29] Despite its promise, the implementation of forensic science in the justice system reveals significant disparities in access and application:

H. Resource Disparities

The glaring disparity in resources between the defence and prosecution teams is one of the biggest obstacles to using forensic science to achieve equal justice. While state-funded prosecution agencies usually have specialised funds for expert witness and forensic testing, public defenders and court-appointed lawyers sometimes have very little funding. Numerous significant ways that this discrepancy shows up have an immediate effect on case outcomes. It is sometimes hard for public defenders to decide whether to use their meagre funds on forensic testing or other crucial defence requirements. For impoverished defendants, the whole case budget is frequently exceeded by the expense of thorough forensic investigation, which can vary from hundreds to tens of thousands of dollars. Due to budgetary constraints, defence teams are forced to either restrict the extent of their research or forego potentially exonerating forensic tests. The disparity in resources also goes beyond the price of testing. While defence teams must find and pay for these services on their own, prosecution teams frequently have ready access to expert witnesses and established links with state crime laboratories. The ensuing discrepancy in forensic skills may have a substantial effect on the capacity to refute prosecution evidence or offer counterarguments to the crime, which may result in unfair processes and results.

I. Quality and Reliability Issues

[23] AIR 2019 SC 3592
[24] Law Foyer, Ritesh Sinha v. State Of U.P & Anr < https://lawfoyer.in/ritesh-sinha-vs-state-of-u-p-anr/#google_vignette > accessed on 20 November 2024.
[25] AIR 2012 DELHI 151
[26] Latest Laws.com, < https://www.latestlaws.com/judgements/delhi-hc/2009/november/2009-latest-caselaw-4434-del > accessed on 20 November 2024.
[27] (2010) 9 SCC 747
[28] Santosh Kumar Singh vs State Th. CbI on 6 October, 2010 < https://indiankanoon.org/doc/760449/ > accessed on 22 November 2024.
[29] Sai YRKM, 'Advancing forensic science: Addressing challenges and embracing emerging technologies,' (2022) 8 (1) Forensic Science Today. 1-5. DOI: http://dx.doi.org/10.17352/fst.000023 <https://www.researchgate.net/publication/370916286_Advancing_forensic_science_Addressing_challenges_and_embracing_emerging_technologies > accessed on 23 November 2024.

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There is a concerning discrepancy in the way justice is administered since forensic analysis quality and dependability differ greatly between jurisdictions and labs. This variance results from a number of interrelated factors that impact the reliability and correctness of forensic evidence. Older equipment used by underfunded facilities frequently produces less accurate findings or has restricted testing capabilities. Due to financial limitations, these labs can also find it difficult to maintain appropriate quality control procedures, which could jeopardise the validity of their results. Additionally, hasty analysis and higher mistake rates might result from heavy caseloads and pressure to handle data rapidly. These quality problems are made worse by the absence of uniform procedures among various jurisdictions. Some labs function with little supervision, while others uphold strict certification and quality control requirements. Depending on where a case is processed, this discrepancy may lead to differing degrees of evidentiary dependability, making it a geographic lottery for those seeking justice.

J. Access to Expertise

A notable disparity between underprivileged villages and metropolitan centres with ample resources is evident in the distribution of forensic competence throughout jurisdictions. Rural and economically poor communities are particularly affected by the multi-tiered legal system created by this discrepancy in access to trained specialists. Many rural jurisdictions are forced to depend on generalists or transport evidence to distant facilities since they do not have access to specialised forensic professionals at all. This restriction may cause analysis to be delayed, expenses to rise, and evidence to deteriorate while being transported. Due to the concentration of highly competent specialists in large cities, the quality of expert testimony offered during trials is also impacted by the lack of local experience. The problem extends to continuing education and professional development opportunities. Forensic scientists in underserved areas may have limited access to training in new techniques or technologies, creating a knowledge gap that affects their ability to perform state-of-the-art analysis. This disparity in expertise can lead to variations in the quality and comprehensiveness of forensic investigations based solely on geographic location.

IMPACT ON DIFFERENT COMMUNITIES

K. Urban vs. Rural Communities

In the criminal justice system, one of the biggest geographical disparities is the difference in access to forensic science services between urban and rural regions. Causes are wide-ranging and intricate, as evidenced by the literature, with both similarities and differences between urban and rural facilitators and obstacles.[30] Modern crime labs, specialised forensic units, and a concentrated pool of expert witnesses are all conveniently located in urban locations, which provides a full range of forensic services. Higher levels of quality control and dependability are ensured by the modern technology, specialised staff, and accreditation from national organisations that these urban institutions frequently retain. Urban centres' concentration of resources enables quick processing of evidence, specialised analysis skills, and convenient access to expert testimony. Urban laboratories also often engage in research collaborations with business and academic organisations, which promotes access to state-of-the-art technology and ongoing methodological advancements. This leads to a vicious cycle in which metropolitan facilities with enough resources keep improving while rural communities find it difficult to sustain essential services. The urban edge goes beyond only tools and infrastructure; it also includes professional networks, chances for further education, and the capacity to tackle challenging or uncommon forensic cases. While keeping broad general skills, urban laboratories can frequently specialise in certain sorts of study, gaining in-depth knowledge in specialised fields. Urban centres also usually maintain a high enough caseload volume to warrant training and specialised equipment investments, resulting in economies of scale that further improve their efficiency and capacities. This extensive infrastructure has a major influence on the standard of justice provided in urban areas by guaranteeing that urban cases receive careful forensic study, professional interpretation, and prompt processing.

[30] Melissa E Cyr, Anna G Etchin, Barbara J Guthrie, James C Benneyan, 'Access to specialty healthcare in urban versus rural US populations: a systematic literature review' (2019) 19 (1) BMC health services research, 14. DOI: https://doi.org/10.1186/s12913-019-4815-5 <https://pmc.ncbi.nlm.nih.gov/articles/PMC6921587/> accessed on 23 November 2024.

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L. Socioeconomic Factors

The relationship between socioeconomic position and forensic service accessibility exposes long-standing structural injustices that have a significant influence on the standard of justice that is accessible to various socioeconomic groups. Via their financial resources, wealthy defendants and well-funded countries may obtain complete forensic services that include specialised studies, independent testing, and numerous expert assessments. This financial advantage establishes a tiered structure in which the level of forensic investigation and its quality are frequently directly correlated with financial resources rather than the case's merits. Private defendants have the ability to hire several expert witnesses, commission independent laboratory work, and conduct in-depth forensic research on competing ideas. Additionally, they have the financial means to contest prosecution evidence with independent confirmation and further testing, resulting in a more equitable adversarial procedure. This financial capacity also allows access to state-of-the-art forensic technology and methods that would not be accessible through public labs. Furthermore, well-funded public laboratories with cutting-edge machinery, sufficient workforce, and thorough quality control procedures may be maintained in affluent jurisdictions. These resources have a compounding effect that results in more extensive investigations, more trustworthy research, and more persuasive expert evidence during the trial. In complicated instances where scientific evidence is essential, having the financial means to conduct thorough forensic investigation frequently proves to be vital. Additionally, wealthy defendants may afford to wait for in-depth study instead of feeling compelled to take plea bargains because forensic testing is either restricted or delayed. The principle of equal justice under the law is challenged by this economic advantage, which results in a fundamental disparity in the quality of justice available to various socioeconomic groups. Numerous social and economic elements have been found to have an impact on health and medical treatment. Therefore, it is expected that racial and ethnic disparities will be further reduced in future health care assessments that are better equipped to quantify and account for socioeconomic differences. [31] This underscores the necessity of systemic reform to guarantee equitable access to forensic services, irrespective of financial resources.

REFORMS AND SOLUTIONS

M. Structural Reforms

1. Increased Funding for Public Forensic Services: One essential step in resolving systematic disparities in access to forensic science is the adoption of comprehensive financial changes. Service availability and quality vary greatly throughout jurisdictions due to current financing arrangements, which frequently depend on erratic state allocations and fluctuating local resources. Both prosecution and defence resources must have distinct funding streams established under a redesigned financial system to provide steady support for public forensic services. In order to do this, sustainable funding methods that take into consideration socioeconomic circumstances, crime rates, population size, and geographic variables must be developed. Specific financing for people training, facility upkeep, equipment modernisation, and quality assurance initiatives should be included in the budget structure. Furthermore, financial changes must take into account the unique requirements of underprivileged and rural regions, maybe by implementing additional financing schemes or targeted grants. By creating specialised funding streams, the present resource gaps between defence and prosecution forensic services would be lessened and both parties would have sufficient access to testing skills and scientific knowledge. In order to guarantee effective resource utilisation and keep the focus on service quality and accessibility, such reforms must be combined with accountability mechanisms.

2. Standardization of Forensic Practices: A crucial first step in guaranteeing consistent quality and dependability in forensic analysis is the development of similar standards among forensic labs. The current differences in accreditation standards, quality control procedures, and laboratory techniques lead to notable differences in service quality among countries. A thorough standardisation framework has to cover a variety of forensic

[31] Institute of Medicine (US) Committee on Guidance for Designing a National Healthcare Disparities Report; Swift EK, (ed) Guidance for the National Healthcare Disparities Report. Washington (DC): National Academies Press (US); 2002. 2, Measuring The Effects of Socioeconomic Status On Health Care. <https://www.ncbi.nlm.nih.gov/books/NBK221050/> accessed on 24 November 2024.

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practice topics, such as reporting guidelines, quality control methods, evidence management protocols, and analytical techniques. For this standardisation effort to be both scientifically sound and practically applicable, input from practitioners, legal experts, and scientific experts should be included. Clear criteria for laboratory performance must be established by the framework, along with requirements for proficiency testing, certain quality measures, and frequent external audits. To guarantee uniform competence across jurisdictions, standardisation initiatives should also address training specifications, continuing education obligations, and employee certifications. For smaller laboratories to achieve and maintain compliance, the adoption of these standards has to be backed by sufficient funding and technical support.

3. Technology and Innovation: The careful integration of technical innovations offers potential solutions for the current disparities in forensic service access. The creation of International Organisation for Standardisation (ISO) standards is currently the most important initiative in the worldwide forensic community.[32] Advanced technology, such as mobile forensic units, automated testing systems, and digital analytic platforms, can help bridge the gaps between underserved and well-resourced areas. It is crucial to develop mobile forensic capabilities in order to extend services to remote areas. This requires investments in portable devices, secure communication networks, and mobile personnel who have received the required training. Through remote analysis and expert engagement, digital platforms can let smaller jurisdictions access specialist expertise while maintaining the integrity of the evidence. In addition, innovation efforts must focus on developing cost-effective solutions that can be implemented at different resource levels to guarantee that technological breakthroughs benefit all communities rather than widen existing disparities. The right training and support must be provided for new technology integration in order to ensure effective usage and maintenance of these systems.

N. Policy Recommendations

1. Legislative Action: A crucial first step in resolving structural disparities in access to forensic science is the adoption of broad legislative reforms. Legislators at the state and federal levels must create required financial sources to guarantee that forensic services receive steady and sufficient support. To ensure that resources are allocated fairly among jurisdictions, this legislation should set minimum budget levels based on geographic variables, crime rates, and population size. Both urban and rural regions must be covered by the financial plan, with special attention paid to the particular difficulties encountered by communities that are physically remote.: The conditions for laboratory accreditation must also be addressed by legislative revisions. Different jurisdictions now have different standards due to the current voluntary accrediting schemes. Legislation requiring accreditation should provide consistent standards for all forensic labs, including private ones, and clearly define the consequences of noncompliance. To keep accredited status, these standards should include external audits, quality assurance initiatives, and frequent competence testing. Additionally, the law need to offer financial support to labs striving to meet and uphold certification requirements. Legislative action is necessary to guarantee uniform quality in forensic testimony by addressing expert witness certification criteria. Forensic expert witnesses should be subject to minimum qualifications set by law, including standards for education, training, and real-world experience. A standardised certification procedure and standards for forensic specialists' ongoing education should also be established by law. Funding provisions for training and certification programs, especially for professionals working in underprivileged communities, must be included with these standards.

2. Institutional Changes: Ensuring fair access to forensic services requires a fundamental institutional change, which is the establishment of independent forensic service providers. These autonomous organisations ought to function independently of law enforcement and prosecutors' offices, upholding scientific impartiality and equitable access for all stakeholders involved in the legal system. Defence services should have their own divisions within the organisational structure to guarantee that all public defenders have

[32] Linzi Wilson-Wilde, The international development of forensic science standards — A review, (2018), 288 Forensic Science International, 1, DOI: https://doi.org/10.1016/j.forsciint.2018.04.009, <https://www.sciencedirect.com/science/article/pii/S037907381830166X> accessed on 25 November 2024.

equitable access to high-quality forensic analysis. This autonomy helps guard against any prejudice and guarantees that institutional influences won't affect scientific conclusions. In order to keep forensic services accountable and of high quality, oversight organisations are essential. At the state and federal levels, these organisations have to be set up with explicit powers to keep an eye on laboratory performance, look into complaints, and enforce regulations. Representatives from a range of stakeholders, such as scientists, solicitors, and community activists, should be part of the supervision framework. To guarantee accountability and transparency in the provision of forensic services, regular audits, performance evaluations, and public reporting requirements must to be put into place. All forensic service providers need to have their quality assurance systems enhanced and standardised. Comprehensive quality management systems, such as frequent internal audits, proficiency testing, and technique validation studies, should be a part of these programs. Every laboratory should create and follow standard operating protocols, which should be updated often to take into account developments in forensic science. Training initiatives should be put in place to guarantee that all staff members keep up-to-date on the latest developments in their fields.

FUTURE DIRECTIONS

O. *Technological Advancement*

Access to forensic science might be revolutionised by the combination of machine learning and artificial intelligence technology. By automating repetitive processes and offering preliminary screening capabilities, these technologies have the potential to democratise sophisticated forensic investigation. Pattern recognition, picture analysis, and data processing might be aided by AI-powered devices, which would lighten the strain for forensic specialists and speed up analysis times. To stop the continuation of current inequities, implementation must carefully take into account potential algorithmic bias and make sure AI systems are verified across a variety of groups. Through DNA analysis, facial recognition, and predictive policing, AI in forensic science improves criminal detection. However, marginalised groups may be disproportionately affected by algorithmic bias, which can result in erroneous convictions. False positives put misidentifications at risk, while inappropriate data processing and widespread surveillance raise privacy issues that compromise accuracy, fairness, and moral integrity. Another advancement in resolving regional differences in access to forensic services is the use of mobile forensic technologies. Sophisticated forensic skills might be immediately delivered to underprivileged populations using advanced portable laboratories outfitted with miniature analytical tools. At crime scenes, these mobile equipment may do real-time analysis, lowering the possibility of evidence deterioration and processing delays. Although it will cost a lot to build reliable, field-deployable technology, doing so might greatly increase access to forensic services in isolated and rural locations. Geographical constraints to forensic knowledge can be addressed through digital platforms for evidence analysis and exchange. Remote expert cooperation, independent assessment of results, and access to specialised knowledge from any place might all be made possible by secure cloud-based solutions. These platforms must provide effective information sharing among authorised parties, adhere to chain of custody regulations, and have robust security features. Automated quality control systems with extensive analytics capabilities may contribute to the standardisation of forensic procedures in various jurisdictions. These tools might guarantee uniformity in the processing and reporting of evidence, keep an eye on analytical processes, and identify any mistakes. The use of such methods might lessen differences in the calibre of forensic analysis between facilities and assist smaller labs in maintaining high standards despite budget constraints. Now a days, 3D scanning and printing are gaining popularity in forensics because of their capacity to provide information in all three axes (x, y, and z), unlike 2D pictures.[33]

P. *Education and Training*

Comprehensive efforts are needed to draw in and assist students from under-represented

[33] Gargi Jani, Abraham Johnson, Jeidson Marques and Ademir Franco, 'Three-Dimensional(3D) Printing in Forensic Science-An emerging technology in India,' (2021) Annals of 3D Printed Medicine 1, DOI: https://doi.org/10.1016/j.stlm.2021.100006 https://www.researchgate.net/publication/348498218_Three-Dimensional3D_Printing_in_Forensic_Science-An_emerging_technology_in_India accessed on 26 November 2024.

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areas in order to increase diversity in forensic science education. To promote diverse involvement in forensic science fields, educational institutions must establish mentorship networks, offer sufficient financial assistance, and design focused recruiting campaigns. These initiatives ought to span high school curricula to graduate degrees, establishing unobstructed routes for learners from diverse backgrounds to pursue careers in the subject. The particular difficulties experienced by forensic scientists operating in distant areas must be included in specialised training programs for practitioners in rural areas. In order to allow rural practitioners to maintain knowledge while reducing travel needs, these programs should integrate possibilities for online learning with practical practice. To guarantee that rural labs can offer complete forensic services, training should encompass both basic methods and cutting-edge technologies. Requirements for continuing education must change to reflect the quick development of technology and the evolving nature of forensic procedures. Online modules, hybrid courses, and virtual training sessions are examples of flexible learning formats that should be included in professional development programs. To ensure consistent progression of forensic knowledge across the profession, these programs must be available to practitioners in a variety of geographic regions and resource levels. Initiatives to educate the public about forensic capabilities are essential for encouraging knowledgeable interaction with the legal system. In order to assist communities understand the services that are offered and to lobby for better access, these programs should explain the promise and limits of forensic evidence. To promote greater knowledge and use of forensic resources, educational outreach should be directed at a variety of groups, such as the general public, law enforcement, and legal professionals. Through community engagement, crime scene simulations, and STEM curriculum, forensic education may be included into schools. Programs like "Project Lead The Way"[34] in the US include kids in forensic science, encouraging critical thinking and a desire for a profession while raising public awareness of justice and law enforcement.

CONCLUSION

Forensic science helps to assess evidence from crime scenes, investigate and prosecute culprits or absolve innocent individuals from suspicion.[35] A complicated interaction between systemic issues and scientific capacity is shown by the function of forensic science in guaranteeing fair access to justice. The use of forensic science today frequently reflects and occasionally perpetuates societal injustices, despite the field's enormous promise as an impartial instrument for justice. The research shows that forensic evidence's democratising promise—that is, its capacity to tell the truth independently of socioeconomic background or demographics—remains largely unrealised because of enduring inequalities in resources, quality variances, and access restrictions. A multifaceted strategy that tackles both short-term practical difficulties and long-term systemic problems is needed for the future. Institutional improvements that support independence and accountability must be combined with structural reforms, such as more financing for public forensic services and practice standardisation. Legislative action that creates consistent quality standards across jurisdictions and guarantees sustainable financing methods is required to support these improvements. Inequalities in resources restrict access to sophisticated forensic methods, producing uneven outcomes. Inaccurate convictions can result from biases in data and analysis, which disproportionately affect marginalised populations and compromise the validity of forensic evidence. In order to minimise erroneous convictions, increase the credibility of forensic evidence in court, correct biases, enhance accuracy, guarantee fair access to technology, and fortify supervision, forensic science must undergo systemic transformation. Promising alternatives for closing existing gaps in service delivery are provided by technological innovation, especially through digital platforms and mobile forensic capabilities. However, the system's underlying injustices cannot be resolved by technology alone. To create a more

[34] Melissa Stebbins and Tatiana Goris, 'Evaluating STEM Education in the U.S. Secondary Schools: Pros and Cons of the «Project Lead the Way» Platform, (2019), 9 (1) International Journal of Engineering Pedagogy, DOI: http://dx.doi.org/10.3991/ijep.v9i1.9277 accessed on 27 November 2024.

[35] Jasmine Kaur Ahluwalia and Dr. Ranjana Sharma, 'The Role of Forensic Science in Criminal Investigation,'
(2023) 5 (6) International Journal For Multidisciplinary Research 1, https://www.ijfmr.com/papers/2023/6/9530.pdf accessed on 27 November 2024.

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equitable forensic science infrastructure, human capital development through increased education and training programs—with a special emphasis on underprivileged groups and rural areas—remains essential. It will take consistent dedication by communities, practitioners, and governments to change forensic science from a tool that might reinforce systemic injustices to one that actively advances equal justice. In addition to scientific progress, success will be evaluated by how well-quality forensic services are made really available to all societal members, irrespective of their socioeconomic background or place of residence. Only with such extensive change can forensic science's potential as an equaliser in the legal system be completely fulfilled.