DIGITAL FORENSICS AND EXTENDED REALITIES – THE TRAJECTORY OF CRIMINAL INVESTIGATIONS

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ABSTRACT

The backbone of science of forensics includes its accuracy, efficiency and the compelling nature of evidence it provides in a criminological investigation. With the advent of time, the nature of the investigation has now grown to accommodate artificial intelligence, virtual reality, augmented reality and mixed reality in this process. From the analysis of post mortem to fingerprints and DNA profiling has now led to virtual recreation of the crime scene and analysis of the same. The main idea to be kept in mind while employing the same in criminal investigation is that it is a growing field and how far it can be trusted in such a sensitive area. For cases like the Burari murders, Sheena Bora murders the presence of these technologies would have helped in ways never possible. The dark-side of the same includes the trustworthiness and non-conventional way added with the allegations of bias and hallucination characteristics of Artificial intelligence. The matter of accountability and the question if our legal frameworks have the space to accommodate them and the experts available and economic dimensions of it are yet to be considered. The matter of admissibility and interoperability is the same with our legal system with the Interpol regulations. It is an art of balancing integrity with innovation.

This paper seeks to address the legal background of the emerging notions of extended realities in criminal investigations, the current practices followed and how it can be changed if these were integrated. A comparative analysis to existing legal frameworks globally that accommodates for these with Indian scenarios.

Keywords: Admissibility, Criminal Investigation, Extended Realities, Forensic Evidence, International Practice.

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INTRODUCTION

Forensic science is vital in crime investigations as it is the link to unfold the intricacies of codified legal structure and practical nuances of criminality. This multidisciplinary technique involves a range of scientific methods and techniques which is used to gather, preserve, and examine physical evidence from crime scenes. Additionally, forensic science aids in crime prevention by identifying patterns and profiles of criminal activities. Attuning with technologies, digital forensics incorporating augmented and extended virtual realities transits the traditional pedagogy. Extended realities bypass the existing gaps of adversarial inquiry. Virtual reality has the potential to recreate realistic scenarios, provide expert assistance and help with visualization and reconstruction of crime scenes. The immersive training and improved evidence analysis substantiate veracity of crimes at court of law. The first part of the paper analyzes the existing forensic technologies used in crime scenes. The second part examines the Indian and International framework including human rights conventions on admissibility of forensic evidence. The concluding part details upon the what if analysis when augmented reality is utilized into the present legal framework.

EVOLUTION OF FORENSIC SCIENCE

Forensic science is the application of scientific concepts and methods for crime scene analysis. It focuses on the examination of tangible evidence gathered at crime scenes, including DNA, fingerprints, fibres, and weapons, in order to ascertain the chronology of events, identify the perpetrators, and comprehend the manner in which the crime was executed. Forensic science is an integral component of the criminal justice system offering unbiased and trustworthy scientific proof that helps in detecting unprecedented crimes. Technological developments and cultural demands have shaped the discipline over time, with breakthroughs like DNA analysis, that altered the investigation and examination procedures of first-hand evidences[2]

Internationally the field of forensic science has sprouted centuries back with different countries developing distinct techniques and methodologies for criminal investigation. The earliest records traces of forensic principles were employed in ancient Indian and Chinese culture to authenticate documents and clay seals[3]. During the 18th century forensic medicine for crime

[2] Durga Bhardwaj, *Evolution of the Forensic Science and Law*, **4** Int'l J. Eng'g & Mgmt. Res. **45** (2014).
[3] Nat'l Inst. of Just., U.S. Dep't of Just., *A Guide for Forensic Science Laboratories* (2009), https://www.ojp.gov/pdffiles1/nij/225321.pdf

detection was developed in Europe through the contribution of French Scientist Mathieu Orfila. Mathieu"s toxicology principles aided in systematic detection of poisons in human body[4]. In the United States, the discipline flourished in the early twentieth century with the establishment of the first forensic laboratory by the Police Department at Los Angeles. A significant scientific upgrade was the 1953 discovery of DNA structure by James Watson and Francis Crick's. DNA structure served as the foundation for DNA profiling in forensic investigations[5]. Later on, during the 1970s computer technology and databases for fingerprint and DNA analysis were developed. DNA analysis and fingerprints evidence upsurged the conviction rates. As the world moved from traditional transgression to modern digital intrusion, the discipline integrated digital technology. The digital forensic technology emulating digital data collection and retrieval expanded the application of forensic science in criminal trials.

In India, forensic science and law have evolved from antiquity to the present. The ancient texts like the Arthashastra state crimes being investigated using techniques like fingerprints, footprints, and handwriting analysis. Modern forensic methods, including ballistics and fingerprinting, were developed during the British colonial era. In 1952, the first forensic laboratory i.e., the Calcutta Forensic Science Laboratory was established. This paved the way for collaboration on forensic evidence by the law enforcement agency. In 1984, the Indian Evidence Act[6] was amended to include admissibility of expert forensic and scientific evidence in court of law. The technique of DNA profiling was initiated in forensic infrastructure wherein individuals can be identified using biological samples. The Criminal Law (Amendment) Act[7]mandated forensic procedures, including DNA profiling of convicted offenders. In the Delhi Gang Rape[8] prime accused were identified by DNA profiling by comparing the accused's DNA to the evidence discovered at the crime scene. The development of forensic science technologies ensures administration of justice to victims.

TYPES OF FORENSIC EVIDENCES IN INDIA: PROS AND CONS

A. DNA Profiling

[4] U.S. Nat'l Library of Med., Nat'l Institutes of Health, *Visible Proofs: Forensic Views of the Body: Galleries: Biographies: Mathieu Joseph Bonaventure Orfila (1787–1853)* (2014), https://www.nlm.nih.gov/exhibition/visibleproofs/galleries/biographies/orfila.htm

[5] The Discovery of the Double Helix, 1951–1953 | Francis Crick – Profiles in Science, U.S. Nat'l Library of Med., Nat'l Insts. of Health, *https://profiles.nlm.nih.gov/spotlight/sc/feature/doublehelix*

[6] Indian Evidence Act, No. 1 of 1872, § 45 (India).

[7] Criminal Law (Amendment) Act, No. XX of 2008, § 53A (India).

[8] *Mukesh v. State for NCT of Delhi*, (2017) 6 S.C.C. 1 (India).

DNA profiling has revolutionized forensic investigations worldwide and brought about notable changes in the examination of high-profile cases in India. DNA serves as a reliable identification method because it acts as a unique personal marker for each individual. At crime scenes, DNA evidence is found in blood and semen samples, as well as in hair, skin cells, and various biological fluids. Proper collection and preservation of DNA can establish highly reliable links between crime scenes and suspects. The widespread use of DNA profiling across India is crucial for thoroughly investigating sexual assault cases, resolving missing persons cases, and prosecuting murders. It is instrumental in exonerating wrongly convicted individuals, highlighting its importance in ensuring justice in legal processes. However, the widespread use of DNA profiling in India faces several challenges. A significant hurdle is the limited number of testing facilities, which hampers the implementation of DNA profiling. Forensic labs are burdened with extensive backlogs, delaying results and obstructing the prompt delivery of justice. The lack of DNA analysis experts further exacerbates the shortage of skilled personnel needed for DNA testing. Additionally, legal issues concerning the proper collection and preservation of biological evidence have raised substantial concerns[9]. Tactile DNA evidence is highly susceptible to contamination, which can lead to judicial errors at crime scenes due to improper handling.

B. Fingerprint Analysis

India has relied on fingerprint analysis as its main forensic method since ancient times due to its widespread acceptance across the country. Fingerprint patterns are uniquely distinct among individuals, making this method highly effective in identifying both criminals and victims. Security personnel collect fingerprints at numerous crime scenes by examining weapons, entry and exit points, and surfaces touched by offenders. Investigators compare these samples with known fingerprint databases to either confirm or rule out potential suspects. Although fingerprint analysis is crucial in Indian investigations, operational issues hinder its effectiveness. The primary challenge arises from the mishandling of evidence. The way police collect and preserve fingerprint evidence at crime scenes often compromises its reliability in many cases. The investigation process can damage fingerprints, leading to difficulties in producing strong evidence for identification. There is a lack of standardization and consistency in India's fingerprint databases. The absence of a unified fingerprint database nationwide

[9] A. K. Rana, Crime Investigation Through DNA Methylation Analysis: Methods and Applications in Forensics, 8 Egypt J. Forensic Sci. 1 (2018).

results in slow and inefficient comparisons between different jurisdictions and their fingerprint records. The National Automated Fingerprint Identification System (NAFIS) represents progress within the Ministry of Home Affairs despite continuing development to enhance its national scope and deployment.[10]

C. Ballistics analysis

Ballistics analysis connects firearms to crimes by meticulously comparing bullet fragments and shell casings left at crime scenes. Forensic ballistics specialists assess bullet paths, identify firearm types, and examine projectiles to understand how crimes are executed and determine their motives. Surveillance plays a crucial role in murder and shooting investigations, providing clear evidence of suspect involvement. In India, ballistics analysis has shown effectiveness, but the lack of modern equipment and skilled forensic professionals, along with laboratory backlogs, leads to delays in results[11].

D. Toxicology

Toxicology serves as an essential branch of forensic science, focusing on the study of toxins and poisons, and plays a crucial role in investigating fatal poisonings and drug trafficking. Through toxicological analysis, scientists can identify substances present in the body and measure their chemical concentrations to ascertain the causes of poisoning and outcomes related to death. This method is particularly valuable for uncovering details in cases of accidental poisonings, drug overdose fatalities, and drug trafficking that might not be evident at first glance. In India, the underdevelopment of toxicology, along with a shortage of trained toxicologists and specialized laboratories, poses challenges during investigative processes.[12]

E. Digital forensics

The digital revolution introduces both novel challenges and opportunities for forensic experts, as digital forensics now plays a crucial role in solving significant cybercrime cases, frauds, and terrorism-related offenses. Digital forensics is a field focused on extracting and preserving data from electronic devices, such as computers, smartphones, servers, and cloud-based systems.

[10] Navin Kumar, Forensics and Justice: Transforming Crime Solving in India, 14(2) 61 (Jul. 2025).
[11] V. U. & S. K. Gill, Development of Scientific Techniques in the Investigation of Criminal Cases in India, 10(2) 207 (2022).
[12] S. Verma, A. Parvez & K. Ashutosh, Forensic Science Application: An Effective Tool for Criminal Investigations, 7(2) 14 (2022).

Criminals leave behind digital evidence through their online actions, allowing forensic investigators to trace back to the essential details of the crime. Cybercrimes, including online fraud, data breaches, identity theft, and cyber terrorism, have driven India to embrace digital forensics, as it has become indispensable for investigative purposes [13]. Law enforcement agencies, along with Cyber Crime Cells, now rely on digital evidence in their crime investigation processes. Digital devices produce crucial data that disclose significant information about the criminal activities conducted by suspects, as well as the content of their communications and intentions. Digital evidence acts as a pivotal element that aids in both identifying and prosecuting criminal offenders in numerous investigative cases.

India is working on enhancing its legal frameworks and digital forensic systems to achieve adequate readiness levels. The lack of specialized training and support for police officers leads to mishandling of digital evidence, as they often fail to collect crucial information accurately. Additionally, the Indian judiciary's insufficient training in handling digital forensics diminishes the reliability of such evidence in legal proceedings due to the intricate technical challenges involved[14]. To boost the effectiveness of digital forensics in India, it is essential to provide training for personnel and improve both physical and legal processes, along with advancing infrastructure development.

TECHNOLOGIES UNDER EXTENDED REALITIES THAT CAN FIT INTO FORENSIC INVESTIGATION

In the realm of forensic investigation, the utilization of extended reality technologies, encompassing virtual reality, augmented reality, and mixed reality, is reshaping processes including crime scene reconstruction, evidence analysis, and professional training. [15] Forensic investigation focuses on documentation and evidence interpretation for reconstructing vital incidents. For this virtual reality technologies that are computer generated simulation of three-dimensional image interacted by persons using special engraved electronic devices can be utilised for 3D documentation apart from traditional photographs. [16] The augmented reality for forensic experts utilizing GPS and indoor positioning with Ultra Wide Band enables users to

[13] M. M. Houck, *Forensic Science: Modern Methods of Solving Crime* (2007).
[14] S. Kengadaran, J. John, D. Anusha, S. Kengadaran & H. Sekar, Utilization of Forensic Odontologic Findings in Solving Unsolved Cases: A Retrospective Study, 42(1) 45 (2020).
[15] Xavier Chango, Omar Flor-Unda, Angélica Bustos-Estrella, Pedro Gil-Jiménez & Hilario Gómez-Moreno, Extended Reality Technologies: Transforming the Future of Crime Scene Investigation.
[16] Ibid.

attach annotations to objects, capture images, and transmit them to a central processing center. The use of UWB beacons necessitates bringing extra equipment to a crime scene, which must be calibrated and could potentially contaminate evidence. Another recent effort in the forensic field employed a head-mounted display (HMD) to facilitate crime scene annotation and collaboration with experts or coordinators over distances. Here users wore a custom-made, opaque head-mounted display, allowing a remote expert to collaborate by "looking over the shoulder." However, the virtual tags that users could place at a crime scene mainly indicated restricted areas rather than evidence traces, which is the primary focus. Augmented realities have collaborative benefits which upgrades the forensic process of securing evidence. [17]Mixed reality devices provide advanced means for analysing criminal tendencies including their movements, behaviour and interactions with digital objects identifying their unique features. The latest technologies including computer generated 3D analysis HoloLens, 3D animations visualize crime scenes accurately. Reconstructing crime scenes in courtrooms helps the judges to critically examine the crime sense and uplift the standard of reasonableness in an offence.[18] Therefore, modern technological advancement brings out accurate evidence in forensic science.

INDIAN LAW FRAMEWORK OF FORENSIC SCIENCE

Since Forensics has placed itself in an indispensable position in the criminal justice system, over the last two decades, the role of forensic evidence over the traditional oral testimony has increased. The credibility of this type of evidence has forced the institution to shift. To accommodate the forensic evidence, certain statutory frameworks and judicial interpretations have also paved the way.

The Code of Criminal Procedure, 1973 provides for multiple provisions which enables the collection and admissibility of evidence of scientific nature. Section 53 of the Act permits for a medical examination of the accused by a registered practitioner which includes the collection of bodily fluids for forensic analysis. [19] Also Section 167, allows for recording of statements before a magistrate which can include confessions, and these can be corroborated with forensic voice analysis or digital evidence presented. Section 53A which was inserted through an

[17] Ibid.
[18] Meshal Albeedan, Hoshang Kolivand & Ramy Hammady, Effect of Augmented Reality and Virtual Reality in Crime Scene Investigations (Paper, School of Computer Science & Mathematics, Liverpool John Moores Univ. & Univ. of Essex) (Oct. 2024) (available at https://repository.essex.ac.uk/36914/1/Manuscript.pdf
[19] Code of Criminal Procedure, 1973, § 53

amendment especially expands the scope of forensic evidence in sexual assaults by allowing the collection of DNA samples and genital swabs. [20] Recently in 2022, Parliament had enacted the Criminal Procedure Identification Act replacing the Prisoners Act of 1920. The new act also allows and authorises the collection of biometrics, DNA samples, Iris scans and traits of behavioral attributes of certain categories of convicts and accused persons. [21] The same had caused a debate on the nature of its proportionality and the privacy rights after the puttaswamy judgement of 2017. [22] The Indian judiciary has also played a decisive role in expanding the scope of forensic evidence linked with extended realities.

In the case of the State of Bombay V. Kathi Kalu Oghad[23], it was established by the apex court that collection of fingerprint and handwriting analysis did not fall under self incrimination. Similarly in Selvi V. State of Karnataka[24], the court discussed the invasive and noninvasive techniques prohibiting the narco analysis, polygraph tests and others without consent. Similarly, the process of DNA profiling has been validates in securing conviction of high profile sexual assault cases as in Santhosh Kumar Singh V. State. [25] In the sister Abhaya murder case which took place in Kerala, it highlighted the significant lapses in forensic evidence and the procedure involved. A narco analysis was conducted in which the accused allegedly confessed to murdering sister Abhaya however, the admissibility of it became a contentious issue. The Kerala High court ruled that such evidence cannot be used citing its concerns over the reliability and voluntariness. Thus we have come a long way and with advent in technology the forensic science evidence dynamics have to evolve and along with the judiciary will have to evolve too.

INTERNATIONAL LAW PERSPECTIVE

At the crux of international law in forensic science, it is built upon several human rights as well as recurring legal issues which includes, a right to fair trial which in turn would comprise of admissibility of such evidence[26] and the independence of experts involved in examining the same, a right to privacy and data protection while retaining DNA and other databases of the

[20] Criminal Law (Amendment) Act, 2005, § 53A.
[21] Criminal Procedure (Identification) Act, 2022.
[22] Justice K.S. Puttaswamy (Retd.) v. Union of India, (2017) 10 SCC 1.
[23] State of Bombay v. Kathi Kalu Oghad, AIR 1961 SC 1808.
[24] Selvi v. State of Karnataka, (2010) 7 SCC 263.
[25] Santosh Kumar Singh v. State, (2010) 9 SCC 74
[26] Jixi Zhang, Fair Trial Rights in ICCPR, 2 J. Pol. & L. 39 (Dec. 2009), https://pdfs.semanticscholar.org/5b84/610b9a61e5121ae3af7a5b1dd21c58c1b81b.pdf

accused[27], the right to see that any evidence obtained as such are with the permission of the person from whom it is beingtaken and the person is protected from torture, the standards and bechmarks used by the institutions to ensure reliability and chain of custody and cross border cooperation in cases of digital evidences. [28] Some international conventions that focus upon these can be examined and determined if the instruments are capable of expansion in order to encompass extended realities.

1. **International Covenant on Civil and Political Rights (ICCPR)**

   Article 14 of ICCPR provides for the right of everyone to "equality before the courts and tribunals", ensuring a fair trial in criminal proceedings. [29] Fair trials are considered a fundamental human right. These have been taken from articles 10 and 11 of the Universal Declaration of Human Rights, which acknowledge the right to a fair trial. [30] Fair trial under these articles provides for equal access to courts, providing a hearing that is fair, public and conducted by an independent judge and the accused has to be presumed innocent until proven guilty through the institutions. [31] The digital reconstructions, and the proposed extended reality constructions, if adopted by the institutions, would become part of the fair trial process. But for them to be classified as a fair trial mechanism, the methods should be transparent, reliable and handled by experts from that field, and any scientific uncertainty in the process should not be hidden.

   The ICCPR has the scope for such expansion and includes extended reality-based forensic evidence to be included within it. The extended reality technologies can be used in recreating the crime scenes neutrally and while allowing a transparent methodology. There yet exists the drawback of the technology such as generative AI hallucinating and being biased in its decision making.

[27] Mark McCormick, Scientific Evidence: Defining a New Approach to Admissibility, 67 Iowa L. Rev. 879 (1982).
[28] Rockne Harmon, Admissibility Standards for Scientific Evidence, in Microbial Forensics at 381–92 (R. G. Breeze & B. Budowle eds., Academic Press 2005).
[29] Centre for Civil and Political Rights, ICCPR Article 14 Factsheets: Right to equality before courts and tribunals and to a fair trial (Mar. 28, 2024), https://ccprcentre.org/ccprpages/iccpr-article-14-factsheets-right-to-equality-before-courts-and-tribunals-and-to-a-fair-trial
[30] Supra Note 1.
[31] Ibid.

2. European Court of Human Rights (ECHR)

Forensic subjects such as genetic privacy, DNA databasing and protection for other personal and physical integrities have been addressed within the criminal justice system by ECHR. But there is no uniformity followed and thus a debate upon the appropriate way of expressing value of the findings by the practitioners on a global level. [32] In the landmark case of S. and Marper v. United Kingdom [33] The fingerprints of two applicants were retained indefinitely by the authorities despite there being no conviction. The UK law allowed for indefinite retention of DNA profiles by the authorities and this practice was challenged before the ECHR. Article 8 of the European Convention on Human Rights provided against it and the grand chamber agreed and emphasised upon the fact that such information were genetic and personal privacy information linked to not just unique identity but also to family lineage and other genetic relationships. The Marper ruling thus succeeded in establishing a permanent and embodied connection between personhood and genetic data and the need for a transparent system. [34] This led to the emergence of the Protection of Freedoms Act 2012 and the ruling has now become a cornerstone on bodily privacy and the proportionality need of biometric retention. If the Extended realities have been implemented the same privacy logic upheld in Marper will also have to be applied to the XR technologies that generate gait signatures, posture maps and facial micro expression databases. The digital representation of the physical body will also have a bodily autonomy right.

3. The Istanbul Protocol

The protocol is issued under the Office of the United Nations High Commissioner for Human Rights (OCHR) and guides the states in the principles of human rights to be followed while developing such technical standards and investigation and against ill treatment or coercing of forensic evidence. [35] Although it in itself is not a treaty, it functions as a recognised standard against torture or ill treatment of medical and

[32] Joëlle Vuille, Luca Lupària & Franco Taroni, Scientific Evidence and the Right to a Fair Trial under Article 6 ECHR, 16 Law, Probability & Risk 55 (2017), https://doi.org/10.1093/lpr/mgx001
[33] (2008) 48 EHRR 50, Apps. Nos. 30562/04 and 30566/04 (ECHR, Grand Chamber, 4 December 2008).
[34] Press Release, European Court of Human Rights, S. and Marper v. United Kingdom, Apps. Nos. 30562/04 & 30566/04 (Dec. 4, 2008), item 003-2571936-2784147, HUDOC, https://hudoc.echr.coe.int/eng-press#{%22itemid%22:[%22003-2571936-2784147%22]}
[35] G.A. Res. 48/141, High Commissioner for the Promotion and Protection of All Human Rights (Dec. 20, 1993).

forensic practitioners asserting due diligence. It sets out the psychological and physical standards the practitioners must identify and provide for the methodology for the reports drafted to be accepted as evidence in court of law. [36] Article 15 of the convention prevents the evidentiary value of any information obtained through torture.[37] Under Extended Realities, the protocol would be applied in obtaining the necessary consent before any immersive reconstruction of the physically extended realities of the person involved. It should incorporate transparency and voluntariness and free consent to digital representations while working within the protective framework of bodily autonomy rights.

4. International Criminal law and Rome Statute of forensic evidence in atrocity prosecutions.

Under the Rome statute, the cases involving , mass genocide and crimes in largscale against humanity and war crimes are discussed and provided for where, the investigations would include exhumations of mass graves, ballistic analysis, digital records and DNA identification of victims to reconstruct such events and to establish criminal responsibility. [38] The statute stresses upon the need to ensure the evidence's integrity, reliability and admissibility of such forensic findings. The interplay of Extended reality technologies such, usage of augmented reality in overlaying of satellite and geospatial data and 3D modeling of mass graves would largely complement the traditional forensic methods in ICC investigations. It must be capable of the same corroboration and technical standard set for traditional methods. By leveraging the advanced technology, advanced visualisation can be used for supporting accountability for mass atrocities while also protecting procedural fairness and evidentiary integrity.

THE WHAT-IF ANALYSIS

An analysis upon hypothetical scenarios of real cases where application of such Extended realities are integrated into the real time investigations to analyse its potential advantages and

[36] United Nations Office of the High Commissioner for Human Rights (OHCHR), Istanbul Protocol: Manual on the Effective Investigation and Documentation of Torture and Other Cruel, Inhuman or Degrading Treatment or Punishment, HR/P/PT/8/Rev. 2 (2022), https://www.refworld.org/reference/manuals/ohchr/2022/en/148355
[37] Office of the High Commissioner for Human Rights (OHCHR), Istanbul Protocol: Manual on the Effective Investigation and Documentation of Torture (2022), available at https://www.ohchr.org/en/publications/policy-and-methodological-publications/istanbul-protocol
[38] Rome Statute of the International Criminal Court arts. 21–24, 66, 67, July 17, 1998, 2187 U.N.T.S. 90.

also the challenges and ethical considerations arising out of it.

1. **Aarushi Talwar and Hemraj Banjade murder**

In 2008, Arushi Talwar and Hemraj who was their family's domestic help were found murdered in their residence in Noida. Arushi's body was found lying in a pool of blood in her bedroom, brutally murdered while Heraj was found on the terrace of the house. The investigation was criticized and widely scrutinised for procedural lapse, mishandling of the crime scene by the authorities and contamination of forensic evidence which compromised the integrity of such forensic evidence. [39] At first, the parents of Arushi Talwar were arrested and charged with murders based on the forensic and circumstantial evidence but it was later disputed and their convictions were overturned due to the procedural irregularities and lack of direct evidence in the other crime. There were gaps in timelines, contaminated physical evidence and it all undermined the case. [40] The case was a best example of showcasing the difficulty of relying solely upon physical evidence such as photographs, written notes and the inability to reconstruct a complex crime scene accurately.

Now, hypothetically the application of the extended reality tools could have helped in mitigating the shortcomings of these investigations. A virtual reality of the Noida residence which is the crime scene along with spatial relationships and points of entry with the alignment of furniture and fixtures which could have captured the finger prints and blood splatter could traject the positions of the victims and provide a clearer understanding of the attack sequence. It could also have preserved the crime scene through a digital reconstruction for repeated analysis, and prevented the risk of contamination. This would have provided enhanced evidential clarity, scenario testing and reduced reliance upon subjective interpretations and could have mandated international complementary standards. On another note, the simulations are as accurate as the input data in case the data feeded into the system was wrong, the digital reconstruction would have freezed an incorrect crime scene and would have given a false sense of certainty.

[39] Sanjeev Nair, The Aarushi Files: The Noida Double Murder Case (Penguin India 2013).
[40] Nilanjana Bhowmick, "Aarushi Murder Case: Investigation Lapses and Forensic Controversies," Indian Journal of Criminology 22, no. 3 (2015): 45–60.

2. Sheena Bora Murder Case

The sheena bora murder involved the disappearance followed by murder of 24 year old Sheen Bora who was allegedly murdered by her mother Indrani Mukherjee, her ex husband Sanjeev Khanna and their former driver Syamvar Rai. The Police initially failed to register a case and registered a disappearance much later on as her homicide was portrayed as being sent abroad by her mother through several forged communications. The case later came into the limelight when the driver was arrested for an unrelated firearms case in which he confessed claiming involvement in the Sheen Bora muder also. Her remains were burned and disposed of in a remote location , a forest near Raigad and the physical reconstruction and recognition of the remains were extremely difficult due to the decomposition and weathering of biological identifications. The lapses included a delayed discovery of her body, absence of a preserved crime scene, absence of digital impersonation and circumstantial evidence alone were relied upon. [41]

Hypothetically, the use of XR would have helped through photogrammetry + LIDAR scanning the Raigad Forest terrain circa 2012 conditions could have helped the forensic experts in analysing the burn sites, the drag patterns and the concealment choices. The vehicle trajectory would have helped in mapping out the consistency with witness testimonies and there would have been digital preservation of such circumstantial mosaics. On a negative side, the visual richness may have over-puided the courts and would have raised the concerns of a fair trial. There are also chances of authenticity challenges.

3. The Burari Deaths

In July 2019, eleven members belonging to the Bhatia family were found hanging inside their house in Burari. The hangings were found to be in some ritual-like formation and irrespective of the age ranging from kids to the eldest member were dead. [42] This raised suspicions of mass homicide, occult practices or coordinated murder -suicide trial. However later certain handwritten diaries were found which suggested the link of these

[41] R v. Indrani Mukerjea, CBI Charge Sheet (2015) (India); see also Rahul Tripathi, "Driver Confession Cracks Sheena Bora Murder Mystery," Indian Express (Aug. 28, 2015).
[42] Delhi Police Crime Branch, Burari Case Investigation Report (2018).

deaths to shared delusional disorder of the family members. [43] The Delhi police investigation combined the handwriting forensics along with a psychological autopsy to reconstruct their mental state and degree of planning but in the absence of any survivor, any motive or sequence tracking the proving of such causation wasn't successful.

If XR had been used, a VR replica of the house and its interior would have preserved the placements and the knot mechanics to see if there had been any external influence upon the deaths. A psycho forensic immersion would have helped in integrating environmental cues to test the plausibility of collective trance-like belief states. At the same time, digital reconstruction of the death poses can be considered invasive and would raise ethical and cultural misinterpretation questions.

4. The Black Dahlia Murder (USA 1947)

The murder of Elizabeth Short who later came to be called as black dahlia, a 22 year old aspiring actress remains to be one of the most famous unsolved murders in the US. Her body was found in a vacant lot in Leimert in Los Angeles severed in two at the waist bloodless and surgically mutilated. The gruesome condition led early investigators to theorise a murderer with medical training. The case was during the pre DNA and Pre modern forensic era thus the LAP had to rely solely upon crime scene photographs, blood typing and eyewitness hearsays. [44] The use of XR would have provided a whole volumetric scan of the dump site and reconstruction of any drag marks, footprints , staging choices and could clarify the familiarity of the perpetrator with the crime scene. A serial signature of the crime, and test the vehicle movement constraints of the crime scene could have been easily understood. On the negative side, a narrative overreach would have played a negative role in reconstructing the scene and a highly immersive model would revive conspiracy than clarity.

CONCLUSION

The integration of the Extended Realities into the domain of forensic science would not be just

[43] NIMHANS, "Psychological Autopsy Methodology and Shared Psychosis in Collective Deaths," Advisory Report to Delhi Police (2018).
[44] LAPD Cold Case Files, Elizabeth Short Homicide File (Los Angeles Police Dep't 1947).

an incremental technological advancement but a whole new paradigm shift in the judicial sphere. The judiciary and criminal investigations have for centuries grappled with the challenges of evidence accuracy and cognitive biases; extended realities might be the solution that we are actually looking for. The use of extended realities would open up a previously unimaginable experience and perspective to investigators, jurors and legal professionals. This helps in bridging the gap between human comprehension and complex forensic data.

However, its adoption is not without challenges. IT poses the risk of manipulation, data authenticity and admissibility. A balance has to be introduced between innovation and critical human judgement. But, as extended realities matures it promises a redefined investigative accuracy, trial engagement and changes the very nature of evidentiary comprehension. In the quest for justice, extended realities may well become the most compelling lens through which truth is both seen and understood.