

# **The Role of Digital Technologies, Forensic Science and Crime Management in the 21st Century**

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## **Abstract**

Crime management is an indispensable specialty in determining crime processing and the quality of criminal justice administration in society. When crime is poorly managed, the stakes are that of criminal proliferation and miscarriage of justice. Therefore, this article was carefully designed to assess the role of digital technologies in crime management and forensic science in the 21st century. The article is theoretically based and descriptive in nature. It relies on secondary data to establish the roles of digital technologies on crime management and forensic science in the 21st century. It revealed that crime management before the 19th century was analog, aiding criminals to evade justice due to the lack of credible evidence. However, digital technologies in the post-19th century have proven integral to crime management and forensic science. The article concludes that digital technologies in the 21st century have aided victim's emergency assistance, crime scene security, videotaping, photographing, sketching, writing reports and taking down notes, collating and processing evidence that is physical in nature, searching, interrogating witnesses and suspects to obtain vital information, identifying suspects, conducting surveillance, raids, stakeouts and undercover operations, and finally witness testimony in court. The study recommends training and retraining of law enforcement and investigation officers on the use and implementation of digital technologies in crime management.

**Keywords:** Crime Management, Forensic Science, Digital technologies, Criminal Investigation

## **Introduction**

As society evolves from simple to complex stages, so does crime. Historically, the acts of crime have evolved from mere infractions requiring little or no efforts in evidence collation and presentation for adjudication of justice; to more complex, highly networked, and sophisticated acts with little or no physical evidence to substantiate the basic elements of crime establishment. However, the need for admissible criminal evidence remains indispensable in the administration of criminal justice. Generally, criminal labeling is a product of conviction arising from proof of

evidence to indicate beyond every reasonable doubt that an offender was indeed criminally liable. With the evolution of digital technologies in the mid-19<sup>th</sup> century, complex technologies have become the hub of criminality as criminals have taken undue advantage of several digital technological innovations in the commission of common and complex crimes. This posed a new challenge in the field of evidence-based criminal investigation and crime management.

The word “Investigate” is etymologically derived from the Latin word “*Vestigare*”, which implies to track or to trace. It entails a patient, step-by-step process of determining, gathering, labeling or identifying, and the presentation of evidence to determine the actual status of a criminal event. Investigations seek to unravel the cause(s) and who is/are the culprits and victims in a criminal case by way of utilizing specific pieces of evidence via deductive reasoning. For instance, finding the suspect’s identification card at the scene of an armed robbery incident is great evidence that the suspect was physically present at the scene of the robbery. The process of crime investigation usually involves careful examination and evidence recording (Donlon, 2007).

The genesis of contemporary criminal investigations has been attributed to several notable individuals and events. The first of these individuals and events was the appointment of Henry Fielding in 1748 as Magistrate of England’s Bow Street. As a response to widespread crime and disorder throughout his jurisdiction, Fielding formed the Bow Street Runners, which became the first paid detective unit. Also, Eugene Francois Vidocq is another important individual in the evolution of criminal investigation. He was a former criminal who later became a crime fighter. In 1811, Vidocq organized a plain-clothed civilian detective unit called the *Brigade de la Surete*, which is also referred to as “Security Brigade”. Consequent upon the realization of the value of this unit, the police officially converted it to the National Police Force, with Vidocq appointed as the first head of the unit. He is credited with the introduction of undercover work, ballistics, and criminology. He made the first plaster shoe cast impression and created indelible ink and unalterable bond paper (Bowen & Scheider, 2007).

Besides, by 1842, England’s Scotland Yard created an investigative branch. However, in the United States, the pioneer municipal detective divisions were beginning to take shape. Allan Pinkerton, who immigrated from Scotland to the United States in 1842 played a significant historical role in modern police investigations. He was appointed the first detective in Chicago in 1849 and was a co-founder of the Northwestern police agency, which later became the Pinkerton National Detective Agency, whose symbol was a watchful eye and whose motto was “We Never Sleep”. Pinkerton’s agents were the forerunners of the United States Secret Service. He developed several investigative techniques still used today in law enforcement such as stings and undercover works, as well as the surveillance method of shadowing and following targets or suspects. Pinkerton was also known for initiating a central database for criminal identification records that is now being utilized by the Federal Bureau of Investigation (FBI). After Chicago, investigative units started developing in other police agencies with Detroit establishing a detective bureau in 1866, followed by New York in 1882 and Cincinnati in 1886 (Hess & Matison, 2013).

In 1882, the use of biometrics and identification systems was incorporated into a criminal investigation when a French police officer, Alphonse Bertillon (who is now recognized as the father of personal identification), unveiled the Thropometry system that identifies offenders by their unique physical measurements, as well as their personality characteristics and individual markings,

like tattoos and scars. In 1884, Bertillon used his technique to identify 241 multiple offenders, demonstrating that the Bertillon system could successfully distinguish first-time offenders from recidivists. Bertillon further standardized the criminal mug shot and advocated that crime scene pictures must be taken before the scene is contaminated in any way (Moradoff, 2010). Other forensic techniques credited to Bertillon include forensic document examination, ballistics, the use of molding compounds to preserve footprints, and the use of the dynamometer to determine the degree of force used in breaking and entering.

## Evolution of Forensic Science

Criminalistics and Forensics gradually evolved in 1910, with Edmund Locard's "Exchange Principles", which held that criminals will intentionally contaminate a crime scene and unintentionally abandon incriminating evidence. Locard was a French Criminologist who is recognized to have set the pace for forensics and criminalistics as many law enforcement agencies and their agents have subscribed to his exchange principle for crime investigations. Evidence gathering is a crucial aspect of crime investigation, the act of which was revolutionized with the advent of technological devices (Ramirez, 2003). Law enforcement agencies now recognize the import of their agents learning the law of evidence in order to extract quality and admissible evidence in any criminal investigation process. August "Gus" Vollmer, also called the father of contemporary policing, became the first recognized American to have implemented the use of blood samples, fiber, and soil analysis in criminal investigations in 1907. Also, in 1920 he became the first police chief to have utilized the lie detector (as developed by the University of California) in criminal interrogations (Hess & Orthmann, 2011).

Before the emergence of forensic science, criminals or lawbreakers often escape punishment because of the absence of justifiable evidence against them. Traditionally, evidence of crime commission was only extracted from suspects via duress or witness testimony. xi Yuan Ji Lu, which is translated as "Collected Cases of Injustice Rectified, was the original trial of medicine and entomology to administer justice to different criminal cases. This was composed in a song "Dynasty China" by Sung Ci, in 1248. An instance of one of the accounts was a murder case where a sickle was the primary tool. The death investigator directed all suspects to bring their sickles to one location. The sickle used in the murder attracted flies due to the smell of blood and the murderer was identified and apprehended. In order to determine the cause and manner of death, medical experts in the army began to explore different strategies in sixteenth-century Europe. At that time, a French army surgeon developed an interest in systematically unraveling the effects of violence (as a cause of death) on internal organs. Additionally, two Italian surgeons began the process of modern pathology by trying to understand the changes that happen to human organs as a result of an infection or disease. The late 1700s witnessed the evolution of scholarly expressions in this area. Some of these expressions include "A Treatise on Forensic Medicine and Public Health" by French Physician Fodere and "The Complete Police Medicine" by German medical expert Johann Peter Frank (Fantino, 2007).

Sweeden chemist, Scheele, determined a way of identifying arsenous oxide in significant quantities. By 1806, this discovery was further advanced by German chemist Val Ross, who specialized in the discovery of poison around the stomach walls of a victim. Whereas, an English chemist James Marsh, utilized chemical processes to implicate arsenic as responsible for death causes in an 1836

murder trial. In forensic science, the use of logic in criminal procedures was demonstrated in some individual legal trials. For instance, in 1784, John Toms was tried and convicted for killing Edward Culshaw using a pistol. After examining the dead body of Culshaw, a pistol wad (A type of crushed paper used to hold powder and balls in the muzzle) was discovered in his head wound. It matched perfectly with a torn newspaper found in Tom's pocket (Fantino, 2007). Similarly, In Warwick, England in 1816, a farm labourer was tried and convicted of the murder of a young maidservant. She had been drowned in a shallow pool and bore the marks of violent assault. The police found footprints and an impression from corduroy cloth with a sewn patch in the damp earth near the pool. There were also scattered grains of wheat and chaff. The breaches of the farm labourer who had been threshing wheat nearby were examined and corresponded exactly to the impression in the earth near the pool. Later in the 20th century, there were several British pathologists, Bernard Spitsbury, Francis Camps, Sydney Smith, and Keith Simpson.

Essentially, forensic science plays a significant role in criminal investigations. It remains crucial in the administration of justice. The discipline of forensic science only became popular in contemporary society. The word "forensic" originated from the Latin word "forensic", meaning "forum"(Safertein, 2007). It implies the application of scientific methods and principles to solving crime issues and answering the questions of law and justice. Forensic science may still be in its formative stage, it is, however, developing its significance dates back to ancient civilizations. Its earliest application dates back to ancient Greek and Roman societies, where significant contributions to the field of medicine and Pharmacology were made.

Forensic laboratories have in most criminal cases been indispensable in the processing of physical evidence. Therefore, it is now common to find law enforcement agencies possessing sophisticated forensic science laboratories for criminal investigations. Usually, these laboratories are located in the most protected and largest city of a state and are available for use by all law enforcement agencies in that state. Hess and Matison (2013) Identified some of the most frequently examined pieces of evidence that are analysed using biometrics. According to Moradoff (2010), Biometrics entails the study of an individual's biological data and identity via the measurement of his/her special physical or behavioural features. A few digital technologies exist for the identification of an individual's biometrics. They range from fingerprints to voice recognition techniques, facial recognition, etc. However, fingerprints and the iris of an eye are considered the most reliable biometric digital evidence.

- **Fingerprint:** Aside from DNA testing, fingerprinting is considered the most novel and significant innovation in crime management and criminal justice. DNA is the only rival to fingerprints concerning a person's identification (Jetmore, 2008). All humans have a unique presence and well-arranged lines at the tip of their fingers. These small lines are called friction ridges. They function to provide the fingers with traction when an individual manipulates an object. There are sweat pores within the friction ridges. Sweat from the sweat pores when mixed with body oils and other matter, can rub off on any surface the finger touches, leaving behind evidence of a fingerprint especially when the surface is smooth. Fingerprints are very essential during criminal investigations. No two persons have the same friction-ridge patterns. An individual's unique friction-ridge are formed even before birth and remains unchanged throughout his/her lifetime. Therefore, fingerprint analysis is useful in determining if a suspect was present at the crime scene or not. Digital

technologies developed by researchers at the Los Alamos National Laboratory in New Mexico are novel in fingerprint detection using x-rays that do not distort the ridge patterns of fingerprints in anyway.

- **Voiceprints:** This is a graphic record produced by a sound spectrograph of the energy patterns emitted by speech. Just like fingerprints, every individual has a unique voiceprint. It is important in identifying criminals who utilize phones illegally. Hence, audio forensic investigations have become invaluable to most law enforcement agencies. Phone calls usually retain voiceprints. Such voiceprints are usually compared with a sample of a suspect's voice to ascertain the actual criminal. Spectrographic examination is a technique used to compare an unknown recorded voice sample with a known verbatim voice recorded and transmitted on the same device (Waggoner, 2007). Although, the use of voiceprints in criminal trials has been controversial. In many cases, criminal convictions via voiceprints have been reversed because they were found not to be sufficiently reliable. It is however worthy of note that advances in voiceprint technology have continued to give investigators an edge on the quality of evidence.
- **Language Analysis:** The origin, gender, age, race or even the nationality of a suspect can be traced via his/her language of communication. An analysis of a suspect's language can further provide a clue into his/her political orientation, religious views and educational level. All these elements put together can provide reliable insight into a criminal motive. The technique of psycholinguistics is often utilized in language analysis. The victim, suspect or witness' state of mind can be determined by the analysis of the language used at the crime scene. The comments at that time are born out of excitement.
- **DNA Profiling:** It is common knowledge that human cells are made up of discrete packs of chromosomes considered as DNA. Deoxyribonucleic acid (DNA) is an organic substance found in the nucleus of a cell. It is utilized in determining an individual's personal characteristics. For instance, DNA can be used to create a genetic fingerprint for the identification of a person. All individuals have their unique DNA structure except for identical twins. Through DNA analysis, forensic scientists can determine an individual's hair colour, eye colour, gender, and ethnicity. The technique of DNA profiling can be done by utilizing cells from any part of the human body for assailant identification, paternity testing, missing persons, unidentified body cases, etc. For instance, DNA testing was the bases of identification for many unidentified bodies in the September 11, 2001 World Trade Centre attack (Garrett, 2009). Before the 21<sup>st</sup> century, DNA evidence was only investigated for violent crimes. However, in the 21<sup>st</sup> century and with the aid of digital technologies that have simplified the process of testing, DNA technologies are now being used for evidence collection for crimes such as burglary and theft (Wilson, 2010).
- **Blood and other Body Fluids:** Although blood is often analyzed for DNA, its combination with other body fluids such as urine and semen can produce useful evidence in a criminal conviction. Evidence of blood is sufficiently admissible to the fact that a violent crime was committed. It could help determine the path of a victim or suspect and in establishing or eliminating a suspect from the incidence of crime. Body fluids are usually evident on clothes, floors, walls, furniture and other objects around the crime scene.

- **Hairs and Fibers:** This is another frequently utilized biometric evidence. Hair and Fibers are however difficult to trace without careful search and good lighting. They are commonly located on beddings, carpets and other surfaces around the crime scene. Hair and fibers are very useful in forensic criminal investigations because they can easily be used to identify suspects around crime scenes.

## **The Interplay Between Digital Technologies and Forensic Science in Crime Management.**

Crime management in the 21<sup>st</sup> century is heavily dependent on technology-enabled forensic examination of criminal events. The digital revolution and preponderance of electronic devices pervading life, such as cell phones, pagers, Personal Digital Assistants (PDA), Computers, iPods, gaming systems and global positioning systems (GPSs) have generated a new class of evidence and requirement for handling it (NIJ, 2007). Digital technologies are being utilized in the forensic examination of nearly every crime today. All digital media relating to an offense or a crime, such as digital cameras, flash drives, computers, cell phones, etc can only be examined forensically (Garrett, 2009). According to Miller and Loving (2009), Crime management and investigation experts must take into consideration any electronic device found in and around crime scenes since data can be saved or stored on any drive.

To effectively identify the specific electronic device utilized by criminals, investigators need to learn about the suspects and their social habits. Digital data recovered from suspect's devices can reveal a lot of information to investigators. For instance, a forensic examination of a suspect's in-vehicle Global Positioning System (GPS), can reveal to investigators the pattern of a suspect's movements and associates (Miller and Loving, 2009). For instance, cell phones dominate the array of digital technological devices with the most criminal information extracted via forensic examination. Cell phones are often pervasive and can contain a large amount of useful information that may facilitate an investigation (Reiber, 2009). Therefore, the seizure of suspects' cell phones is a critical aspect of investigators for forensic examinations (Heinecke, 2007). According to Puente (2007), cell phones usually leave trails. As soon as they are powered on, they register their presence including a serial and phone number to any communication tower nearby. Spraggs (2009) pointed out that data gathered from cell phones are often vital in determining the exact period during which a criminal event happened. Ultimately, the inbuilt Global Positioning System (GPS) in cell phones enables law enforcement agents to track and apprehend criminals as well as victims in need of rescue.

Evidence collection from a cell or mobile phone is a very delicate process. Handling the device is the first and most crucial aspect. This is because handling the device carelessly could lead to the contamination of evidence. Every investigator must be careful not to change the state of the evidence. Maintaining the state of the device as a piece of evidence is a basic rule of evidence collection. It is also important for investigators to keep themselves abreast with the state's law on evidence collection concerning electronic technologies. While some states may require a search warrant, others may need a court order (Miller, 2008).

Aside from cell phones, a plethora of other digital technologies that can preserve vital digital evidence exist. However, the need for proper training of investigators for forensic examinations and evidence collection is crucial. According to Reiber (2009), Computer forensic training is designed to ensure that investigators do not only have an idea of understanding complex data, how they are

stored and how to extract them but also how to present digital evidence in court when they are expected to do so. Therefore, the study of digital forensics is trending in most Universities to equip potential forensic experts/investigators with the requisite skill and knowledge on how to conduct forensic examinations (Whitcomb, 2007). Additionally, several academic publications are available to enrich the investigator's knowledge. For instance, a journal titled "The Investigative Uses of Technology: Devices, Tools and Techniques published by the National Institute of Justice to provide vital information regarding digital evidence is a good example.

Forensic science plays a vital role in criminal investigation and management, especially in the area of criminal tracking and suspect development. Forensic tracking is often defined as the science of finding, keeping and explaining footprints and tyre treads impressions to justify criminal events. Footprints have become the "missed evidence in many jurisdictions" (Hanratty, 2007). This is because it can provide valuable clues to criminal tracking and crime establishment. Through forensic examination of the length of strides and depth of impression, footprints can reveal the height of a criminal and also tell if the criminal was with a heavy load or not (Sonenshein & Nilon, 2010). For instance, forensic experts usually determine the height of criminals from their show prints by measuring the shoe print length in inches and dividing it by two to arrive at the height in feet. An example of this is a footprint that measures 22 inches in length will reveal that the criminal is 11 feet tall. This instance helps investigators to rule in or rule out potential suspects (Hanratty, 2007).

Tyre prints are also an important element of evidence gathering by investigators (Ashibi, 2023). Criminals who commit offenses using a vehicle can be tracked by their tyre prints. For instance, sticky soil marks on the road are a fantastic way of ascertaining the direction of the criminal vehicle(s), as wet sand, clays or mud will stick to the tyres. According to Lee (2007), "as the vehicle continues moving, this material will fall off the tyres in the direction the vehicle is headed. If the tracks shine in the grass, they have headed away from you. Tyre tracks coming towards you will show faintly as an off colour to the surrounding grass". Tracking of footprints and impressions has the potential of revealing many investigative leads. Criminals seeking refuge outside are likely to leave foot, hand, knee, body or heel impressions. Broken tree branches can expose when the branch was broken; the lighter the colour of the branch, the more recently it was broken. The dirt or moist side of stones can indicate how recently they were overturned.

Another area where technology has significantly influenced crime management is surveillance. Several technological devices and procedures exist in the conduct of surveillance. Devices such as telescopes, body wires, binoculars, night vision equipment, costumes and disguises are prominent in conducting surveillance. Over the years, surveillance equipment and systems have been advanced and sophisticated. For instance, there exists a surveillance system that conceals a periscope in what mimics an air vent on the rooftop of a van. It rotates 360 degrees and remains undetachable. The area under surveillance is usually videotaped using remote motion detectors. Additionally, GPS technology play an important role in surveillance operations. Areas that are inaccessible by foot or vehicle are accessed via Aerial surveillance. Operational movements are often facilitated by communication between ground vehicles and air surveillance. The aerial pilot is usually a police officer with good knowledge about the area under surveillance. Visual or video surveillance provides video images that stand as viable evidence, especially in the investigation of high-profile criminal cases. Today, criminal acts are increasingly being captured on analog video tapes and in

digital formats from closed-circuit television systems, cell phone cameras and other forms of security and surveillance equipment. Such video pieces of evidence are generated from places like schools, Banks, malls, office complexes, retail shops, hotels, parking lots, restaurants, etc (Pincince, 2007).

According to Dee (2009), crime-prone zones are increasingly being monitored using 24-hour surveillance cameras strategically mounted on utility poles, buildings and other strategic points. These surveillance cameras are being monitored at a central recording station. Although there may not be someone viewing or monitoring the output of the cameras all the time, the live activities are however recorded for reassessment in the event of any criminal incident or accident. Most surveillance cameras are equipped with night-vision or telephoto lenses as well as time and date generators and printers that can produce digital evidence against criminal suspects. In other to secure admissible evidence, investigative officers normally place surveillance cameras overtly to conduct covert surveillance. They do this by disguising the surveillance recording equipment in a variety of ways unknown to the culprit. These cameras can be hidden in picture frames, clocks, domes and exit signs to record criminal acts such as drug trafficking, shoplifting, money laundering, Bank robberies, etc.

The vitality of digital technology with specific reference to audio or electronic surveillance cannot be overemphasized. In very unique instances, electronic devices are utilized in surveillance. The technique of surveillance may include secretly wiring a person who is going to be interacting with a suspect or getting involved in a fraudulent business establishment through participant observation. The most frequent forms of lawfully authorized electronic surveillance at the disposal of law enforcement agents are pen registers, contents interceptors and trap and trace devices. Trap and trace devices and pen registers record dialing and signaling details used in processing and routing telephone communication, such as the signals that identify the dialed numbers of outgoing calls or the originating numbers of incoming calls. Electronic surveillance and wiretapping are considered forms of search and are therefore permitted only with probable cause and a court order (Katz, 1967).

## **Some Digital Forensic Techniques for Crime Management in the 21<sup>st</sup> Century**

A good number of advanced technologies have evolved for solving crime problems. Ranging from retinal scanning to unraveling the nature of criminal evidence, to fingerprint identification; forensic technologies of the 21<sup>st</sup> century have assumed an advanced position in solving complex crime problems in society. The increasing demands for Forensic experts and forensic science technicians have given credence to the fast-growing relevance of the field of forensic science. Some basic knowledge of forensic science techniques and digital technologies are often dramatized on television programmes like the Crime Scene Investigation (CSI) and Naval Criminal Investigative Service (NCIS). Several advancements in forensic science technologies have continued to develop to bridge the gaps that criminals utilize to evade justice. Kimmy (2023) identified some advanced digital technologies used in forensic science investigation and crime management as follows:

- a. **Carbon Dot Powders:** This is a technology developed by researchers for easy fingerprint reading and identification. Fingerprints are crucial in any crime scene investigation; however, their detection has been hampered by factors such as high toxicity, low sensitivity, low contrast, etc. Consequently, carbon dot powders have been developed to give

fingerprints a fluorescent appearance under Ultraviolet (UV) lights which makes them quite easy to detect and analyse (Jetmore, 2008). The application of the Carbon Dot Powder makes fingerprints under Ultraviolet light reflect as red, orange, or yellow.

- b. **Artificial Intelligence (AI):** This technique, although applied in many other fields, is new in forensic science but developing rapidly. AI is being utilized in key stages and processes of criminal cases today. It is utilized in the analysis of crime scenes, comparing fingerprints and arriving at a conclusion about the various factors of crime establishments.
- c. **Nanotechnology:** Nano sensors have been developed to be utilized for forensic investigations at the molecular level. Forensic analysis at the molecular level allows investigators to x-ray all possible evidence available at a crime scene. This technology is often used to scrutinize the availability of explosive materials, illegal drugs, or even biological agents at its minutest level. Hence, scientists utilize this technology to analyse the existence of carbon and polymer-based nanomaterials. This has significantly aided many investigations.
- d. **Proteomes:** The use of Deoxyribonucleic Acid (DNA) to ascertain if an individual is a suspect or a victim is a common practice by forensic scientists. Similarly, in the 21<sup>st</sup> century, technological advancement has made it possible for scientists to identify and detect proteins. This has given credence to Proteomes as a crucial tool in forensic investigations. Generally, Proteomes are regarded as the total set of proteins that an organism or a living being can produce. They can be detected and analysed in biological materials such as bones and blood. The analysis of these biological materials can allow scientists to determine if a person is connected to a criminal incident or not. The dynamic nature of Proteomes makes them different from DNA and gives scientists an edge to determine a victim's age and other causal environmental factors that may be cumbersome to detect via other forensic investigative methods.
- e. **Foldscope:** This can be described as a 21<sup>st</sup> century paper microscope that is small in size, easily disposable and inexpensive technology. The foldscope is highly portable and as a result, it can be utilized in any crime scene for on-the-spot investigation of forensic samples like soil, hair, blood, etc. However, the findings from foldscope are usually preliminary, but they can facilitate early investigation processes of criminal cases.
- f. **DNA Phenotyping:** DNA serves an important purpose in identifying suspects by comparing their samples with those found in the crime scene. It can also be used to determine the physical outlook of suspects. Essentially, there are 23 chromosomes embedded in DNA that can reveal the outward appearance of a person (Berson, 2009). Forensic scientists utilize DNA Prototyping to aid investigation processes by providing investigators with relevant traits of suspects such as skin colour, eye and hair. Advanced technologies can further provide investigators with a prediction about the age and biological background of suspects.
- g. **Biosensors for Fingerprint Analysis:** Fingerprints are very essential elements that could authenticate suspects in criminal incidences. Available fingerprints at crime scenes are matched and compared to identify suspects. The major setback with fingerprints is that they are most times not readable. With the aid of Biosensors, scientists can now seamlessly analyse body fluids found in fingerprints to determine the actual suspects. The biosensor can detect the suspect's age, lifestyle, gender and possible medications the suspect could be on. This technology is also useful in analysing other bodily fluids found at crime scenes.

- h. **Immunochromatography:** This technology is a method that is utilized to ascertain suspects' existing diseases. It is operationalized by applying a small sample onto a prepared test strip. The results or findings from this technique are quite quick and reliable. Most tests that utilize this technique are HIV, COVID and even pregnancy tests. The technique of immunochromatography is utilized primarily to detect substances in suspects' bodily fluids like medications and drugs. Scientists have advanced this technology by developing a smartphone sensor capable of evaluating a saliva sample on the spot without necessarily going to the laboratory.
- i. **Suspect/Victim Geolocation:** Forensic scientists have also developed techniques for stable isotopes of water for the tracing and geographical location of suspects or victims (Donahue, 2007). Atom-to-atom variations between isotopes exist with a unique signature. By the isolation of isotopes in water samples found on suspects or victims, investigators can ascertain the origin of such samples. In the event that there are multiple samples, the isotopes can recreate suspect's or victim's paths. This method of isotopes is further utilized to know the number of people presents at a time.
- j. **Forensic Palynology:** This technique of forensic science deals with the study of pores, pollens, grains or seeds, which can be utilized to determine the location of subjects. Pollen and pores are atomic in nature and can be stored on skin and clothes largely undetected. Therefore, forensic palynology is a technique used by scientists to collate and compare these trace materials as evidence to be presented in court.
- k. **Blockchain-Based Solution Cloud Forensic:** Cloud storage has become the trending and ideal storage location for individuals and corporate organisations and institutions. According to Kimmy (2023), "over 50 percent of personal and corporate data are now stored in the cloud or remote servers". Consequently, it is pertinent for digital forensic scientists to innovate techniques that will enable them to collect, analyse and evaluate data from the cloud. The use of blockchain technology ensures that the privacy, security and integrity of the cloud data are guaranteed.
- l. **Counter Currency Detectors:** Currency counterfeiting is a trending type of criminal activity with a high rate of victimization. The emergence of technologies to facilitate digital printing and scanning has simplified the act and heightened the sophistication of currency counterfeiting. How is it possible to detect counterfeit currencies? Identifying a counterfeited currency is usually not an easy task (Erin, 2008). Therefore, scientists have developed counter-currency detectors to identify fake currencies and ring an alarm when it finds them. Different types of counterfeit currency detectors have been developed by forensic scientists. They include but are not limited to counterfeit money detector pens, counterfeit currency UV detectors, magnetic currency detectors, magnifying currency detectors, currency watermark detectors, etc (Shermer, 2004).

## Conclusion

Crime management in the 21<sup>st</sup> century could have suffered significant setbacks in the absence of advancements in digital forensics. Forensic investigations are essentially targeted at exposing leads and to objectively pursuing such leads to logical conclusions that will establish victim and suspect status for criminal justice administration (Safertein, 2007). Digital technologies play significant roles in forensic investigations. According to Oetinger, (2010), investigators perform numerous

functions including victim's emergency assistance, crime scene security, videotaping, photographing, sketching, writing reports and taking down notes, collating and processing evidence that is physical in nature, searching, interrogating witnesses and suspects to obtain vital information, identifying suspects, conducting surveillance, raids, stakeouts and undercover operations, and finally testifying in court. Crime management is more effective and well-coordinated when the 21<sup>st</sup> century digital technologies are utilized. Investigators utilize crucial information extracted from the findings of forensic analysis of crime incidence and institute legal actions with verifiable and admissible evidence. Crime scene management is exemplified when patrol officers on the beat are usually the first officers detailed to arrive at a crime scene. Such officers need to establish priorities by handling emergencies first and securing the crime scene before they can commence investigations. Professionally, any suspect found at the crime scene should be detained for interrogation and later arrested or released depending on the outcome of the interrogation. If the officers got a hint that a suspect has recently left the crime scene, the description, vehicle, direction of the suspect and items taken from the crime scene must be obtained, and the headquarters must be notified immediately.

Once emergencies have been taken care of, it is of utmost importance for officers to protect the crime scene and the evidence embedded. To aid preliminary investigations, necessary measures (including barricading, locking, roping, and guarding) to protect the crime scene must be put in place to avoid contamination of critical evidence. Officers are bound to commence the preliminary investigations as soon as the crime scene is secured. The preliminary investigations should include interrogating witnesses, suspects and victims; photographing, measuring, videotaping, sketching the crime scene; evidence collection, identification, examining, and processing; and statements recording (Miller, Hess & Orthmann, 2011). The process of evidence establishment is the crux of criminal investigations. Forensic experts are required to authenticate relevant evidence to ascertain the actual suspects and victims of crime. It is important for investigation officers to ascertain as early as possible if a crime has been committed or not. This should be done by establishing the main elements of each crime and admissible evidence that supports the crime committed. It is also important to determine exactly when the crime happened.

Law enforcement agents are primarily saddled with the responsibility of solving crime issues. This responsibility should be deliberately made cooperative, and well-coordinated. This is expected especially outside the police stations. There is a need for investigators and uniformed law enforcement agents to interrelate with agents of the criminal justice system and key players of the correctional institutions. This is because the investigation of criminal activity is a collaborative and mutual responsibility. Effective crime management is therefore a product of the utilization of advanced digital technologies and the collaboration of relevant stakeholders in criminal investigation, prosecution and rehabilitation.

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