

Using Forensic Ballistics in the Courtroom in South Africa

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Abstract: In today's world forensic ballistics experts gather shell casings and bullets collected at crime scenes or by test firing guns found at crime scenes to collect shell casings and bullets to create ballistic images, which are uploaded to crime databases to match other crimes with matching ballistics. Criminal laboratory technicians use the Ballistic Image databases to match evidence collected in other crimes. The expert must demonstrate the following four factors to the courts satisfaction; scientific, technical, or other specialised knowledge that will help the trier of fact to understand the evidence or to determine a fact in issue; the testimony is based on sufficient facts or data; the testimony is the product of reliable principles and methods; and the expert has reliably applied the principles and methods to the facts of the case. This article summarises the importance of ballistic evidence to the courts. Recently, there has been increased scrutiny of the ballistics field within South African courts, with defence teams arguing that it is not a forensic science. For this study, a qualitative methodology was employed to gather data. Articles from various platforms and interviews with participants were utilised, along with transcriptions from selected court cases. Non-probability sampling was utilised in the form of purposive sampling. The purposive sampling method provided authors with the opportunity to handpick participants who were suitable for the research. Fifteen (15) key informants were purposively sampled experts from the SAPS (9), National Prosecuting Authority (NPA) (4), private analyst (1) as well as private attorney (1) and the least experienced analyst had minimum experience of 7 years. Thematic analysis was chosen as the method to analyse the collected data. Forensic science, as defined, involves the examination of crime scene evidence using standardised and proven foundational principles, with the aim of assisting the court in making informed decisions. The study adequately addresses various factors, including manufacturing processes, class, sub-class, and individual characteristics, the AFTE-Theory of Identification (AFTE-TI), and the subjective versus objective nature of analysis. This study concludes that these factors have been thoroughly investigated through numerous research studies and ongoing research, ultimately strengthening the fundamental validity of firearm individualisation.

Keywords: Ballistic evidence, courts, firearm, forensic science, fundamental.

Introduction

Law-enforcement agencies employ this ballistic evidence during criminal investigations (especially those of gun violence), and in almost all the court cases where applicable. Firearm evidence is becoming a crucial part during court cases and ballistic-forensic-examiners (analysts) that testify during these court cases, considering themselves as experts according to law. Tshikalange (2023) points out in a news article that the defence in the Senzo Meyiwa murder trial is seeking its own ballistics expert to challenge the evidence of the state's ballistic expert, Lt. Col. Christian Mangena. Ballistics as a Unit operating under the Component: Forensic Science Laboratory (FSL) in the Division: Detective and Forensic Services of the South African Police Service (SAPS). The researcher has observed an e-mail by Menigo (2019) that raised issues of concern and proposing of intervention for the development of the following:

1. An adaptable pro-forma ballistic court report (addressing the scientific principles, scientific validity, error rates and the examination process of evaluation, comparison, conclusion and evaluation with reference to the Daubert-standards).
2. Court charts that include labelling striations of interests.

3. A Glossary of technical terms and their definitions.
4. A list of references to textbooks and articles, if needed for further research.

The concerns of Menigo, link directly to the research aim and objectives of the study. The value of the findings and the recommendations of the study will lead to closing knowledge gaps and can only contribute to be advantageous in terms of the professional operation, reliance and dependence of the ballistics environment. It is understood that processes, examination and presentation of ballistic evidence are presented based on the same operating procedures. What became evidently clear is that there is an absence of a foundational argument that analysts can rely upon and easily respond to during the addresses by critics and cross-examination. During a Section 174 application in the matter of State (S) versus (v) Conradie (SA: 2018), the defence is of the opinion that the analyst, during her testimony, did not provide any scientific basis of the accuracy of her bold statement of individualisation to the court. SA (2019:1) is another case where the defence is of the opinion: "...there is insufficient scientific basis for admitting evidence seeking to link a particular component of spent ammunition to a particular firearm, and that the court should, therefore, exclude all of the ballistic evidence tendered by the State". Considering the fact that ballistic-related evidence forms such a critical part of the prosecution in court cases, it is necessary to inform not only the analysts, but also the general public of the fundamental material of ballistics. This study has reiterated the importance of ballistic evidence during court judgements.

Literature Review

Background to ballistic evidence

Bolton-King (2017A:160), states that the three disciplines are different scientific concepts and could be described as follows:

1. Forensic firearm examination deals with the processes of the examination of firearms in order to evaluate their forensic value and establish their functionality;
2. Forensic firearm identification deals with the comparison of fired ammunition components to the test-fired samples obtained from a suspected firearm; and
3. Ballistics deal with the motion of the projectile from the moment ammunition were fired until the time it reaches its static point.

Thus, taking in consideration the description of Bolton-King, the aim of this study is to deal with the second point namely, forensic firearm identification. Bolton-King (2017A:160) states that ballistics is furthermore sub-divided into three key areas, namely, 1. Internal (what happens to the projectile prior to leaving the weapon), 2. External (the motion of the projectile as it travels through the atmosphere) and 3. Terminal (the motion of the projectile when it encounters an object). Grzybowski et al. (2003:211) define forensic toolmark identification as a scientific discipline that deals with identification of a toolmark, compared to a specific tool that made the mark and of which firearm individualisation is a specialised field of toolmark identification that deals with firearms. Saks and Faigman (2008:162), describe the Daubert as the process where criminal courts establish, among other things, whether the foundation for scientific expert opinion had been sufficiently verified and the thorough methodologically testing, had acceptable error rates and were generally accepted in the relevant environment. Another process, called Frye, is described as the enquiry to establish whether the knowledge and process that the scientific opinion was based on is generally accepted in the relevant environment that it came from (Saks and Faigman, 2008:163). Bunch, Smith, Giroux and Murphy (2009:3), state that the scientific foundation for the basis of firearm individualisation environment is constituted by two general propositions. The first proposition that Bunch, *et. al.*, (2009:6), mention is that "Class and microscopic marks imparted to objects by different tools will rarely if ever display similarities sufficient to lead a qualified firearm-toolmark examiner to conclude that the objects were marked by the same tool". The researcher will summarise the second proposition as Bunch, *et. al.*, (2009:4), explain that the working tools during the manufacturing processes will transfer random marks onto parts such as barrel bores, breech faces, firing pins, etc. This is due to toolwear and chip formation or by electrical/chemical erosion.

Miller and Beach (2005:305), point out that a toolmark identification is when a qualified analyst opines, after an examination has been taken, that a questioned toolmark (exhibit cartridge case) was created by the same tool working surface (breech face) as the test toolmark (known-firearm test cartridge case). Miller and Beach (2005:305), state that "The toolmarks are significant when individual features are represented by their height, width, depth, curvature and spatial relationship are in sufficient agreement. Sufficient agreement is achieved when the agreement of the pattern of features between two toolmarks meet the level of agreement observed in known matching toolmarks and exceeds the level of agreement observed in known non-matching toolmarks". Smith (2004:130), states that firearm

individualisation is made possible through the ability to recognise patterns together with specialised training by analysts through developing an identification threshold during training, which he describes as a position of subjectiveness to establish sufficient agreement of the value of the individual microscopic marks that enable the determination of a common source. Smith (2004:130), explains that this is obtained through examination of numerous Best Known Match (BKM) and Best Known Non Match (BKNM) to understand what is required to be in sufficient agreement for identification. The examination process, through which such individual association or identification conclusion is effected, is based not on absolute certainty, but rather on the practical certainty of the underlying (validated) scientific theory (SWGGUN, 2017:183).

According to Thompson, Miller, Ols & Budden (2002: 7 & 26), the ability to place a specific firearm at the scene is vital to law enforcement, because information about the weapon can be of use in identifying a suspect or confirming an individual's connection to a crime and that no investigative tool is perfect or will be effective in every situation, this obligates law enforcement to use a variety of techniques for generating investigative leads. In *S v Peters and 1 other* (SA, 2013:15), in its judgment the court mentions of a ballistic analyst attached to the FSL, Western Cape that testified in conformation of the content of the affidavit made by himself in terms of section 212 of the criminal procedure act. The most relevant part of this evidence as the court describes, is that both fired cartridge cases, found at the crime scene at a specific location, were fired by the same firearm and that this evidence was not challenged. This evidence could critically assist the court to conclude as it mentions in SA (2013:27) that accused 2, as established through the evidence, was in possession of a firearm and that it must have been loaded with at least two rounds of ammunition. Grzybowski et al. (2003:210) give an example of a case where the judicial rejection of the statement: "I know it is a match because I have sufficient background, training and experience", used by analysts during their testimonies, but contrary to this, analysts should rather explain a convincing, logical and scientific based explanation for the basis of their identifications. The case mentioned by them is called, *Joseph J. Ramirez v. State of Florida*, Florida Supreme Court Case No. SC92975, 2001-12-20. According to Grzybowski et al. (2003:209) the court in the Ramirez case was concerned that the analyst testified with absolute certainty of his identification and with that, no objective criteria is required. They furthermore state that the court found no evidence in the record that the analyst's test had ever been subjected to meaningful peer review or publication, which is a requirement of scientific acceptance and that firearm and toolmark identification, irrespective of the jurisdiction, will require a scientific foundation to obtain continuous recognition in the courts.

Stroman (2014:161) states that different firearm parts in its operation are interacting with the cartridge case during the cycling and firing process, of which individually their working surfaces should be evaluated and through leaving either impressed or striated toolmarks of varying levels of reproducibility making cartridge case identification a unique challenge. Stroman (2014:161) mentions a research project with the involvement of two .40 Smith & Wesson calibre Smith & Wesson model 4006TSW semi-automatic pistols and that these pistols possess firing pins that are not fixed, but they are rotating during the firing process. According to Stroman (2014:161), this free-floating firing pin causes the identification process of the firing pin impression very challenging due to the fact that it present a different portion of itself to the surface of the primer during the creation of the firing pin drag mark and the orientation relative to the extractor and ejector is also different. The breechfaces possess manufacturing marks of a linear parallel configuration, possibly due to the broaching process and these marks can be considered as sub-class characteristics, (Stroman, 2014:161). Through the examination of physical evidence gathered during the investigation process, the forensic sciences generally have been used to support or refute case theories, (Reno and Kotas, 2015:238). According to Reno and Kotas (2015:238) the use of databases within the forensic science environment and specific Integrated Ballistics Identification System (IBIS) to firearm identification, has an intelligence tool used during the investigation process to solve crime. According to Bolton-King (2017A:170), the nature in striae of sub-class- or individual characteristics cannot be identified through objective computerised methods, thus to interpret this potential during matching, the subjective human opinion will always be required. Bunch, et. al. (2009:6), in all sciences, elements of subjectivity are present, especially during applications of a theory or technique, thus even with objective elements present in firearm individualisation, the subjective interpretation of examinations cannot be regarded as unscientific.

Hill (2016:108) states that the objective to acquire IBIS was to eliminate the high labour-intensive and time-consuming comparisons of fired evidence to determine linkages among cases, but to have a computer database where the details of all the fired evidence can be stored and automatically be compared by the system. Hill (2016:2) states that the system, through its own processes, takes all data available on it and compares it, searching for possible matches between the exhibits, thus without the influences of any analyst. According to Hill (2016:2) the results of these searches are then viewed on the computer system by the analysts and if a potential agreement between different exhibits is found, then those case details are taken and the physical exhibits are re-examined by means of a microscopic

comparison. The aim is to determine whether the exhibits are a match or not, in other words, whether they were fired from the same firearm or not.

The importance of the Association of Firearm and Toolmark Examiners (AFTE)

According to Thompson (2010:11), the AFTE that publishes the AFTE Journal is the largest organisation that distributes scientific information with regards to firearm and toolmark science.

AFTE (1992:337), states the following adopted Theory of Identification (AFTE-TI):

- (a) “The theory of identification as it pertains to the comparison of toolmarks enables opinions of common origin to be made when the unique surface contours of two toolmarks are in sufficient agreement”.
- (b) “This sufficient agreement is related to the significant duplication of random toolmarks as evidenced by the correspondence of a pattern or combination of patterns of surface contours. Significance is determined by the comparative examination of two or more sets of surface contour patterns comprised of individual peaks, ridges and furrows. Specifically, the relative height or depth, width, curvature and spatial relationship of the individual peaks’ ridges and furrows within one set of surface contours are defined and compared to the corresponding features in the second set of surface contours. Agreement is significant when it exceeds the best agreement demonstrated between toolmarks known to have been produced by different tools and is consistent with the agreement demonstrated by toolmarks known to have been produced by the same tool. The statement that sufficient agreement exists between two tool marks means that the agreement is of a quantity and quality that the likelihood of another tool could have made the mark is so remote as to be considered a practical impossibility”.
- (c) “Currently the interpretation of individualisation/identification is subjective in nature, founded on scientific principles and based on the examiner’s training and experience”.

This formulation and adoption (AFTE-TI) was done after studies conducted, to explain the basic theory that permits opinions of common origin to be made with tool comparisons (Grzybowski *et. al.*, 2003:212). Thompson (2010:11), mentions that AFTE, based on the AFTE-TI, developed the following range of conclusions. In order to represent a spectrum of statements, the following range of conclusions are suggested as AFTE (1992:337 & 338), describes:

- Identification – “agreement of a combination of individual characteristics and all discernible class characteristics where the extent of agreement exceeds that which can occur in the comparison of tool marks made by different tools and is consistent with the agreement demonstrated by toolmarks known to have been produced by the same tool”.
- Inconclusive – (1) “some agreement of individual characteristics and all discernible class characteristics, but insufficient for an identification”, (2) “agreement of all discernible class characteristics without agreement or disagreement of individual characteristics due to an absence, insufficiency, lack or reproducibility”, and (3) “agreement of all discernible class characteristics and disagreement of individual characteristics, but insufficient for an elimination”.
- Elimination – “significant disagreement of discernible class characteristics and/or individual characteristics”.
- Unsuitable – “unsuitable for comparison”.

When applying the AFTE range of conclusions, the examiner can conclude to make an identification if the consecutive agreement meet or exceed the proposed minimum criteria, or if there is less consecutive agreement, the examiner may conclude to any other option of the conclusion that is best suited (Grzybowski *et. al.*, 2003:214).

Equipment utilised for comparisons

Wheeler and Wilson (2008:112), describe the comparison of the stereomicroscope consists of two stereomicroscopes that are combined by an optical bridge. They explain that prisms and mirrors, utilised to direct the light to a common set of oculars, are attached to the optical bridge. Furthermore, in order to allow the analyst to view two different items side-by-side on a microscope scale, split areas of the field of view from each microscope can be viewed as a combination image, that will allow the analyst to do comparison of unique markings visible on the evidence or

exhibits. Leica (2008:13), illustrates to us the appearance of the microscope and describing the different utilisation features as follows in figure 1:

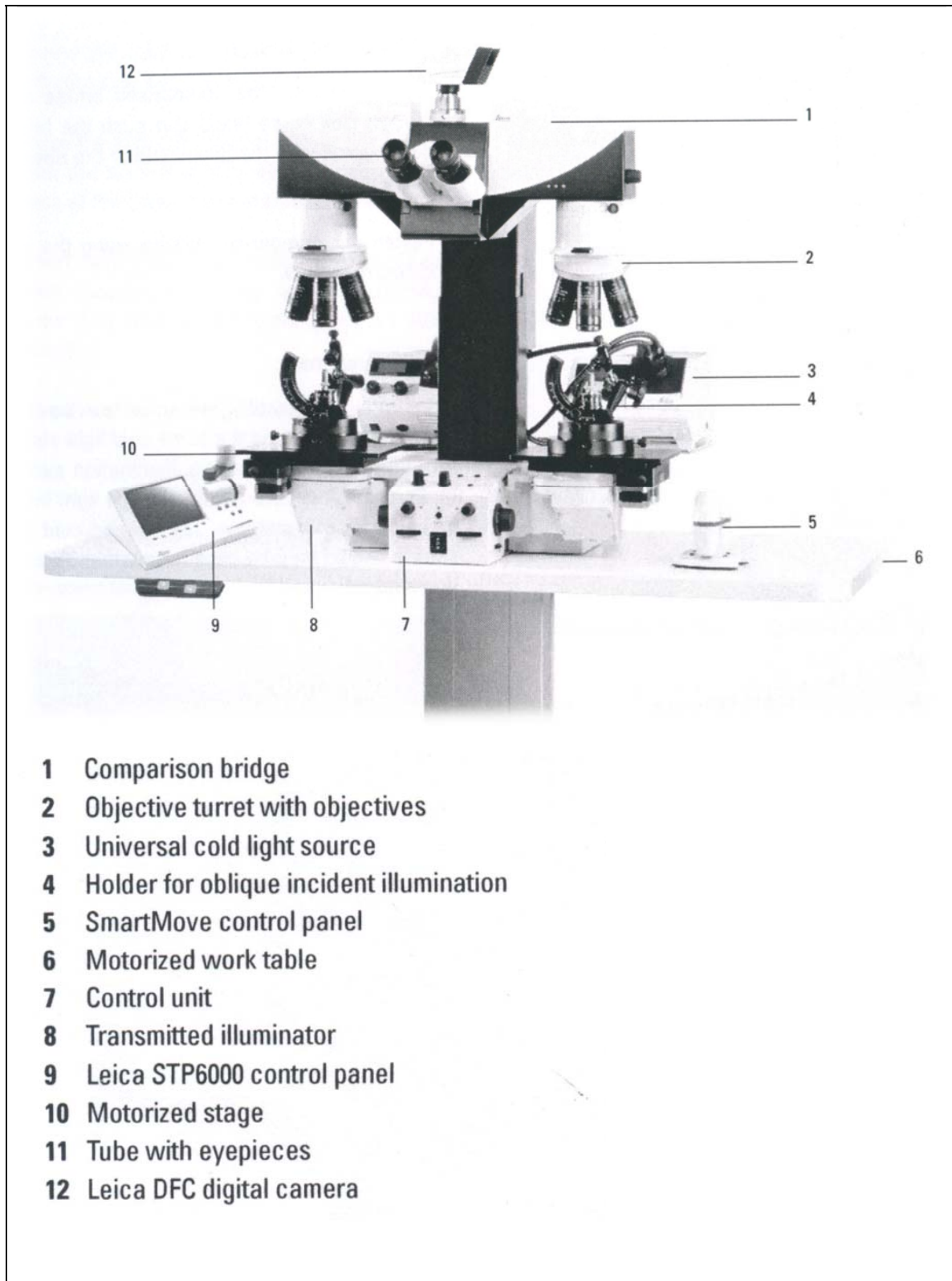


Figure: 1 - Source: Leica (2008:13)

Critics to ballistic evidence

The existence of critics to evaluate the validity or just commentating to the environment of ballistic examinations are so evident that it cannot be denied. Some of the points highlighted by critics will be mentioned as follows:

- According to Schwartz (2005:42), considering the key role that ballistics have in obtaining convictions, all firearm individualisations should not be accepted until the development of firm statistical empirical foundations for identifications and a meticulous system of blind proficiency testing.
- NAS (2009:155) is of the opinion that the scientific knowledge base for the firearm analysis is fairly limited, even though some studies were conducted to demonstrate the similarities between marks created by different firearms or the variability between marks created by the same firearm.
- PCAST (2016:113) mentions two directions needed to improve ballistics and ultimately paying dividends to the CJS namely:
 - Additional black-box studies like the Ames Laboratory black-box study in conjunction with third parties that has no stake in the outcome and the utilisation of more rigorous proficiency testing of analysts with challenges that are sufficient to the environment and reported publicly after the test.
 - The conversion of ballistics from a subjective method to an objective method. This would mean that image-analysis algorithms will be developed for the comparison of similarity of toolmarks.

Nichols (2007:591) explains the following argument: “Is there a role for statistics in the discipline of firearms and tool mark identifications?” He mentions that Schwartz argues that analysts do not even attempt to answer this question, but it might be true from the testimony that she has observed, but there is existing published literature that addresses this issue. He states the following: “The implied need for representative statistical databases for each and every tool one might encounter is not founded because the science of ballistics is based on manufacturing methods and an ability to assess and distinguish among the class, subclass and individual characteristics produced by the tool manufacturing process”.

AFTE-1 (2008:238) states that many studies had been performed in support the concept of the possibility that toolmarks are sufficiently unique to serve as a means to identify the specific tool that created the questioned toolmarks. It is of the opinion that many such studies had been performed, looking at consecutively manufactured tools, it is expected that consecutively manufactured tools might be more likely to exhibit sub-class characteristics, but even under such rigorous conditions, it still able for such tools to leave unique toolmarks, (AFTE-1, 2008:283).

In AFTE (2016:195), it responds to the 2016-PCAST-report as follows:

- It is in agreement that additional ongoing research strengthens the foundational and applied validity of ballistics, as well as undertakings to reduce the effects of cognitive bias and subjectivity.
- It is highly disappointed in the PCAST’s decision to ignore the research that has been conducted.
- The foundational literature of science has been presented to the groups such as PCAST and NAS on various occasions and this can be found at the links on the AFTE-website: <https://afte.org/resources/afte-position-documents> and <https://afte.org/resources/swggun-ark>.

Mattijssen (2020:389) states that the PCAST committee made the following conclusions concerning firearm examinations: there exist insufficient studies with the required quality and quantity that provide sufficient foundational validity or that estimate the reliability of the method as applied. Mattijssen (2020:389) also mentions the recommendation made by the PCAST-committee, that the situation (as mentioned above) could be improved by considering:

- continuous developments in computer-based methods and
- more validation studies of the judgement of analysts that are vulnerable to human error inconsistency across analysts and cognitive bias.

Mattijssen (2020:389) states that when considering the recommendations noted in the NRC- and PCAST reports and also including recent literature within the firearm examination environment, the following topics have received specific attention:

- development of computer-based methods,
- validation studies and proficiency testing and
- influence of the human factor on forensic judgments.

Studies that evaluated statistical approaches and probabilities have demonstrated that toolmark identifications are reliable, but using such an approach is not practical in casework and has significant limitations, SWGGUN (2017:183). Knoetze-Le Roux (2017:2) postulates the purpose of an expert as exceptional due to the fact that an expert can assist the court in cases where it lacks in such specialised knowledge. Knoetze-Le Roux (2017:2) opines that the evidence of such an expert, when relevant and of probative value, is permissible. According to Knoetze-Le Roux (2017:2), the probative value can be determined through the expert rendering his knowledge and experience in affecting a solution to questioned issues before the court.

S v Conradie 2018 SSB123/2016:

During the defence heads of arguments for a Section 174 application, the following arguments were discussed:

- The defence describes the behaviour of the analyst both arrogant and disrespectful towards the court with her actions of being an evasive witness who was unable to substantiate the evaluation of comparisons through her personal and subjective perspective. The defence further points out that the analyst stated that her 212-affidavit should be sufficient to the court and she is not required to provide any further justification for her comparison findings.
- The defence points out that the analyst that matched 2 different fired cartridge case exhibits, retrieved from 2 different crime scenes, did not provide the basis for her finding and simply stated the following bland statement which is insufficient and unhelpful: "...her conclusions were based on facts established by means of an examination and process which require a knowledge and skill in forensic ballistics". See the following comments of the judge in the case of S v van der Sandt 1997 (2) SACR 116 at page 135 as referred and quoted to by the defence: "Viva voce evidence by an expert that he established a fact by a process without further explanation would be inadequate the more so where it is blandly stated in an affidavit or certificate. For the subsection to become operative the court must be convinced that the fact was established by a process and that such process requires a skill and chemistry on the part of the person utilizing it. This cannot be affected by a bland allegation. The process has to be explained to enable the court to determine that it is in fact requires skill on the part of the operator".
- The defence is not satisfied with the manner of how the analyst recorded her analysis on her personal notes, which are documented inside the case file, part of the evidence and also could be made available to the defence upon request. The defence fails to accept the process explained by the analyst of the identifications made which exhibited the analyst to reach a conclusion. The defence cannot accept the court charts prepared and presented by the analyst, which was absent of any indication marks to assist the court in understanding pattern marks or lines that were used for the identification.
- According to the defence, the analyst during her testimony does not provide to the court any scientific basis of the accuracy of her bold statement of individualisation.
- The defence argues that the analyst's credibility was further compromised on the aspect of the firing pin. She testified that the firing pin was modified, how it was done, is unknown and in the absence of a firearm, she is not able to explain what the class- or sub-class characteristics should appear like and therefore the defence argument as the analyst would not know what the original firing pin should appear like, the class and sub-class.
- The defence mentions the following aspects that could be established during the cross examination:
 1. "the forensic science laboratory at which the witness is employed, is not accredited"
 2. "The ballistics section of the laboratory is not ISO accredited"
 3. "the three-year in-service training course which the witness attended is not an accredited course"
 4. "her interpretation of matching marks is an entirely subjective interpretation"
 5. "sub-class characteristics can be confused for individual characteristics, particularly when dealing with cartridge case identification"

6. “The witnesses claim about uniqueness and individualisation implies a probability of a 100% match. However, the witness is unable to supply any statistical calculations or empirical study data to back up this averment”
7. “the two cartridges involved in this case are made of different metals accordingly, one is not matching like for like, as the different metals have different qualities”
8. “although the witness ascribes to the identification theories of AFTE, she does not read all the articles and research, as published in the AFTE journals”
9. “the witness failed to mention any scientific basis or accepted foundation for her opinion”
10. “the witness is unable to explain either how many lines or patterns must match in order to make a finding and although she has been made aware, in training, of consecutive matching markings, her laboratory has chosen not to follow this more definitive criteria”
11. “when taking the photographs through the microscope, the witness used lighting, the angles of which she set by eye, without the use of a set protractor and concedes that the concept of shadowing can adversely affect the accuracy of discerning matching patterns or marks”
12. “although the AFTE theory dictates that one must observe the patterns which have the same density, height, width, depth, spatial relationship, curvature and position, this witness failed to consider density and height of the tool markings”
13. “the witness is unable to explain differences in tool markings on the separate cartridges and in effect, ignored substantial differences”
14. “it was apparent that the witness utilised selected portions of the exhibits in regard to the court charts which were provided and that she had difficulty explaining from the court charts how she arrived at her conclusion. This was so dramatic that the witness in fact, stated that the only way which she would be able to explain to the court how she come to the conclusion, is if the court was able to view what she viewed at the time through the microscope. The obvious logical conclusion to this was that the evidence which was placed before the court was insufficient for the witness to assist the court in understanding at how she arrived at her conclusions”.

The submission that the defence presents is: “...this witnesses’ evidence lacks any credibility or reliability and is not based on any objective or established scientific validity”.

S v CAKASAYO + others [2019] SS01/2016

During the Judgement of this matter, the following are some of the critical concerns pointed out by the judge.

- It was the submission of the accused that there is not sufficient scientific foundation for the admission of evidence where a particular fired ammunition component could be linked to a specific firearm and therefore accordingly the ballistics evidence presented by the state fails to be considered.
- The following concerns were also submitted as part of the accused arguments:
 - the two analysts were insufficiently qualified to express the opinions that they have formed,
 - the analysts did not succeed in providing sufficient evidence of their ability to express such evidence,
 - the analysts were insufficient in their demonstration of the reasons for forming their conclusion to which they testified, and
 - during their examinations failed to conform themselves properly to making the identifications that they purported to make.
- The value and purpose of an expert witness is summarised as follows: “An exception to this rule is the evidence of an expert. Such an expert may ‘assist the court to reach a conclusion on matters on which the court itself does not have the necessary knowledge to decide. It is not mere the opinion of the witness which is decisive but his ability to satisfy the court that, because of his special skill, training or experience, the research for the opinions he expresses are acceptable’,
- In our law both civil and criminal matters, the evidence of a witness’ opinion in relation to an issue before the court, is inadmissible because it is irrelevant.
- The court points out to be aware of the considerations the court has to make in cases of expert witness evidence and highlight a few principles as set out in the matter by Judge J. Vally in *Twine* and another v *Naidoo* and another [2017] ZAGPJHC 288 on 17 October 2017, as follows:
 - “(a) The admission of expert evidence should be guarded, as it is open to abuse”.

- “(b) Expert witnesses are allowed to explain their opinions, but are not the ones that determine the fact or facts in issue. That determination resides within the exclusive province of the judicial officer. An expert witness is not allowed to usurp this function, nor is a judicial officer allowed to abdicate this responsibility”.
- “(c) The expert’s evidence must be capable of being tested. It must be verifiable”.
- “(d) A court is not bound by, nor obligated to accept, the evidence of an expert witness”.
- “(e) The court must actively evaluate the evidence. There is no need for the court to be persuaded with the competing opinions of more than one expert witness in order to reject the evidence of that witness”.
- The court points out the awareness for courts as noted by Judge J. Boruchowitz in *S v Mkhize and others*, 1999(1) SACR 256 (WLD): In the absence of photographic evidence in support of the conclusions made, by the official of the SAPS Ballistics Laboratory, after observing the matches found between fired ammunition components of firearms tests and exhibits, the court could not accept his evidence.
- The court explains the following fundamental propositions that it does not dispute - a firearm firing ammunition components could be identified through certain gross or class characteristics, thus:
 - “a bullet of a particular calibre can only have been fired by a firearm using or permitting the use of that calibre of ammunition”,
 - “a rifled barrel of a firearm will impact grooves to a bullet fired through it that will establish the number of lands in that barrel and also the direction of that rifling”,
 - “a spent cartridge with a central primer has been fired by a firearm using a firing pin, but a rim fire cartridge case has been fired in a different type of firearm”,
 - “a cartridge case bearing an ejector mark has been fired by an automatic weapon”,
 - “ammunition fired by weapons from a particular manufacturer may bear marks that enable an examiner to determine the identity of that manufacturer”,
 - “these characteristics can usually be detected by a macroscopic, rather than a microscopic examination”,
 - “these characteristics as a whole, are known as class characteristics and therefore cannot be used to link fired ammunition components to an individual firearm”,
 - “imperfections in the firearm that come into contact with the ammunition in the firing process impart marks, often microscopic to the ammunition components”,
 - “imperfections that caused such marks can in the manufacturing process of the firearm be common to a series of such firearms made in the same manufacturing plant, but will not necessarily be found in all firearms made by that manufacturer. These are known as sub-class characteristics and therefore can also not be used to link fired ammunition to an individual firearm”,
 - “due to a number of variable factors, identical marks will not be made on all ammunition fired by the same firearm”,
 - “ammunition components fired by different firearms may well bear certain matching marks. Research has shown that up to 25% of such random matching marks may occur”, and
 - “marks made by imperfections occurring only in a particular firearm are referred to as individual characteristics”.
- The court accepts that statement by analysts within the ballistics environment that it is possible to link questioned fired ammunition components (bullets and cartridge cases) with a specific firearm, with tests available of such firearm, based on the presence of sufficient individual characteristics, thus the examination should be done following the above mentioned fundamentals, with considering sub-class characteristics, but using individual characteristics as matching marks.
- The court mentions of a comparison microscope, that can be used to superimpose (placed or laid over something else, typically so that both things are still evident) and juxtapose (place or deal with close together for contrasting effect) surfaces of the image of the two ammunition components, is used to determine whether there is sufficient correspondence to enable a match.
- The court refers to the known AFTE-TI and also take cognisance of the fact that although they are not members, the ballistics analysts of the SAPS laboratory subscribe to the principles of AFTE.
- “The definition of ‘sufficient agreement’ is circuitous”.
- In this matter the court was not properly informed by the analysts of the processes involved of concluding a match of striated marks, because the analysts failed to demonstrate to the court on photographs created by them:
 - the marks used for best known non-match,

- which apparent striated matching marks are random, and
- sub-class characteristics could not expressively differentiated from individual characteristics and therefore sub-class characteristics could not be assessed by the court.
- The court states that the firearm analyst agreed with the statement of reported research that up to 25% of marks considered to be matching striations on two exhibits maybe random, are being made by different firearms. The analyst informs the court that there could be no doubt that his identified matches are correct and he confidently declared that his error rate is zero.

USA v DEMONTRA HARRIS 1:19-cr-00358-RC:

USA (2020:1) In this matter we will discuss the judgement after Demontra Harris (defendant) charged with unlawful possession of a firearm, challenged to exclude the expert testimony of firearm examination. The defendant is prior felony convict of assault with a dangerous weapon and possession of a firearm during a crime of violence. USA (2020:2) points out that the defendant argued that the environment of ballistics is lacking a reliable scientific basis and is not premised on sufficient facts or data, thus it is not the product of reliable principles and method and is furthermore argued that were not properly applied to the facts of the case by Mr. Monturo the analyst. USA (2020:2) states that the court however disagrees with that as it was satisfied with the testimony of Monturo based on the Department of Justice’s Uniform Language for Testimony of Reports for the Forensic Firearms/Toolmarks Discipline – Pattern Matching Examination (DOJ ULTR). USA (2020:3) states that the testimony of a qualified analyst could be admissible based on the Federal Rule of Evidence 702 as follows:

“(a) - the expert’s scientific, technical or other specialised knowledge will help the trier of fact to understand the evidence or to determine a fact in issue”,

“(b) – the testimony is based on sufficient facts or data”,

“(c) – the testimony is the product of reliable principles and methods” and

“(d) – the expert has reliably applied the principles and methods to the facts of the case”.

USA (2020:3) points out that the Supreme Court with regards to ‘Daubert, 509 U.S. at 596’ noted that “it is not exclusion, but rather vigorous cross-examination, presentation of contrary evidence and careful instruction on the burden of proof that are the traditional and appropriate means of attacking shaky but admissible evidence”. Evidently in this document is also the fact that the defendant relied upon the PCAST-report in order to disqualify the credibility of the ballistics evidence. According to USA (2020:3) that district courts, when evaluating the admissibility expert evidence under Federal Rule of Evidence 702, have to fulfil a ‘gatekeeping role’ ensuring the expert’s conclusions are based on good grounds as a result of the valid methodology underlying its testimony. USA (2020:4) describes this gatekeeping analysis as “flexible and the law grants a district court the same broad latitude when it decides how to determine reliability as it enjoys in respect to its ultimate reliability determination”. USA (2020:4) points out that even though the district courts in order to assess reliability, apply a variety of different factors, the Supreme Court through Daubert provided a non-exhaustive list of five factors to guide the determination as follows:

“1. Whether the technique has been or can be tested”;

“2. Whether the technique has a known or potential rate of error”;

“3. If the technique has been subject to peer review and publishing”;

“4. The existence of controls that govern the technique’s operation” and

“5. Whether the technique has been generally accepted within the relevant scientific community”.

USA (2020:5) states that although the tendered-expert-testimony is considered reliable, the Court may still exclude it “if its probative value is substantially outweighed by a danger of one or more of the following:

- Unfair prejudice;
- Confusing the issues;
- Misleading the jury;

- Undue delay;
- Wasting time; or
- Needlessly presenting cumulative evidence.

Methods and Material

This study utilised the qualitative research method to analyse the fundamental validity of ballistic evidence. To understand the phenomenon analysing ballistic evidence, a qualitative case study was deemed the appropriate research methodology for this study. It is important to note that the Ballistics Unit is a national environment that is operated from, ① Pretoria examining cases for the provinces of Gauteng, Limpopo, Mpumalanga, Free-State and North-West; ② Plattekloof examining cases for the provinces of Western Cape and Northern Cape; ③ Gqeberha examining cases for the province of the Eastern Cape, and ④ Amanzimtoti examining cases for the province of Kwazulu-Natal. Thus, it was possible for the researcher to travel and approach any analyst and even any prosecutor countrywide for the purposes of data collection. As you could understand, our courts are guided by one criminal law that is applicable and the analysts also work under one Standard Operating Procedure (SOP) for the purpose of examinations. So, an analyst as a state employee is only employed at one of the four laboratories and not at any of the police stations. The SAPS permission for the researcher to conduct interviews were for any analyst employed at any laboratory, whereas the approval by the NPA head-office is only approved for prosecutors to be interviewed employed within the borders of the Western Cape.

Two groups of participants were interviewed and their background is summarised as follows:

Group 1: Ballistic analysts

This group comprises of experienced forensic scientists, who are all qualified and had completed the 3-year in-service training course, except for one who is an experienced researcher and lecturer within the environment. Thus, all analysts are experienced in the examination of ballistics-related evidence, except for the researcher who is only familiar with the theory.

Group 2: Attorneys and Prosecutors

This group comprises of experienced prosecutors, all involved with the prosecuting of criminal cases, except for one who is a private attorney (defence). Thus, during the completion of their duties, they must deal with ballistics-related evidence.

The literature review reported on the issue of analysts and forensic evidence being increasingly criticised, by especially the defence councils during criminal trials.

Results and Discussions

When participants were asked what qualifies ballistic analysts to testify in courts to report on the cases that they examined and how important their testimonies are to the courts in South Africa, the following responses were obtained:

So, question in issue in ballistics maybe probably is, does this piece of ammunition or ammunition component emanate from this particular firearm. The first question that the judge must ask himself is the person who is coming to court to give an opinion on that question qualified, how and if so, is the person qualified, what is his training, what is his experience, how many years is he in the job, how many examinations has he undertaken in order to determine whether that person can be expected to assist the court to come to a particular conclusion.

The expert is there to assist the judge to come to a conclusion, by explaining first of all expertise, secondly the method that he has adopted, thirdly the underlying principles of that method and fourthly to illustrate his conclusion (Participant 3).

The CPA provides permission by the mere admission of the 212-statement submission. If you work in any capacity for the government, you use your expertise, experience or your qualification (doesn't have to be a degree), had the following training in-house training from time to time, attend the following courses, explain chain of custody from your side, received the exhibit inside the bag and mentioning the bag I am an expert in my field, I have testified in so many cases thus far in my field, that document can be handed in as an exhibit and the court has to accept it as far as the defence can challenge it, but they have to accept it, they can call their own expert to say No we don't agree with that, but they cannot deny or prevent that document being submitted as evidence (Participant 7).

Analysts undergo a 3-year in-service training that include theory work, practical work and competency tests. The results of examinations are recorded in a 212-affidavit (Participant 10).

Experts have to be trained and possess a specialised skill. The conclusion of their examinations should be recorded in a 212 (Participant 15).

Participants were asked how important ballistic evidence is to the courts in South Africa? Furthermore, whether the courts are obliged to determine that, prior to accepting such evidence or testimonies, if it is scientifically valid or reliable? (Expert evidence or not). The following responses were obtained:

One of the problems in my opinion is that too many ballistic experts are coming to court testifying to a definite opinion without possibly properly explaining underline problems, underline research and underline methods which they followed and a zero critical examiner acceptance of that has a severe risk of unlawful convictions.

That is one of the danger areas, because the ballistics examiner comes to court, gives an absolute unqualified statement, which if it is not properly questioned and examined will be accepted (Participant 3).

Participants were asked to provide an opinion on the validity of firearm examination and identification, as currently presented in courts, whether it can be relied upon as reliable and accurate, the following responses were obtained:

I believe if you want to test the analyst's training and qualification, you do it through cross-examination. The 212-affidavit should be accepted and there is sufficient case law to back this up, until such time that other credible evidence is presented that convinced the presiding officer that he can no longer rely on the contents of that 212-affidavit. The defence can only object to the submission of the 212-affidavit if there is a problem with the formal requirements of 212-affidavit, i.e. this person is no longer employed by the State, but if the other 4 or 5 formal requirements of the 212-affidavit are met, the prosecutor should hang in the 212-affidavit (Participant 9).

When analysts testify in court, it is considered critical information that could be considered as an aid to assist the prosecution to prove a case against an accused. This evidence however will remain irrelevant until the court decide that the evidence is acceptable for consideration (Participant 15).

According to Grzybowski *et. al.*, (2003:216), by adding weight to the analyst's testimony, the court is interested in the known or potential error rate, therefore, should the analyst testify about the reported error rates in firearm individualisations, the actions taken individually and the peer and administrative review processes of the laboratory to ensure that the possibility of error is cut in the work, should also be mentioned.

Menday v Protea Assurance – The court also reiterates that it is not the mere fact of the expert's opinion that is decisive, but also the ability of the expert's witness to satisfy the court based on his specialised skill, training and experience, for the reasons of the expert witness' opinion that is acceptable for the court.

S v Mkhize – This affidavit was prepared in accordance with the provisions of SS 212(4)(a) and 212(8)(a) of the Criminal Procedure Act 51 of 1977 (the Act). Therefore, from its observation, the court, because of the specialised nature of the investigation and its untrained eye, considers itself not sufficiently qualified to draw any conclusions and would therefore depend on the evidence of a forensic ballistics' specialist.

S v Cakasayo – It was the submission of the accused that there is not sufficient scientific foundation for the admission of evidence where a particular fired ammunition component could be linked to a specific firearm and therefore, accordingly the ballistics evidence presented by the state fails to be considered. The court explains the following fundamental propositions that it does not dispute – a firearm firing ammunition components could be identified through certain gross or class characteristics. The court accepts that statement by analysts within the firearm identification environment, that it is possible to link questioned fired ammunition components (bullets and cartridge cases) with a specific firearm, with tests available of such firearm, based on the presence of sufficient individual characteristics, thus the examination should be done following the above-mentioned fundamentals, with considering sub-class characteristics, but using individual characteristics as matching marks.

S v Conradie – The submission that the defence present is: "...this witnesses' evidence lacks any credibility or reliability and is not based on any objective or established scientific validity".

USA v Demontra Harris – USA (2020:9 to 20), mentions that it willingly undertakes to discuss factor-by-factor the relevancy of the environment's reliability as it pertains to the Daubert standard in response to the defendant's claims or request to exclude the proposed testimony of the analyst:

1. Whether the methodology has been tested:

Thus, all the reasons rose by the court, it concludes that the testability factor is sufficiently admissible for the analyst's testimony.

2. The known or potential error rate:

The court then favourably admitted the expert testimony of the analyst, considering the error rates for false identifications made by analysts were low, even under the PCAST's black-box study requirements.

3. Whether the methodology has been subject to peer review and publication:

Thus, the court also favourably admitted the expert testimony of the analyst as it is of the opinion that his evidence fulfilled to this requirement.

4. The existence and maintenance of standards to control the methodology's operation:

However, the court still opines that the non-meeting of this required test does not disqualify the evidence of the analyst.

5. Whether the methodology has achieved general acceptance in the relevant community:

According to the court it is satisfied that the prosecution submitted more than sufficient evidence to prove that the AFTE theory utilised by the analyst enjoys widespread scientific acceptance.

This study has pointed out the importance of a 212-affidavit. If all requirements have been met, that the conclusion of examinations performed can be credible evidence, as *prima facie* suggest during criminal matter in court. This study has also pointed out matters where analysts made critical mistakes in their 212-affidavits. The researcher highlights some of the important aspects of ballistics and analysts as pointed by the courts:

- Analysts should possess knowledge, training and experience of the specialised field they are testifying about.
- The court considered microscopic comparisons as reliable.
- The court does not dispute the foundational validity of ballistics.
- The court accepts the statements of analysts regarding their opinion to individualise firearms.
- Sub-Class characteristics be considered when making identifications, but individual characteristics should be utilised to make such identifications.

This of course convincingly addressed the argumentative submission by the defence that there is no existence of a scientific foundation for ballistics, that the analysts were insufficiently qualified to express the opinions that they have formed and during their examinations failed to conform themselves properly to making the identifications that they purported to make.

The researcher highlights some of the flaws by analysts during court proceedings:

- The analysts omitted to provide proper explanations for the opinions they expressed.
- Failure to complete all prescribed documentation.
- Taking of photographs of all positive microscopic comparisons at the time of the examination and comparison.
- Several significant errors contained in the 212-affidavit of the analysts.

The defence also mentioned that the analyst made a bland statement after matching two fired cartridge cases. It is clear from the court cases discussed during this study' that the aspects that are targeted by defence attorneys and critics are the following:

- The scientific foundational validity of ballistics has not been proven.
- The accreditation status of the FSL.
- Sub-Class characteristics, the fact that it might be confused with individual characteristics.
- The subjective interpretation of comparison results.
- The unavailability of photographic evidence displaying the proof of identification marks.
- The non-existence of a known error rate to verify reliance on analysts' accuracy.
- Statistical standards to make identifications.
- Absence of black-box studies.

This study has pointed out that in the USA, two standards are employed as a gatekeeping role to ensure that ballistic examinations and testimonies are valid and reliable namely:

- The Federal Rule of Evidence 702.
- The Daubert 509 US at 596.

Opposed to this in South African courts, there is no gatekeeping system, the analysts only have to meet the requirements of the 212-affidavit. Participant 6 has pointed out that the authority to prosecute rests with the NPA and thus, no other gatekeeping system exists. This study has determined that the evidence of ballistics is extremely important to the courts and it can assist the courts in reaching conclusions in firearm related cases like murder and robberies, just to name a few. However, the literature and participants (see participant 6) state that the analyst cannot exert the function of the court. So, in the case where the court is convinced and accepts the reliability of the evidence, then only the evidence will become relevant and be accepted by the courts. That decision and obligation rests with the courts, therefore the analyst has to be very thorough and competent during his testimony. Analysts report the results of their examinations in a 212-affidavit and this document proves to be a very powerful weapon when all the requirements are met. What the participants 6, 7 and 15 emphasised is that an analyst has to be in the service of the State, highly trained and skilful and should be able to testify about their examination where a layperson is not able of doing so. It is also important as suggested by researchers such as Grzybowski *et. al.*, (2003), that results of proficiency tests can be utilised to strengthen the reliability of the firearm individualisation evidence. The court in the matter of S v Cakasayo has accepted the fact of firearm individualisation and thus makes it easier or confirms that such evidence has a rightful place within the CJS, if correctly, reliably and convincingly explained of all the processes involved. This completely overpowers the argument of participant 3 that states the ballistics examiner comes to court to give an absolute unqualified statement. The court in the matter of USA v Demontra Harris has outlined and confirmed its acceptance that the fundamental validity of firearm individualisation evidence completely met the requirements of the Daubert-standards.

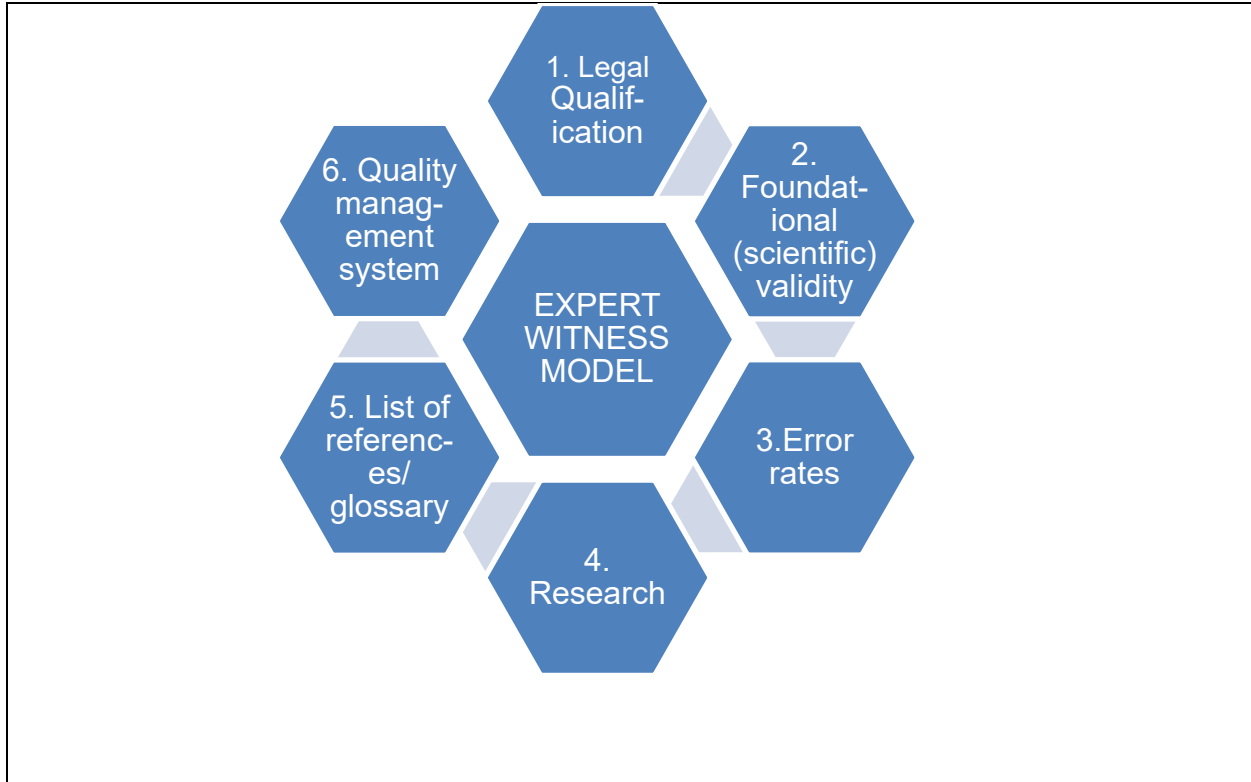
This study has pointed out certain manufacturing processes that created influencing marks, whether sub-class or individual characteristics. This is also evidently noted by researchers like Grzybowski *et. al.*, (2003), Smith (2004), Miller and Beach (2005), Bunch *et. al.*, (2009), SWGGUN (2017). This study has brought forward sufficient information that fundamental validity of ballistics is founded on the manufacturing processes and assembly of the different firearm parts, as well as the manufacturing and assembly of ammunition components to a lesser degree. What stood out during this research, as various researchers and participants indicated, is the effect that the different tools have on the different firearm parts and the marks left during the different processes.

Recommendations

Through a comprehensive analysis of the data, evidence-based recommendations are presented that can guide stakeholders, including forensic analysts, legal professionals, and policymakers, in making informed decisions regarding the utilisation, presentation, and interpretation of ballistic evidence. These recommendations are intended to ensure the reliability, validity, and overall effectiveness of ballistic evidence, thereby contributing to the fair and just administration of justice.

Analysts should take cognisance of the fact that their evidence is considered irrelevant, and they are not the ones that determine the fact or facts at issue, but that determination resides with the court. Analysts should ensure that they testify with clarity and precision. Thus, it is recommended that each local analyst, during casework, create a microscopic database in the form of microscopic comparison photographs of identifications, to build a profile. The microscopic database can be utilised for demonstration purposes to the court in addressing the issues of BKM, BKNM and subjectivity. This will prove the analyst's experience, being exposed to such a huge variety of different kinds of marks appearing, thus building a threshold of evaluation for him/her.

In the context of a court setting, one model that can be utilised to provide assurance of the fundamentals of ballistics, is the Expert Witness Model. The researcher recommends that this model be developed to ensure that analysts presenting their documents and their findings to the court have the necessary training, expertise and credibility to provide reliable and unbiased information. The Expert Witness Model is illustrated as follows in figure 2:



1. Legal qualification

- 212-affidavit
- service of the state
- formal qualification achieved
- specialised training and skills
- experience
- better technological advanced developed court chart

2. Foundational (scientific) validity

- manufacturing processes where machined tools leave marks on firearm part surfaces
- marks appear in striated and indented shapes forming unique patterns on ammunition components
- microscopic comparisons utilised to observe marks on cartridge cases and bullets respectively

3. Error rates

- no published local error rates or proficiency test results
- Fadul (2011) - 0,4%
- Fadul (2013) - 1,2%
- CTS (2019) - 2,1%, 2,1% and 0,4%
- CTS (2020) - 0,4%, 1,1% and 0,4%

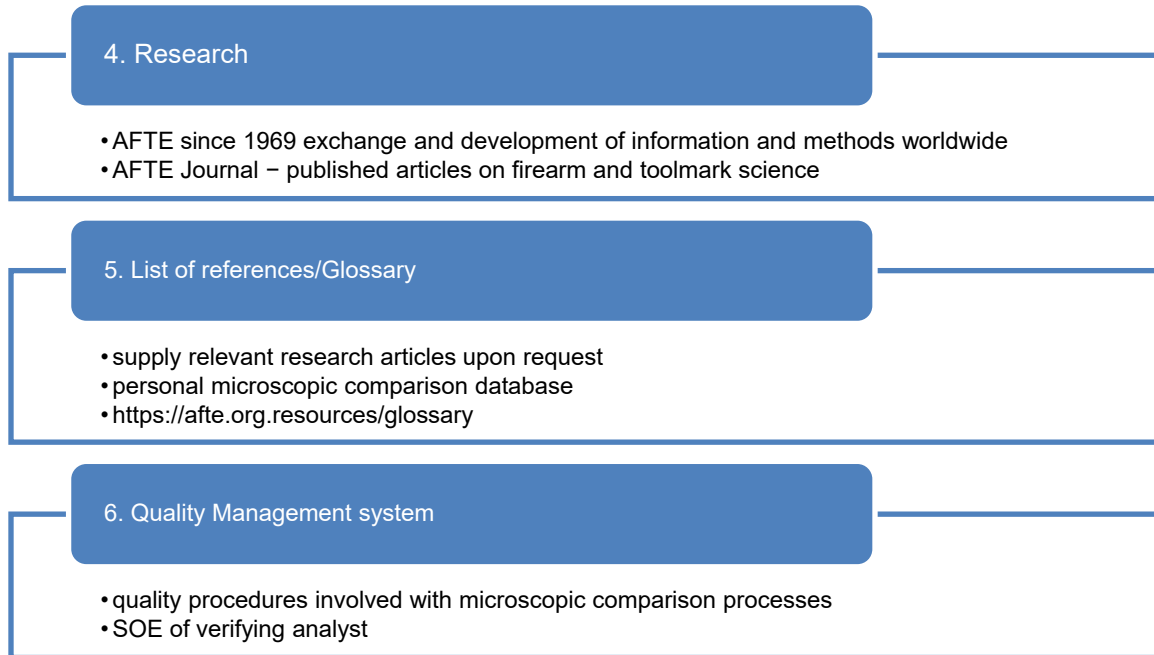


Figure: 2 - Source: Authors illustration

Conclusion

Ballistic evidence plays a crucial role in criminal investigations and trials, providing valuable information to establish facts, determine the origin of fired exhibits, and contribute to the overall understanding of forensic science. The aim of this study was to investigate the fundamental validity of ballistics and its alignment with the requirements of forensic science. Through this research, several critical factors essential to the fundamental validity of ballistics were identified and addressed. These factors include manufacturing processes, class, sub-class, and individual characteristics, AFTE (Association of Firearm and Tool Mark Examiners) standards, subjectivity versus objectivity, biasness, absolute versus practical certainty, research studies, error rates, laboratory accreditation status, training and skills of analysts, and the compliant expert evidence of the 212-affidavit. Thus, this study concludes that ballistics, as a forensic science, is extensively studied and enables analysts to perform examinations and provide conclusions to the criminal justice system. By implementing the Expert Witness Model, courts can rely on qualified and credible analysts who provide reports, documents, 212-affidavits, or testimonies that assure the court of their expertise. This practice will enhance the accuracy and reliability of expert evidence, promoting fairness and justice in legal proceedings.

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