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A critical analysis of ballistic evidence in South Africa

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Abstract: Ballistic imaging systems will facilitate solve gun crimes by comparison pictures of cartridge cases, that are recovered from a criminal offense scene or test-fired from a taken gun, to an information of pictures obtained from past crime scenes. Automated ballistics imaging and analysis systems, admire the integrated identification system (IBIS) have advanced gun enforcement operations by permitting pictures of gun crime proof to be chop-chop compared to an outsized inventory of proof collected from alternative crime scenes. When small-arm examiners ensure candidate matches, detectives will use the data generated by the links among gun crimes to assist solve their cases. Links between recovered cartridge casings represent most trajectory matches created through wader. This study focused on the operations within the field of ballistics, specifically from the perspective of South Africa. Its primary objective was to establish a reliable process for determining the origin of fired exhibits such as cartridge cases and bullets, which is crucial for firearm individualisation in the context of forensic science and its applicability in South African courts. Ballistics is a specialised unit within the South African Police Service (SAPS), operating under the Division of Forensic Science Laboratory. Recently, there has been increased scrutiny of the ballistics field within South African courts, with defense teams arguing that it is not a forensic science. This study followed a qualitative research technique utilising a non-probability sampling 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. The research findings highlighted two key disciplines relevant to the study: forensic firearm examination and forensic firearm identification. 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 recommends that local analysts should have more opportunities to visit firearm factories for research purposes. Additionally, it suggests that sub-class characteristics should be given greater consideration, like class characteristics and individual characteristics, particularly in the context of the 212-affidavit. The study adequately addresses various factors, including manufacturing processes, class, sub-class, and individual characteristics, the AFTE-Theory of Identification, and the subjective versus objective nature of analysis. The researcher 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, bullet, cartridge case, firearm, forensic science, fundamental.

Introduction

Notwithstanding the acceptance of firearm identification by courts, the scientific community has been reluctant to recognise firearm identification as a reliable method of conclusively establishing a connection between a particular bullet and a particular firearm. The research which informs this article was prompted by the fact that the relevant scientific community has reservations regarding the way in which firearm identification has traditionally been accepted in courts and is sceptical regarding the assumption that current firearm identification methods can conclusively establish a connection between a specific bullet and a particular firearm. Ballistics is a

specialised unit within the South African Police Service (SAPS), operating under the Division of Forensic Science Laboratory (FSL). Recently, there has been increased scrutiny of the ballistics field within South African courts, with defense teams arguing that it is not a forensic science. This study intended to determine whether the field of forensic science is valid and whether the environment of firearm individualisation (ballistics) conforms to that validity, especially from a South African perspective. This is important because law-enforcement agencies employ this ballistic evidence during criminal investigations (especially those of gun violence) and in almost all the court cases where applicable. The findings of this study will close the gap regarding the ongoing debates regarding admissibility of evidence – what it serves as a determining or crucial factor, to assist the judicial entities to reach conclusions. South Africa is confronted with violent crime such as cash-in-transit (CIT) robberies, political assassinations, and taxi violence where, the uses of firearms are common. The Southern African region is awash with small arms and munitions, flowing freely across borders of countries. Nowhere is the impact felt more than in South Africa. It is estimated that there are about eight million illegal small arms circulating in South Africa. In addition, there are four million licensed small arms in South Africa (Beri, 2000:151). According to Bruce (2023), multiple murders in South Africa have escalated considerably in recent years. The number of incidents in which three or more people were killed in 2022 was 140% higher than in 2019/20. Together with major increases in the murder rate, these killings highlight a significant shift in violent crime, characterised by the rise of firearm use and entrenched organised crime, particularly in some provinces. The rise of violent crime linked to proliferation of small arms and assault rifles is one of the major threats to the security of South Africa in the post-apartheid era. Thus, firearm evidence becoming such a crucial part during court cases and ballistic-forensic-examiners (analysts) that testify during these court cases considering themselves as experts according to law.

Literature Review

The impact of illegal firearms

Bruce (2023) points out that the South African Police Service (SAPS) data shows that these attacks make up a small proportion of total murders. In the 2022 calendar year, 2 430 people – 9% of the 27 066 murdered – died in multiple-killing incidents. Nevertheless, this is a substantial increase from the 5.3% of victims who died in this way in the 2019/20 financial year. According to SAPS figures, there were 1 057 multiple murder incidents in 2022. In 806 (81%), two people were killed. There were 174 incidents (17%) in which three or four people died, and 20 (2%) in which between five and seven were killed (see pie chart). In two incidents (0.2%), eight people were murdered in each attack. The major driver of rising multiple murders is criminals' increased use of firearms. The killings are in some respects part of the normal epidemiology of gun use in crime, which often results in more than one person dying or being injured. The provinces where multiple murders contribute most to the overall murder rate – notably KwaZulu-Natal, but also Gauteng and the Western Cape – have the highest levels of firearm use in violent crime. Many deaths in multiple killings can be considered 'incidental'. The perpetrator's intention may be to kill a specific person, but one or more die in the ensuing gunfire. Such multiple murders reflect an extraordinary degree of callousness regarding the potential loss of life.

Ballistics: Background Information

According to Heard (1997:75), there are basically three categories of ballistics:

- Internal ballistics is the study of what happens inside the barrel of a weapon from the moment the firing pin hits the primer to the time when the bullet leaves the barrel. It is mainly concerned with propellant pressures, acceleration of the missile whilst it is in the bore, muzzle velocity and recoil;
- External ballistics deals with the flight of the bullet from the muzzle of the weapon to the target. This is a most complicated subject as it involves taking into account many variables such as bullet shape, sectional density, atmospheric pressure and in larger calibre weapons, even the rotation of the earth; and
- Terminal ballistics deals with the behaviour of the bullet on reaching the target. Its performance and wounding capabilities in animal tissue are addressed as well as its performance in water, soil, brick, concrete, wood or bullet resistant materials.

According to Bolton-King (2017A:159 & 160), the common abuse of the term 'forensic ballistics' to holistically cover all three core disciplines namely, 1) forensic firearm examination that deals with the mechanism examination and functionality of the firearm, 2) forensic firearm identification that deals with the microscopic comparison of fired exhibits; and 3) ballistics that deals with the motion of the bullet since being fired until reaching a target.

The Significance of Ballistics: the cornerstone to firearm individualisation

According to Thompson (2010:11) the Association of Firearm and Toolmark Examiners (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). The AFTE-TI is scientifically valid through utilising scientific method it is empirically testable, has been scientifically tested and has not been proven false, Grzybowski et al. (2003:213).

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).

The fundamental principles of ballistics evidence

Bunch, Smith, Giroux and Murphy (2009:3), state that the scientific foundation for the basis of the ballistics environment is constituted by two general propositions. The first proposition that Bunch, *et. al.,* (2009:6), mention is: "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, the working tools during

the manufacturing processes will transfer random marks onto parts such as barrel bores, breechfaces, firing pins, etc. This is due to toolwear and chip formation or by electrical/chemical erosion.

Thompson (2010:13), states that a unit of ammunition is referred to as a cartridge and this consists of components namely a cartridge case, primer, propellant and a bullet. Walker (2013:46), explains the four components that would be assembled in a cartridge as follows:

1. A cartridge case constructed of metallic or non-metallic material (this is usually brass, nickel or aluminium);
2. A primer that detonates when acted upon by an external force (this is usually brass or nickel material);
3. Propellant assembled inside the cartridge case, a charge that provides the energy for the expulsion of the bullet;
4. A bullet is pressed into the mouth of the cartridge case (this usually consists of a lead core for weight and covered by brass or copper).

Walker (2013:20), also mentions that, upon firing, the primer will ignite that causes an intense super-hot fire passing through the flash holes which detonate the propellant. This detonation creates a gas as a by-product and this gas causes pressure to build up inside the cartridge case and forces the bullet to be separated from the cartridge case, forcing it to move through the barrel, and the cartridge case is forced against the walls of the firearm. The walls of the firearm mentioned here, is called the breech face and the chamber. During this process where the bullet moves through the barrel and the cartridge case is forced against the walls, identifiable marks are transferred from the firearm parts onto the ammunition components. Here we also have to note that the firearm parts (hardened steel metal) are harder metal than the cartridge (usually brass or nickel for cartridge case and brass or copper for the bullet). 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”. During most manufacturing processes, the transfer of rapidly changing or random marks occurs onto work pieces such as barrel bores, breech faces, firing pins, etc. of which is the result of the phenomena of tool wear and chip formation or by electrical/chemical erosion (SWGGUN, 2017:182). As a result of further wear or abuse, microscopic marks on tools may then continue to change and these irregularities are considered unique and they are used to individualise one tool from another, because during the contact of the edges of these tools with the work piece, those random irregularities may be transferred to the work piece in the form of a toolmark (SWGGUN, 2017:182).

It is argued that the existence of sub-class characteristics are individualised through the combination of hand-sanding, sand blasting and glass-beading that could be the cause of the granular finish as a result of the abrasives changing the planar structure of the surface of the toolmarks on the breech faces (Lightstone, 2010:321). Lightstone (2010:308), informs us that usual identifiable appearances of sub-class characteristics are gross, continuous, uniform, evenly spaced, parallel and concentric marks and mostly consecutively produced firearm parts will possess it, as they are produced from machined surfaces of the same tool with the same state of wear. Therefore, in order to validate the science of ballistics, many studies have been conducted, utilising consecutively manufactured firearm parts, and some of the studies identified the end mill, lathe turner and broach as some of the processes that are likely to cause sub-class characteristics. Even though sub-class characteristics may not appear on all working surfaces, they are directly related to the manufacturing process by which a tool was created and finished (Nichols, 2018:84).

According to Owens (2017:208), the manufacturing processes involving the production of the finished parts are the origin of the individuality of firearm components. Owens (2017:208), states such processes can include filing, sanding and grinding as a result of the randomness of which the tool surface makes contact with the component part, as well as the relative quickness of the wear changing the tool surface. Smith (2004:130), states that the foundations of firearms individualisation have been supported by prior validation studies through obtaining test samples from consecutively manufactured barrels. Smith (2011:45), summarises the following interests from a 2007 survey:

- in 2007 a total amount of 1,7 million firearms were imported or manufactured in the United States,
- broach method used by 11 companies (36,6% of firearms),
- button method used by 16 companies (39,1% of firearms),
- electrochemical method used by 01 company (10,6% of firearms), and
- hammer forged method used by 07 companies (13,7% of firearms).

Bolton-King (2017B:226), states that, based on the research conducted for her article, the following process is still used by semi-automatic pistol manufacturers:

- Cut – rifling occurs when scraping or cutting away metal from the barrel bore to create the spiralled grooves;
- Forged – rifling occurs through the compression and displacement of barrel material opposed to material removal, whereas hammer forging is typically an elongation of the barrel. The effect of the work-hardening of the compression process, caused the forged barrel to increase in hardness, becomes wear and corrosion resistant and therefore is more durable. Hammer forging is the process of the outside of the barrel being hammered onto a mandrel at room temperature that possesses the inverse rifling profile. With button rifling, the mandrel is forced and rotated through the barrel bore of a smaller diameter than the button (rifling tool); and
- Chemical removal – electrochemical rifling generates the grooves through chemically stripping away the metal from the barrel bore using electrolysis.

Lightstone (2010:321), explains after a tour at the Smith & Wesson factory how the manufacturing process could influence the causes of the marks on the breech face as follows: “Even though the breech faces have the overall same striated appearance when viewed perpendicularly, topographically they are different in that the raises and depressions caused by the abrasive finishing causes them to mark differently during the dynamic process of firing. The slight breaks on the surface of the gross striae on the breech face perhaps caused them to produce individual characteristics which allowed differentiation of the cartridge cases produced by each slide”. Lightstone (2010:321), points out about this very important detail, that even though some tests displayed general appearances due to the gross broach striae, the actual patterns displayed, as a result of individual characteristics, were too different for a competent firearm analyst to make a false identification, and it is noteworthy to mention during comparisons. It could be observed that, considering the influence of sub-class characteristics with similar appearance and layout generally, the fine detail was never in agreement to make a false identification. According to Owens (2017:208), the manufacturing processes involving the production of the finished parts are the origin of the individuality of firearm components. Owens (2017:208), states that such processes can include filing, sanding and grinding as a result of the randomness of which the tool surface makes contact with the component part, as well as the relative quickness of the wear changing the tool surface. Unlike this, casting, forging and moulding are processes that tend to produce relative uniform component parts and as a result of this each component part makes contact with the tool surface in the same manner, and the wear and tear is slower and therefore, during these processes, to typically impart significant individuality is highly unlikely (Owens, 2017:208). Thus, two consecutively manufactured items might have similar physical characteristics imparted by the manufacturing process and tools used and be more similar than items manufactured by different tools (Owens, 2017:208).

According to Owens (2017:209), the reason for his study was to answer the following two questions:

- will there be sub-class characteristics present in the consecutively rifled barrels of the Hi-Point 9mm pistol as a result of the manufacturing or rifling processes; and
- are there sufficient quality and quantity of individual characteristics present on bullets fired from consecutively rifled Hi-Point 9mm pistol barrels to determine the barrel they were fired from.

Owens (2017:213), concluded that, consecutively rifled barrels used for his research proved that the barrels possess individual characteristics that are transferred onto the bullets during the firing process which could be used to identify the exact barrel that the fired bullet travelled through. Owens (2017:213 & 214), states that no significant sub-class characteristics were observed as a result of the button rifling process used by Hi-Point firearms and as a result of two steps in the manufacturing process, namely specifically cold drawing and deburring, sub-class characteristics should not be expected in the Hi-Point 9mm pistol, as those two processes create individual characteristics on the barrel surfaces that subsequently might be transferred to the bullet during the firing process.

Mejia, Cuellar and Salyards (2020:298), inform us that an important tool to add to the forensic quality assurance programs is blind proficiency testing, which can demonstrate quality and provide insight into the errors that occur in a laboratory in everyday casework. Thompson and Cásarez (2020:663-668), point out the following benefits when implementing blind testing proficiency testing:

- Enabling the calculation of error rates and other statistical evaluation of forensic methods.
- Improving quality control procedures.
- Testing all laboratory systems.
- Exposing forensic fraud.

Fadul, Hernandez, Wilson, Stoiloff and Gulati (2013:2), concluded that their research established an error rate of less than 1.2%. Fadul *et. al.,* (2013:5−6) point out several studies that dealt with the Ruger Consecutively Manufactured Gun barrels as follows:

- Brundage (1998) – Tests fired from 10 consecutively manufactured 9mm Ruger gun barrels were sent to 30 analysts throughout the United States to determine whether analysts could properly identify the questioned bullets and match them to the consecutively manufactured barrels which resulted in no incorrect answers after the evaluation of the submitted results.
- Hamby (2001) – utilising the same barrels as the 10 consecutively manufactured 9mm Ruger gun barrels in Brundage (1998), sent to 204 analysts [including the 30 of Brundage (1998)] of several countries and 201 analysts returned their results with no incorrect identifications made.
- Hamby and Brundage (2007) – utilising the same barrels as the 10 consecutively manufactured 9mm Ruger gun barrels in Brundage (1998), sent to 438 analysts in 17 countries with no incorrect identifications made, but Hamby reported an error rate of .001% based on the data collected from the 438 analysts.
- Hamby, Brundage and Thorpe (2009) – utilising the same barrels as the 10 consecutively manufactured 9mm Ruger gun barrels in Brundage (1998), sent to 507 analysts in 20 countries with no incorrect identifications made,
- The existence of the hypothesis of the ability of firearm analysts, on an international level, to identify bullets and determine that they have been fired through a particular barrel with a reasonable degree of scientific certainty has been repeatedly supported, as well as the foundational concepts of firearm examination.

Nichols (2007:589), explains that ballistics is both objective (with the observations) and subjective (the interpretation of those observations) orientated. He uses the example of a bullet to explain – it consists of a series of striated marks on the land impression, a discrete location and a certain distance from the shoulder, with a particular width and depth and a pattern appearance. When the analyst is exposed to similar, but knowingly different toolmarks, he can develop a Best Known Non Match (BKNM), that will enable him to evaluate the quantity and quality of individual characteristics in questioned toolmarks experienced during casework (Bolton-King, 2017A:167).

Nichols (2007:593), concludes in his article with the following suggestions:

1. Firm scientific foundations are the root of firearm individualisations.
2. The precepts of the scientific method culminating in the AFTE-TI have been employed to critically study firearm individualisations.
3. Sub-class characteristics and the change a tool surface undergoes over time cannot propose to the invalidation of firearm individualisation as a science nor should it add less dependence for admissibility in a court of law.
4. The environment of firearm individualisation has been validated in a manner that is appropriate for evidence of the kind to be expected for such an environment.
5. The court and the environment can be provided with measured proficiency tests and error rates as a useful guide to the frequency with which misidentifications are reported within the environment, utilising appropriate methodologies and controls.

Hill (2016:108) states that the objective to acquire the Integrated Ballistics Identification System (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. According to Hill (2016:2), IBIS is a computer system administered by an international company that captures pictures of the marks on fired cartridge cases and bullets. Hill (2016:2) mentions that the details of the different cases and the physical exhibits are loaded on the computer system by analysts as they initiate the

acquiring process of the fired exhibits. 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.

According to Grzybowski *et. al.,* (2003:216), the only source of international proficiency testing results in the ballistics environment is Collaborative Testing Service (CTS) and from whom a potential error rate may be obtained. They furthermore mention that international subscribers receive about 20% of CTS firearm proficiency tests.

CTS (2020:3), describe the following proficiency test of ballistic results, after 237 responses were obtained during 2019. Each participant received one of the samples which was made up as follows: three bullets each marked as **Item 1** fired from a known firearm (1st firearm), two bullets marked **Item 2** and **Item 3** respectively being fired by the same firearm (2nd firearm), one bullet marked **Item 4** fired from another firearm (3rd firearm) and one bullet marked **Item 5** fired from the 1st firearm. CTS (2020:10), illustrates it (figure 1) as follows:

Response Summary — Participants: **237**

Were any of the recovered questioned bullets (Items 2-5) fired in the same firearm as the known bullets (Item 1)?

Responses	Item 2	Item 3	Item 4	Item 5
Yes	**5** *(2.1%)*	**5** *(2.1%)*	**0** *(0.0%)*	**236** *(99.6%)*
No	**198** *(83.5%)*	**198** *(83.5%)*	**236** *(99.6%)*	**1** *(0.4%)*
Inc	**34** *(14.3%)*	**34** *(14.3%)*	**1** *(0.4%)*	**0** *(0.0%)*

Figure 1 – Source: CTS (2020:10).

CTS (2021A:3), describe the following proficiency test of firearm examination results, after 283 responses were obtained during 2020. Each participant received one of the samples which was made up as follows: three cartridge cases each marked as **Item 1** fired in a known firearm (1st firearm), three cartridge cases marked **Item 2, Item 3** and **Item 5** respectively being fired in the same firearm (1st firearm), one cartridge case marked **Item 4** fired in another firearm (2nd firearm). CTS (2021A:13), illustrates it (figure 2) as follows:

Response Summary — Participants: **283**

Were any of the questioned expended cartridge cases (Items 2-5) discharged from the same firearm as the known expended cartridge cases (Item 1)?

Responses	Item 2	Item 3	Item 4	Item 5
Yes	**282** *(99.6%)*	**280** *(98.9%)*	**1** *(0.4%)*	**283** *(100.0%)*
No	**1** *(0.4%)*	**3** *(1.1%)*	**270** *(95.4%)*	**0** *(0.0%)*
Inc	**0** *(0.0%)*	**0** *(0.0%)*	**12** *(4.2%)*	**0** *(0.0%)*

Figure 2 – Source: CTS (2021A:13).

CTS (2021B:3), describe the following proficiency test of firearm examination results, after 345 responses were obtained during 2021. Each participant received one of the samples which was made up as follows: three cartridge cases each marked as **Item 1** fired in a known firearm (1st firearm), four cartridge cases marked **Item 2, Item 3, Item 4** and **Item 5** respectively being fired in another firearm (2nd firearm). CTS (2021B:13), illustrates it (figure 3) as follows:

Response Summary Participants: **345**

Were any of the questioned expended cartridge cases (Items 2-5) discharged from the same firearm as the known expended cartridge cases (Item 1)?

Responses	Item 2	Item 3	Item 4	Item 5
Yes	**0** *(0.0%)*	**0** *(0.0%)*	**0** *(0.0%)*	**0** *(0.0%)*
No	**332** *(96.2%)*	**332** *(96.2%)*	**332** *(96.2%)*	**332** *(96.2%)*
Inc	**13** *(3.8%)*	**13** *(3.8%)*	**13** *(3.8%)*	**13** *(3.8%)*

Figure 3 – Source: CTS (2021B:13).

Sanas (2016:38), states that: "A proficiency-testing program is a reliable method of verifying that the laboratory's technical procedures are valid and that quality of each examiner's work is being maintained". Sanas (2016:3), states that the requirements to be met by the laboratory, if it is to be recognised as being competent to carry out tests and/or calibrations, including sampling, are recorded in the ISO/IEC 17025. Thus, what it mentions is applicable to all such facilities, regardless of the size or type of services provided.

Wheeler and Wilson (2008:112), describe the comparison microscope 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 (2008:7), states the intended purpose of the Leica FS C (Forensic Solution Comparison) comparison microscope, as well as the Leica FS CB comparison bridge microscope variant and the Leica FS4000 with two imaging beam parts, was designed for the comparison of items as mentioned below in split images in forensic laboratories, banks, etc.:

- evidence on fired ammunition components,
- toolmarks,
- hairs and fibres,
- documents, etc.

Critical challenges to ballistic evidence

According to Schwartz (2005:42), considering the key role that firearm identifications have in obtaining convictions, all firearm identifications should not be accepted until the development of firm statistical empirical foundations for identifications and a meticulous system of blind proficiency testing.

Schwartz (2005:5−12), argues the following three points as pitfalls in the examination of ballistics:

- "The individual characteristics of toolmarks are comprised of non-unique marks". Individual characteristics of toolmarks are made up of non-unique marks similar to the agreement of parts of each individual's fingerprints and nuclear DNA.
- "Sub-class characteristics shared by more than one tool may be confused with individual characteristics unique to one and only one tool". A toolmark might also be incorrectly identified as being created by a specific tool when sub-class characteristics might be confused with individual characteristics, which is supposed to be unique to one and only one tool. "Firearms and toolmark examiners have also failed to develop any rules for distinguishing between sub-class and individual characteristics". For the analyst to equip himself to avoid the aforementioned: "…examiners can only rely on their personal familiarity with types of forming and finishing processes and their reflections in toolmarks".
- "The individual characteristics of the marks made by a particular tool change over time". Due to the changes in toolmarks, the differences between fired exhibits and test fires can sometimes be attributed to changes on the surfaces of the suspected firearm between the time of firing the exhibits and firing the tests, whereas at other times, such attribution might be incorrect because the source of the fired exhibits could be a similar firearm to that of the suspected firearm.

With regards to the AFTE-TI, NAS (2009:155), argues as follow: "The meaning of exceeds the best agreement and consistent with, are not specified and the examiner is expected to draw on his or her own experience. This AFTE document, which is the best guidance available for the field of toolmark identification, does not even consider, let alone address, questions regarding variability, reliability, repeatability or the number of correlations needed to achieve a given degree of confidence". 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 (2016:12), opines that the path forward to strengthen the scientific underpinnings of the ballistics environment is one of two directions, namely (a) by conducting more black-box studies to assess the scientific validity and reliability and examiners partaking in more rigorous proficiency testing utilising more appropriately challenged problems and publically reports that the test results will ensure an improved firearm analysis environment as a subjective method, and (b) the conversion of the environment from a subjective method to an objective method which will require a process of development and tests of algorithms on image analysis for comparing the agreements of marks on bullets. Encouraging progress has already been done on this process, but the continued development of the method can be benefited through access to large and complex databases. PCAST (2016:40 & 41), also describes two court cases utilised as references in the courts of the USA to determine the validity or admissibility of forensic evidence namely, *Frye v United States* in 1923 in the Court of Appeals for the District of Columbia and 1993 in the United States Supreme Court, the case of *Daubert v Merrell Dow Pharmaceuticals*.

AFTE-1 (2008:239), is of the opinion that the final step in reaching conclusions of individualisation is subjective in nature but founded on scientific principles and based on the training and experience of the analyst. It continues to mention that the subjective process is preceded by several objective observations that greatly narrow the possible source of firearms and that include:

- Determination of the calibre.
- The number of lands of grooves.
- The width of the lands and grooves.
- The firing pin shape.
- The general type of finish of the breech face.
- The orientation between the extractor and the ejector in semi-automatic firearms.

According to AFTE-1 (2008:237), AFTE a professional organisation, was formed in 1969 by a dedicated group of forensic scientists that came together, and these founders realised the need for the exchange of information and methods, the development of standards and the progression of research in this specialised area of forensic science.
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.

For ballistic evidence to be accepted by the courts, the evidence should have valid legal basis to be presented.
Knoetze-Le Roux (2017:2), postulates the purpose of an expert as exceptional because an expert can assist the court in cases where it lacks in such specialised knowledge.

S v Mkhize + others 1998 (2) SACR 478 (W):

The court states that the evidence against the accused was entirely circumstantial due to the testimony of a single witness, ballistics evidence and an extra curial statement made against an accused. All five accused had their licenced firearms in their possession respectively upon arrest as follows:

- .45 Auto calibre Colt pistol with known serial number.
- 9mm Parabellum calibre Taurus pistol with known serial number.
- .45 Auto calibre Llama pistol with known serial number.
- .357 Magnum calibre Rossi revolver with known serial number.

- .45 Auto calibre Norinco model 1911 pistol with known serial number.

The firearms were all recovered and sent to the FSL for ballistics testing by the investigating officer (IO). A Criminal Record Centre member testified that exhibits totalling to 11 of .45 Auto calibre, 23 of 9mm Parabellum calibre fired cartridge cases and numerous fired bullets and fired bullet jackets collected at the crime scene and from the deceased bodies, were sent to the FSL. The state called two ballistics experts to give evidence. Ballistics expert A, who is junior ranked member to expert B, during evidence in chief read into the record the details of an affidavit made by himself that was declared as exhibit "W". "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)". Ballistics expert A testified that the affidavit he compiled was done after concluding the relevant examinations and that the affidavit was due, as part of operations, to be reviewed by a senior member to check for its correctness and any departure from the required operational procedures. Some of the exhibits from the crime scene were identified and linked, to have been fired by firearms of accused 1, 3 and 5 respectively.

The court points out that the analyst explained that during his ballistics examinations, a comparison microscope was used to reach conclusions of any linkages or not. These microscopes purposively enlarge images of the relevant exhibits to be viewed in juxtaposition. The positive identification of such comparisons will be required to be checked by a superior, and such findings were to be recorded on a microscopic results form. The forms related to this matter were handed in as evidence, namely FF and GG. The analyst testified that the exhibits that were linked to the firearms of the accused were returned to the IO and by the time of the trial, some of these exhibits had been lost and therefore all the photographs of such linkages could not be made possible.

The court reiterated the basis of expert evidence especially such as ballistics evidence: "The use of a comparison microscope for comparing exhibits is a technique which is well-known and considered to be reliable. The need to receive expert evidence arises from the fact that the Court, by reason of its lack of special knowledge and skill, is incapable of drawing properly reasoned inferences from the various images which are to be seen under the microscope". 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.

The court exhibit "W", the 212-affidavit by ballistics expert, the court describes as follows: "Affidavits of this nature are frequently used in courts throughout the Republic of South Africa. Their mere production affords the contents thereof the status of prima facie proof and in the absence of other credible evidence, conclusive proof, see S v Veldthuizen 1982 (3) SA 413 (A) at 416G – H". Then the court points out various critical mistakes made by the expert in the 212-affidavit which made the court doubt whether this expert can be characterised as an expert, as well as his inability to recognise or describe general well-known characteristics with regards to common firearm characteristics. The court then rule that it views the opinions and findings expressed by both ballistics experts unreliable, and would therefore be unsafe to be accepted.

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).

Methods and Material

This study followed a qualitative research technique utilising a non-probability sampling in the form of purposive sampling (Leedy & Ormrod, 2005:211). The purposive sampling method provided authors with the opportunity to handpick participants who were suitable for the research. The "purposive sampling method" allowed authors to intentionally find units of analysis in such a way that the sample obtained could answer the research question (De Vos, Strydom, Fouché & Delport, 2005:69). 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. An average experience of other analysts was between 10 to 20 years' experience in ballistics analysis. Prosecutors had an average of 20 to 40 experience of processing ballistic evidence in court. The interview length ranged from 30 to 56 minutes. In determining the sample size of interview participants, the first author selected participants who were experienced, knowledgeable and best placed to answer questions on firearms-related crimes. The first author selected ballistics experts with experience and knowledge of IBIS and firearms' related investigations. Welman and Kruger (2001:161) pointed out that, with a semi-structured

interview schedule for participants, the researcher can use standard questions based on study aim and research questions. Open-ended questions were used so that the participants could respond comprehensively. Both the authors have more than 12 years' service in the SAPS though the second author no longer in the employ of the SAPS. In addition, the first author had more than 10 years' experience as a ballistics forensic analyst. Personal and practical experience helped the authors to interpret the interview transcripts and data from the literature review.

Results and Discussions

The following four emerging themes were identified namely 1) the fundamental validity of ballistic examinations and evidence as a forensic science; 2) the critical importance of ballistic evidence to the court; 3) the critical importance of AFTE to establish the environment of ballistics, 4) the accreditation status of the FSL.

Results

Semi-structured interviews with an interview schedule were utilised to gather information from participants. The responses from the participants show clearly that ballistic evidence is needed and that it is an acceptable mechanism within the environment to assist in the investigation of crime. An interpretation of the findings, in terms of the respective themes, is presented.

Emerging Theme 1: The fundamental validity of ballistic examinations and evidence as a forensic science

For ballistic examinations to be presented as expert evidence, it would have to be qualified as a forensic science and thus, it has to be determined whether its examinations conform to the required definition of a forensic science. This theme is divided into the following five sub-themes namely:

Sub-emerging theme 1.1: Forensic Science

The question was put to participants that, if it is argued that ballistics is not a forensic science, what in your opinion is required to determine whether ballistics is a forensic science? Some of the responses from the participants were as follows:

The application of science to the law. How that information or evidence has been utilised to suggest whether a crime has occurred and whether tells law has been broken. The manufacturing process is the original point of the scientific principles. With our scientific principles, we will actually be looking at repeated test fires from firearms of all same make aware of what the natural and normal variability would be on those toolmarks that were made (**Participant 1**).

I would say forensic science is a discipline with certain rules and guidelines in existence to be used to prove a specific thing. Forensic Science is for ballistics the reproducibility of marks, the uniqueness of the marks and to give you the opportunity to compare those marks to give a scientific answer (**Participant 2**).

Forensic science is something which have a number of definitions. It is to be a science, it must be verifiable, it must be repeatable and it must be capable of explanation to somebody who specifically doesn't have the technical knowledge and that explanation might take time and effort on the part of the person who is doing the explanation.

In my opinion ballistics at this stage cannot be called a forensic science in the sense that it does not contain enough basic scientific knowledge and research to be able to qualify it under the word of science (**Participant 3**).

We don't do the in-depth ballistics analysis, bullet trajectories and velocities, etc. we do have some instances, where you do need to do or know these calculations and do the examinations, where the analyst has to go back and do their research and perform the test (**Participant 8**).

When looking at the definition of Ballistics, this study has pointed out that it is quite a broad definition or area of focus. It is evident that as the topic of this research guides: "A critical analysis of the utilisation ballistic evidence", the primary function of the Ballistics Unit as it is called, is not the study of the movement of the bullet with every case being examined. It is rather the examination of the firearm mechanisms and firearm individualisation. This agrees with participant 8 who mentioned that the majority of examinations do not include in-depth ballistic analysis, e.g. bullet trajectories and velocities. So, this study has pointed out that the best suitable argument is raised by Bolton-King (2017A:160) that describes the three disciplines of: 1) forensic firearm examination - that deals with the mechanism examination and functionality of the firearm, 2) forensic firearm identification - that deals with the microscopic comparison of fired exhibits, and 3) ballistics - that deals with the motion of the bullet since being fired until reaching a target. Therefore, this research determined that the two most important disciplines relevant for this research is that of forensic firearm examination and forensic firearm identification (also referred to as firearm individualisation or ballistics for the purpose of this research).

Grzybowski *et. al.* (2003:211), that describe science as a formalised method of observation and conducting tests that provide a theoretical explanation of what is being examined. Based on the experience and information of this study the researcher applied the following responses to the suggested requirements of the scientific method:

- Statement of the problem – The individualisation of firearms is fundamentally valid.
- Data collection of the problem – History of firearm individualisation. AFTE research articles publications.
- Hypothesis formation to explain the problem – Tools possess unique features known as individual characteristics which are random in nature. These individual characteristics allow a trained and competent analyst to conclude in matching between two unknown samples with great accuracy.
- Development of controlled experiments to test the hypothesis – Obtain fired samples of various kinds that would usually be represented in real life.
- Recording and analysing the data – Side by side microscopic comparison that allows the analysis of a questioned toolmark features to the features of a known source of toolmark in a pattern recognition.
- The formation of a conclusion of the validity of the hypothesis – AFTE-TI and AFTE-Range of conclusions.
- The repeating of the previous steps to form a new hypothesis in the event that the former hypothesis was proven to be false – Continued research through the testing model utilised for many years in studies of toolmarks produced from consecutively manufactured firearm parts where there would be the highest possibility of similar toolmarks carry over.

The study has proven that sufficient studies were carried out prior and is still ongoing. It is quite evident that many of such studies met the required standards of a forensic science.

Sub-emerging theme 1.2: Manufacturing processes

During this study, it was established that various researchers including Smith (2011), Lightstone (2016), Bolton-King (2017B), Owens (2017), Nichols (2018), etc. have explained the different processes involved during the manufacturing of firearm parts.

Processes involved in the production of finished parts is where the origin of individual characteristics and the processes could possibly be, which could include filing, sanding and grinding. These resulting from the randomness of which the tool surface contacts the contact part as well as the relative quickness of the wear changing the tool surface.

Sub-emerging theme 1.3: Fundamentals of ballistics

On the question to provide an opinion on the scientific principles or foundational validity of ballistics, whether it has been proven? The following responses were obtained from participants:

The manufacturing process is the original point (scientific principles). Beyond that, there is levels of variations that occur when a firearm is brand new, there are changes in the toolmarks of that firearm, as it is used, the toolmarks that is transferred to the surface of its components by ammunition, there might be small changes we don't know how much. Any deliberate damage, filing particularly the rifling, it all affects the change of the markings over time.

Then there is also the scientific principles around how impressions and striations are made on ammunition, say the chemical and material property itself and the scientific principle of combustion, you know how propellant and how primer ignite that ammunition (**Participant 1**).

This study has also highlighted some of the discussions by critics and experts with regards to the fundamental validity of ballistics. According to Grzybowski *et. al.,* (2003:219), that one of the methods they can utilise to evaluate the scientific validity and reliability of a proffered technique, as the court has stated in Daubert, is whether the technique has been peer reviewed by other examiners within the environment.

This study has pointed out some of the main critical issues highlighted by the critics namely Schwartz (2005), USA (2016), and participant 3 include:

- Analysts failed to distinguish between sub-class characteristics and individual characteristics with various research projects this was addressed to the foundational validity of ballistics.

- Development of a firm statistical empirical foundation for an identification as an objective measure, but as researchers within the environment has indicated, that is currently not feasible.
- Subjective v Objective interpretation, the researcher is of the opinion that continuous research be conducted to prove when it will be viable or not, as technology develops.
- The absence of a black-box study, the researcher agrees that this should be a recommended implementation as it will strengthen, ensure reliability and might even create awareness possibly where development or training is required.
- Rigorous proficiency testing, proficiency testing is evident within the environment and what more can attribute to this, is the extensive theoretical and practical training of analysts, the BKM and the BKNM. Marks observed with different exhibits during casework are enhancing the analyst's exploration with BKM, BKNM and his or her subjective orientation.

What is critical about ammunition is that the correct calibre combination or corresponding with the firearm is utilised to fire. This study has noted that participant 1 has commented that the fundamentals of ballistics further depend on the striations and impression marks on fired ammunition components. This study has shown that the correctly regulated propellant loaded in the cartridge case is important, as this detonation of the propellant should give sufficient power to push the cartridge case against the different firearm parts of the firearm, e.g. breech face and chamber walls and the bullet that moves through the barrel so that the marks will be transferred sufficiently. The primer should have sufficient liquid explosives to ensure that it will supply the required ignition to the propellant. This was noted during an interview discussion of the manufacturing of ammunition. 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.

Sub-emerging theme 1.4: Empirical Studies

The question was asked in regard to the concerns raised by critics with regards to empirical studies, the existence or non-existence of empirical studies, error rates and tests performed internationally and specifically in South Africa. According to your opinion, is there a need for such studies? The following were some of the responses from the participants:

We don't know what our error rate is (**Participant 2**).

Translated from Afrikaans into English: "There are more than sufficient tests carried out and for that we can go to scientific journals like AFTE where empirical tests were done and are published. SWGGUN is another example of where tests are carried out and they even recommend that more tests should be done" (**Participant 4**).

Many research studies have been performed discussing the manufacturing processes. There is no known error rate (**Participant 14**).

The following responses were obtained from participants on the question of whether there is any knowledge of proficiency testing within the environment of ballistics:

Yes, there is proficiency testing in order to be measured against the same international standard you need to do such, hence I mentioned earlier that we do partially comply to ISO-17025 (**Participant 5**).

This study has highlighted some proficiency tests results that were administered by CTS in 2019, 2020 and 2021. This study has pointed out that researchers such as Mejia, Cuellar and Salyards (2020), Thompson and Cásarez (2020), Nichols (2007), Saribey, Hannam and Tarimci (2009), Fadul *et. al.,* (2013), SWGGUN (2017), and Bolton-King (2017), just to name a few, utilised their various studies to prove that the fundamental validity of ballistics had been met and ongoing empirical research is evident. As it is evident in the responses from participants 4 and 5, proficiency tests are being conducted locally, but there exists no platform of the reporting of such test results. The purpose of such tests is to test the operation and/or examination processes, as well as the competency of analysts.

Sub-emerging theme 1.5: Class, Sub-Class and Individual Characteristics

When participants were asked to explain what Class, Sub-Class and Individual characteristics are, the following responses were obtained:

You use Class to put a firearm in a specific class. The Class for me is the major thing like pistol or revolver, different calibres, rifling, etc. Sub-class is the difficult one, because what it tells is, those bend marks are also class because of the tool. Now a little corner chipped out and you manufactured 600 breech faces with that little chip on and all the breech faces with all have that chip mark on them. And then you realised oops this cutter is broken, and you put in a new one where the process stops (**Participant 2**).

Class marks are caused by the actual manufacturing process e.g. drilling or milling. A drill causes circular motion, thus Class are usually those large circular motions made on an exhibit e.g. a fired cartridge case. Sub Class can be caused by e.g. a large piece of a drill bit off during its drilling and its causing deformation in the barrels to the next other 50 barrels in the line. Because other barrels also have that definition, you cannot put it in the individual category (**Participant 8**).

As this study has pointed out, reference is also made to pattern comparison and that is what analysts used when they classify or just another phrase for individual characteristics. In evaluating the pattern of individual characteristics, the height, width, depth, curvature and spatial relationship of the appearance of marks are considered. Based on this, the analysts use their subjective influence to determine whether sufficient agreement exists between the marks to conclude whether they originate from the same source. This study has pointed out that sub-class characteristics are identified as gross marks resulting from broaching, whereas discontinued unrelated marks were observed as individual characteristics. Sub-Class characteristics could be individualised through hand-sanding, sandblasting and glass-beading. Sub-Class characteristics are likely to be caused during the manufacturing processes by the end-mill, lathe-turner and broach processes. This usually happen when surfaces of firearm parts are machined by the same tool characterising the same state of wear and chip formation. Filing produces marks that are straight and irregular in length, spacing and direction, because it is primarily done by hand, which results in individual characteristics rather than sub-class characteristics. During the study of the consecutively machined Ruger bolt faces, it is shown that sub-class characteristics originates as a result of the milling process, but also marks were present, classified as abrasion and chatter marks to be utilised as individual characteristics. These individual characteristics were as a result of the vibrational movement of the milling, as well as chip breakage, thus will not be reproduced as sub-class characteristics.

Emerging theme 2: The critical importance of ballistic evidence to the court

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**).

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**).

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 matters 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.

Emerging theme 3: The critical importance of AFTE to establish the environment of ballistics

Research as this study has pointed out from such an important basis of forensic science and the organisation called AFTE is the platform where numerous research articles are published, but having access to those publications can be restricted and only fully paid-up subscribed members can have access. This theme is divided into three sub-themes namely:

Sub-emerging theme 3.1: AFTE-TI

The following were asked from participants − What is AFTE? Please provide your opinion on AFTE's Theory of Identification, that two exhibits have a common origin if their marks are in sufficient agreement. These conclusions are made from a subjective perspective. The following responses were obtained:

From knowing AFTE, they constantly conduct tests on ballistics-related subject like firearms and toolmarks. They run their tests on hypothesis and they eventually come up with conclusions. So numerous tests had been done to my knowledge of the manufacturing of firearms. You must carry out tests through a hypothesis and then reach conclusions. Sadly I would love to become a member of AFTE. I love my job, I love being a ballistic analyst and I love new things. Unfortunately being a member of AFTE, you need to pay a subscription fee and I cannot afford that. I would have love for our department to register each analyst with AFTE, solely because I think should you have any question related to any kind of firearm manufacturing processes or studies it so easy to have information available if you are a member. As non-member you only getting abstracts. We are getting very rare cases coming through for example, I had a case involving cellotape where I needed tons of research (**Participant 8**).

AFTE is an organisation based in USA. The AFTE-theory of identification is a set of criteria that analysts can use individualise firearms (**Participant 10**).

This study highlighted the responses from participants 8 and 10 that AFTE is an organisation being a critical factor in regulating and facilitating peer review structures with studies performed on ballistics. The AFTE-TI is a summary of ballistics and describes very well how individualisation is established. Participant 8 noted that AFTE is a very important platform for the research that they are performing within the environment. This study has pointed out that it agrees with participants 8, 10 and Grzybowski *et. al.,* (2003), that just as in the case of AFTE-TI, the AFTE-Range of Conclusions is a very well-structured applicable and well workable tool to assist analysts to report their conclusions and it serves as proof that analysts do not only have to make matches of comparisons, but gives the analysts room to report the comparison conclusions in a descriptive manner.

Sub-emerging theme 3.2: Subjectivity v Objectivity

Participants were asked to explain the difference between subjective and objective examination and whether the existence or utilisation of a database like IBIS is required within the environment.

I think the level of subjectivity could be seen to be reduced by improving our note taking on the areas that we used to make our identifications and it was in the past very challenging to that, taking an image down at the microscope. I think especially if we use modern technology and 3D-imaging techniques, we could implement a system to whereby we are bringing the marks that we are using to make our decisions and we could report on those "patronal" notes.

So that could seemed to be more slightly objective and we could maybe make more use of the data of IBIS and the 3D-imaging system in order to support our interpretation, but because a virtual microscope is only able to look at breech face marks and firing pin impressions, because the examiner wasn't able to see extractor marks and any chamber marks (**Participant 1**).

IBIS is currently our closest objective tool, but a human interpretation is still required. IBIS is a very important tool, because it can link up a few crime scenes (**Participant 8**).

IBIS is currently utilised as a computer system that does comparisons of the evidence and an analyst review those results for possible linkages. So, IBIS will be considered as objective whereas there is still a subjective interpretation by the analyst (**Participant 11**).

This study pointed out as it agrees with Nichols (2007), and Bolton-King (2017), that analysts built an understanding and knowledge of individualisation by recognising patterns, together with specialised in-depth training, and with the observation of multiple evidence of BKM and BKNM. The ballistics environment is criticised for its subjective interpretation. Even with an objective interpretation, as mentioned by Nichols (2007), the subjective human opinion will always be required to interpret the results. As indicated by participants 1, 8 and 11, IBIS is the only tool that can be looked at as a possible objective measurement. Currently as Hill (2016) and participant 8 describe, IBIS still requires human intervention for analysis and reporting.

Sub-emerging theme 3.3: Absolute Certainty v Practical Certainty

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**).

As part of the AFTE-TI, AFTE (1992:337), states that "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". Fadul *et. al.* (2013:34), explain that, to make an absolute determination, all firearms in the world must be examined and because of that impossibility the identifications are not absolute. Not all firearms in the world are examined and because of that impossibility, the individualisation of firearms are considered a practical certainty and not an absolute certainty as mentioned by Fadul *et. al.,* (2013), as well as AFTE-TI and proves the argument of participant 3 to be untruthful.

Emerging theme 4: The accreditation status of the FSL

The participants were asked whether the laboratory or the institution you are employed at accredited or affiliated to any type of regulating authority? How will that status (accredited or not) be beneficial to the ballistics environment, especially in South Africa? Please state the advantages or disadvantages if any. The following responses were obtained:

We are excluded by law not to be accredited, but we all know that QMS is an excellent system if properly implemented and maintained, because it pushes up your assurance, because we working all with the same process to make sure the assurance of our processes, test methods, validations and verifications, all those things are in place, so it gives a better weight towards the end-product (**Participant 2**).

On the question of whether the laboratory maintains certain ISO-standards and if so, what are they? The following responses were obtained:

Yes. For the lab including ballistics, ISO 17025 (**Participant 2**).

Currently the laboratory is not accredited, as it is not a requirement, but we do follow ISO 17025 standards (**Participants 10 and 12**).

This study has pointed out that accreditation is not a requirement for ballistics to function as a forensic science, but with a working operation in line with ISO 17025, a developed QMS guides the working operation. Ballistics locally or anyone of its individual analysts, are not affiliated to any peer review organisations e.g., AFTE. Even so the accreditation status is not a prerequisite in the court of law in South Africa.

Recommendations and Conclusion

Through a comprehensive analysis of the data, this study will present evidence-based recommendations 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.

Recommendations

Emerging Theme 1: The fundamental validity of ballistic examinations and evidence as a forensic science

In the absence of a public study locally and non-existence of an error rate locally, it is recommended that an official error rates platform be established. It is further recommended that analysts engage in ongoing training, that they know the different manufacturing processes and ensure that they familiarise themselves with the fundamental validity of ballistics. Furthermore, the study recommends that local analysts would more frequently be exposed and partake in firearm factory tours for research purposes. Seeing that the issue of sub-class characteristics is so important and critical that analysts report on them similarly to their responses as with class- and individual characteristics, especially in their 212-affidavits.

Emerging Theme 2: The critical importance of ballistic evidence to 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. 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 Expert Witness Model is illustrated as follows in figure 4:

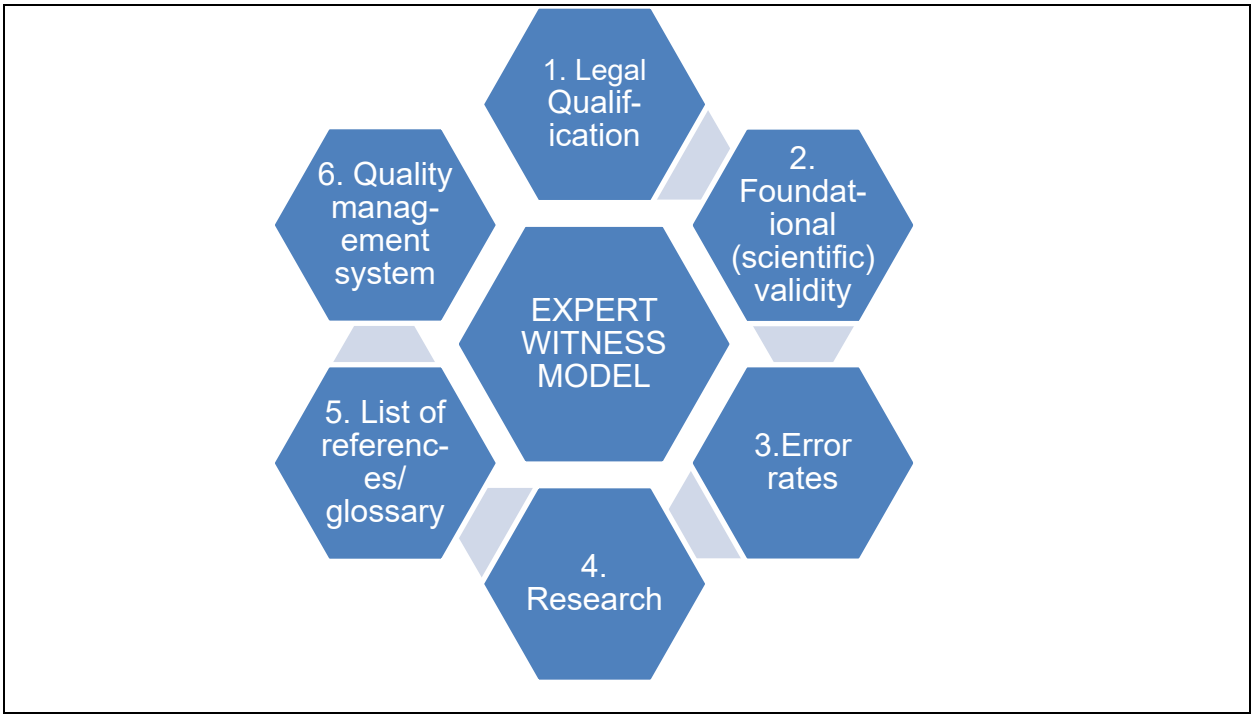

Figure 4 - Source: Authors illustration

Emerging Theme 3: The critical importance of AFTE to establish the environment of ballistics

It is recommended that local analysts subscribe to AFTE to stay informed and contribute their experiences to the bigger environment. To follow guidelines recommended by AFTE, as this will ensure that analysts will follow standardised norms and processes. This will also create an inspiration amongst analysts to conduct research locally to enrich the environment of ballistic examinations.

Emerging Theme 4: The accreditation status of the FSL

Ensuring that the QMS-procedures are followed and that SOP's stay relevant (updated). Ensure guidelines recommended by ISO 17025 are followed.

Conclusion

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 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. In examining the field of forensic science, it was found that there is no specific requirement for a predetermined number of studies to be conducted. Instead, the key criterion is the existence of fundamental criteria that can be hypothetically tested. Forensic science, as defined, is an examination based on proven scientific methods that addresses a problematic phenomenon to assist the criminal justice system. Factors such as manufacturing processes, class, sub-class, and individual characteristics, AFTE-TI, and subjectivity versus objectivity are continually and intensively researched, contributing to the foundational definition of ballistics as a forensic science. 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. In conclusion, the researcher suggests that future research should focus on the local investigation of issues such as biasness in microscopic comparisons, the possibility of an objective approach utilising IBIS, exploration of virtual ideas to advance the Expert Witness Model, and the establishment of a publication on error rates. These areas of study would contribute to the ongoing development and improvement of the field of ballistics. Thus, it is necessary to conclude that ballistics and firearms are essential aspects of crime scene investigation, which require the use of effective strategies to provide physical evidence and integrate scientific methods and deductive reasoning in the process of crime investigation.

References

AFTE-An AFTE Criteria for Identification Committee. 1992. *Theory of Identification, Range of Striae Comparison Reports and Modified Glossary Definitions.* AFTE Journal volume 24, number 3:336-340.

AFTE-Committee for the Advancement of the Science of Firearm & Toolmark Identification. 2008. *The Response of the Firearm and Tool Mark Examiners to the National Academy of Sciences 2008 Report Assessing the Feasibility, Accuracy, and Technical Capability of a National Ballistics Database August 20, 2008. AFTE Journal* volume 40, number 3:234−244.

Beri, R. 2000. *Coping with Small Arms Threat in South Africa*. Retrieved from https://ciaotest.cc.columbia.edu/...,on 2023-10-14.

Bruce, D. 2023. *Incidents that claim more than one victim have soared with Kwazulu-Natal as the epicentre of the phenomenon.* Retrieved from https://issafrica.org, on 2023-10-14.

Bolton-King, R.S. 2017A. *Preventing Miscarriages of Justice: A Review of Forensic Firearm Identification*. AFTE Journal volume 49, number 3:159-180.

Bolton-King, R.S. 2017B. *Rifling Methods of Factory Fitted 9mm Luger (9 x 19mm) Pistol Barrels: A Reference Resource*. *AFTE Journal* volume 49, number 4:225−238.

Bunch, S.G.; Smith, E.D.; Giroux. B.N. and Murphy. D.P. 2009. *Is a Match Really a Match? A Primer on the Procedures and Validity of Firearm and Toolmark Identification.* Forensic Science Communications volume 11, number 3:1–10.

Collaborative Testing Services (CTS). 2020. *Firearms Examination Test No. 19−527 Summary Report.* Retrieved from *www.cts-forensics.com* on 2021-11−30.

De Vos, A.S., Strydom, H., Fouché, C.B. & Delport, C.S.L. 2005. *Research at grass roots: For the social sciences and human service professions*. 3rd ed. van Schaik. Pretoria.

Fadul, T.G., Hernandez, M.S., Wilson, E., Stoiloff, E. and Gulati, S. 2013. *An Empirical Study to Improve the Scientific Foundation of Forensic Firearm and Tool Mark Identification Utilizing Consecutively Manufactured Glock EBIS Barrels With the Same EBIS Pattern.* Report Submitted to the U.S. Department of Justice with Award number 2010-DN-BX-K269.

Grzybowski, R., Miller, J., Moran, B., Murdock, J. Nichols, R. and Thompson, R. 2003. *Firearm/Toolmark Identification: Passing the Reliability Test Under Federal and State Evidentiary Standards*. AFTE Journal volume 35, number 2:209-241.

Hill. B.T. 2016. *An analysis of the utilisation of the Integrated Ballistics Identification System within the South African Police Service: The Case of the Western Cape.* Dissertation for Magister Technologiae: Policing. Tshwane University of Technology. Unpublished.

Knoetze-le Roux, I. 2017. *Ways to curb expert bias.* Retrieved from: *http://www.derebus.org.za*.

Leica Microsystems. 2008. *Leica FS C, Leica FS CB and Leica FS4000-Operating Manual*. Wetzlar, Germany.

Lightstone, L. 2010. *The Potential for and Persistence of Subclass Characteristics on the Breech Faces of SW40VE Smith & Wesson Sigma Pistols.* AFTE Journal volume 42, number 4:308-322.

Mejia, M.; Cuellar, M. and Salyards, J. 2020. *Implementing blind proficiency testing in forensic laboratories: Motivation, obstacles and recommendations.* Forensic Science International: Synergy number 2:293-298.

Miller, J. and Beach, G. 2005. *Toolmarks: Examining The Possibility of Subclass Characteristics.* AFTE Journal volume 37, number 4:296-306.

Nichols, R. 2007. *Defending the scientific Foundations of the Firearms and Tool Mark Identification Discipline: Responding to Recent Challenges.* Journal of Forensic Science volume 52, number 3:586-594.

Nichols, R. 2018. *Subclass Characteristics: From Origin to Evaluation.* AFTE Journal volume 50, number 2:68-88.

Owens,S. 2017. *An Examination of Five Consecutively Rifled Hi-Point 9mm Pistol Barrels with Three Lands and Grooves Left Twist Rifling to Assess Identifiability and the Presence of Subclass Characteristics.* AFTE Journal volume 49, number 4:208-215.

Saks, M.J. and Faigman, D.L. 2008. *Failed Forensics: How Forensic Science Lost Its Way and How It Might Yet Find It*. The annual review of law and social science 04:149−171.

Schwartz, A. 2005. *A Systemic Challenge to the Reliability and Admissibility of Firearms and Toolmark Identification.* The Columbia Science and Technology Law Review. Volume 6.

Smith, E.D. 2004. *Cartridge Case and Bullet Comparison Validation Study with Firearms Submitted in Casework*. AFTE Journal volume 36, number 4:130-135.

Smith, J. 2011. *Method of Rifling by Manufacturer*. AFTE Journal volume 43, number 1:45-50.

South African National Accreditation System (Sanas). 2016. Criteria for Laboratory Accreditation in the Field of Forensics. South-Africa.

SOUTH AFRICA. 2019. *The State vs. Cakasayo and 3 others*. 2019 SS01/2016. High Court of South Africa, State's Heads of Argument. Western Cape Division, Cape Town:

(a) S v Mkhize and others 1998(2) SACR 478 (W)

SWGGUN. 2017. *The Foundations of Firearm and Toolmark Identification*. AFTE Journal volume 49, number 3:181-185.

The National Research Council. 2009. *Strengthening Forensic Science in the United States: A Path Forward.* National Academy of Sciences. Washington, D.C.

Thompson, RM. 2010. *Firearm Identification in the Forensic Science Laboratory.* 1st ed. Alexandria. National District Attorneys Association.

Thompson, SG. and Cásarez, NB. 2020. *Solving Daubert's Dilemma For The Forensic Sciences Through Blind Testing.* Houston Law Review volume 57, number 3:617-670.

U.S.A. 2016. *Report to the President, Forensic Science in Criminal Courts: Ensuring Scientific Validity of Feature-Comparison methods*. Executive Office of the President's Council of Advisors (PCAST) on Science and Technology. Washington, D.C.

U.S.A. 2020. *United States of America v. Demontra Harris.* Case 1:19-cr-00358-RC. United States District Court For The District Of Columbia.

Walker, RE. 2013. *Cartridges and Firearm Identification.* Boca Raton. CRC Press.

Welman, J.C. and Kruger, S.J. 2001. *Research methodology.* 2nd ed. Oxford University Press. Goodwood.

Wheeler, B. and Wilson, L. 2008. *Practical Forensic Microscopy: A Laboratory Manual*. John Wiley and Sons. West Sussex.