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An Exploration of Technological Models in Combating Stock Theft in South Africa

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ABSTRACT---- ***A high prevalence of stock theft is observed in selected South African communities. In the year 1996; a new high-tech technology (Deoxyribonucleic Acid - DNA) was introduced in South Africa through the partnership between South African Police Service (SAPS) and the Animal Genetics Laboratory (AGL) of Animal Research Council (ARC) – Animal Production Institute (API) to combat stock theft, this system was envisaged to be a powerful tool in assisting the livestock farmers in most hit areas. This introduction relies on providing accurate evidence against potential stock thieves. However, the practicality associated with the use of this system remains elusive to the potential livestock farmers.***

The aim of this paper was to explore six (06) technological models in combating stock theft in the selected areas of KwaZulu-Natal (KZN) Province (Bulwer, Ladysmith and Utrecht), South Africa. For data collection; documentary study, Focus Group Discussion (FGDs) and Key Informant Interviews (KIIs) were conducted with the selected participants. The findings to this paper suggest that stock theft remains a significant problem in selected areas of KZN with evident extreme failure of implanting technologies in combating this scourge. For recommendations; this paper provides that the integration of the available technological models in a form of conceptual model and provide emphasise that this framework can play an essential role in combating stock theft in the selected areas of KZN.

Keywords---- Combating, Deoxyribonucleic Acid technology, Model, Stock theft, South Africa

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1. INTRODUCTION

In dealing with issues of stock theft; the use of technology in combating stock theft in South Africa is gaining momentum daily. This process is guided by the concept described as “effective stock theft control and monitoring system.” The rationale of this system encompasses the following mechanisms to monitor and prevent stock theft in a given location, as guided by the Agri-Alert system, among others, as well as enhance productivity for the livestock farmers: Activity alarm - Global Positioning System (GPS) alarm - Water-level monitoring - Panic alarm; and Temperature alarm (Burger, 2012).

The available systems provides for livestock farmers to monitor their animals’ movements and any disturbances, using their cell phones. GPS coordinates are also available everywhere, for the farmers in question to receive Short Message Service (SMS) in this regard.

This system makes use of sensors fixed around an animal’s neck, and sends signals to the base station as soon as abnormal or unexpected behaviour occurs (Agri-alert, 2013). The base tower then sends an SMS message to the cell phone of the farmer, informing him of this behaviour.

Furthermore, the Electronic Identification (EID) is another system, which is nothing more than a data capture system, livestock producers can decide how to effectively integrate it into their programs. For basic compliance; the simplest option might be to purchase the uniquely numbered Radio Frequency Identification (RFID) ear-tags and maintain simple records for animals by means of the ear-tags. A connection to this system; Animal Identification System (AIS) is also used as a technological device in combating stock theft, this system includes the following:

- **Transponder:** This comes in different forms, including ear-tags, rumen boluses, and implantable microchips and it also recommended for the National Animal Identification System (NAIS) (Evans, Davy & Ward, 2005);
- **Transceiver / Reader / Interrogator:** The reader sends an electronic signal to the tag, the tag is charged, and replies with the stored information. The two basic readers are a portable hand-held and a stationary panel device. The hand-held readers can be powered by a rechargeable battery or plugged into a wall outlet, Evans, *et al.* (2005);
- **Data accumulator:** The laptop computer is a popular form of data accumulator. Other types include: hand-held computers or Personal Digital Assistants (PDAs), desktop computers, and scale-heads. The data accumulator contains software that allows communication with the reader (Evans, *et al.* 2005); and

- **Software / Data management system:** For the reader to communicate with the data accumulator, software is necessary. Software allows for communication between the data accumulator with the database and the reader (Evans, *et al.* (2005).

2. RESEARCH DESIGN AND METHODOLOGY

This paper was descriptive in nature adopting qualitative research approach, (Creswell, 2007) advocates that "to study this problem, a qualitative research approach is used to inquire, the natural setting comprising human subjects and places that inform the collection of data, and inductive data analysis establishes the study themes"). The sample size and procedure of this paper comprised of relevant stakeholders (2 Department of Agriculture, Forestry and Fisheries - DAFF - Assistant Directors: Animal Technicians and Animal Production officials, 1 SAPS Stock Theft Unit – STU Provincial Coordinator – formed part of KIIs; and 14 STUs members – FGDs and 5 Anti-stock Theft Association managers (KIIs) who understand the subject matter. Overall, the population for this paper consisted of 22 participants in the anti-stock theft structures. Their strategies were explored for the use of DNA technologies in combating stock theft in the selected areas of KZN. Non-probability sampling was used, whereby a purposive sample was selected as the members of the population for FGDs and KIIs were chosen haphazardly.

The FGDs and KIIs were guided by an interview schedule guide aimed at ascertaining their viewpoints on the use of DNA technologies in combating stock theft in the selected areas in KZN. Before this study was conducted, ethics approval was obtained from the Tshwane University of Technology (TUT) and SAPS.

To accomplish this objective, this paper combined both social constructivism and phenomenology to formulate constructivist phenomenology to underpin this paper on epistemological foundations. The combination of these designs enabled the researcher to explore and describe the use of DNA technologies in combating stock theft in the selected areas of KZN, South Africa and also to ascertain theoretical points of reference to attain theoretical triangulations. To this course; the phenomenology as a philosophical worldview is aligned with the qualitative paradigm to transform the scientific knowledge into meaningful facts about particular events within a social setting (Matlala, 2012). For this paper, this was achieved through the exploration of technological models in combating stock theft in the KZN selected areas. The data collected generated a number of themes that were analysed qualitatively. Data analysis process involved reducing the volume of raw information, sifting significance from trivia, identifying significant patterns, and constructing a framework for communicating the essence of what the data reveals. Therefore, the collected data was analysed to reach a structured, reliable and valid conclusion (De Vos, Strydom, Fouche & Delport, 2005). During this record-taking process, the interviewer takes notes, with a view to writing a more detailed and complete report afterwards and a voice recorder was also used when interviews were conducted, with a view to transcribing the information gathered at a later stage. The researcher then organised the data by categorising it on the basis of themes, concepts, or similar features. The researcher further organised the data obtained from the selected participants, while ensuring that the elicited data answered the original objective of this paper. The researcher read the data several times to grasp the perspective of the participants and take down the notes as expressed. This was done by making cryptic written notes of what the participants were saying during FGDs and KIIs. The actual words used by the participants were written down verbatim (word for word).

3. LITERATURE REVIEW: TECHNOLOGICAL MODELS ON STOCK THEFT COMBATING

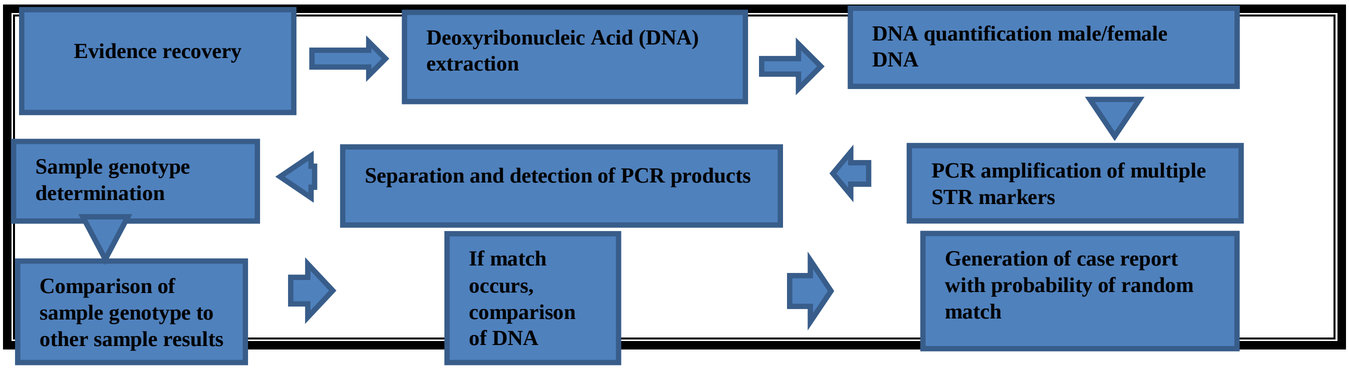

Figure 1: The Deoxyribonucleic Acid analysis process - Steps in Deoxyribonucleic Acid sample analysis and interpretation **(**Source: Geldenhuys, 2011).

Figure 1 was adopted as one of the models to underpin this paper. This model illustrates that when evidence is recovered, DNA extraction, quantification, amplification, separation and detection of PCR products, as well as sample genotypes, should be determined. This South African model (Model 1 – Figure 1) relies on the use of DNA technology to generate matches from the verified samples to effectively combat stock theft in the selected areas of KZN, as a comparison of sample genotypes to other sample results can be conducted, and if there is a match in the comparison of the DNA profile to the population sample (reference sample), the probability of a random match can be ascertained. Geldenhuys (2011) argues that the process of analysing DNA is not as fast as it is portrayed on television. It is a lengthy process if it is to ensure proper results.

From the moment the sample is received at the Forensic Science Laboratory (FSL) until its final preparation for court, the processes it has to pass through include administration such as registration, evaluation, analysis and interpretation before a court report is compiled. The Short Tandem Repeat (STR) kit used consists of ten tests, of which one determines the gender of the person the DNA belongs to. Only certain parts of the DNA are selected to ensure a more workable sample.

Extraction of DNA evidence from livestock crime scenes cannot be separated from this practice. Geldenhuys (2011) further argues that if a suspect's DNA is matched to a crime scene by the National DNA Databases of South Africa (NDDSA), but there is no other evidence linking the said suspect to that specific case, the laboratory will request confirmation by means of a second reference sample in order to verify the database match.

Figure 2: The chain of custody of forensic samples (Source: Mapholi, 2015).

For the purpose of this paper, another model was adopted (this must be read in conjunction with Model 1 of this paper. This model (Model 2 - Figure 2) emphasises that the process of collecting samples from crime scene to laboratory has to be documented thoroughly in an attempt to combat stock theft effectively, thus the importance of DNA technology to combat stock theft is covered by the model herein. More emphasis is placed on chain of custody, which is the cornerstone of this paper.

Mapholi (2015) highlights that the success of the DNA forensic service used in combating stock theft relies heavily on the chain of custody of forensic samples, for example, the entire process of collecting samples from crime scene to laboratory is shown in Figure 2 above.

To ensure adherence to the chain of custody, the Animal Research Council (ARC) provides continuous training to South African Police Service (SAPS) personnel, several times per annum. The training focuses on DNA sample collection, storage, and dispatch to the laboratory. The benefit of the training is demonstrated by the quality of DNA exhibits that are brought to the laboratory by SAPS. The author went on to say that stock theft has broader implications than the loss of animals; the issue also affects food security.

Through the use of DNA microsatellite marker technology we have managed to resolve the problem of establishing the identity of lost or slaughtered livestock, livestock paternity in livestock ownership dispute cases, and uncertainties in animal origins of meat products. Although some of the cases remain unsolved, those that are reported and investigated have led to an increase in the rate of stock thieves. In addition, DNA technology can be used as an important forensic instrument to combat stock theft and is becoming an increasingly important component of the criminal justice system. DNA-based technology is used largely for the determination of identity, ownership, percentage, traceability and the species origin of animal products such as tissue, blood and skin.

Apart from identical twins or clones, no two animals are genetically the same. This means that the DNA of an animal is a fingerprints or unique identification. Only small quantities of DNA are needed to confirm the fingerprint of an animal. But how does DNA technology help to combat stock theft? Hair samples (a source of DNA) are collected from individual animals and stored in the laboratory as reference samples. When animals are injured or have sloughed at a crime scene, or a piece of meat from a stolen animal is found in possession of a suspect, a tissue sample is taken and compared in the laboratory to the reference sample.

If the DNA fingerprint of the reference samples agrees with a sample from the crime scene, the suspect can be connected to the crime scene or the crime itself, and evidence can be used to put the offender behind bars. Even if there is no reference sample available, conviction is still possible if DNA from the blood, bloodstains , meat or other tissues found at the crime scene compares with blood found on the suspect‘s clothes, tools that were used, or meat found in his possession. The success of the forensic DNA services is dependent on all parties involved correctly collecting samples at a crime scene, processing and analysing them in the laboratory, and reporting the findings.

To ensure that each part of the process is handled correctly, the ARC continuously provides training to the SAPS staff. The training focuses on aspects such as DNA sampling, preservation, documentation, and dispatching of samples to the laboratory (National Stock Theft Prevention Forum - NSTPF, 2016). The ARC started working with resource-poor farmers in Limpopo (LIM) in 2005 to introduce the Livestock Identification Catalogue (LIDCAT) as part of controlling stock theft.

The project concentrated on hotspot areas, which included Polokwane, Giyani, Marble Hall and Zebediela. Additional equipment for ear-tagging, brand-marking and handling of animals was purchased, while the record-keeping process was streamlined. The LIDCAT team also designed and presented tailor-made information sessions to the rural farmers in order for them to grasp the concept of the project.

The NSTPF (2016) further reports that the SAPS and the AGL of ARC –API in Irene entered into a partnership in 1996 to combat the challenge of stock theft with the aid of DNA technology. According to the SAPS, various court cases have been successfully concluded through the use of DNA. In these court cases, which included more than 3 000 pieces of evidence, results of DNA analyses have been used as evidence. Approximately 95% of cases were solved and the suspects prosecuted.

In the year 2007 it was reported that close to 3 000 animals from 270 farmers have been entered into the LIDCAT system. A very encouraging fact is that in certain areas and according to official SAPS statistics, stock theft declined dramatically subsequent to the field excursions. It seems that the LIDCAT system in itself acts as a deterrent against theft. The vision of the LIDCAT team is to transform the project into a national initiative and contribute to the competitiveness of the developing livestock sector.

In another report, Greyling (2006) points out that “they say that the easiest way to make money is to stop losing it. Because of stock theft, farmers lose a lot of money every year. Stock theft hurts all farmers, whether you are a commercial, stud or small-scale farmer. Stock theft is very bad for small-scale farmers who have only a few animals. They do not always have the money to buy new ones.” One of the biggest problems when animals are stolen is that you cannot tell which one is yours. The law says that you must brand-mark animals older than six months so that you can see which animals are yours. But some people do not do this. Stock thieves also often try to change the brands that were made. This makes it very difficult to see which animals are yours. It is very important to be able to identify animals so that the police can find the real owner.

The AGD of the ARC has been helping the stock theft units of the SAPS for many years. They make use of DNA to determine which animals are yours. Then they can help the police find stolen animals. DNA is found in the blood, skin, meat, bones, intestines and even hair roots of animals and it can be used to identify an animal. DNA is almost like a person’s fingerprint. No-one’s fingerprints look the same. In the same way, no-one’s DNA is the same. The DNA of the animal is not something one can see. This makes it impossible for thieves to change the DNA of animals.

Police all over the world have been using human DNA in the courts for a long time. Now it can also be used when animals are stolen. AGD has a new product called LIDCAT that helps the police to catch stock thieves by using the DNA of animals. Because the DNA “fingerprint” of the animal stays the same throughout its life, and because no one can change it, police can use it to find animals. The DNA of an animal can still be used even if it is dead. Even a drop of blood or a hair can be used to identify a stolen animal.

When the livestock farmers use the LIDCAT system, they take a hair sample of each of their animals. This hair is then stored with the livestock owner’s particulars, such as the surname/name. When livestock get stolen, the AGD-ARC takes a hair or blood sample from the located animal or animal under dispute, with reference to ownership. If the livestock under dispute do belong to the livestock farmer in question, the DNA will definitely prove it. The inception of the LIDCAT system in South Africa is the brainchild of AGD, which created the system as a result of taking note that there are many small-scale farmers in the country, and that their cattle often get stolen. They started a project to help these farmers to use the LIDCAT system. As a result, they send out a team of their people, together with the STU of the police, to take hair samples of all the animals belonging to a specific farmer. They also brand-mark the animals and give them ear-tags. During this process, each animal gets a special number, almost like your Identity Document (ID) number. When people then fight over an animal, or if an animal is stolen, they can simply take a sample of that animal and check whether it is the same as the one whose details they have saved under the special number. By using this method, one can easily tell which animals belong to whom. Police say that there are already fewer cattle thefts where people use the LIDCAT system. This shows that the LIDCAT system can stop cattle theft / stock theft holistically. This way, the farmer will save a lot of money by not having to replace stolen cattle / livestock.

The researcher is of the view that the principal link between DNA technology and livestock farming lies in combating stock theft. It appears that the conventional / traditional methods are falling short to address this scourge. With that said, the consulted literature further reveals that **s**tock theft is a threat to South Africa livestock producers' very existence, impacting on the long-term sustainability and profitability of the industry. It has become a lucrative business and affects the emerging farmer and commercial farmer alike. An average of 30 000 cases per year have been reported for the past five years, representing a monetary loss of R750 million annually. From 1 April 2013 to 31 March this year, 56 954 head of cattle to the value of R592 321 600 were stolen. Of this figure, 22 070 were recovered, meaning that 34 884 head of cattle to the value of R363 793 600 were lost. As regards to sheep, 79 713 with a value of R135 512 100 were stolen. A total of 16 663 were recovered, resulting in the loss of 63 050 sheep. This cost sheep producers R107 185 000 million. A total of 34 988 goats were stolen, of which 10 600 were recovered, resulting in a loss of R47 556, 00 (forty-seven thousand, five hundred and fifty-six rand) (Maré, 2014).

Furthermore, on the 24th of January 2016 when the Police ministry brief the media on the Programme of Action for SAPS for 2016, it was highlighted that only 727 cattle, 1716 sheep and 116 of other livestock were confiscated in the 2014 / 2015 financial year, says Lieutenant General Phahlane (the current SAPS Acting National Commissioner) in his report, as a recourse Police Minister (Honourable Nkosinathi Nhleko) further mention that the SAPS management are in the process of introducing Animal Movement and Animal Procedure Bill, this Bill seeks to repeal the Stock Theft Act (Act No. 57 of 1959) by providing livestock farmers with the framework for monitoring animals and animal procedure, currently; the livestock farmers are finding it problematic to monitor their animals (ENCA, 2016).

However, the researcher thinks that this legislative framework cannot combat stock theft in isolation with the use of DNA technology and other available strategies, other forms of technology included.

Therefore, livestock farmers are encouraged to mark all livestock, as without identification, it is impossible to prove ownership. Many of the respective role-players in the livestock production sector contribute directly to the high incidence of stock theft by ignoring the legal requirements as set out in the Animal Identification Act (Act No. 6 of 2002), Stock Theft Act (Act No. 57 of 1959) and other related Acts, which control the marking and movement of livestock. A legal, permanent mark is the farmer's responsibility and the first line of defence. Unmarked livestock also means that feedlots, producers, speculators, auctioneers, buyers and abattoirs cannot tell whether an animal was stolen or not. Should the animals be stolen, these parties are contravening the law and are at risk of prosecution in terms of the Animal Identification Act (Act No. 6 of 2002). Hot-iron brand marks for cattle and tattoo marks for small stock are the most effective and cost- effective ways of marking.

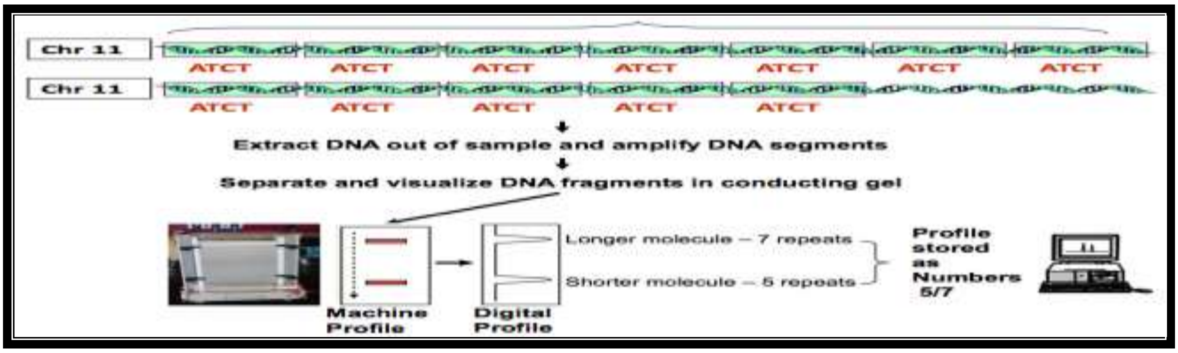

Figure 3: The process of obtaining a profile (Source: http://dnaproject.co.za/dna-project/the-science-behind-dna).

Another South African adopted model (Model 3 – Figure 3) to guide this paper focuses on the extraction and amplification of DNA samples and segments detailing the separation and visualisation of DNA fragments from a machine that generates longer and shorter molecules, repeats digital profiles, and stores the numbers to interpret the results. This model could work effectively in combating stock theft, as many livestock profiles can be generated and stored as reference samples, using numbers as representations (this must be read in conjunction with the identified adopted Model 1 of the paper. During the visit by SERVAMUS to the Biology Section of the SAPS FSL, Pretoria in 2011 to learn more about DNA, it was explained by Lieutenant Colonel Michelle Thompson that the DNA consists of coding as well as non-coding areas.

The coding sequences of DNA are interrupted by long stretches of non-coding DNA, also known as “junk DNA,” in which there are numerous chromosomal locations that contain short stretches of DNA, where a particular sequence of two to eight nucleotides such as DNA building blocks are repeated a number of times after each other (in tandem). These repeat units are known as STRs or microsatellites.

Although STRs are part of 95% of the human genome, it is not a fundamental basis of the body’s make-up. This means that it contains no information on personal, medical, physical or physiological characteristics. STRs are ideal for degraded or limited DNA (Geldenhuys, 2011). Recently (2015), forensic DNA profiling techniques have undergone rapid development and have become more sensitive to allow degraded and limited samples to be analysed. At present, the technique used in forensic DNA analysis is called STR forensic DNA analysis, as described above (Kimpton *et al*., 1993; Lygo, *et al*. 1994; and Mulero, *et al*. 2008, as cited in Manamela *et al*., 2015).

The authors went on to indicate that the STR is viewed as repeating sequences of two to six base pairs of DNA. They are very useful as tools in forensic DNA typing because of their abundance and small size. These traits are valuable when working with forensic samples, as the DNA of these samples tends to be degraded and is present in very small amounts. Manamela *et al*. (2015), citing Buttler, *et al*. (2003), further highlight that within a specific STR locus (the position of the gene on a chromosome; plural: *Loci*) the number of times a repeat unit is repeated varies, leading to a large number of polymorphisms within a given population because there is such a larger number of possible allele variations. Polymorphism means when two or more clearly different observable characteristics or traits such as the colour of eyes, for example, exist in the same population of a species.

These characteristics are called phenotypes, and they make it possible to use allele designation in forensic investigations to match the forensic DNA profile obtained from the crime sample to that of the reference sample of the suspect(s). The SAPS FSL performs forensic DNA analysis, typically on given *loci* (DNA regions) that have repeat units, for example on four base pairs in length, such as the Tetra-nucleotide Repeat Unit (TRU), with a size range of 75 to 400 base pairs.

‘Base pair’ refers to one of the pairs of chemical bases joined by hydrogen bonds that connect the complementary strands of a DNA molecule, which has two strands. With that mentioned, forensic DNA analysis consists of the following steps:

- The DNA within the cells of the exhibit material is released during the DNA isolation step;
- The amount of DNA isolated has to be quantified. An aliquot (the exact factor of a quantity) of isolated DNA is then normalised so that the required DNA can be used for amplification;
- The target area of interest in the DNA is amplified by a process called PCR. Amplification is done in order to multiply the targeted area of the genome so that it can be detected and visualised during the fragment separation step or electrophoresis step to enhance the visualisation of the resultant DNA segments (alleles);
- The DNA segments (alleles) are then separated according to size by means of a process called electrophoresis;
- The separated DNA segments (alleles) are interpreted by examiners, using expert software systems to provide a forensic DNA profile;
- The forensic DNA profiles are contextualised in a report (for example, a suspect is excluded or included, or no finding is made); and
- Computer-generated results are interpreted by the DNA reporting officers to make a finding on whether a suspect(s) is excluded or included as the donor of the DNA, Barbisin and Shewele (2010), Stray, *et al*. (2010) and Shewale (2010), as cited in Manamela, *et al.* (2015).

3.1 The use of science in crime detection

Forensic science provides the link between a crime scene and a suspect. Since 1901, fingerprinting has been used to track offenders. However, the current international forensic tool of choice is DNA profiling, as evidence may be collected in many forms such as hair, blood, saliva, semen and perspiration. While blood, saliva and semen are still the main sources of DNA for forensic testing, trace amounts of DNA, for example from epithelial cells from the surface of the skin, can now be acquired from objects touched by the suspect. Scientists can use the saliva on the rim of a glass, or the skin cells and hair shed on a cap, to compare with a suspect’s blood or saliva sample. Similarly, DNA collected from the perspiration on a hat or scarf, discarded by a rapist, can be compared with DNA in the saliva swabbed from a bite mark on a rape victim.

Another model (Model 4 – Figure 4) was adopted to guide this paper. Models 1 (Figure 1) and 2 (Figure 2), as already depicted in this paper, must be read in conjunction with this model (Model 4 – Figure 4) below. The chosen model illustrates the comparison of three DNA profiles. Two are from suspects and one is the DNA profile obtained from evidence collected at a crime scene. It is clear that the evidence taken from the crime scene matches the DNA profile of Suspect 2, as the sequence of numbers (the DNA profile) is identical to the evidence.

The designations, namely D3, vWA and FGA in the model represent three different chromosomal locations such as STRs under analysis to initiate a comparison between a crime scene sample and two suspects.

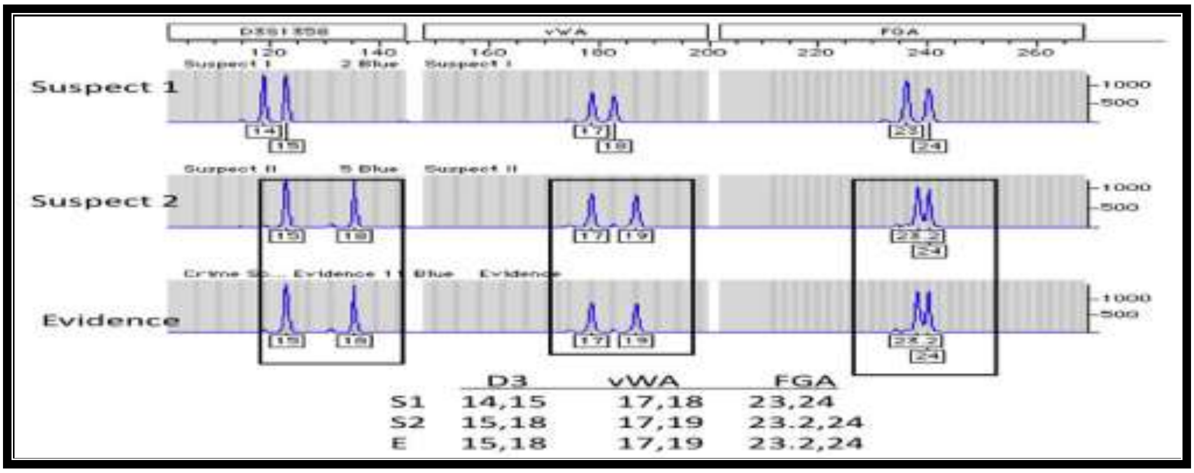

Figure 4: Simplified example of the comparison between a crime scene sample and two suspects (Source: http://dnaproject.co.za/dna-project/dna-database).

In criminal investigations, the sequence of numbers from a DNA profile found at a crime scene may be compared to that of a known suspect stored in the DNA database. Alternatively, where there is no suspect for a particular crime, DNA samples collected at a crime scene may be compared with DNA profiles stored in a National DNA Database (NDNAD). The database is the resource that contains DNA profiles of people suspected and convicted of offences, as well as DNA profiles obtained from evidence left at crime scenes.

A match or "hit" between the crime scene evidence and a database profile may identify a new suspect. This can help to identify or rule out a potential suspect at an early stage, thereby saving valuable police and other crime detection resources, leaving them free for other investigations. For this reason, an NDNAD is considered to be one of the most powerful tools in crime prevention and detection used in the world today.

The time, effort and expense required to develop DNA databases are justified by the facts that:

- Criminals tend to re-offend. For example, 90% of rapists and 50% of armed robbers have a previous conviction;
- The severity of crimes committed by repeat offenders often increases over time, with criminals committing their first offence between the ages of 16 and 19 years; and
- A small number of criminals are often responsible for numerous crimes. DNA databases can assist in linking these crimes to one another (http://dnaproject.co.za/dna-project/dna-database).

Williams and Johnson (2008) confirm that despite the alignment of DNA technology with the general physical sciences and the technologies derived from them, criminalists remain necessarily and resolutely informed by an interest in the application of particular investigatory and analytical techniques to solve individual and sometimes a series of criminal cases under investigation (Sekula 1986, as cited in Williams & Johnson, 2008). For this reason, DNA profiling research protocols and efforts have traditionally been directed towards the improvement of techniques and methods for the delivery of more accurate, more reliable, speedier and cheaper forensic artefacts, and to provide guidance in respect of the appropriate forensic strategies for use in particular kinds of investigations.

Such research has furnished forensic investigators, analysts and other participants with important information about both the benefits and the risks of the use of particular techniques and methodologies, as well as the likelihood that successful profiling can be carried out on differing qualities and quantities of biological material. In addition, research on the generic information that can be derived from crime scene samples when profiles fail to match suspect profiles currently held on a database, provides new resources for investigators.

The recent development of criminalistics depends upon the history of DNA profiling in particular. The dissemination of knowledge of the continuously increasing potential of new and enhanced methods of DNA extraction from biological materials among criminal investigators and crime scene examiners has been a central feature of its successful implementation within policing in the United Kingdom (UK).

In turn, the integration of DNA profiling into the Criminal Justice System (CJS), based on its dependable availability, the robustness of methods for its recovery and analysis, and the increasing clarity of probabilistic reasoning about its significance, has meant that new experimental and inferential methods have been developed to deal with many of the practical problems associated with the collection, analysis and interpretation of biological materials in forensic contexts. All of these scientific and technological advances in the collection and analysis of generic material from crime scenes are germane to an understanding of the increased use of genetic information in support of policing in the UK and elsewhere, South Africa is no different. However, the authors (Williams & Johnson, 2008) indicate that they are driven by a wider Forensic Services (FS) processes that promotes the necessary elements of an investigation, namely the collection, storage, and speculative searching of genetic material taken from known subjects.

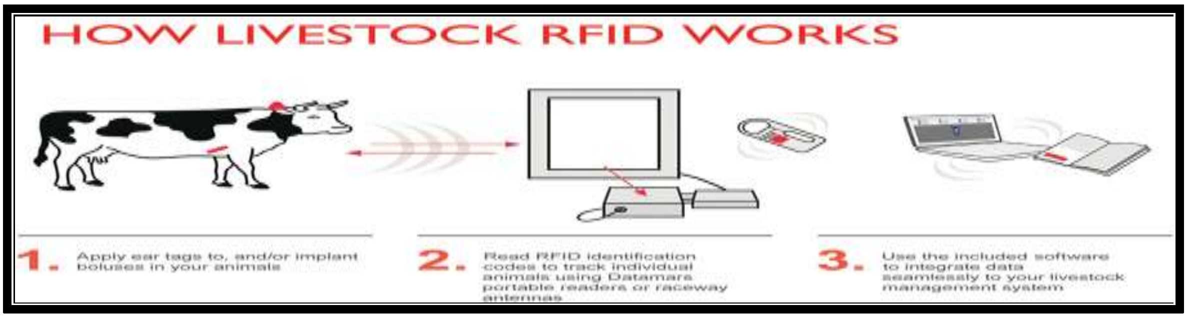

Figure 5: How livestock Radio Frequency Identification works? **(**Source: Datamars, 2015).

RFID on livestock was another model (Model 5 – Figure 5) adopted to underpin this paper. This is an international model whereby the livestock farmers can opt for a technological advancement that uses ear-tags and implantation of boluses into their animals. A tracking device is used to track an individual animal's movement, using portable Datamars livestock readers that quickly and easily capture unique identification information, helping farmers and ranchers make quick work of herd management (Datamars, 2015).

Software to integrate data to the livestock management system is also operated by the RFID system. The integration of Models 1 (Figure 1) to 4 (Figure 4) effectively complements Model 5 (Figure 5) (livestock RFID works), detailing the detection of livestock within their determined boundaries to trigger quick response to the crime scene or area of danger, as livestock moving out of their set boundaries can be detected rapidly to trigger a quick response to the crime scene or area of danger. The models are (1) Steps in DNA sample analysis and interpretation, (2) The chain of custody of forensic samples, (3) The process of obtaining a profile, and (4) Simplified example of the comparison between a crime scene sample and those of two suspects. Notwithstanding these indications, it is essential to note that it is no longer easy to make a living from livestock farming. Farmers have to employ various preventive measures in an attempt to protect their livestock. Moreover, they are expected to manage integrated advancements in the use of DNA technology to combat stock theft within their respective communities.

Globally, the demand for the use of DNA technology in combating stock theft is increasing, but at the same time the number of livestock farmers is decreasing year after year. As a consequence, stock theft will continue to increase if it is ignored, as is currently the case. This trend is also driven by the low profit margin with regard to domesticated livestock. The keeping of such livestock is not based on the income or profit gained by the rural livestock farmers and the number of livestock kept does not determine the business viability, therefore commercialisation is not their main priority. The livestock are kept in order to be sold when the need arises, therefore more effort is expended on the use of conventional methods to combat stock theft, making it more difficult to effectively protect livestock and prevent the scourge of stock theft.

3.2 Wireless Sensor Node / Network

According to Nkwari (2014), many systems have been developed to identify animals and track the movement of animals on South African farms However, certain limitations and high costs are characteristic of the current animal identification and tracking system. Among those systems, the system based on passive RFID technology shows its limitations in the short communication range and real-time mobility for automated monitoring of the animal. On the other hand, the system based on Global System for Mobile Communication (GSM) is expensive because in addition to the system's price, the costs of SMS and General Packet Radio Service (GPRS) data have to be added, therefore the total increases. The typical design structure of a Wireless Sensor Node (WSN) consists of sensors, Central Processing Unit (CPU), transceiver and a battery. Figure 37 indicates the wireless node of constitution and the WSN of which the main parts are the transceiver, the sensors, the CPU and the battery.

- A sensor is a device that converts a physical measurement into an electrical or optical signal. Nowadays, these devices are indispensable and are found everywhere in our daily lives. An example is the camera inside our cell phone. The camera is an image sensor that converts the optical image into an electrical signal that can be treated and sent somewhere else. There is also the temperature sensor that converts the temperature in the vicinity where it is installed into a voltage. The voltage is always proportional to the temperature;

- A transceiver is a device that converts the electrical signal into an electromagnetic signal and vice versa. This equipment allows transmitting the data sensed by the sensor to another transceiver that is situated far way. The transmission is performed wirelessly, meaning there is no physical connection between the two devices; and

- The CPU is the main device that coordinates all other devices, such as when the node has to sense and send data, and which data has to be sent. The CPU acquires the raw data coming from the sensor. Samples of data are taken at regular time intervals and sent to the transceiver, which sends the data to the next transceiver, which may be the base station. It is assumed that the CPU has sufficient memory to perform the tasks.

- All electrical equipment has to be powered. Because the node is using battery power, the use of this resource has to be optimised to prolong battery life (Nkwari, 2014).

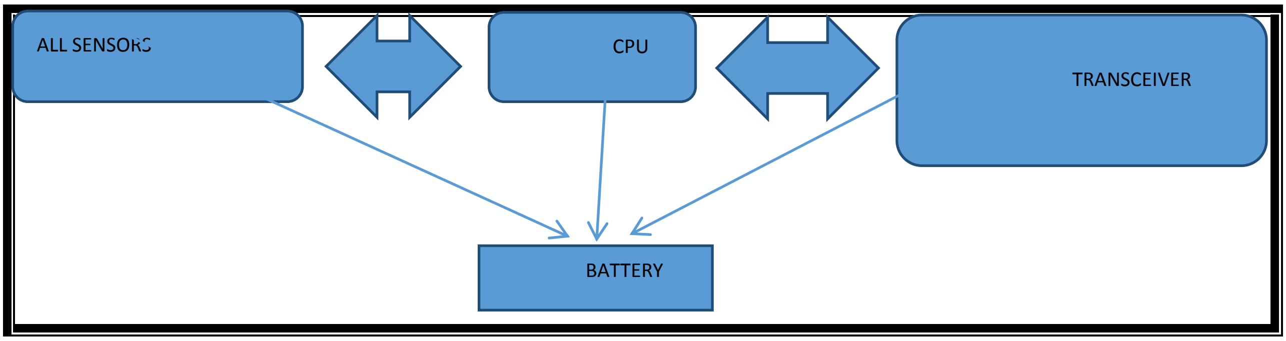

Figure 6a: Wireless Node of Constitution (Source: Nkwari, 2014).

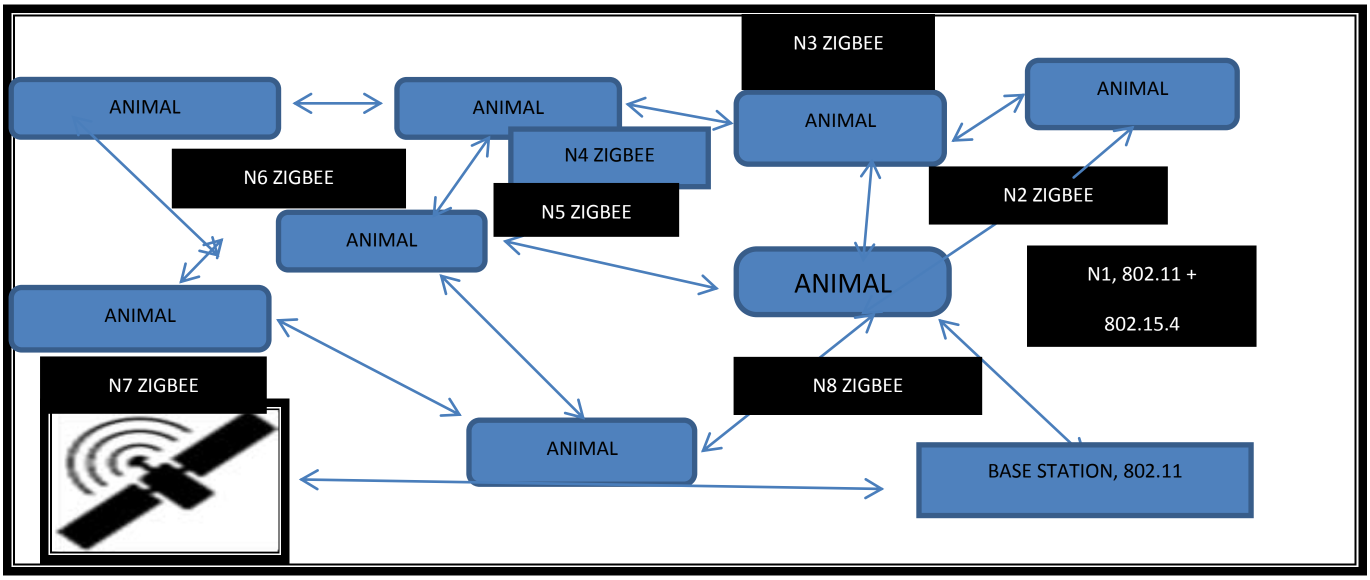

Figure 6b: Wireless Sensor Network / Node (Source: Nkwari, 2014).

Figure 6a and 6b shows the combination of the Institute of Electrical and Electronics Engineers (IEEE) 802.11 and the IEEE 802.15.4. The combined figures (6a and b respectively) represent Model 6 (Figure 6a and 6b), to guide this paper. The researcher reveals that the use of RFID can be expensive to the communal farmers. However, the use of Wireless Fidelity (Wi-Fi) and ZigBee with the application of WSN can be cost-effective (affordable) to the communal farmers.

Sahu, *et al.* (2010), as cited in Nkwari (2014) show that knowing the structure of the node can help the designer to choose the right sensor for his application. In many situations the designer is confronted by a multitude of choices of different sensors available in the market. The choice can be difficult for a designer who has not mastered the tools to build a reliable wireless sensor node. A reliable wireless sensor node must be able to gather information, compute the information and then send it to the base station, where the information is processed and stored. The WSN is composed of four main parts, which are the CPU, the transceiver, the sensors and the power supply. The WSN uses both a Wi-Fi module and a ZigBee module for communication. Figure 6a and 6b shows the combination of the IEEE 802.11 and the IEEE 802.15.4. For this paper, a prototype of the node was built and tested. This early node worked on 5 volts. Then, because the author's GPS and transceiver require 3,3 volts, it was then decided to run the microcontroller on 3,3 volts as well. This was a way to establish communication between two devices that require different power supply voltages. The solution was to use a logic-level converter from 5 volts to 3,3 volts, among other things. Because cost is one of the major issues in the design of wireless sensor nodes, it was decided to use a microcontroller that uses the same range of voltage (3,3 volts) (Nkwari, 2014).

Cattle management is a task that requires an enormous amount of physical energy and human resources. A novel approach, using a WSN system based on ZigBee and Wi-Fi, was proposed and has the potential to decrease cattle rustling and improve the quality of remote cattle management. The WSN application determines and circumscribes a safe zone where the herd has to be, according to the behaviour of the animal and the herd in general. The WSN was built based on ZigBee technology and it can determine an animal's position and speed, which were analysed to get the probability distribution function for the cattle behaviour. The cow's position is obtained and sent to a control unit for centralised monitoring (Nkwari, 2014).

Then, a Continuous Time Markov chain Process (CTMP) was used to model the behaviour of the cattle. The WSN system can mitigate livestock theft and assist the farm manager by monitoring the position of cattle. This system can alert the farm manager when the cow is out of the safe zone. A heterogeneous wireless network was formed with ZigBee and Wi-Fi technology. These two technologies provide the system with the advantages of gathering the data in real-time and increasing the network's coverage range. The author showed how GPS data can be computed at a node, and then the speed, altitude, longitude, date and time can be sent to the sink and the data stored at a base station. It was also emphasised that cattle should be near a boundary for the devices (ZigBee and Wi-Fi technologies) to determine an animal's position in the field. A prototype system for cattle monitoring was designed. The results illustrated the capability, suitability and limitation of the chosen technologies (ZigBee and Wi-Fi technology) (Nkwari, 2014).

4. RECOMMENDATIONS AND CONCLUSION

4.1 Proposing a new Deoxyribonucleic Acid technology conceptual framework in combating stock theft in South Africa

4.1.1 Introduction to a proposed conceptual framework

The conceptual framework is presented in this section of this study that contains the description of the proposed new DNA technology conceptual framework for combating stock theft in SA; the process followed for developing a new conceptual framework, including its components, was explored. The relationship between the research purpose, objectives and research question is provided, together with the components of the proposed conceptual framework for this paper.

4.1.2 The new Deoxyribonucleic Acid technology conceptual framework in combating stock theft in South Africa

Previous researchers of stock theft have not recommended to future researchers of the humanities, forensic science and related research areas to explore and describe the use and value of DNA technology in combating stock theft. The development of a new DNA technology conceptual framework for combating stock theft in South Africa has also been neglected. However, examination of the previous studies regarding the combating, policing and prevention of stock theft across the globe highlighted the conventional methods of responding to this scourge and the importance of the use of DNA technology. This paper proposes a new conceptual DNA technology framework for combating stock theft in South Africa and especially the selected areas in KZN, and comprises five (5) components.

4.1.3 Deoxyribonucleic Acid technology conceptual framework for combating stock theft in South Africa

Prior researches on policing and prevention of stock theft have demonstrated that there is a basic relationship between DNA technology and livestock farming. The available literature highlighted that DNA technology can be used to link a potential suspect to a stock theft scene or act as a reference sample in combating this crime.

Therefore, a new DNA technology framework to combat stock theft in South Africa has been conceptualised in this paper, based on the presented literature review, documentary analysis, FGDs and KIIs conducted in this paper. The DNA technology can be used effectively to combat stock theft in South Africa, including selected areas in the KZN Province.

A newly proposed conceptual South African DNA technology framework for combating stock theft in South Africa envisages that stock theft can be combated effectively with the use of DNA technology and other available conventional methods. The proposed conceptual framework consists of five components, namely:

- Knowledge Management (KM);
- Available devices for combating stock theft;
- The preliminary investigation phases;
- DNA Technology analysis; and
- Court procedures and conviction rates.

The researcher foresees that the combination of the components listed above could effectively lead to the combating of stock theft in the selected areas of KZN, South Africa. The framework in question further represents the combination of KM, other available technologies (RFID, WI-FI, WSN, ZigBee) and DNA technology, with integration of conventional methods (brand-marking and tattooing) in combating stock theft to cater for both the commercial and emerging farmers in the KZN Province.

The international identification methods for combating stock theft were considered in designing the conceptual framework for combating stock theft in South Africa, the selected areas of KZN included. The countries considered included: Argentina, Chile, Botswana, Brazil, Malawi, Namibia, Paraguay, Uruguay, Lesotho, Swaziland and South Africa, among others.

It was revealed that the majority of the identified countries still rely on conventional means of combating stock theft. Many of the adopted technological systems for use in these countries include ear-tags, either visual ear-tags or ear-tags containing electronic microchips with detailed information of each animal, and conventional means such as brand-marking and tattooing. The use of DNA technology is focused on genetics for the purpose of exporting the meat to foreign countries, rather than on combating stock theft. The new challenges faced in the livestock farming industry to combat stock theft will continuously engender solutions and improvements. This calls for the relevant stakeholders to become the front runners in using the latest technology to combat stock theft effectively, while simultaneously aligning the South Africa methods with the international standards, using the best practices from across the globe and being able to compete on the world stage in terms of protecting and preserving our valuable assets.

It is the researcher's view that the proposed new conceptual framework for combating stock theft should be widely disseminated. This will bring new methods of combating stock theft into South Africa and other countries, as this scourge is becoming a world problem. The importance of investigating stock theft will also be put in the spotlight, as smaller samples and more degraded samples for analysis positively link potential suspects with a stock theft scene. This framework calls for reference sample databases for all types of livestock farmers to allow stock theft to be solved through the use of DNA technology in conjunction with the available technologies and the conventional methods. This will strengthen the evidence gathered by the SAPS STUs in line with admissibility and reliability in court, thereby further increasing conviction rates. With the CJS, this framework will not only identify potential stock theft criminals but also exonerate the innocent individuals on the other end.

The purpose, objectives and research question of this paper forms part of the proposed conceptual framework. Figure 7 depicts the proposed conceptual framework for combating stock theft in South Africa. Figure 7 also indicates how serious and lucrative stock theft is becoming in South Africa, as well as the impact it has on the livestock farming industry (commercial and emergent/communal farmers). KM could obviously lead to the implementation of a comprehensive approach to intensify the relevant stakeholders' efforts to combat stock theft, not only in the selected areas of KZN, but in broader society in general.

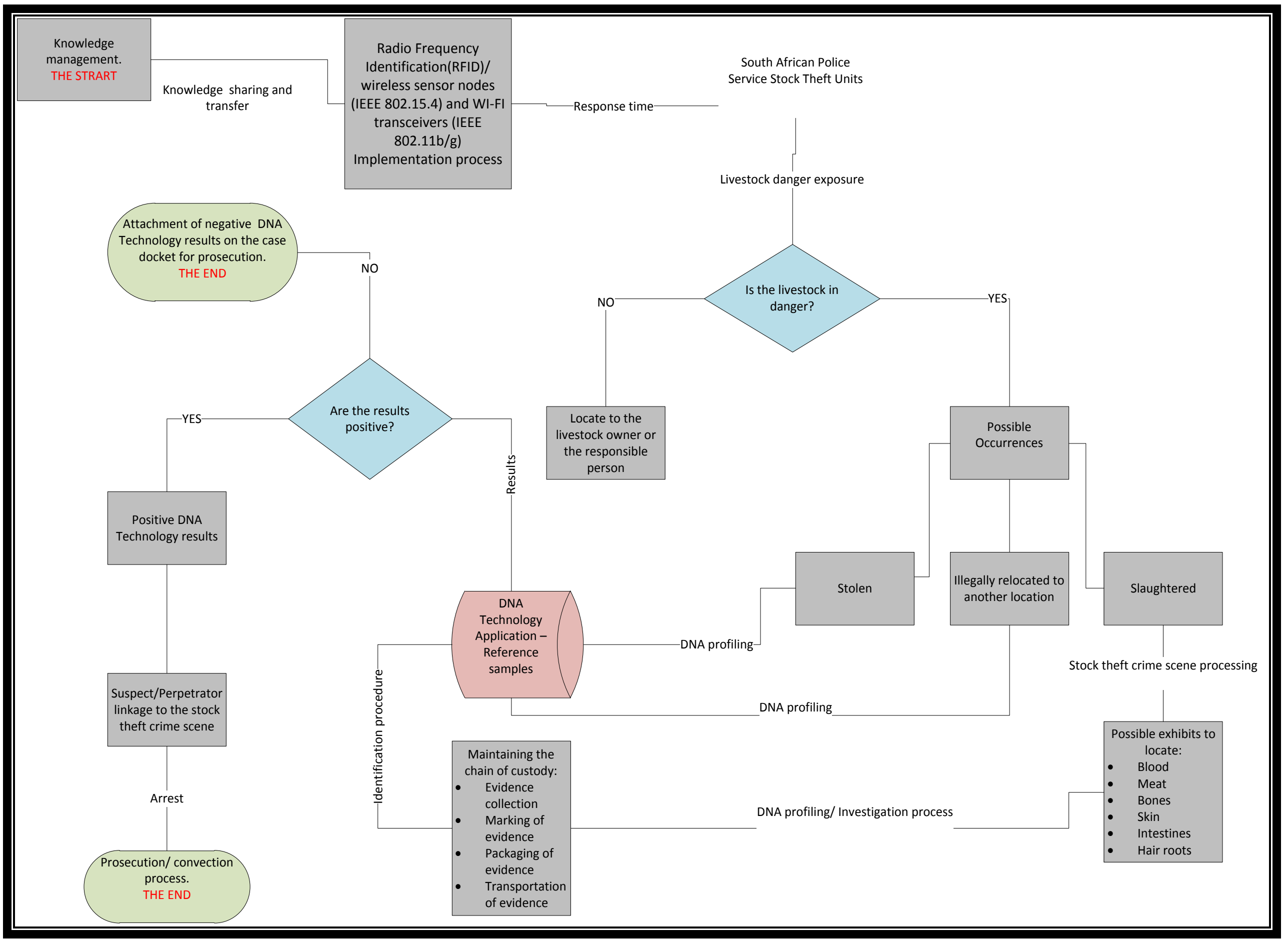

Figure 7: Schematic representation of a proposed new conceptual Deoxyribonucleic Acid technology framework for combating stock theft in South Africa (Source: Researcher's illustration).

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