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Combating Stock Theft with Deoxyribonucleic Acid Samples and Innovative Technology in South Africa

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Abstract

Stock theft strips the South African economy of a great deal of money. This scourge threatens both the commercial and emergent farming sectors. The goats, sheep and cattle losses amount to millions of rands in Eastern Cape (EC), Limpopo (LIM) and KwaZulu-Natal (KZN) Provinces, which in 2021 were touted as the top Ten (10) hot spot police stations. As a recourse, the Deoxyribonucleic Acid (DNA) samples are used as an important forensic evidential tool to resolve this crime and ensure accuracy and fairness in the Criminal Justice System (CJS). Equally, the Mobile Telephone Network (MTN) (The South African cellular service provider) and Huawei Technologies collaborated to launch the 'connected animal solution-Internet of Things (IoT),' a digitised innovation, which allows livestock farmers to improve their animal management and health screening through activity and movement-monitoring and related analysis. Therefore, the purpose of this study was to explore the combating of stock theft with DNA samples and innovative technology (IoT), in this regard, focusing on the selected areas of KZN Province. From a qualitative standpoint, empirical research, documentary studies, Focus Group Discussions (FGDs) and Key Informant Interview (KIIs) were adopted as data collection methods. The collected data was analysed employing the inductive Thematic Content Analysis (TCA). This paper found that the indicated nexus can adequately aid in evidence gathering relating to identification by DNA characteristics (I.e. Typing and sample usage), ownership (I.e. Kingship identification), paternity testing, management and monitoring of livestock movements, potential danger minimisation, tracking of straying livestock, improving efficiency and reduction of costs. It is recommended that livestock farmers should exercise their actionable educational insights regarding the effective use of the DNA samples and IoT by exercising physical matching of ear notches and brands, providing specific descriptions, and verifying their near real-time visibility in varying periods.

Keywords: *Combating; Deoxyribonucleic Acid Samples; Innovative Technology (Internet of Things); Stock Theft; South Africa*

Introduction and Problem Formulation(S)

Negatively, the Criminology and Criminal Justice scholars rarely pay attention to agricultural crimes, stock theft included. A mythology of agriculture free from crime risks, this is part of a larger mythology still accepted by many in the criminological community that assumes rural people and rural communities are immune to crime when contrasted with the criminogenic conditions of urban localities (Donnermeyer, 2012; Barclay & Donnermeyer, 2011) (in Donnermeyer, 2014:1). Positively, Clack (2013:77) argues that agriculture is one of the cornerstones of any country's economy. Therefore, the various crimes committed within the rural agricultural communities have to be researched, as they influence the economy and food security of the country.

The Stock Theft Act (No. 57 of 1959) (SAPS, 2011:2) stipulates that 'livestock' means any horse, mule, ass, bull, cow, ox, heifer, calf, sheep, goat, pig, poultry, domesticated ostrich, game, or the carcass, or portion of the carcass of any such stock. Livestock refers to farm animals (such as cows, horses and pigs) that are kept, raised, and used by people or are kept or raised for use, pleasure and profit, especially farm animals (Webster, 2015). In support of this statement, Wehmeier (2006:865) states that livestock refers to the animals kept on a farm or ranch, those kept in a kraal within a community's facility for their meat, wool or breeding, for example cattle, horses, goats or sheep. Marckwardt, Cassidy and McMillan (1995:745) define livestock as domestic animals kept for use, pleasure and profit, especially marketable animals such as cattle, horses, and sheep. Whereas animal means any horse, mule, ass, cattle, sheep, goat, pig, or ostrich, or the carcass, or a portion of the carcass of any such animal, animal produce means whole, or any part of, skins, hides, horns, intestines, heads, parts of bones, claws, semen, or embryos, and any wool, mohair, or ostrich feathers, and ostrich eggs (SAPS, 2011:7). For the purpose of this study, the concept livestock must be read in conjunction with the definition of animals, comprising of the cattle, goats and sheep, as domestic livestock and commonly targeted by stock thieves in the selected areas of KZN Province, South Africa.

According to [Richard] Chelin (2020), the researcher at ENACT Africa: Enhancing Africa's capacity to respond more effectively to transnational organised crime, an organisation working in partnership with the Institute for Security Studies [ISS] (in Dean, 2020), the threat of growing transnational organised crime involving stock theft is posed by syndicates who steal cattle in South Africa, taking them across the border to Lesotho for a cooling-off period, and then selling them back to South Africa. This scourge is nothing new to livestock farmers from a South African perspective. The available research (Clack, 2013; Doorewaard, 2020; Lombard, 2016; Lombard, Van Niekerk & Maré, 2017; Lombard, van Niekerk, Geyer & Jordaan, 2017; the KZN Department of Community Safety and Liaison - DCSL, 2008; Maluleke, 2014; Maluleke, 2016; and Manganyi, Maluleke & Shandu, 2018) contend that stock theft is as old as agriculture itself. The recorded cases of stock theft in South Africa can be traced as far back as 1806. Livestock theft affects the livestock industries in all nine provinces of South Africa, as it has become a lucrative business and affects all livestock farmers (Maluleke, 2014; Maluleke, 2016; Maluleke, 2018; and Maluleke & Mofokeng, 2018). The selected areas in KZN (Bulwer, Ladysmith and Utrecht) are prone to stock theft, which causes long-term pain and suffering to the livestock farmers.

The New South Wales [NSW] Stock Theft and Trespass Review Final Report (2016:3) confirms that stock theft remains a major problem in the agricultural sector in South Africa and threatens both commercial and the emerging farming sectors in most of the country. It is further established that stock theft, rural trespassing and illegal hunting are crimes of major concern to rural and isolated communities. These crimes can lead to significant economic loss for primary producers and rural communities, with one incident potentially leading to tens or even hundreds of thousands of rands in property theft and malicious damage, as well as the loss of future breeding potential, (The NSW Stock Theft and Trespass Review Final Report, 2016:3).

Nkwari, Rimer and Paul (2014:1) agree that stock theft remains a major problem in the agricultural sector in South Africa and threatens both commercial and emerging farming sectors in most of the country. Although there have been several techniques to identify cattle and combat stock theft, the persistence of this crime has not been eradicated in the farming sector. Crime on farms have been an integral part of South Africa's history; the KZN DCSL (2008:16) observes that "what is certain is that at some point in the mid-1990s, the age-old cycle of theft and counter-theft, which had long been integrated into communal life, was ratcheted up to a new level" (KZN DCSL, 2008:16). Presently, more than a century later, little has changed, and the current strength of livestock prices has led to a record number of reported livestock thefts across the country, as stated earlier. This has led to considerable public debate over how best to deal with the problem of stock theft. However, no study has been done on the use of DNA samples and IoT in combating stock theft in any province of South Africa.

The importance of livestock farming practices and stock theft are neglected by researchers in the field of humanities and related research areas, when compared to other property-related crimes across South Africa (Clack, 2013; Clack, 2018; and Maluleke, 2016) since stock theft may seem to be a minor crime to the public. The existing literature proposes a variety of methods of combating stock theft across South Africa and globally (Maluleke, 2016). DNA samples are designed to revolutionise modern science. As the criminal elements of stock theft evolve, more applications to combat this crime are discovered. DNA samples, the focus of this study makes it possible to provide a means of irrefutable identification of livestock, while the IoT, manage and monitor livestock movements.

Advances in Information and Communications Technology (ICT) affect various aspects of human life, resulting in positive impacts on technological developments in society (Imtihan, Bagye, Zaen, Fadli, Ashari, 2021). Thus, with the growing adoption of the IoT, connected devices have penetrated every aspect of our life, from health and fitness, home automation, livestock theft prevention, combating and investigations, the automotive industry and logistics, to smart cities and industrial IoT, among others. Thus, it is only logical that IoT, connected devices, and automation would find its application in agriculture and tremendously improve nearly every facet of it. Livestock farming has seen a number of technological transformations in the last decades, becoming more industrialised and technology driven. By using various smart agricultural gadgets, farmers have gained better control over the process of raising livestock and growing crops, making it more predictable and improving its efficiency (Chalimov, 2022).

The IoT can be efficiently used for livestock monitoring and management by attaching agriculture sensors derived from IoT to the animals on a farm to monitor their health and to log performance. Livestock tracking and monitoring help identify stock health and well-being, and physical location. For example, such sensors can identify sick animals so that farmers can separate them from the herd and avoid contamination (Chalimov, 2022:1). Chalimov (2022:1) further points out that using drones for real-time cattle tracking also helps farmers reduce staffing expenses. This works similarly to IoT devices for Petcare, for example, 'SCR' by Allflex and Cowlar use smart agricultural sensors (I.e. Collar tags) to deliver temperature, health, activity, and nutrition insights on each individual cow as well as collective information about the herd (Chalimov, 2022:1). Imtihan *et al.* (2021) conclude that IoT related tools can function properly, starting from taking pictures, sending images and the coordinates of the location of criminal points so that it has great potential to help find stolen livestock and to increase the number of thieves who are arrested as an effort to reduce stock theft.

It is also revealed by Nana (2021:1) that African countries have more mobile phone access than clean water, a bank account or electricity. These high levels of connectivity and cell phone penetration mean that farmers can benefit from real-time data. This can materially enhance crop yields, soil quality analysis, resource management, *tracking of livestock*, farm security management, sustainable pest control and reduction of post-harvest wastage. To leverage the power of the IoT, MTN, present in 19 African countries, has partnered with 'Aotoso' Technology in a proof-of-concept process to provide connected collars for cattle. Using the Subscriber Identity Module or Subscriber Identification Module (SIM) cards on the collar, farmers can, using their cell phones, receive vital information about the cattle, which they can use to inform feeding and breeding strategies as well as prevention of cattle theft, even in rural areas (Nana, 2021:1).

It was established by Memon *et al.* (2016:1) that all livestock have a unique DNA profile. In the event that livestock are stolen, illegally relocated or even slaughtered, biological samples of such livestock can simply be taken and their DNA profile compared to those of the reference samples in order to verify their identity, effectively linking criminals to crime scenes. The advantage of this practice lies in identifying criminals with incredible accuracy when biological evidence exists. It can also clear suspects and exonerate persons who have mistakenly been accused or convicted of crime, making it increasingly vital to ensure accuracy and fairness within the CJS.

Whereas Kevin Ashton first defined the term 'IoT' in 1999 (Gubbi *et al.* 2013, in Memon *et al.* 2016:1). This is a new paradigm about the ability of connected devices to sense and gather data, and then share that data using the Internet facility so that it can be processed and utilised to fulfil common goals, Atzori, Iera, Morabito (2010) (in Memon *et al.* 2016:1). The IoT refers to a technology that tells that in the near future billions of devices will have internet connectivity and can be accessed from anywhere in the world. Thus, there can be many IoT enabled applications such as smart parking, smart animal farming, and smart waste management systems, to name a few (Memon *et al.* 2016:1).

The Smarter Technologies (2022:1) mentions that operationally; the Global Positioning System (GPS) livestock tracking collars provide real-time data analytics on individual animals, giving accurate visibility into the location of individual animals, allowing livestock farmers to quickly identify any unusual patterns or movement. It is regarded as a 'comprehensive smart farm solution' as livestock security and asset tracking monitoring and recovery solutions with low-power radio, GPS and IoT technologies become feasible by feeding back real-time data on the location, health and security of livestock and other valuable assets.

This critical data allows for the protection and securing of rural businesses *(Including livestock farming practices and challenges caused by stock theft - Researcher's emphasis)* and homes, raising productivity, automating to help combat labour shortages and attracting young farming talent as through the use of modern technologies, the livestock location can be monitored and a livestock 24/7 status provided through animal tracking with an IoT Cattle collar, ear tag or other similar location-tracking hardware with in-built GPS and GeoFencing capabilities. This equipment also allows livestock farmers to locate a lost or stolen cow and track them with scanners in beacon mode for fast recovery, increasing the opportunity to arrest and convict the perpetrators, combined with other smart farm solutions, the IoT Cattle tracking collar allows livestock farmers to manage local farms and livestock with more ease and accuracy (Smarter Technologies, 2022:1).

The basis of this study centred on the roles and competencies of the SAPS and other relevant stakeholders in combating stock theft through the use of the DNA samples and IoT to combat stock theft in the KZN, focusing on Ladysmith, Bulwer (Pietermaritzburg) and Utrecht (Newcastle) policing areas respectively. The purpose of this study was to explore the value of DNA samples and IoT in combating stock theft in the selected areas of KZN Province, while guided by the following objective:

- Identify factors that hinder effectiveness in applying the DNA samples and IoT to curb stock theft.

The following section provides the adopted methodology, consulted literature studies and adopted theoretical frameworks. The findings and discussions sections are also covered herein, as well as the presentation of the identified themes and challenges based on the purpose and objectives of this study. This was accomplished ensuring coherent linkages between the reviewed studies, applied theories, empirical study findings and identified study themes and challenges. A recollection of the literature review section and collected data was showcased to present a true and accurate picture of what was claimed by the cited authors, empirical data and the identified themes and challenges, as referred to in the reported study findings.

Methodology

This study was carried out with questions that were tailored along the descriptive and exploratory paths and complemented with the use of both FGDs, KIIs and documentary studies. The participants were drawn from the KZN Province. A purposive sampling technique was used based on the researchers' rationale that certain categories of participants could provide more detailed information on the phenomenon under examination. Such selections were also based on the participants' years of experience in relation to the subject matter and being relevant stakeholders in the combating and prevention of stock theft in that province. All participants were Africans and Whites, fluent in both IsiZulu and English.

The sample size for this study was 49 participants, inclusive of both Males and Females, and the procedure comprised of relevant stakeholders who participated in a series of FGDs and KIIs, as follows: Two (02) Department of Agriculture, Forestry and Fisheries (DAFF) staff (Assistant Directors: Animal Technicians and Animal Production officials] (KIIs); One (01) SAPS Stock Theft Unit (STU) Provincial Co-ordinator (KII); 38 KZN, South African Police Service Stock Theft Units (SAPS STUs] members, 14 by means of KIIs; and 24 formed part of the FGDs; Eight (08) livestock farmers; Three (03) [Community Police Forum (CPF) members/chairpersons (KIIs); and Five (05) Anti-Stock theft association managers (KIIs).

In addition, the researcher was interested in assessing the strategies used by these stakeholders versus the use of DNA samples and IoT in combating stock theft in the selected areas of KZN Province. During the record-taking process, the researcher took notes, with a view to writing a more detailed and complete report afterwards. A voice recorder was also used for FGDs and KIIs, with a view to transcribing the information gathered at a later stage, with interviews lasting for 30-60 minutes. For the purpose of this study, the researcher abided strictly by the SAPS National Instruction 1/2006, as well as by Tshwane University of Technology's (TUT) Policy on Research Ethics of 2004/2012.

For data analysis, the researcher categorised the obtained data based on themes, concepts, or similar features. The researcher further ensured that the elicited data answered the objective guiding the research study. The researchers read the data several times to grasp the selected participants' perceptions on this subject. This was done by taking written notes of what the participants were saying during the FGDs and KIIs to solicit study themes via the inductive CA. The actual words used by the participants were written down verbatim (Manganyi, Maluleke & Shandu, 2018:99, 100; and Matlala, 2012:113, 114). The collected data was analysed by reducing the volume of consulted studies and empirical study findings in terms of study significance, identification of significant patterns based on what the analysed data revealed was practiced to reach structured and trusted conclusions. Braun and Clarke (2006) provide that the inductive TCA focus on the identification and classification of patterns or themes from collected qualitative data. The researcher followed Clarke and Braun's (2014) models of inductive TCA for data analysis:

- **Phase 1: Familiarisation with data:** The researcher familiarised himself with the collected data from the 49 selected participants in the KZN Province. This was achieved through listening to the voice and reading the written notes to transcribe and collate them at the later phase.
- **Phase 2: Generating codes:** Codes were initiated to identify thematic features from the collected data. This process ensured simplification of all the collected data and determined meaningful segments of the selected participants' responses by identifying keywords from the participants to check the commonality of the responses based on the objectives of this study.
- **Phase 3: Identifying themes:** After identification of the different codes across the data set, themes (and challenges) were identified by organising themes based on the generated codes from the collected data.
- **Phase 4: Reviewing themes:** The identified themes were reviewed and correlated with the generated codes from the collected data to ensure correspondence with the objective of this study.

- **Phase 5: Defining themes:** The identified 02 study themes (And challenges) were outlined and discussed based on the objective of this study, aided by the reviewed literature studies, theoretical framework and empirical findings.
- **Phase 6: Article writing:** This study explored the use of DNA samples and IoT in combating stock theft in the selected areas of KZN Province for the final production of this study.

Literature Review and Theoretical Framework

The Use of Deoxyribonucleic Acid Samples in Combating Stock Theft

Every animal is unique and will have permanent marks from being handled over the years. These can all be used for identification purposes to link stolen livestock to their owners' herds, taking these factors into account and using research, DNA samples, as well as circumstantial evidence; prosecutors can reconstruct stock theft cases successfully and secure a possible conviction. To achieve this, however, they need some understanding of stock handling methods and the correct use of livestock farming terminology. Many thieves do their best to change the appearance of livestock shortly after it has been stolen. Typically, they dehorn, remove ear tags, or smudge brand marks with a hot spade or other object. Thus, the Prosecutor has to link evidence to an animal whose appearance may have been changed or to a farm that may be far away from where animals or parts of animals have been found. Being able to match wool, ear notches, branding, dehorning methods, castration and age to stolen livestock is crucial (Uys, 2017).

To the contrary, Maluleke and Mofokeng (2018) and Maluleke (2016) contend that existing studies on stock theft mainly focus on combating theft using conventional methods such as brand-marking and tattooing, with the emphasis being placed on the current legislative frameworks of South Africa's Stock Theft Act, 1959 and the Animal Identification Act (No. 6 of 2002). Limited studies have been done to explore the use of DNA samples and IoT in combating stock theft in the selected areas of KZN Province and other provinces of South African.

Mapholi (2015) asserts that stock th*eft* and poaching are major challenges to livestock farming and game production in South Africa. The author is of the opinion that this practice has an impact on the economy, affecting all sectors of the farming community, from large commercial organisations to stud breeders, and extending to the rural farmers who may own one or two animals. As a result, economic losses due to stock theft are estimated to be R750 million per annum. Mapholi (2015) went to mention that the South African government through the SAPS has identified stock theft as one of the priority areas, and a partnership has been established between SAPS and the Animal Genetics Laboratory (AGL) of the Animal Research Council (ARC), Animal Production Institute (API) at Irene, Pretoria, to address the challenge of stock theft through the use of DNA samples and IoT in combating stock theft. The agreement between the two organisations was established in 1996.

Mapholi (2015) continues that based on SAPS statistics, approximately 45 000 stock theft cases are reported for court purposes per year, but only about 8 000 cases go to court. More than 500 of the court cases, involving more than 3 000 exhibits, use evidence obtained from DNA sample analysis. About 95% of these cases are resolved and suspects are prosecuted Mapholi (2015). Furthermore, Kempen (2015:10) is of the view that DNA samples can be used to link criminals to crime scenes. The advantage of this practice lies in achieving the identification of criminals with incredible accuracy when there is biological evidence, and it can also clear suspects and exonerate persons who have mistakenly been accused or convicted of crime. Thus, DNA samples are increasingly vital to ensure accuracy and fairness in the CJS.

In addition, the researcher presents that the DNA samples can be used as an important forensic instrument to combat stock theft and is becoming an increasingly important component of the criminal justice system. The researcher also highlights that the DNA samples are largely used for the determination of identity, ownership, age, 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 fingerprint or unique identification. Only small quantities of DNA samples are needed to confirm the fingerprint of livestock (Maluleke, 2016) and help to combat stock theft through the applications of this process:

Hair samples (I.e. 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 suspects' 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 (NSTPF, 2016:34-35).

The application of Internet of Things in Combating Stock Theft

Dieng, Thiare, Diop and Pham (2017) present that the IoT is not a new technology, it is simply the integration of several technologies that have matured, to communicate almost all objects to collect more data that is used in improving decision making. These technologies can be found at all levels of the structure that define the IoT. The agricultural sector always had end-devices that collect data and route them to one or more processing centre through the Internet or another network that may or not go through the internet. These technologies are those related to hardware for end-devices and gateways, sensors for data collection, communication for different networks, and data processing.

The SAPS STUs monitoring system is applied based on the use of cell phones and personal computers of the livestock farmers and other relevant anti-stock theft stakeholders. This process is guided by the concept described as "effective stock theft control and monitoring system, designed by the Agri-Alert system". This system encompasses the different mechanisms such as the activity alarm; GPS alarm; water level monitoring; panic alarm; and temperature alarm to monitor and combat stock theft in given locations (Burger, 2012:1). This system provides for livestock farmers to monitor their animals' movements and any disturbances, using their cell phones. The GPS coordinates are also available everywhere, for the farmers in question to receive an SMS in this regard. Agri-alert (2013:1) states that 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. The base tower then sends an SMS message to the cell phone of the farmer, informing him of this behaviour.

Dieng *et al.* (2017) share that the implementing a solution of IoT is regarded as an adequate technological choice regarding the domain and the needs of this solution. The choice of technologies may involve several criteria such as cost, commercial or free, the nature of the data to be collected, and deployment type. The choice of technologies to prevent and combat stock theft; cattle, goats and sheep, among others in the African context should be made considering criteria specific to the rural areas and the social conditions of farmers in this environment. In this context, the major criteria include cost and internet access. The rural farmers are mostly poor and so will be less sceptical about a solution if it does not require high costs. In addition, they live in areas where Internet access is difficult and Third Generation [3G] (I.e. Third generation cell phone network technology, capable of fast rates of data transmission that support electronic-mail (e-mail) communications, high-speed internet access, and video streaming, among others) or Forth Generation [4G] operators do not generally cover them, Dieng *et al.* (2017).

With high levels of technological application approaches, the concept of IoT is gaining popularity and becoming a major source for smart innovations. An added advantage of internet application is that the technology enables sensing, processing and execution automatically and remotely with a fingertip. The IoT makes sure of easy availability and access to the information available at any corner of the world (Harikrishnan & Gaikwad, 2021). The IoT can be harnessed to solve real-world problems, for example, the 'FindMy' software delivers new functionality, including delivering a complete herd/flock location update at particular convenient times of day as specified by the farmer. If the track points suggest something is wrong, the farmer knows exactly where to head. The system also now includes an improved accelerometer and motion detector sensitive enough to detect if an animal is in distress, such as if it's frightened or being chased.

Geldenhuys (2011:36) suggests that DNA samples are a powerful tool for convicting the guilty and exonerating the innocent. This application can also be used to link crime scenes with one another. Geldenhuys (2011) adds that DNA samples are available technologies that bring significant changes to the CJS, including revolutionary techniques to analyse crime-scene evidence in highly sophisticated crime laboratories for evidential purposes. The author mentions that crime detection in the form of generating reliable information and the role of the police are pivotal in the CJS. Compared to the other sections of the CJS, the DNA samples and IoT has had the most far-reaching effect on the realm of policing. Available technologies and new ways of obtaining information have enhanced the capacity of the police to "collect, retrieve and analyse information". The researcher concurs with the author [Geldenhuys, 2011] as the DNA samples and IoT are no exception in this regard. The use of DNA samples could bring about the much-needed changes in policing of stock theft across South African communities and elsewhere.

With the diffusion of the IoT paradigm, objects are being connected to the Internet, thus realising a global network of connected things. This new concept is being used in several scenarios, such as smart cities, industrial manufacturing, healthcare and transportation. Another application scenario is in rural areas, and specifically on smart livestock farming, on which this work is focused. The design and implementation of a small-scale sensor network devoted to the monitoring of cattle's vital parameters and cowsheds environmental parameters using the Long-Range (LoRa) (I.e. From 'long range,' *de facto* wireless platform of IoT) and Low Power Wide Area Networks (LPWAN) technologies. The choice of the LoRa network technology has proven advantageous due to the resilient transmission, the wide coverage, and the long-lasting battery lifespan, which meet the needs of rural area IoT applications (Germani, Mecarelli, Baruffa, Rugini & Frescura, 2019).

The combined views provide detailed explanations of DNA make-up in an attempt to direct the reader to the inception of the use of DNA samples and the noted benefits to the CJS. The researcher further acknowledges that simplified explanations, as presented above, provide the reader with clear theoretical viewpoints on the importance of DNA samples in combating stock theft and its applications in relation to livestock farming, while also considering bio-technologies for efficient productivity. Biotechnologies integrated with conventional methods are used for efficient productivity and for combating, investigating, policing and preventing stock theft. The researcher submits that the necessity of using DNA samples in combating stock theft should be measured by the successfully prosecuted cases across the country and selected areas of KZN.

The Centre for African Journalists [CAJ] News (2018) reports that the MTN South Africa and Huawei Technologies have partnered to launch the Connected Animal Solution, an IoT innovation aimed 'at solving the rampant problems of stock theft and rhino poaching'. This partnership offers solutions to the increasing number of stock thefts across South Africa to allow local livestock farmers to improve animal-management and health screening through activity and movement, monitoring and analysis. Stock theft was touted as one of South Africa's most persistent crimes with about 400 000 domestic animals, valued at more than R1billion reported stolen between 2006 and 2010, as revealed by the South African Society for Animal Science. Worryingly, over 500 rhino have been poached since the beginning of 2018. These farmers received actionable insights and early warning information to make decisions that help them manage their livestock, better improving efficiency and reducing costs. By using the IoT, the local livestock farmers have near real-time visibility of their livestock, which acts as a deterrent to stock theft. This solution would help farmers also track straying animals and is a similar wildlife tracking solution to that which allows for the monitoring of our precious rhino populations in our game parks, giving rangers better tools to fight poaching.

As illustrated in the 'introduction and problem formulation' section by Clack (2018); Clack (2013); Dean (2020); Maluleke (2018); Maluleke (2014), NSW Stock Theft and Trespass Review Final Report(2016), the cited study by Zantsi and Nkunjana (2021) further support that stock theft is among the major challenges faced by livestock farmers in South Africa, with severe consequences especially for smallholder farmers, who collectively own a large share of the South African livestock herds but individually keep small herds. Moreover, technological improvements and innovations have made it possible to track livestock movements by using GPS animal tracking devices. This includes low-cost GPS developed used elsewhere and in the local commercial sector. Given the well-known role of extension, for example, information and technology dissemination, however, the possibility that smallholders adopt GPS animal tracking devices should be evaluated, as very few studies have made a case for using this technology in combating stock theft among smallholder farmers. This cited study addresses the likelihood that smallholder livestock farmers in South Africa adopt GPS animal tracking devices to mitigate the impact of this crime.

The results of the cited study by Zantsi and Nkunjana (2021) suggest that the likelihood of GPS animal tracking device adoption by smallholders will depend on the following facets: A) The awareness of the devices and how they work, B) The acuteness of stock theft for a farmer and how livestock contributes the farmer's livelihood, and; C) The income level, access to mobile phones and risk behaviour of farmers. Generally, some of the conventional practices to efficiently respond to stock theft in South Africa are outdated and will not help the rural smallholder farmers acquire knowledge, skills, and attitudes (I.e. Competencies) in order to transform or empower them and make them able to solve their problems. This calls for an urgent shift of mind-set and current strategies by relevant anti-stock theft stakeholders, as smallholder livestock farmers are still in the rural areas unnoticed and neglected although there is much rhetoric about them. It should be noted that research is a means to either discover or extend theoretical knowledge or solve community-related problems (Tarekegne, 2021:1, 4).

The Adopted Theoretical Frameworks

The Crime Patterns Theory

The Crime Patterns Theory (CPT) was developed by the Environmental Crime theorists Paul and Patricia Brantingham (1993), and confirmed by Clark and Felson (2017). This theory connects rationality with the routine activities of potential offenders (Stock thieves) and victims (I.e. Livestock farmers/livestock; cattle, sheep and goats) interactions with places where crime (Stock theft) is committed, while acknowledging that human mobility patterns are non-random and places where crime occurred, as well as why offenders select a certain target in their specific physical and social environment, form essential components of this theory (Sidebottom & Wortley, 2016; and Eck & Weisburd, 1995). The term 'pattern' is used to describe recognisable interconnectedness between the physical or conceptual of objects, processes, or ideas (the use of DNA and IoT in combating stock theft in the selected areas of KZN) (Brantingham & Brantingham, 1993).

Essential to the theory is that crime is deemed not to occur randomly or seen as evenly distributed; crime is more likely dependent on the opportunities presented to the potential offender. Opportunities for crime are presented by the overlap of daily life routine activities of offenders and their targets. Opportunities tend to relate more to the characteristics of a place (Eck & Weisburg, 1995). The routine spatial and temporal movement of potential offenders between the nodes and paths creates an awareness space, in which offenders becomes acquainted with suitable targets (Livestock) (Brantingham, Brantingham & Andresen, 2018). When activity spaces overlap, motivated offenders are able to process suitable targets based on their knowledge (Awareness) of the environmental cues (stock theft scenes and the demographic profiles) of what is good and what is bad. All these variables establish a crime template (Andresen, 2014). The latter refers to what offenders use to determine whether they will commit the criminal act or not. The crime template consists of a target choice, which is dependent on many factors, such as the characteristics of the potential crime site, the characteristics of the target, and the characteristics of the environmental backcloth (Brantingham & Brantingham, 1993). It can be considered as a checklist of items or circumstances that must be present or absent, such as an alarm systems or guard dogs in the case of burglary at residential premises (stock theft included) (Andresen, 2014).

In an attempt to evaluate this theory, Doorewaard (2020:63-64) highlights that as with the Routine Activities Theory and the Rational Choice Theories, this theory does not place emphasise on why offenders commit crime but focuses more on the spatial movement of offenders (Gialopsos & Carter, 2015:54). Van Sleeuwen, Ruiter and Menting (2018:539) reveal that this is accomplished by focusing on the spatial movement and choices of offenders, although the CPT does not address the timing of these choices. Nonetheless, this theory presents an explanation of how crime patterns dominate in both urban and rural areas. It contributes towards crime reduction interventions and designs by looking at crime locations and considering both the offender and his or her network of friends and their routine activity spaces and how they intersect with the activity spaces of victims and targets as in the case of livestock theft (Eloff & Prinsloo, 2009:25; and Wortley & Townsley, 2016:91).

The Activity Theory

The Activity Theory (AT) is an umbrella term for a line of eclectic social-sciences theories and research with its roots in the Soviet Psychological AT pioneered by Sergei Rubinstein in the 1930s. It was later advocated for and popularised by Alexei Leont'ev. This theory is more of a descriptive meta-theory or framework than a predictive theory, accounting for environment, history of the person, culture, role of the artefact, motivations, and complexity of real-life activities (Stock theft in this case). One of the strengths of AT is that it bridges the gap between the individual subject and the social reality. This theory study, both through the application of mediating activity.

The unit of analysis in AT is the concept of object-oriented, collective and culturally mediated human activity, or activity system. This system includes the object (Or objective), subject, mediating artefacts (Signs and tools), rules, community and division of labour. The motive for activities directed to the AT are created through the tensions and contradictions within the elements of the system (Yrjö; Reijo & Raija-Leena, 1999:1). Moreover, the core objective of the IoT concept is that everyday objects can be equipped with identifying, sensing, networking and processing capabilities that will allow them to communicate with one another and with other devices and services over the Internet to achieve some useful objective (I.e. The application technologies, such as the DNA samples and IoT to effectively combat this crime in the selected areas of KZN) (Whitmore, Agarwal & Da Xu, (014, in Kim, Lee & Ha, 2015).

In future, there will be intelligent applications for smarter homes and offices, smarter transportation systems, smarter hospitals, smarter enterprises and factories, as well as for effective combating of stock theft (Bandyopadhyay & Sen, 2011). The IoT holds the promise of improving people's lives through both automation and augmentation. The capabilities offered by the IoT can save people and organisations time and money as well as help improve decision making and outcomes in a wide range of application areas, Whitmore, Agarwal & Da Xu (2014 (in Kim, Lee & Ha, 2015). IoT was likened to the livestock farmers' activities based on the AT. This theory can be efficiently used to understand the livestock farmers works and related learning, and analyse the behaviours of livestock and their owners for the purpose of both experimental and analytical methods for adequate combating strategies against stock theft. Equally, considering problems associated with the design of human performance, man-machine systems, human computer interactions and computer-based learning, the associated activities in terms of hierarchy can be easily described by the AT (Bedny & Harris, 2005) (in Kim, Lee & Ha, 2015).

Therefore, with the emergence of the IoT, interactions between humans and machines and indeed among machines themselves can be better understood using Leontiev's AT. This theory has been relevant to Human-Computer Interaction research for some time. Kuutti (1995) notes that the real world experience always involves an intertwined network of activities, while providing a more general definition of 'activity' as a form of doing directed to an object. Activities are hence seen over longer periods, as objects are transformed into outcomes through a process that can be deconstructed, relating to a sequence of actions, which in turn consists of operations. The AT refers to the recognition of the process in which human behaviour is monitored and processed to infer the underlying activities. Thus, sensors are essential for data collection, as they detect stimuli by generating measurable signals. Human activities are linked with the performance conducted through the applications of internet-enabled objects, such as the IoT in this instance (Wilde & Zaluska, Sa).

Presentations of Study Findings and Discussions

The 49 participants' responses were tested regarding the use of DNA technology samples and IoT in combating stock theft, while considering the introduction and problem formulation sections of this study. Therefore, the findings of this study are categorised under the objective of this study, to explore combating of stock theft with DNA samples and IoT, focusing on the selected areas of KZN. The referencing method for the interviews in this study comprised a numerical sequence, and an example of this notation is as follows: (5:1:2). The first digit (5) refers to the folder number in the voice recorder, the second digit (1) is the interview number in the said folder, while the third (1) is the sequence in which the cited interview was conducted.

- During the data collection methods, the following question was posed to the participants to elicit views on DNA samples and IoT in combating stock theft: "What processes have been followed to implement the use of DNA samples and IoT to combat stock theft in your area?" This is what they had to say:

▪ *"The following have been already done:*
✓ *Investigators are nominated to attend Stock Theft Learning Programmes (STLP) where they also attend a workshop and module at ARC- Irene.*
✓ *The KZN SAPS STUs members are familiar with IoT to combat this crime, with a huge room of improvement to be re-addressed.*
✓ *National Instructions, policies and procedures forms part of the programme.*
✓ *In-service training is given to inexperienced members by experienced and senior members.*
✓ *SAPS STUs investigators are encouraged to always seek the possibility of DNA samples support during investigation of stock theft cases."* **(KII-06-02-01)**

"We are using DNA samples and IoT effectively; sometimes livestock can be stolen while still young before the branding process can be staged. In this instance, we normally use the bull and cow to prove ownership only if the complaint(s) still have them. This method is very excellent and is assisting us a lot as stock theft cases can be solved easily." **(KII-03:07:07)**

"We do quite a bit of DNA samples and efficient use of IoT here and we had successes with it use, obviously you cannot dispute DNA evidence in the court of law if all procedures were followed properly. It is a fact; it gives you an idea of initiating an investigation. For example; if you get to a stock theft crime scene whereby four animals are slaughtered, you have to take DNA evidence from each animal as discovered and record (Mark) that as A, B, C and D and get a sample from a suspect (Sample E) found with a meat or suspected to be from the slaughtered stock theft scene and compare with the collected four samples in the initial stages (A,B, C and D) to see if it compares with any of those or validate if the samples under analysis as recovered in Umlazi matches the carcass number B/C and place a suspect on the scene." **(KII-5:1:1)**

The steps that have been taken to optimise the implementation of DNA samples and IoT in combating stock theft in the selected areas of KZN cover only the KZN SAPS STUs works, which the researcher understood, owing to specific Acts, rules and regulations governing SAPS procedures and Code of Conduct. The researcher emphasises that even though the local KZN SAPS STUs members are not required to reveal how they conduct their operational duties in terms of applying DNA samples and IoT to effectively combat stock theft, it is highly advised for them (SAPS) to familiarise the local livestock farmers about the value of DNA samples and IoT in combating stock theft, without giving a detailed description of the work they do. The livestock farmers should be in the know about the processes followed once DNA samples are collected and IoT applied and the local KZN SAPS STUs should attend refresher courses on the use of these tools. This is supported by the following verbatim expressions:

"I would say a lot about the use of DNA samples and IoT in combating stock theft; without the use of DNA we would not have been able to solve many cases that we had. The fact is without the use of DNA samples and IoT lot of our cases will not be solved, definitely. The DNA analysis done at this stage of the fight of stock theft in Irene is of high quality, we cannot complain of the testing of DNA but we acknowledge the challenges faced at times." **(FGDs-04:16:3)**

On the other hand, one of the participants had this to say about the training they attend in this regard:

"We do go to courses, which are referred as once-off stock theft courses. This normally takes six weeks and it is offered by the DAFF and other relevant department and private companies. The courses offered are used correctly in practical and it is working properly." **(KII-03:07:07)**

"Stock theft investigation is the specialised field. The KZN SAPS STUs members are lectured on regular basis internally and when they go to on courses STLP and Detectives courses and we also deal with this crime on daily basis, while focusing on the use of DNA samples and IoT." **(KII-5:1:1)**

In contrast, this is a verbatim account of what some of the participants revealed:

"We seldom receive training but it should be mentioned that we did in-service training concerning the taking of animal DNA samples for the members who never previously attend

it. Hopeful they (KZN SAPS STU members) are doing it on their own at this stage." (FGDs-04:16:7)

"Communal grazing lands, in that one bull may mate with several cows of different livestock owners over a period of time. When animals are stolen, one will for example find DNA samples of both parents in the offspring. Little knowledge of Livestock Identification Catalogue (LIDCAT) utilisation within the livestock owner Community. A secured database for animal identification systems are built to collect biological materials from individual animals and storing it under ideal condition. In the case of theft or dispute, the system can be used to identify the animal beyond doubt for court purposes and build a database for research purposes." (KII-06-01-01)

"To be quite honest with you, we have had several problems now at ARC-Irene where I think the people who are currently analysing the DNA evidence are not up to standard. In the past we use to have successes but lately it is clear that the people doing the analysis are inadequate, we are experiencing couple of problems." (KII 5:1:1)

"The feedback from the laboratory takes long ... In a criminal case it can take up to six weeks and sometimes three months, the deadline is not adhered to and this create problems with the court of law as stock theft cases get reminded, but is good to note that they are improving now, it is bit better but it is a big challenge for us to get the DNA reports quickly." (KII-5:1:1)

- *"These refer to the experienced challenges among others:*
    - *Lack in community involvement in some areas.*
    - *Late detection and reporting of cases to SAPS by livestock owners.*
    - *Non-marking of livestock by owners.*
    - *Improper or non-safeguarding of livestock by owners.*
    - *Inadequate understanding of the IoT applications.*
    - *Ineffective actions by livestock owners themselves to prevent stealing of their stock.*
    - *Porous international borders (Lesotho, Swaziland and Mozambique) – however, cross-border stock theft in the KZN Province is very low in comparison to the total stock theft picture of the province.*
    - *Filling of vacancies at remote KZN SAPS STUs because of accommodation and schooling challenges."* **(KII-06-01-01)**

This ancient crime, stock theft, is proven to be as old as the field of agriculture itself, dating back to 1801, however, limited attention is given to this scourge in the field of humanities, as well as related disciplines, with Criminology and Criminal Justice scholars included rarely paying needed attention to it (Clack, 2013, Clack, 2018; Maluleke, 2016), even though it forms an integral part of the South African economy. As a result, this organised crime is growing in South Africa, as highlighted by researchers (Clack, 2013; Doorewaard, 2020; Lombard, 2016; Lombard, Van Niekerk & Maré, 2017; Lombard, van Niekerk, Geyer & Jordaan, 2017; KZN DCSL, 2008; Maluleke, 2014; Maluleke, 2016; Manganyi, Maluleke & Shandu, 2018). Stock theft is touted as a rural crime, consisting of misleading assumptions in terms of prevalence, as compared to urban localities, as confirmed by Donnermeyer (2012); and Barclay & Donnermeyer (2011) in Donnermeyer, 2014) in the introduction and problem formulation section of this study where the economic value of livestock farming is described as enormous, contributing to South African food and security (Clack, 2013).

The negative effects of stock theft in the agricultural sector of South, and the lucrative nature of this crime, was mentioned by Maluleke (2014; 2016; 2018), Maluleke and Mofokeng (2018), the NSW Stock Theft and Trespass Review Final Report (2016); and Nkwari, Rimer and Paul (2014). Moreover, this crime is still a major problem in the South African agricultural sector and its threatens both commercial and the emerging livestock farmers in most of countries across the globe, rural and isolated locations were also painted as targeted areas, this can reportedly lead to the already cited economical losses for the 'primary producers and rural communities.' The loss of millions was also indicated, coupled with property theft and malicious damage and loss of future breeding potentials, as discussed by the NSW Stock Theft and Trespass Review Final Report (2016).

Nkwari, Rimer and Paul (2014) further contended that several techniques to identify livestock (cattle, sheep and goat included) combat stock theft, the ever-persisting nature of this crime has not been eradicated in the livestock farming sector. The KZN DCSL (2008) also observed that this crime had long been integrated into communal life and little has changed and the increasing pricing of livestock led to the reported cases of stock thefts across South Africa. Therefore, this study explored the use of DNA samples and IoT in combating stock theft in the selected areas of KZN Province, South Africa.

Maluleke (2016) highlighted that the DNA samples are used to revolutionise modern science by it possible to provide a means of irrefutable identification of livestock, while the IoT, manage and monitor livestock movements. Nevertheless, advances in the ICT sector positively and negatively affects various aspects of human life, stated (Imtihan, Bagye, Zaen, Fadli, Ashari, 2021). However, for the purpose of this study, the adoption IoT effectively contributes to stock theft prevention, combating and investigations. This application found it ways into the agricultural sector, bringing different technological transformations by using various smart agriculture gadgets, the livestock farmers have gained better control over raising of their livestock and growing crops [Stock theft combating cited] (Chalimov, 2022). This can be efficiently used for livestock monitoring, management and tracking, just like crop monitoring. The agriculture sensors can also be derived from the IoT that is attached to livestock for monitoring their health, log performances, well-being and detection of physical locations. The adopted sensors can be used to identify even sick animals for the livestock farmers to separate them from the herd and avoid possible contaminations, stated Chalimov (2022).

Chalimov (2022) points out that drones for real-time livestock tracking also help the livestock farmers to reduce staffing expenses. The IoT devices works similar with the following applications 'Petcare ['SCR' by Allflex and Cowlar, using smart agriculture sensors, such as the 'Collar tags' to deliver temperature, health, activity, and nutrition insights on each individual livestock and collect information about the herd (Chalimov, 2022). Imtihan *et al.* (2021) concluded that IoT tools takes pictures, send images and coordinate criminal points' locations, helping to find stolen livestock and increasing the numbers of arrested stock thieves in efforts to reduce [Combat] stock theft.

The 'introduction and problem formulation' section also revealed that African countries have more access to mobile phones, than other essential basic services. This confirmed that the reported high levels of connectivity and cell phone penetrations can benefit livestock farmers to accomplish real-time data, Nana (2021). This can be positively used to *track livestock*, offer assistance to 'farm security management.' The South African MTN collaborated with 'Aotoso' Technology to use IoT across 19 African countries to provide connected collars for Cattle. Using the SIM cards on the collar, the livestock farmers can use their cell phones to get vital information about livestock movements to prevent stock theft, even in rural areas (Nana, 2021:1).

Memon *et al.* (2016) stated that livestock have a unique DNA profile, if stolen, illegally relocated or even slaughtered, biological samples of such livestock can be extracted to be compared to the reference samples to verify their identity, this can positively link potential criminals to the stock theft scenes. This technology can identify stock thieves accurately when biological evidence exists. It can also clear suspects and exonerate them from mistakenly accused or convicted of stock theft, making it increasingly vital to ensure accuracy and fairness within the CJS. Whereas, the IoT connectivity can sense and gather data to share with 'Internet facility' for processing and utilisation to achieve common goals, this can be accessed anywhere across the world, involving smart parking, smart animal [Livestock] farming, and smart waste management systems, as illustrated by Gubbi *et al.* (2013) (in Memon *et al.* 2016) and Atzori, Iera, Morabito (2010) (in Memon *et al.* 2016).

The Smarter technologies (2022) in the 'introduction and problem formulation' section revealed that the in-built GPS and GeoFencing capabilities can be also used for the 'livestock tracking,' with the application of collars, ear-tag and other similar location-tracking hardware to provide real-time data analytics and management aspects on livestock, this can give accurate visibility into their farming locations, allowing livestock farmers to identify any unusual patterns or movements. To this end, the GPS and IoT technologies are becoming feasible by providing real-time data on locations, health, 24/7 monitoring and security of livestock and other valuable assets. The livestock farmers can be able to locate lost or stolen livestock and track them with scanners for fast recoveries, increasing opportunities for arrest and convictions of perpetrators (Smarter Technologies, 2022).

The consulted studies in the 'literature' section, focusing on the use of DNA samples in combating stock theft confirmed that 'every animal is unique and will have [Some] permanent marks from being handled over the years. These can all be used for identification purposes to link stolen livestock to their owners' herds, taking these factors into account and using research, DNA samples, as well as circumstantial evidence; Prosecutors can reconstruct stock theft cases successfully and secure a possible conviction'. To achieve this, the correct usage of livestock farming terminologies should be applied to be able to match wool, ear notches, branding, dehorning methods, castration and age of the stolen livestock (Uys, 2017).

In contrary, Maluleke and Mofokeng (2018) and Maluleke (2016) portrayed that existing studies on stock theft mainly focus on combating theft using conventional methods such as brand-marking and tattooing, with the emphasis being placed on the current legislative frameworks of South Africa's Stock Theft Act, 1959 and the Animal Identification Act, 2002. Limited studies have been done to explore the use of DNA samples and IoT in combating stock theft in the KZN Province and other provinces of South Africa.

Mapholi (2015) asserted that *stock theft* is a major challenge to the South African livestock farming practices. However, the recorded effects are mountainous economically, affecting all livestock farming sectors from large commercial organisations to the stud breeders and extending to the rural farmers, who owns one or two livestock. Mapholi (2015) further shared that the SAPS identified stock theft as one of the priority crimes, establishing a partnership with the AGL of the ARC, API, situated at Irene in 1996, Pretoria, to address the challenge of stock theft with the use of DNA samples in combating stock theft. The result of this union revealed that, from approximately 45 000 stock theft reported cases yearly, about 8 000 cases go to court and more than 500 of the court cases, involving more than 3 000 exhibits, often use evidence obtained from DNA sample. About 95% of these cases are resolved and suspects are prosecuted, further highlighted Mapholi (2015).

Furthermore, Kempen (2015) agreed that the DNA samples can be positively used to link potential stock thieves to respective scenes. The identification of stock thieves can be achieved with accuracy owing to the availability of biological evidence, and it can also clear suspects and exonerate them if mistakenly accused or convicted of this crime. Maluleke (2016) and NSTPF (2016) pointed out that the DNA-based unique samples [sources of DNA] can also be applied for the 'determination of identity, ownership, %age, traceability and species origin' of livestock, such as the 'tissue, blood and skin'.

The reviewed studies in the 'literature' section suggested that the IoT is not a new technology, however, the integration of several technologies matured, allowing object to communicate, [Almost] collect and process data from different networks to improve decision-making practices, using hardware-for-end-devices and gateways, sensors (Dieng *et al.* 2017). Practically, it was reported by (Burger, 2012; and Agri-Alert, 2013) that the SAPS STUs use the monitoring system designed by the Agri-Alert, consisting of 'cell phones and personal computers' to combat, control and monitor livestock in a given area. This technology enables livestock farmers to monitor the movements of livestock and protect them from any disturbances. The GPS coordinates, sensors and SMS are used to send signals of abnormal or unexpected behaviour occurrences.

The IoT provides valuable solutions to the livestock farming practices. Available technologies enable them to make decisions based involving various criteria, such as 'cost, commercial or free, internet access, nature of data to be collected and deployment type.' The demographical nature of rural settings and social conditions should be considered during selections of technologies to prevent, combat and investigate stock theft; targeting Cattle, Goats and Sheep, to name the Three (03), in African context, Dieng *et al.* (2017). Dieng *et al.* (2017) further elaborated that rural livestock farmers are mostly poor and they can be less sceptical to apply IoT for the combating of Stock theft, if it does not require high costs. To curtail the associated difficulties relating to the internet access, involved the induction of 3G, capable of providing fast rates of data transmissions supporting e-mail communications, high-speed internet access and video streaming, among others.

The IoT reportedly gaining popularity and becoming major source for smart innovations across the world by enabling sensing, processing and automatically executions, in a remotely manner. This can also ensure easy availability and access to available information (Harikrishnan & Gaikwad, 2021). This technology [IoT] can be used to solve real-world problems, including stock theft. The 'FindMy' software deliver complete herd/flock locations and updates at specific times, as projected by the livestock farmer. If the track point suggests 'something's wrong,' they can locate the exact position of the |herd. This system can also detect if a livestock 'is in distress, such as if it is frightened or being chased.'

Furthermore, Geldenhuys (2011) suggested that DNA sample is regarded as one of the powerful tools for convicting guilty potential stock thieves, and exonerate the innocent. This application can also be used to link stock theft scenes, with the stock thieve. This technology can also bring significant changes to the CJS, by analysing stock theft scenes and collect DNA evidence [Sources/profiles], extracted from the laboratories. Compared to the other sections of the CJS, the DNA samples and IoT provides positive effects on policing stock theft by "collecting, retrieving and analysing detailed information about this crime." To this course, the DNA samples and IoT could generally bring much-needed changes in combating of stock theft across South African rural communities and KZN Province specifically.

The use of IoT provided that objects can connected to the internet to realise global network of the connected appliances. This technology is used in the agricultural sector, more especially in South African rural areas, focusing on *smart livestock farming*. The LoRa and LPWAN technologies monitor livestock [Cattle] parameters, supported by resilient transmissions, wide coverage and the long-lasting battery lifespan, and meeting the needs of rural areas (Germani *et al.* 2019).

The provided literature section also revealed that the South African MTN and Huawei Technologies partnered to launch 'the Connected Animal solution,' referring to the IoT innovation aimed at solving increasing stock theft cases, as reported by the CAJ News (2018). This can allow the local livestock farmers to improve animal-management and health screening through activity and movement, monitoring [tracking stray livestock] and analysis. The 'near real-time visibility' of their livestock van be achieved, further acting as a deterrent to this crime. The cited study by Zantsi and Nkunjana (2021) further confirmed that stock theft is the major challenge faced by livestock farmers in South Africa, with severe consequences especially for smallholder farmers, who collectively own a large share of the South African livestock herds but individually keep small herds, this study findings reads with the information provided in the 'introduction and problem formulation' section by these researchers (Clack, 2013, Clack, 2018, Maluleke, 2014; Maluleke, 2016; Maluleke, 2018, Maluleke & Mofokeng, 2018; NSW Stock Theft and Trespass Review Final Report, 2016; and Nkwari, Rimer and Paul, 2014). The application of IoT offer technological improvements and innovations to track livestock movements by using the GPS livestock tracking devices to mitigate the effects of this crime.

Importantly, Zantsi and Nkunjana (2021) suggested that the likelihood of GPS adoption o track livestock by smallholders. It was revealed that this will only depends on the following revelations: a) The awareness about the devices and how they work, b) The acuteness of stock theft for a farmer and how livestock contributes the farmer's livelihood; and **c)** The income level, access to mobile phones and risk behaviour of farmers. Tarekegne (2021) highlighted that some of the conventional practices to combat stock theft in South Africa are outdated and they will not help rural smallholder livestock farmers to acquire knowledge, skills, and attitudes (I.e. Competencies) to make them transformed or empowered and be able to solve their livestock protection and preservation problems, the Anti-Stock theft stakeholders should change their mind-sets in this regard, as it is confirmed that the rural smallholder livestock farmers are often unnoticed and neglected (This reads with Clack, 2013, Clack, 2018; and Maluleke, 2016), as covered 'in the introduction and problem formulation' section of this study. Although, this study can be best used as a means to either to discover or extend theoretical knowledge or solve community-related problems, relating to stock theft in this regard (Tarekegne, 2021).

Furthermore, this study was guided by Two (02) theories, namely; the CPT and AT, the later theory was developed by the Environmental Crime theorists Paul and Patricia Brantingham (1993), connecting rationality with the Routine Activities Theory by suggesting that stock theft occurs when an interaction between offenders [Stock thieves], victims and locations exist, this theory acknowledges that human mobility patterns are non-random in nature and the place where stock theft transpire, as well as the reasons stock thieves selects a certain target, relates to their specific physical and social environment, this was supported by these researchers (Sidebottom & Wortley, 2016; and Eck & Weisburd, 1995). Stock theft cannot occur randomly or be committed in a similar way. It is likely dependent on created daily life opportunities presented to the potential stock thieve versus environmental characteristics (Brantingham & Brantingham, 1993; and Eck & Weisburg, 1995).

In support to this submission, (Brantingham, Brantingham & Andresen, 2018) confirmed that the 'routine spatial and temporal movement of potential stock thieve between nodes and paths often creates an awareness space, which a stock thieve becomes acquainted with suitable targets (Livestock in this regards).' It is also revealed by Andresen, (2014) that 'when activity spaces overlap, motivated stock thieves are able to process livestock [Cattle, Sheep and Goats], as suitable targets based on their knowledge (Awareness) of the environmental cues, by evaluating chances of being caught or getting away with stock theft.'

The theoretical evaluation of the CPT was done by Doorewaard (2020), this researcher highlighted that while acknowledging the works of Routine Activities Theory and the Rational Choice Theory; the CPT, does not place emphasis 'on the reasons for stock thieves to commit stock theft, nevertheless, more focus is rooted on spatial movement of possible stock thieves, as revealed by (Gialopsos & Carter, 2015). Van Sleeuwen, Ruiter and Menting (2018) share that this can be achieved by paying attention to the spatial movements and choices of stock thieves, notably; the CPT does not address the timing of these choices. However, this theory explains how the crime patterns dominate in both rural and urban areas, while contributing towards stock theft combating methods by offering necessary interventions and designs, this is accomplished by closely looking at stock theft locations and considering the stock thieve and his or her organised networks and their respective routine activities, relating to spaces and how they intersect with activity spaces in terms of victims and targeted livestock (Eloff & Prinsloo, 2009:25; and Wortley & Townsley, 2016:91).

On the other hand, the AT was pioneered by Sergei Rubinstein in the 1930s and later advocated for and popularised by Alexei Leont'ev. This theory is also touted as the 'Descriptive Meta-theory or Predictive Theory' accounting for environmental real-life activities. This theory bridged the gap between individual subject [Livestock - Cattle, Sheep and Goat] and the social reality [Stock theft]. It is object-oriented; collectively mediating human activities, including the object [DNA samples and IoT], subject [Livestock – Cattle, Sheep and Goat and Stock theft /Stock thieves], mediating artefacts (Signs and tools used to combat stock theft, DNA samples and IoT in this regard), as well as the existing rules [Legislative frameworks and regulations on stock theft], community [Local community members and Anti-Stock theft stakeholders] and division of labour [Relating to the Law Enforcement Agencies – LEA geared towards stock theft prevention, combating and investigation, such as the SAPS STUs]. The tensions and contradictions created by stock theft form the crux of the AT, as hinted by Yrjö; Reijo and Raija-Leena (1999).

While emphasising the importance of the IoT to combat stock theft in South Africa, it was stated by Whitmore, Agarwal and Da Xu (2014) (in Kim, Lee & Ha, 2015) that everyday objects [DNA samples and IoT] can be well-equipped with 'identifying, sensing, networking and processing' capabilities allowing them to communicate with one another and with other devices [Livestock management, movement and tracking in this study]. In future, the intelligent applications for combating this scourge are envisaged, to improve livestock farmers' lives through automation, augmentation and combating of stock theft, as presented by Bandyopadhyay and Sen (2011). For the purpose of this study, the IoT was likened to the livestock farmers' activities based on the AT. This theory can be adopted to clearly understand the operations of livestock farmers by analysing related behavioural patterns of livestock and their owners for the purpose of accommodating experimental and analytical methods. The problems associated with design of human performances, man-machines systems, human computer interactions and computer-based teaching and learning forms part of this application, as discussed by Bedny and Harris (2005) (in Kim, Lee & Ha, 2015).

The emergence of the IoT, suggests the interactions between livestock farmers and available technologies (Machines). The operational nature of machines can be better understood through the use of the Leontiev's AT. This theory is relevant to Human-Computer Interaction (HCI) research for a long period of time, as highlighted by Kuutti (1995), the real world experience involves intertwined networks of human [Livestock] activities, while considering this notion relating to 'activity:' "A form of doing directed to an object [This can refer to the DNA samples and IoT, as well as the targeted livestock - Cattle, Sheep and Goat for protection]." This is referred to the performed activities where objects [DNA samples and IoT] are transformed into outcomes [Combating of stock theft] through a process accommodating sequence of actions, which in turn consists of operations [Of the livestock farmers, LEA and other Anti-Stock theft stakeholders]. Through the application of the AT, recognition is referred to the monitoring of human [Livestock and livestock owners] behaviour and process their underlying activities. The sensors are used for data collections, after detecting stimuli and generating measurable signals. Therefore, the cited activities are linked with performance conducted through applications of internet/technological-enabled objects, such as the DNA samples and IoT for the purpose of this study, these assertions are supported by (Wilde & Zaluska, Sa).

The are several challenges associated with the use of the DNA samples and IoT to combat stock theft in South Africa. These challenges include, but are not limited to ***1)*** *Delay in obtaining DNA samples feedback from the responsible laboratories and limited applications of IoT*, and; ***2)*** *Inadequate knowledge and application of the use of the DNA samples and IoT*. The noted limitations contribute to sample degradation and contamination, which negatively influence stock theft prosecution rates. Thus, the identified themes and challenges were demarcated to the following:

- **Delay in obtaining DNA samples feedback from the responsible laboratories and limited applications of IoT:** During the fieldwork, the livestock farmers indicated a need for the establishments of an STFL in the selected areas of KZN Province to avoid the long distances they have to travel to submit the DNA evidence in Cape Town, Port Elizabeth and Pretoria. They did not shy away from the fact that KZN Province should be prioritised in this regard. On the positive side, the University of Pretoria and other private companies were acknowledged to be quick in providing the required feedback to the affected parties.
- **Inadequate knowledge and application of the use of DNA samples and IoT:** In stock theft cases where there is no prima facie evidence before the SAPS STU members to initiate investigation or carry out an arrest, DNA technology can be positively used to link the potential suspects with the crime in question. In light of this finding, DNA technology is widely used internationally and locally to solve stock theft cases. To combat stock theft in the specified areas plagued by this scourge in the selected areas KZN Province can be very problematic. At the same time, it is acknowledged that there are no plans to establish the STFL in the province.

Specifically, the majority of the participants had experienced or dealt with stock theft cases in the selected areas of KZN Province using the DNA samples and IoT to combat stock theft. However, they suggested improvements of these applications and shared their own concerns. They also made a number of recommendations for combating stock this crime holistically. These included the following that arose from similar challenges experienced by the selected participants (Not in order of importance):

- The local livestock farmers should look after livestock.
- They livestock farmers embrace the importance of the Stock Theft Act, 1959, Animal Identification Act, 2002 and the Criminal Law (Forensic Procedures) Amendment Act (No. 37 of 2013) (the 'DNA Act'), to name the Three (03).
- The livestock farmers should frequently count their livestock to avoid discovering that their animals are missing only after a few days, or two to three months, making the investigation process difficult to initiate and complete.
- The applications of IoT to combat stock theft is unclear to many livestock farmers.
- The livestock farmers should report stock theft cases immediately, immediately.
- The majority of local commercial livestock farmers, more especially white individuals, use Radio Frequency Identification (RFID) to control and monitor their livestock's movements within their enclosed facilities. It was also stated by the participants that this system, amongst others could be very expensive for emerging black livestock farmers. This study introduced the optional combination of DNA samples and IoT in the selected areas of KZN Province.

Conclusions and Recommendations

The value of using the two applications was not clear to most study participants, thus instead of using these applications, they reverted to using conventional methods, such as brand-marking and tattooing, with more emphasis placed on the current legislative framework of the Stock Theft Act, 1959 and Animal Identification Act, 2002 respectively, while further invalidating the use of the new the Criminal Law (Forensic Procedures) Amendment Act, 2013 and other related international Acts (World Organisation for Animal Health standards – OIE standards). This study further found that the effective use of DNA samples and IoT could provide a positive and significant contribution to ensuring the safety and protection of livestock, as well as the economies of South African rural communities.

Based on the findings of this study, and the analysis of the data from the consulted literature and the selected study participants, the inadequate use of DNA samples and IoT was established, the integration of DNA samples and IoT was unfounded, the conventional methods were heavily relied upon, while invalidating IoT applications for combating stock theft, such as the RFID, Wireless Fidelity (Wi-Fi), Wireless Sensor Node/Network (WSN), ZigBee and the involvement of the relevant stakeholders in the selected areas of KZN Province.

For recommendations, the South African National government should further initiate relationships with other relevant forensic laboratories across the country. Reliance on the ARC-Irene will not effectively combat stock theft. The University of Stellenbosch in Cape Town and the University of Pretoria are some examples of the notable forensic laboratories that can add much value by their speedy analysis of DNA evidence. Other private laboratories should also become part of this solution. The SAPS management should also consider building their own SAPS Forensic Science Laboratory (FSL), focusing on stock theft in the provinces mostly affected by this scourge. It is highly advised that SAPS management reconsider the single use of ARC-Irene as their efficiency and capacity are currently being questioned. It is very hard to blame them since the processing of DNA evidence takes time and intense scrutiny. Thus, a heavy workload remains part of their daily agenda, as they cater for the entire country, with different focus areas, which are proving to be problematic at this stage.

Moreover, a full description of how to use the DNA samples and IoT for combating stock theft, and that an expert is required and other relevant stakeholders should also be trained in this application to capacitate them to intensify the mobilisation against stock theft in the selected areas. Combating of stock theft in the selected areas of KZN Province requires the relevant stakeholders to maintain and strengthen their deliberations on special law enforcement operations and to ensure that ‘hot spots’ are stabilised and criminal elements are addressed. The literature indicates that the Criminal Law (Forensic Procedures) Amendment Act, 2013 came into effect on 31 January 2015. This Act ensures that the creation of the National Forensic DNA Database of South Africa will function effectively, not only as a tool for gathering incriminating evidence, but also for gathering evidence to eliminate suspects and to safeguard against wrongful convictions/arrests as stated previously or other miscarriages of justice. On 27 January 2015, the Minister of Police appointed the Forensic Oversight and Ethical Board.

The Board monitors the implementation of the Criminal Law (Forensic Procedures) Amendment Act, 2013 with regard to the attendance and processing of crime scenes, the collection and storage of exhibit material and DNA samples, as well as the performance of the SAPS FSL and the National Forensic DNA Database of South Africa. It will continue to work with willing role-players in the forensic field because this is the way we win or lose cases. These assertions also relate to the use of DNA samples in combating stock theft in South Africa (SAPS, 2015). Collaborated operations should be initiated from a multidisciplinary approach, involving teams including SAPS STUs, Crime Intelligence, ICT, farm safety structures and Anti-Stock theft initiatives. The current activities are not up to the task of fighting this problem, owing to many factors, not limited to poor SAPS leadership, shortage of staff, and shortage of the necessary expertise in this study field. This study recommends that knowledge of the DNA samples and IoT in combating stock theft should be interpreted, disseminated and implemented correctly by the relevant stakeholders, to effectively address challenges associated with this scourge.

The implementations of CPT and AT theories in combating stock theft should be introduced by looking at the criticisms and lasting values of these theories. It is deemed that this can enhance the operations of the DNA samples and IoT as some of touted technologies to positively combat this crime, while placing more emphasis on environmental factors and suitable targets for the commission of this practice. This also reads with the relevance, effective applications and relook into some sections of the Animal Identification Act, 2002, and the Stock Theft Act, 1959 and induction of the DNA Act, 2013, as supported by Maluleke (2016), South Africa, 2002, South Africa, 2011; and South Africa, 2014), as illustrated in most parts of this study.

The researcher is of the view that the findings of this study will prompt readers of this study to think of other contexts, settings or situations with stock theft problems across South Africa and elsewhere, and to recognise the similarities. This study will not involve broad claims but invites readers to make connections between elements associated with the participants of this study in line with their own experiences on this subject. Thus, the researcher explored and gave rich descriptions of the findings of this study for probably application to other settings in order to contribute to the building of a new and technological pool of knowledge in respect of combating stock theft in the KZN Province and elsewhere.

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