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Advanced Animal Track-&-Trace Supply-Chain Conceptual Framework: An Internet of Things Approach

Richard Addo-Tenkorang[a]*, Norman Gwangwava[b], Enoch N. Ogunmuyiwa[b], Albert U. Ude[b]

[a]*Aalborg University, Department of Materials & Production, Fibigerstræde 16, 9220 Aalborg. Denmark.*

[b]*Botswana International University of Science and Technology (BIUST), Faculty of Engineering & Technology, Private Bag 16, Palapye. Botswana*

Abstract

Information and data transmission, as well as total visibility in terms of supply chain track-&-trace, is seriously lacking in current industrial logistics-&-supply-chain management activities. This paper proposes the application of RFIDs and the Internet of things' enterprise systems architecture to, propose a low-cost feasible cloud solution. This solution would keep track of health history, birth records, ownership history and track location of each animal by using an electronic solar-powered tag instead of the current passive ear tags. This paper employs GPRS, GSM and the Google Earth function along with RFIDs to design an enhanced proposed enterprise system-architecture framework in the form of a business process model. Various areas such as e-health, e-commerce, and cloud-based manufacturing have been revolutionized by discoveries in digitized practices. Advancements in the Internet of things led to the advent of asset tracking systems, condition monitoring and various intelligent systems that exchange data over the cloud. Farmers are very vulnerable to stock theft, straying animals and high business risks due to poor animal health management practices. Existing tracking systems have high ownership costs since some of them rely on GSM network providers whose services are costly for farmers. Innovations in digitized systems continue to add more value to businesses and individuals across broad range sectors. Authors of this paper propose a low-cost intelligent animal tracking system for an African free-ranging environment. Economies worldwide are ever becoming digital and animal husbandry practices stand to benefit from this digitisation approach.

Keywords: The Internet of things, Cloud/Virtual Network, Supply Chain Management, Animal Identification and Tracking, Google Earth, Digital manufacturing – 3D Printing

* Corresponding author *E-mail address:* raddotenkorang@yahoo.com

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1. Introduction

Although there are a plethora of useful applications of Radio-Frequency Identification (RFID), there are also some challenges to their effective and efficient implementation and/or adoption in the supply chain. There is no doubt that RFID, is among the most promising and accepted technologies in recent years in terms of effective and efficient industrial tracking-&-tracing activities. The industrial large-scale return-on-investment (ROI) benefit on RFID cannot be overemphasized; in that, it is a smart technology which is capable of saving the firms good ROI.

This research attempts to propose an advanced animal track-&-trace Supply-Chain Management (SCM) network for activities and real-time data collection and storage by employing certain Internet of Things' solutions (RFID, Cloud Network, GPRS, GSM, Google Earth function, etc.). Advancing with the use of the Internet of things, integrated smart solution would enable this research's advent of animal tracking-&-tracing conceptual framework system along with the condition monitoring and various intelligent systems that would exchange data over the cloud network. Farmers turn to be or are very vulnerable to certain pertinent business and environmental factors such as stock theft, straying animals and high business risks due to poor animal health management practices. However, existing tracking-&-tracing solutions seem to have high ownership costs among other unbearable issues since some of them rely only on GSM network providers for intermittent Short Message Service (SMS) notifications whose services are costly for the farmers.

Industrial organizations in different sectors have come to realise that RFID technology does a lot more than just tracking boxes and other manufacturing products in supply-chain activities. The trend of research in industrial Supply-Chain (SC) tracking-&-tracing indicates a slow but fierce re-emerging of RFID technology solution as a valuable way to improve internal efficiencies [1]; [2]; [3]; [4]; [5]. A research forecast by ABI Research also indicates that the global RFID technology solution market will exceed $8.25 billion in 2014, enjoying nearly a 14% compound annual growth rate over the next few years [6]. Research shows that SCs have to rely on industrial technology enablers to deliver a higher-level potency of performance in satisfying consumer needs [7].

Farmers globally, but with a special focus on those within the Southern African Development Community (SADC) keep several livestocks, facing fundamental challenges in their industry in terms of stock theft, straying animals and high business risks due to poor animal health management practices when evaluating, planning and implementing their business strategies in their livestock supply chains network activities. Therefore, this research attempts to propose an advance animal track-&-trace SC conceptual framework by employing some integrated Internet of Things system solutions. The following sections in this research paper include Background review on the research; Digital Manufacturing – 3D Printing & Material Selection Criteria; Proposed Animal Track-&-Trace Conceptual Framework and then the Conclusion and Recommendations.

2. Background Review

It has become more evident that economies worldwide, both the developed and developing economies, are ever becoming digitalized in various sectors and animal husbandry practices cannot be excluded. In that, they stand to benefit from this digitisation approach in a much larger perspective. Thus, tracking and tracing of livestock among others are becoming more commercialized from the usual small and medium-scale butchery into a full-fledged industrial agri-business. Therefore, it has become imminent that the entire supply-chain of this very important industry properly studies and developed into a more versatile and dynamic integrated industrial sector. Research has shown that, existing animal tracking-&-tracing systems have high ownership costs as most of the ones on the market today rely mostly on GSM network providers whose services are costly for the farmers. Currently, within the SADC and other parts of the developing as well as some of the developed economies; farmers identify their stock by cutting unique marks on the ear as well as hot or cold branding on the thigh or any other part of the animal.

Therefore, this research employs GPRS, GSM and the Google Earth function along with RFIDs to propose and design an enhanced enterprise system-architecture framework as well as a business process model powered by Bizagi Business Process Modeller software. These integrated enterprise system enablers (in the form of the Internet of things - IoT) would enable farmers and ranchers alike to locate their animals in the real-time. Thus, authors of this paper propose a low-cost intelligent animal tracking system for an African free-ranging environment. This solution would keep track of health history, birth records and ownership history in addition to tracking the real-time location of each animal by using an electronic solar-powered tag instead of the current battery-powered passive ear tags.

It became necessary to track the health history, birth data and the ownership history of the animal to enhance small, medium/large enterprises (SMEs) agri-business activities. This is so because, for example, Botswana a country within the SADC regional bloc in Africa is an exporter of both raw and processed beef to Europe and its surrounding countries. Botswana's beef exports stand at about 9,000 tonnes to the EU and 10,000 tonnes to South Africa. The country enjoys unlimited preferential market access to the EU, because of the Southern African Development Community (SADC)–

European Union (EU) Economic Partnership Agreement (EPA). Brazil is among countries that compete with Botswana in the EU beef market. The EPA agreement enables Botswana to export beef duty-free and quota-free to the EU. The Botswana Meat Commission (BMC) takes care of the country's beef exports. Rearing cattle is a major driver of economic activity, part of culture and means of expressing wealth in Botswana. The annual number of the combined slaughtered cattle for beef export and domestic markets is estimated to be 220,000. Despite the preferential access to the EU market, only 20% of the cattle received from local farmers in Botswana comply with EU requirements. By virtue of being the sole exporter of beef in Botswana, BMC becomes an important stakeholder in the new research towards an advanced animal tracking-&tracing system. The system forms part of crucial investment towards meeting the EU quality standards.

It is a standard drawn out for them by the European Union (EU) to only supply not more than a year-old animal beef to Europe. Hence, the Botswana Meat Commission (BMC), which supplies beef to the EU, has a responsibility of checking or ensuring that not all the animals slaughtered for the EU market are more than a year-old, and the animal is healthy before and during slaughter. This directive is in order for them to ensure that they provide the best or premium quality beef for international (EU, etc.) and local or domestic consumption. According to information accessed through the BMC website on "Price Structure by Grade" thus, ensuring their precise requirements are met BMC processes a range of cattle types from prime cattle finished through its extensive feedlot systems [8]. Hence, this approach turns to reveal that, younger cattle coming straight off the veld provide a better quality and premium beef. – (*see Figure 1 below*).

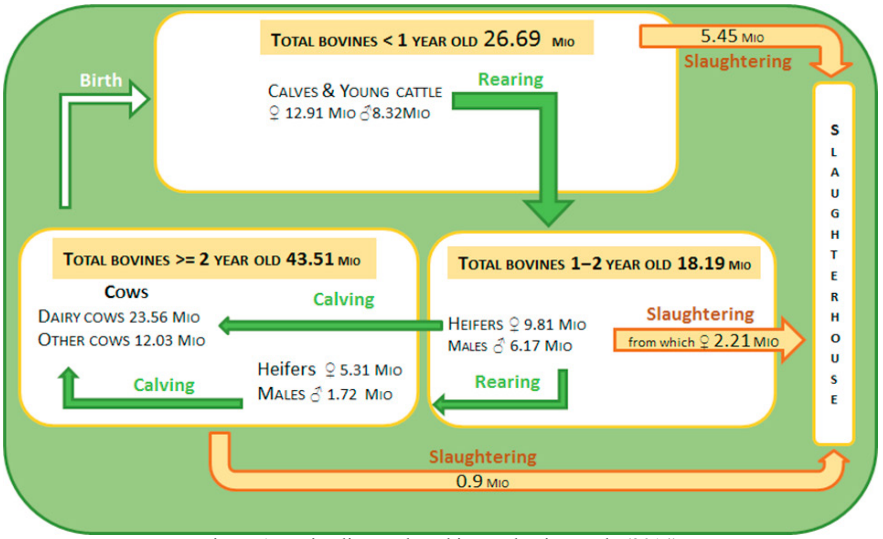

Figure 1 Bovine livestock and its production cycle (2014)
Source: [9] - Eurostat (apro_mt_pcatlhs)

The required data specified to be collected by this proposed advanced animal tracking-&-tracing SC conceptual frameworks were curtailed to just the very relevant data needed by authors for the immediate functionality of the integrated system. Hence, the RFID system would be configured to read and update data such as health history, birth records, ownership history and also track the real-time location of each animal tagged with the prescribed RFID tag. Furthermore, because the RFID technology employed by this conceptual framework would be further designed in a way to also be powered by a micro-solar technology, which is assumed to, constantly charge the RFID cells, a special material with certain favourable properties would be selected and employed. Thus, the selected suitable material would easily allow the Sun's rays to penetrate it. This is in order to enable the micro-solar technology to function as expected, it will be made into a powdered form and then drawn into the form of a filament to be used in 3D-printing the special tags to house the entire RFID data collection technology proposed in this research's conceptual framework. Detailed illustration of the entire enterprise SC system architecture and the business process model is illustrated in Figures 3 and 4 respectively below.

3. Material Selection Criteria & Digital Manufacturing – 3D Printing

This section first presents an overview of the expected suitable material selection process for the RFID tag housing. This housing is expected to be tough and durable enough to be able to withstand the harsh weather condition as well as the terrain the animals would subject it to. It must also be such that the selected material would easily allow and not

interfere with the signal transmission functions as well as efficient solar ray receptiveness for the RFID technology system. It is also expected that the suitable material once identified and selected would be pulverized into a powder form where it will be extruded through an extruder into a 3D-printing filament form to be used in 3D-printing the housing of the RFID technology system. The 3D-printing digital manufacturing technology's true potential is progressively being recognized by more companies as they integrate it into their design and production processes. Hence, the hysteria boosted awareness of the 3D-printing technology in almost every industrial sector nowadays. However, this has not yet exhausted and truly demonstrated 3D-printing's full impact such as its business influence as well as it's further trending into other industrial areas such as the healthcare and pharmaceuticals, buildings, etc. [10].

The authors adopted a research finding on a chipless radio- frequency identification (RFID) sensor reader conducted by [11] published by John Wiley & Sons, Inc. In their reader architecture of the chipless RFID sensor, they proposed using continuous- wave sinusoidal signals for interrogation, which is also known a frequency- modulated continuous- wave (FMCW) reader. Their reader seems to operate in three main steps to decode a tag sensor; that is, sensor calibration, real- time sensor data decoding, and tag ID decoding [11]. In order to calibrate the reader across the bandwidth, two standard tags are employed. One of the tags having all resonance dips (data ID 0) and another tag having no resonance dips (data ID 1) [11]. The reader then determines the necessary amplitude and phase threshold for each data bit. It is proposed in this research paper that, the RFID technology would be powered by a micro-solar power harnessing technology for continuous and consistent power supply to the RFID technology system.

4. Proposed Animal Track-&-Trace Conceptual Framework

4.1. The Internet of Things – IoT Approach (DBMS, RFID, GPRS, GSM)

The Wireless Sensor Network (WSN) technologies cut across many areas of modern-day living as well as industrial businesses. They enable the measurement, inference and effective comprehension of certain required environmental factors, such as delicate ecosystems and natural resources rural to urban environmental factors. The Information Communication and Technology (ICT) devices' proliferation in a synchronized communicating–actuating network system creates what is known as the Internet of Things (IoT). The IoT is recognized as one of the most important areas of future technology and is gaining vast attention from a wide range of industries in order to enhance customer value [12]. The IoT has stepped out of its infancy and is the next revolutionary technology in transforming industrial businesses into fully integrated future smart businesses. This constitutes a communication network of system devices wherein sensors and actuators interact and integrates seamlessly with the environment around us. Thus, providing an effective enabling environment for data/information to be shared across the system platforms in order to develop a common operating platform. This enabling environment or enterprise system platform is fuelled by the recent adaptation of a variety of enabling wireless technologies such as RFID tags and embedded sensor and actuator nodes [13].

The technological evolutions of wireless network communication, smartphones, sensor network technologies, etc. are becoming more and more networked in value-adding integrated things or smart objects approach into IoT. Hence, these inter-connected "things or smart objects" (IoT) technologies have also made a large impact on new information and communication technology (ICT) in an enterprise-systems technology's perspective. This is to ensure the effective and efficient functioning of the proposed advanced animal track-&-trace conceptual framework in this research. To enable these functionalities and also for the benefit of the end users or stakeholders, IoT's technical standards need to be adapted to define the specification for information exchange, processing, and communication between things [14]. The success of IoT depends on standardization, which provides interoperability, compatibility, reliability, and effective operations on a global-scale [15].

Radio-frequency identification system (RFID) is an automatic technology system, which enables machines, and/or computers to sense or identify objects, record metadata or control individual targets through radio waves [16]. RFID reading devices can identify, read, track and monitor the objects embedded or attached with RFID tags when within the required or recommended proximity of the reader. They effectively and efficiently read and update data/information automatically and in real-time, if needed in a manner that is now termed as the Internet of Things (IoT). Therefore, the RFID technology is often seen as an efficient prerequisite WSN technology for the IoT. Hence, this paper employs the technologies of RFID and other WSN technologies such as the GPRS, GSM, etc. in an IoT approach in proposing the advanced animal supply-chain conceptual framework as introduced in this research paper. Figure 2 and 3 below, illustrate the advanced animal track-&-trace enterprise supply-chain conceptual framework and the business process model respectively.

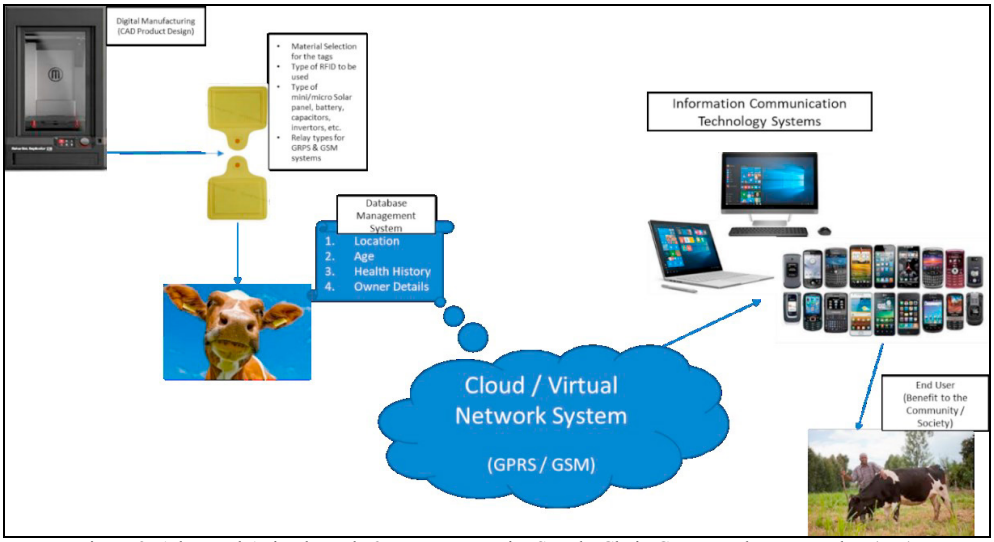

Figure 2. Advanced Animal Track-&-Trace Enterprise Supply-Chain Conceptual Framework – (IoT)

Figure 2 above illustrates the proposed advanced animal tracking-&-tracing enterprise supply-chain conceptual framework proposed in this research paper. The above illustrates the flow of data/information and the integration of internet of things devices needed for the proposed enterprise SC framework.

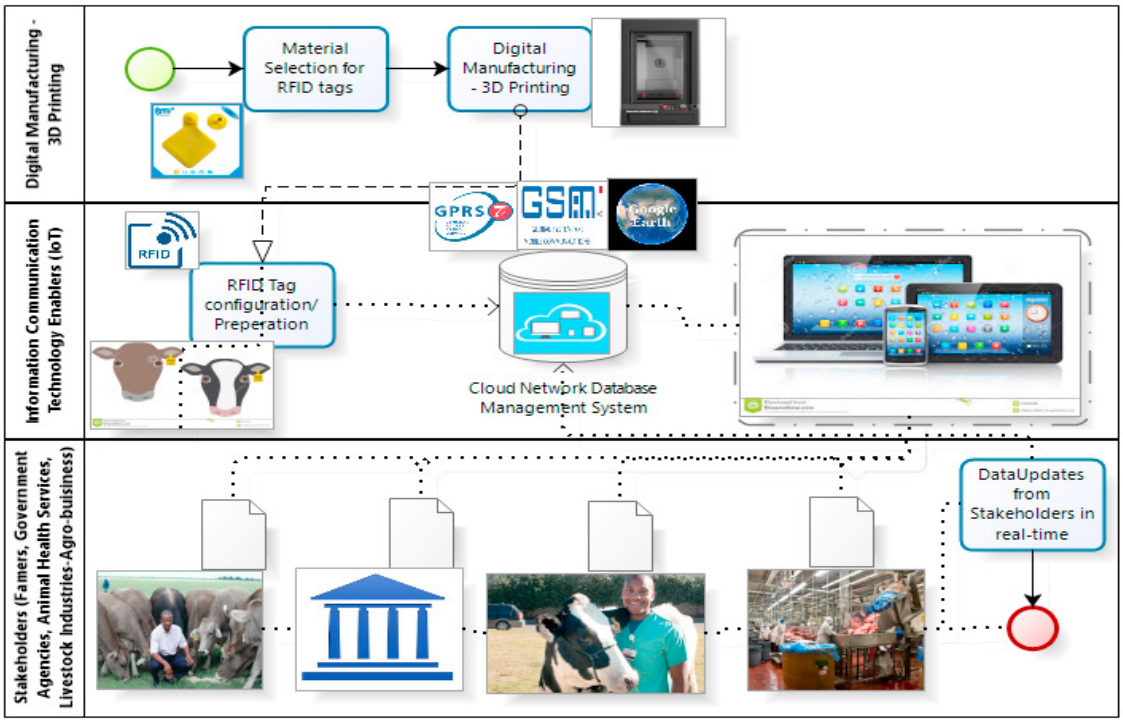

Figure 3. Advanced Animal Track-&-Trace Business Process Model (BPM) Conceptual Framework – (IoT)

Figure 3 above illustrates a BPM of the proposed advanced animal tracking-&-tracing enterprise supply-chain conceptual framework proposed in this research paper. The BPM is categorized into three unique sections starting from the digital manufacturing 3D-printing section and flowing through the mid-section where the ICT system architecture enablers are mapped out and finally the stakeholder or end-user section where the livestock farmer, relevant government agencies, the veterinary and the SME agro-businesses belongs. This last section receives information in real-time from the ICT (IoT) section and also updates the ICT (IoT) section whenever any data/information is updated.

The envisioned animal tracking-&-tracing system has broad benefits that span across various stakeholders for the agro-business and supply chain. Integration with the Google Earth application informs the farmer of the location of their animals, whilst saving other stakeholders with key information. The location for animals is of interest to the veterinary services responsible for control of disease outbreaks such as anthrax, foot and mouth and other threatening diseases. Emergency response is envisaged to be more efficient as a result of real-time data updates. Quarantining affected areas and animals become more efficient with live tracking devices placed on the animals, unlike the current practices where only the physical boundaries are demarcated for quarantine purposes. Traditional methods are prone to violations, leading to serious consequences, which may get out of control because farmers and stock thieves may not heed the warnings from veterinary services and enforcement maybe required. The benefits that integrated ICT enablers provide in the form of IoT offer to industries are enormous: especially SMEs and agro-businesses. Furthermore, the meat production and processing industries such as BMC and the like as well as their suppliers (livestock farmers) and end users/customers also benefit tremendously from the innovative digitisation of the SC processes. This approach amounts to total supply chain visibility of the entire stream in real-time as well as traceability in terms of proximity. The health history of the animal and enhanced flexibility of the entire enterprise SC process. [17] SRI Consulting Business Intelligence, has illustrated in their research that, RFID technology as a key part of the IoT system solution is very important and fundamental in building an efficient and effective IoT system for advanced animal tracking-&-tracing for real-time results.

The insurance and banking sectors also play key roles in the flourishing of agro-businesses. The ready availability of crucial data about livestock management practices, stock count, weather patterns and stock feed status based on the location of animals, help the insurance and banking sectors to gain more visibility about the business of their clients in order to enable them provide tailored services to their clients. Farming is a huge business in Africa and the trend is more likely to continue based on the existing geographic factors and vast lands. Cloud computing and the internet of things (IoT) led to the proliferation of service-oriented business models that support the customer in this age of digitalisation. Hence, this advanced animal tracking-&-tracking conceptual framework promises to be a hub of several services as crucial business models. The insurance sector, for instance, gives discounted rates for motorists with alarm and tracking systems installed on their cars. This offers more value to customers, whilst at the same time improving business management processes and accountability. The following sub-sections 4.2 and 4.3 seeks to outline the proposed hardware components and software needed to facilitate a functional first piloting of the proposed Advanced Animal Track-&-Trace Supply-Chain Conceptual Framework which is structured in an Internet of Things Approach.

4.2 Estimated Cost of Proposed Hardware Component and Software Needed for Piloting

Table 1: Estimated Cost of Proposed Hardware Component and Software

#	**Proposed Hardware Components Needed**	**Quantity / Type**	**Estimated Cost**
1	3D Printer	MakerBot / UltiMaker 2 or 3	$1,500 - $7,000
2	(Customized) PLA or ABS Filament Material		
3	Micro Tempered Solar Panels	Similar to FLiteTraX (GPS / GSM / GPRS) 100 pieces for initial piloting	$50,000
4	Micro Solar Invertors		
5	Micro Re-chargeable cells or batteries		
6	Mini tags equipped with Telemetry RFID	Micro Sky RFID Tags – EPC global C-1 Gen-2 standard (860 MHz ~ 960 MHz) – 100 pieces	$120
7	Wireless / GPRS / GSM Transmitters	2G, 3G & 4G – Tractive GPS/GPRS Technology ($50x 100)	$5,000
8	SIM Cards with roaming function – World SIM	2G, 3G & 4G ($ 30 - $ 150) x 100	$3,000 - $ 5,000

#	Proposed Software Components Needed	Quantity / Type	Estimated Cost
1	Cloud Database System / Server	Cloud System / Server (sync.com)	$15
2	APIs	Webservices Interfaces	Free up to 2,500 requests per day.
3	APPs	Smart APPs (Mobile Gadgets)	$25 - $20,000
4	OS	Android, OIS, LINX, Windows	Unlimited free usage.
5	Google Earth	Keyhole Markup Language or KML	Unlimited free usage.

4.3 Data/Information Format, Modes of Transmission and Security Status

Table 2: Data/Information Format, Modes of Transmission and Security Status

#	Type / Format for Data or Information	Mode of Data / Information Transmission	Type of Security on Trans.
	Cloud Database System / Server	JavaScript, PHP, ASP, AJAX, Perl, Java, SQL, FAT files, FAT32, NTFS files, CSVs, etc.	Encrypted
	Web Service APIs	HTML, WSDL, SOAP, WSFL, XINS	Encrypted
	Smart APPs	SmartApp Basics, Groovy Basics, SmartThings API, RESTful, LIFX bulb, WSCL, HTTP Post, HTTP URL, Web Hook, etc.	Encrypted
	Android, iOS, LINUX, Windows, etc	POSIX standard	Encrypted

5. Conclusion and Recommendations

Trending research indicates that total visibility in terms of supply chain track-&-trace within the livestock farming has imminent challenging issues. These issues include but not limited to, animal theft, accidents on the road by being knocked down by automobiles, straying animals and high business risks due to poor animal health management practices, etc. These are just a few of the seriously lacking and imminent issues in current industrial logistics and supply-chain management activities within agri-business sector such as livestock farming. This paper thus attempts to propose the application of RFIDs and the Internet of things enterprise systems architecture to propose a feasible cloud-based solution as illustrated in Figures 2 & 3 above. This proposed cloud database network system and the IoT system solution approach can keep track of the health history, birth records, ownership history and also track location of each animal by using an electronic (RFID) tag instead of the current existing passive ear tags. This initial data collection in the cloud is presumed to be the most relevant data needed for the system solution to function effectively and efficiently as required or expected to. Furthermore, these prescribed initial data collected are the only relevant and significant data needed for the functionality and purpose of this research's proposed advance animal tracking-&-tracing conceptual framework; so that the database management system would not be cluttered with irrelevant data.

The originality and validity of these initial data and information collection are carefully selected such that, the animal owner details collected will indicate who the owner of the animal is and the particular farmyard the animal is registered to as its current status when it's found strayed or stolen. The animal real-time location will also enable effective and timely pinpointing of the location of the animal again when found, lost, stolen or strayed from its owner's farmyard at any point in time. This important function or core functional factor of this research has proposed advance animal tract-&-tracing conceptual framework which would be enabled by integrating the Internet of Thing's enterprise system solution: comprising of GPRS, GSM, RFID, Google Earth function, etc. Now the relevance of the animal's age and health history data is especially relevant to enhance agri-businesses and also serves as a rich, readily available and much-updated repository for government agencies and the private sector that needs these statistical data and information to enhance their work and activities. For example, both government and the private sector agri-businesses would need the age and health history records of an animal to be able to qualify it for sale and slaughter for export onto the international market (EU) who would not buy cattle that are over one year old. Hence, the easier it is to track-&-trace the age and health data for one's animals the better and more efficient businesses would ramp-up on ROI. Furthermore, both relevant agencies in government such as the Health Ministry's Veterinary departments and the private sector NGOs interested in consumable livestock animals would need these data and information for research purposes.

Thus, the findings and the proposed advanced animal track-&-trace SC conceptual framework contribution of this research attempts to lay a solid feasible foundation in an Internet of Things approach towards digitalisation and digitising the livestock agri-business industrial SC processes as an upgrade to the current mechanised approach. This approach will make the current mechanised approach leaner, more competitive, much-enhanced performance and an overall improved ROI. This research is still work-in-progress (WIP) in terms of actual integration and configuration of the systems or devices into an enterprise SC IoT as well as the onward testing or piloting of the project for evaluation purposes. Therefore, further research will be addressing but not limited to the areas mentioned above because it is believed or assumed that, a few interesting abstract issues or discoveries will still be uncovered and incorporated into the big picture for utmost functionality.

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