The Development of an e-Traceability System for Cattle Delivery Chains

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***Abstract*— Transparency of livestock supply chain management is still a significant problem in Indonesia due to the unavailability of data and information accessible by the stakeholders of cattle supply chains. It is difficult to obtain information for queries, monitoring, and control purposes at any node along cattle supply chains, and thus introducing some risks of insecurity and uncertainty of cattle conditions along the supply chains. Nowadays, consumers are getting smarter and more curious about selecting healthy and high-quality beef. This requires the provision of an easily and securely accessible traceability and transparency system. This research aims to develop an e-traceability system for cattle supply chains. The proposed e-traceability system was developed based on a web-platform that provides wide access and easy links to all actors within a cattle supply chain and stakeholders. All actors in the cattle supply chain need to be registered and the data related to cattle need to be recorded in the traceability system database for prudent analytics and decision-making. The potential applicability of the developed e-traceability system is examined and demonstrated to highlight the benefits of the system in improving transparency and traceability cattle deliveries from land to table for better managerial tasks.**

***Keywords*—** *cattle delivery chains; decision-making systems; e-traceability systems; RFID; supply chain.*

1. Introduction

A traceability system is defined as the ability to trace the history, application, or location of that which is under consideration [1]. The research on livestock supply chain traceability systems has been aggressively done in this millennial age where the concerns of food safety and security and technological advancements are significantly increasing in the world [2-6]. Indonesia is one of the potential countries producing cattle and beef. However, traceability and transparency of livestock supply chains in Indonesia are still inadequate due to the unavailability and inaccessibility of data and information required by the stakeholders of cattle supply chains. These problems introduce difficulties for the government, policymakers, observers, buyers, meat industries and consumers to obtain information for query, monitoring and control purposes at any node along the cattle supply chain [2]. Consequently, insecurity and uncertainty of cattle conditions along the supply chain will occur. According to Feng et al. [4], consumers and buyers of beef are getting smarter and more curious in selecting healthy and high quality. Traceability is useful for monitoring and protecting the health of livestock and improve the safety of the meat supply, and for the quick and effective tracing of animal disease to its source [7]. A traceability system can be used as a method of serving safer food supplies and of interconnecting producers and consumers [8, 9].

One of the vital requirements of cattle supply chain traceability is the unique identification number of each cattle. In conventional systems, identification of a cattle uses a non-digital mark such as ear notching, a burn cap (tattoo), branding (hot iron or freeze iron branding), or an ear tag [10]. This is not suitable for implementing digital a traceability system and is susceptible to lose and illegibility. Therefore, a digital identifier (e-ID) is required using RFID (Radio Frequency Identifier), microchip, and electronic collar. Some researchers have been exploring the use of bio-identification systems using nose prints, iris prints or retina prints that can be read by a digital camera or a digital sensor [7, 9]. This research aims to develop an e-traceability system for cattle supply chains, especially in Indonesia. The proposed e-traceability system has been developed based on a web platform that provides wide access and easy links to all actors within a cattle supply chain and stakeholders from land to table in different geographical areas. All actors in the cattle supply chain are required to be registered and to record relevant data that will be stored in the traceability system database for various for various analysis and decision-making needs. An RFID is used for unique cattle identification. The basis architecture model for IT-based traceability system has been developed by Seminar [11], which has been embedded in the development of traceability systems for several agricultural products such as tuna-fish [12], broilers [13], coconut palm sugar [14], and rice [15-17]. This paper also examines and discusses the functionality and applicability of the developed e-traceability system prototype to highlight the benefits of the system in improving transparency and traceability cattle deliveries from upstream to downstream (land to table) for some better operational and managerial purposes.

2. The Development Method

2.1 Case Study Area

The case study area was limited at the Nusa Tenggara Timur (NTT) province, as the source of cattle being delivered to Jakarta, as the capital city of Indonesia, using Camara ships that have been specifically developed and used for marine transportation of cattle delivered from NTT to Jakarta. Camara ships have been provided by the government of Indonesia to improve the capacity and security of cattle delivery in Indonesia, as well as to maintain the best-practices of animal welfare aspects during transportation. The live cattle export from NTT province to another province is around 65.000-70.000 heads of cattle per year, with Jakarta and West Java being the main consumer areas for the cattle. The beef cattle is distributed all over region in NTT, and Kupang regency as the largest beef cattle producer with cattle population around 217.146 heads. In addition, Kupang regency has a good access and infrastructure as well as has a short distance to the seaport. Therefore Kupang regency has become the major cattle source in NTT and is one of the cattle centers in Indonesia.

2.2 Development Stages and Tools

The logical flow of a traceability system development consists of stages as described in Figure 1. It starts with system analysis to investigate cattle supply chain structures and actors involved, with their respective functions, in the chain in Indonesia through literature review and field survey. Questioners were used to interview the cattle supply chain actors in the case study area. The supply chain model for cattle, a set of relevant data and information flows in the chain were identified. Finally, functional and non-functional requirements of the system were formulated based on users' perspectives combined with theoretical aspects.

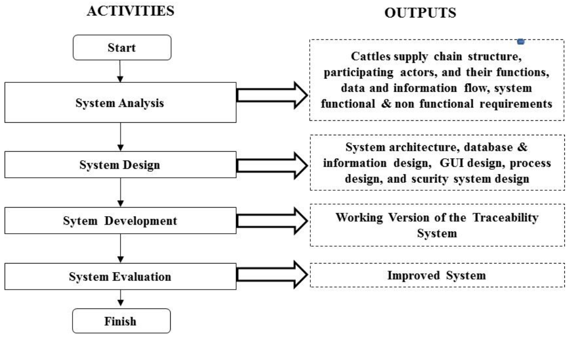

Figure 1. Logical staging of the traceability system development.

The design stage is to develop the logical design based on the output from the analysis stage. This logical design includes the system architecture, database and information structure, graphical user interface (GUI), process and security specifications. Several software tools used in this design stage included MySQL as a Database Management System (DBMS), HTML as s Web Programming Languages, and Google Chrome, Firefox, Internet Explorer as web browsers.

The system development stage is to produce a working system which can be run, tested and evaluated. RFID labels and an RFID reader were used to develop an e-ID system for cattle identification, recording and monitoring. The last stage is to assess the developed working system mainly on the functionality of the systems from users' perspectives. System evaluation was done through a focus group discussion (FGD) involving representative stakeholders of the developed traceability system.

3. Results

3.1 Cattle Supply Chain Characteristics

Based on the scope of our research and on the real facts of our case-study, the supply chain of cattle in Nusa Tenggara Timur (NTT) province to Jakarta (the capital city of Indonesia) is shown in Figure 2. The proposed traceability system will include all actors from cattle farmer groups (actor 1) at NTT to the slaughterhouse Darmajaya at Jakarta (actor 7). Actors 8 and 9 are not covered in our research scope; these actors are only observed to see the logical connections and implications the whole network actors. The actor's activities or functions can be identified as listed in Table 1.

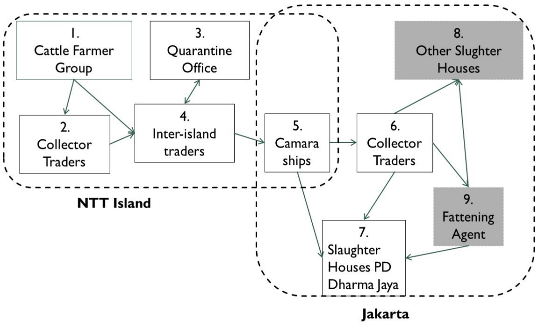

Figure 2. Supply chain structure of cattle in the study case areas from NTT to Jakarta.

Farmer groups buy productive cows from the cattle market or individual farmers which are then raised in the housing or in the pasture to produce the offspring (calves) until the calves are weaned around 6-10 months. Sometimes farmer sell the weaning calves or continue to grow them, and it is called as stocker or backgrounding program until the age of the cattle reaches around 18-24 months with average body weight around 250-275 kg, and it is called feeder cattle. In addition, farmer can sell the feeder cattle at the cattle market or directly to traders, or the farmers continue to grow them, it called as finishing or fattening program until the age of cattle reach minimum 24-36 months with average body weight around 300-350kg, and it is called as ready to slaughter cattle. Among the farmer groups some investors provide funds to farmers to buy cattle. Farmers sell cattle and share the net selling profit with the investor with profit-sharing varying for the investor and farmers from 60:40 to 50:50. Some farmer groups like Fajar Mandiri obtain funding support from local banks (Bank NTT) with 7% interest rate.

Nowadays, several farmers' groups have been established at Kupang regency. Farmer groups have an essential role in the farming community to share knowledge and to foster good practices in cattle farming. Mostly the farmer group focuses on cattle finishing. Cattle was breed and fattened intensively by feeding them with forage such as *lamtoro* tree leaves, banana stem and sago trunk. Commonly, after two years, the cattle are brought to sale markets. Farmer groups have no data record about their cattle, except ownership and number of cows. There is no recording on periodical cattle weight, amount of feeding, cattle health condition and medication or vaccination. Table 2 summarized the existing data records (column 2) and the recommended data record (column 3) for actors in a cattle supply chain.

3.2 The Developed e-Traceability System

The developed cattle traceability system accommodates interaction and communication among actors in the cattle supply chain, as shown in Figure 2. Interaction among actors are outlined in Figure 3.

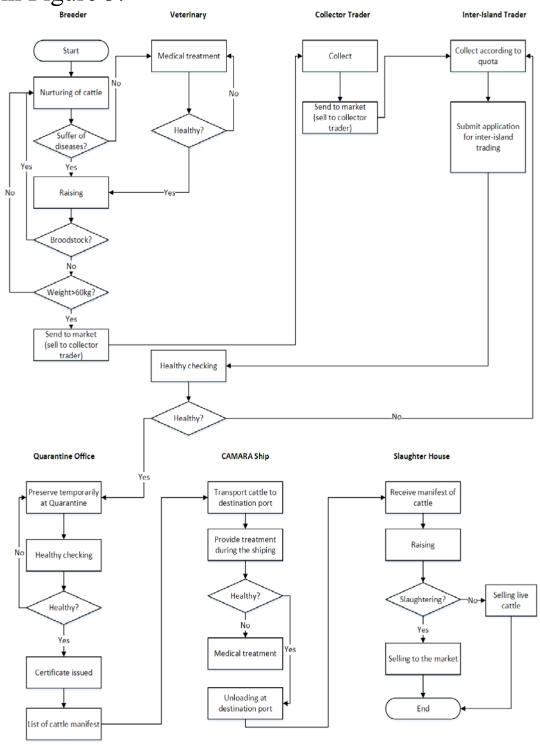

Figure 3. Actors' interaction and communication within the developed e-traceability system.

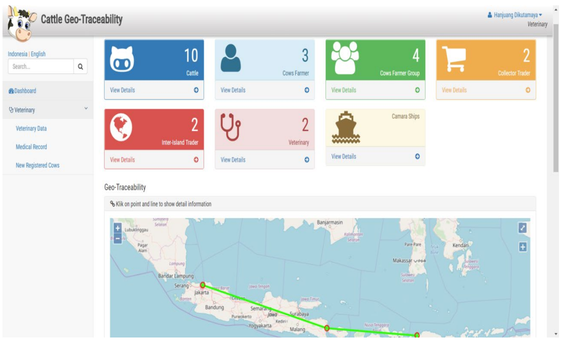

Figure 4. The user interface dashboard.

The web-based architecture was chosen to enable the system is widely and easily accessible by wider stakeholders and users at any place and time. This enables the monitoring of actors and their respective cattle and activities along the supply chain, including the condition of cattle during shipment. The dashboard contains information including the number of cattle which is stored/recorded by the system, number of actors and their respective role, map of cattle delivery paths from origin departure port to intermediate or final destination ports and information of cattle population structure (Figure 4). This allows tracking and monitoring of cattle treatment and delivery, including the position and condition of cattle during shipment at every destination points on the map (green line).

Table 1. List of actors and their activities of cattle supply chain from NTT to Jakarta.

No.	Actors	Activities
1.	Smallholder farmers/Farmer group	Beef cattle production, mainly breeding/cow-calf operation, rearing and fattening activities to produce weaning calves, feeder cattle, slaughtering cattle and replacement heifer and bull
2.	Collector traders	Collecting cattle from the farmer and sold to inter-island traders at Tenau port, Kupang Regency
3.	Quarantine Service of NTT Province	Cattle health check procedure and certificate provision of animal quarantine release
4.	Inter-island trader	Collecting cattle from village and district traders, then sold to inter-island trader at Jakarta
5.	Camara Ship Owners	Cattle transportation services, loading and unloading of cattle and on board cattle housing
6.	PT Dharmajaya Jakarta	Cattle slaughtering, meats storage & distribution, and cattle and beef

Table 2. Actors and their respective data.

Actors	Existing Records and Documents	Recommendation Records and Documents
Farmers : 1. Smallholder breeder 2. Intermediate fatteners 3. Smallholders feedlotter	• ID (hot iron branding) • Cattle Weight	• Breeds, Type, Sex, Dam, Sire • Date of birth, Weight of Birth, Weaning Weight • Age of cattle (weaning, yearling and feeder), Yearling Weight, Feeder weight • Feed type, Vaccine, Morphometric • Address of farmer/group farmer
Village and district trader and Inter-island traders	• ID (hot iron branding) • Cattle weight • Cattle health certificate (SKKH)	• Trader Code • Address of trader • Cattle weight at Quarantine • Feed at Quarantine • Vaccine at Quarantine • Cattle weight at Sale
Camara shipowner	• Number of cattle to ship • Schedule of shipping • Destinations	• Number of cattle to ship • Shipping schedule, Destinations • Weight of cattle at loading and unloading • Conditions of cattle on ship • Feed and water for cattle
Quarantine	• Cattle health treatment (medicine, vaccine or other health treatment), SKKH • Certificate of animal quarantine	• Cattle health treatment (medicine, vaccine or other health treatment), SKKH • Certificate of animal quarantine
Jakarta Trader (PD Dharma Jaya)	• Arrival time • Bodyweight after arrival (weighted after five days from arrival time)	• Internal Trader data, Address of trader, Time of Arrival • Bodyweight after arrival • Days on feed at holding ground • Cattle health program

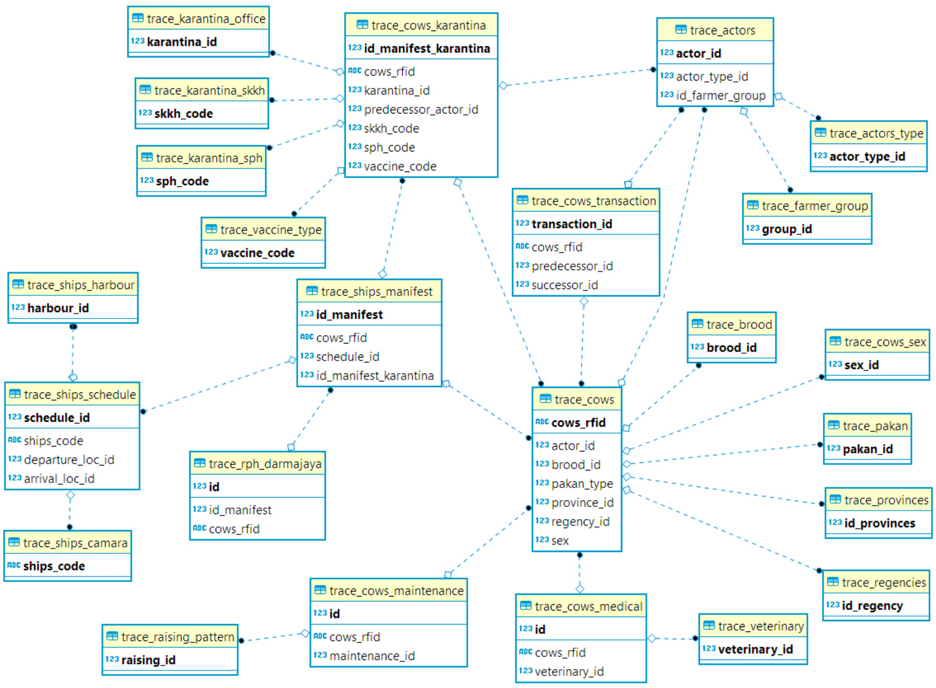

Figure 5. The conceptual database design of the developed traceability system.

Figure 6. (a) RFID based registration; (b) identity of cattle.

This e-traceability system provides a data repository that was built on the basis of the PostgreSQL DBMS platform, one of the reliable and credible open-source Object-Relational Database Systems. The conceptual design of the developed e-traceability database is presented in Figure 5. The database was developed based on the relevant data needed by actors in the chain. The database supports data retrieval and prudent analytic for various needs of decision making and surveillance purposes.

Actors and cattle belong to farmers must be registered into the e-traceability system to ensure transparency and security objectives. This will prevent illegal actors and undesired activities and penetration done by illegal actors. Each registered cattle is provided an electronic identifier (e-ID) using RFID to allow quick and accurate unique identifications electronically (Figure 6).

The system will record any treatments to the cattle, thus it enables actors to monitor and trace any treatments that have been applied (Figure 7). The registration and delivery of cattle to quarantine office can be done to obtain health status and release certificate after inspection from quarantine office (Figures 8-10).

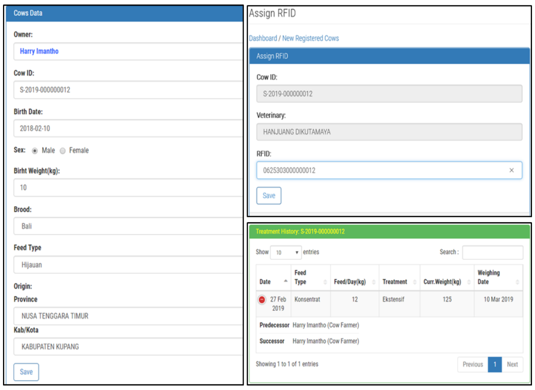

Figure 7. Cattle registration and cattle treatment recording system.

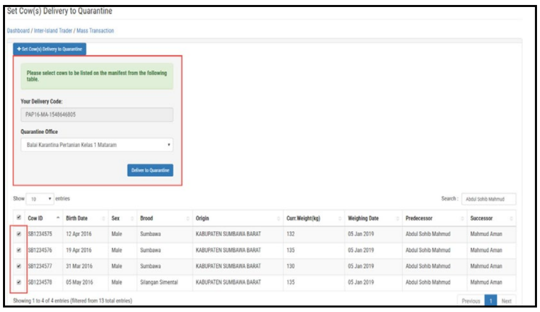

Figure 8. Sending cattle to quarantine by inter-island traders.

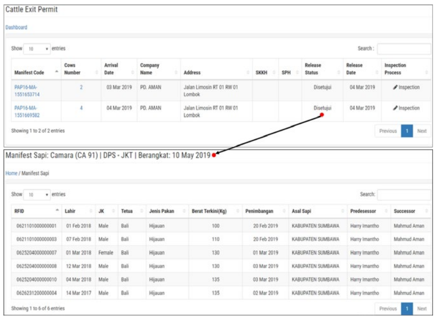

Figure 9. Selection of cattle for manifest in the quarantine office.

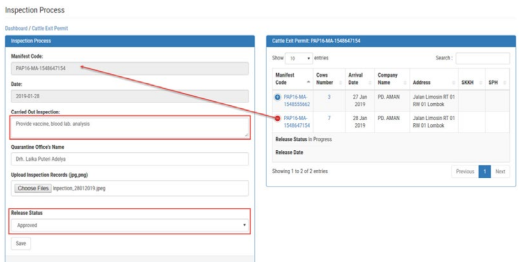

Figure 10. Inspection process of the cattle manifest.

4. Discussion

Traceability, by definition, is inherently broad since foods or any traceability objects are complex and traceability is just a tool to achieve different goals, as discussed in Golan et al. [1]. Our research shows there are several different purposes and requirements of developing traceability systems for different agricultural products, such as tuna-fish [12], broilers [13], coconut palm sugar [14], and organic rice [17]. No exception with the cattle traceability system proposed in this paper. The system does not provide functionalities required for tracking the genomic or genetic profiling for the sake of developing superior cattle seedlings by conducting genetic crossing or genetic engineering. Our proposed system focuses on improving the transparency of cattle supply chain and on providing forward- and backward- tracing of cattle in the supply chain for food safety and quality. According to Golan et al. [1], there are three primary objectives for firms to use traceability systems: improving supply management, facilitating traceback for food safety and quality, and differentiating and marketing foods with uneasily detectable quality attributes. To assure the health of livestock and improve the safety of the beef supply, quick and effective tracing of its source must be provided by a traceability system [7, 18]. Moreover, traceability is an enabling tool for upstream-downstream (land-to-table) integration in a cattle supply system and interconnecting producers and consumers [8, 9, 19-22].

Table 3. Benefits of web-based traceability for cattle supply chain in Indonesia.

No.	Benefits	Stakeholders					
		Farm-ers	Gover-nment	Traders	Transp-orters	Slaughtering Houses	Consumers
1	Quick and easy access of cattle, actors and their respective activities and function in the supply chain	√	√	√	√	√	√
2	Better transparency and functionalities in cattle management locally and nationally	√	√	-	-	-	-
3	Prevention of unidentified actors, illegal conducts and unregistered cattle	√	√	√	√	√	√
4	Better assurance and surveillance of food security and safety, uniformity of food products and public health	√	√	-	-	-	√
5	Better control of genetic erosion and livestock populations, inventory and cattle logistic management	√	√	-	-	-	-
6	Better price and market destination planning for cattle	√	√	√	-	-	√
7	Easy knowledge and best practice sharing among farmers, relevant actors and consumers	√	√	√	√	√	√
8	Better coordination on cattle supply and delivery	√	√	√	√	√	√
9	Faster detection and responses to consumers' complaints	√		√	√	√	√
10	Increase of trust nationally and internationally on cattle supply chains of Indonesia	√	√	√	√	√	√

An on-line, web-based traceability system can be well developed and implemented by enforcing electronic identifiers (e-ID) to allow quick and unique identification of cattle at any point in the cattle supply chain. Animal identification is one of the important components in traceability which has been used for hundreds of years. As discussed in Feng et al. [4], RFID technologies, which apply radiofrequency to identify objects and provides reliable and efficient tracking for the RFID tag, can store/retrieve data wirelessly and electronically [23-27].

Of course, the implementation cattle traceability through a traceability system raises policy implications, including (1) advocation for the government and legal authorities as national policymakers to support legal, financial and infrastructure support to promote a better traceability system for the cattle supply chain in Indonesia, (2) education and promotion for increasing awareness of actors, particularly farmers (groups), on the traceability program. According to Liao et al. [28], improving management performance or allocating more financial budgets on the local agricultural authorities should effectively increase the food traceability program participation at the farm level. With increasing consumers' awareness and governments' regulations and supports on beef quality and safety, traceability is becoming an obligatory requirement in the cattle/beef industry [4].

Through the literature [29] and field survey, as well as a focus group discussion conducted in our research and literature, the benefits of the development and implementation of a web-based traceability system in Indonesia, can be formulated in Table 3.

5. Conclusions

A web-based traceability system for cattle supply chains has been developed to improve transparency of cattle movement from farmers to customers in Indonesia. The motivations, functionalities, system prototype and benefits of the system have been discussed. In the global market era, the implementation of cattle traceability systems is strategical and critical for ensuring food safety and security since foods are intensively imported to and exported from many places in the world in Indonesia. Future work is to address the implementation and evaluation strategies, the development and integration of smart tools for enhancing the traceability system and the formulation of the traceability system success factors in Indonesia.

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