Developing a Traceability System for Tuna Supply Chains

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Abstract*— Tuna is one of the flagship export commodity from Indonesia which has special characteristics such as high perishable food and has complex supply chain network. According to the characteristics, the potency of deterioration and cross contamination along the chain will be a challenge for every actor in tuna supply chain, to provide tuna product with the best quality and safe to consume. One of the tool to ensure the standard safety and quality is doing traceability system along tuna supply chain. It is very crucial because every actor in chain has a responsibility to ensure food safety and quality through handling, manufacturing, packaging, and transporting the product. The critical point that should be covered by traceability system in tuna supply chain includes temperature, content of histamine, quantity of TPC, and contents of bacterial pathogens like Salmonella, and the sanitation for workers, equipment and processing room. The Information Technology (IT) based tuna traceability system is proposed and discussed in this paper to optimizing the traceability system in tuna supply chain. This paper discusses the development of a traceability system architecture and prototype for tuna supply chains. The developed system prototype shows the functional capabilities required for backward and forward tracing of tuna fish transformation and movement along the chain involving many actors (from fishing vessels to retailers). The system also permits the monitoring of processes and products based on microbiological analysis and on existing SOPs owned by some actors in a tuna supply chain. The implementation issues are also described in this paper.

***Keywords*—** *food quality, food safety, information technology, supply chain, traceability, tuna*

1. Introduction

Food traceability system is one of the important tools in food safety management system and required by Codex Alimentarius Commission to follow the movement of the food through every specific stage [2]. At the moment, most of the country have been adopted this system through their food safety system policy in every commodity [4] [6]. Tuna fish is one of the flagship export commodity from Indonesia. The Ministry of Fisheries and Marine Affairs states that tuna fish contributes 15.1% for seafood export with shrimp (45.1%), crab (8.9%), and seaweed (6.1%) in 2014 [18]. However, tuna supply chain in Indonesia is facing several bottlenecks and one of the bottlenecks is traceability [14]. Traceability is one of the most important issues in tuna supply chain due to the specific characteristics, such as complex supply chain network and high perishable food. These characteristics making food safety as one of critical point in tuna beside Illegal, Unreported, Unregulated (IUU) fishing and eco labelling in fisheries [5] [8] [9]. The food safety issue is indicated by histamine and pathogen bacterial content in tuna due to cross contaminations and poor handling. Based on FDA data in 2016, there are several tuna processing companies in Indonesia got the rejection of tuna product in America due to Salmonella. In addition, the most of rejection are caused by filthy [7]. To reduce these potency, all of the actor in tuna supply chain should obey and practice the standard of tuna processing and record it into the document. Documentation is the key aspect to make a perfect traceability system. In addition, the transparency of information along tuna supply chain is needed to reduce the different standard, especially about tuna quality.

Currently, the traceability system in tuna industry, especially in Indonesia is doing by paper based traceability system [17] [13]. The system works with manual documentation by the people to input, process, analysis, and keep the document in every stage along tuna supply chain. This system is required by HACCP standard and followed by the Ministry of Fisheries and Marine Affairs

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regulations. However, paper based traceability system has several limitations such as the potency to be manipulated, error by the human, language barrier, and physical damaged [11]. Regarding these factors, it needs to develop IT-based traceability system for tuna supply chain. The IT-based traceability has been developed by several research in other industry like ginseng industry [12], convenience store [10], and dairy industry [16]. In fisheries industry, especially in Indonesia, there is Proactive Vessel Register (PVR) as a piloting effort to improve transparency in small fishing vessel [1]. However, there are not any system to support the real time data acquisition and focus on food safety and quality in tuna industry, which is tuna has special characteristics than other commodity, to improve transparency in the chain [20]. The proposed IT-Based traceability system is expected to solve the limitations of paper based traceability through their special features, like real time acquisition data and shows the integrated data along the tuna supply chain. This paper proposes the design of tuna traceability system in Indonesia which is equipped with system architecture, Data Flow Diagram (DFD), and the interface of the prototype system.

2. Tuna Supply Chain Model

Tuna supply chain consists of several actors such as fishing vessel, transit, fish processing unit, transporters, distributor, retailer, and government. The chain has product and information flow for every actor. In addition the actor has the coordination flow with the government especially for permission and certification. Tuna supply chain model is shown in Figure 1.

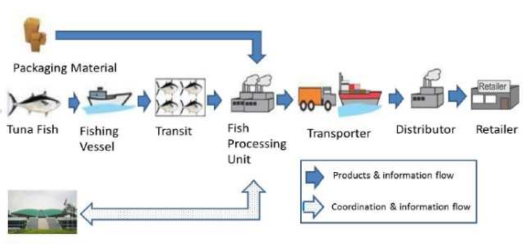


Figure 1. Tuna Supply Chain Model [2]

Fishing vessel is the first actor in the tuna supply chain which catch tuna from the sea with long line method, do on board handling, and keep the tuna in the vessel. Transit has a role in unloading tuna form the fishing vessel, checking the grade of tuna, and sell it to fish processing unit. Fish processing unit is the chain captain of the tuna supply chain. It receives the tuna from transit, checking the quality of tuna, process the tuna into several frozen products, like tuna loin, tuna steak, tuna cube, etc. In addition, fish processing unit also do the quality assurance of the product and the process by laboratory test. Transporter deliver the product from the fish processing unit to the distributor in America. Transporter consists of container to deliver the product from fish processing unit to the port, and the ship to deliver the product from Indonesia to America. The container must keep the temperature in -25 °C to maintain the quality of the product. Distributor is located in America. Tuna product from Indonesia must be checked by the Food and Drugs Administration (FDA) by random sampling to ensure the products meet the America standard. If the products pass, they can distribute to the retailer, otherwise the products should be returned to the fish processing unit in Indonesia. Every stage in tuna supply chain should meet the standard to ensure the quality and safety of tuna. The main standard is about the temperature of the fish, histamine score, and consistency of pathogen bacterial. Fish processing unit has applied the Hazard Analysis Critical Control Point (HACCP) system to ensure the process and the products to meet the standard. Every actor like transit and fishing vessel are required to practice the Good Handling Practices and Sanitation Standard Operating Procedure (SSOP) to keep the quality of tuna. The HACCP system emphasizes in process inspection and documented the process. The document will be the key aspect to trace the product and process in the emergency situation [13].

3. Developing A Tuna Traceability System

Regarding the limitations of paper based traceability system, the development of IT based tuna traceability system is important. The IT based traceability system can support various algorithmic and computational scenarios. In addition, the system support real time acquisition data from the actor and process, and linking and tracing all actors at different stages, geographical areas, and time zones [19].

3.1 System Architecture

The traceability system architecture is built based on the modification of the general architecture of tuna traceability system and tuna supply chain model [20]. The traceability system architecture that is developing namely multiple functional structure of tuna traceability system as shown in figure 2.

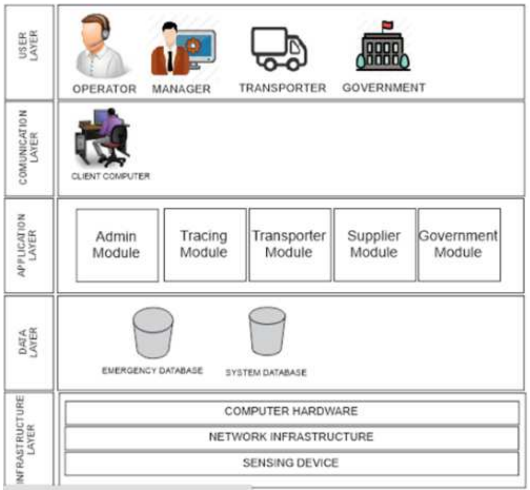


Figure 2. IT Based Tuna Traceability System Architecture with Multiple Functional Structure

The architecture consists of several layers, namely infrastructure layer, data layer, application layer, communication layer, and user layer. Infrastructure layer consists of computer hardware, network infrastructure, and sensing device. Computer hardware functioning as the hardware to process the system. It will be helped by network infrastructure to deliver the information from the product to the user, and the sensing device will be a data acquisition along the chain for every actor. The sensing devices such as CCTV, GPS, and RFID can be developed based on the characteristic and needs of the actor. Data layer will be a database of the system which be a storage of the data in the system. The architecture shows two types of database namely emergency database and system database. System database is the main database for the system whereas emergency database needs in the emergency situation to run the system. The application layer consists of some module such as admin module, tracing module, transporter module, supplier module, and government module. They are the module that can be accessed by the registered actor. Each actor access the different module and different interface in the system. User layer are the users of the system which are the registered actors in the system.

3.2 Data Acquisition

The traceability system will be equipped by data acquisition system like sensing devices to support real time data acquisition. Every actor will use the specific sensing devices based on the characteristics of the actors. Fishing vessel, transit, fish processing unit, distributor, and retailer will be equipped by Radio Frequency Identification (RFID), Global Positioning System (GPS), and Closed Circuit Television (CCTV). The other actor, which is transporter will be equipped by GPS. GPS can take real time data about actor location, such as location of transit, fish processing unit, distributor, retailer, and the vessel on fishing ground. The implementation of GPS is based on several research, one of them is about RFID and GPS combination approach in fisher boat tracking system [3]. The research shows that GPS and RFID can monitor the vessel position and the cargo. CCTV can take real time video during the actor activities, such as monitoring on board handling in the vessel, fish loading in transit, loin processing in fish processing unit, and the transaction process in distributor and retailer. The monitoring stage is very important to ensure the standard and tuna quality. RFID is selected considering its advantages such as can be applied in any media (plastics, paper), storage more data, and can be updated with the old tag [15]. The RFID tag can be tagged in fish or plastics batch to inform the fish temperature, processing stage, and date of the product.

3.3 System Analysis

Based on the architecture, system analysis is needed to show the data flow through Data Flow Diagram. The DFD in tuna traceability system consists of context diagram, DFD level 1, DFD level 2, and DFD level 3. Context diagram shows the overall process and the data flow to and from entities [21]. The system namely as Tuna Quality Management System and the entities namely transit, transporter, packaging supplier, distributor, and government. Context diagram shows in figure 3. DFD Level 1 shows all the process on tuna quality management system. Tuna quality management system consists of three main process, namely registration, processing, and transaction. DFD level 1 shows in figure 4.

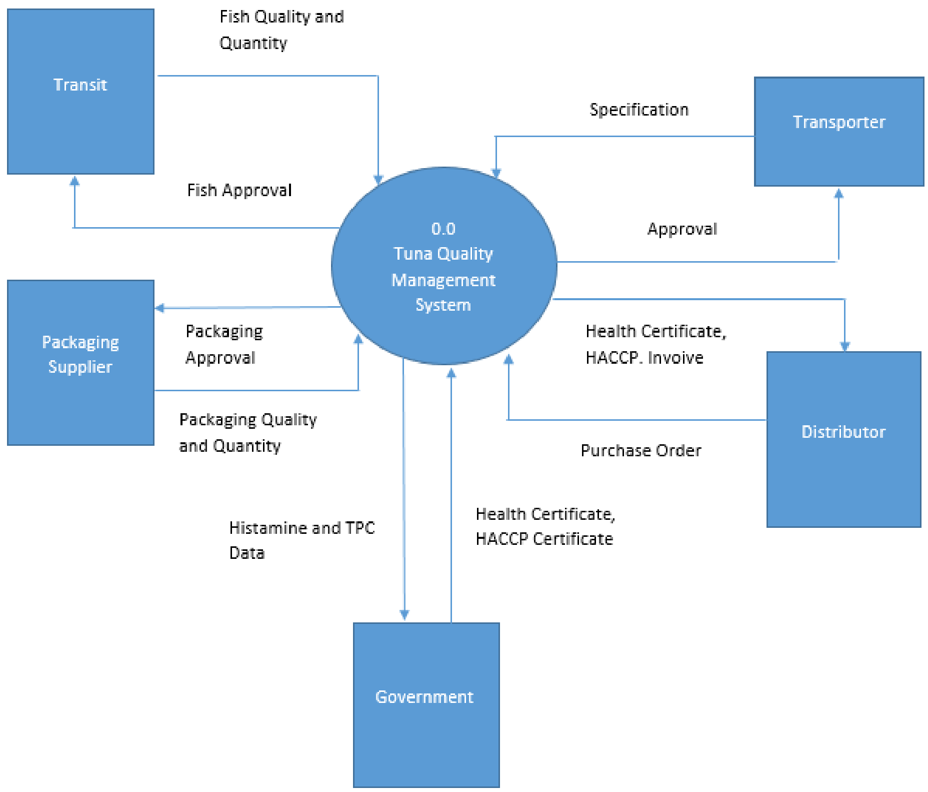


Figure 3. Context Diagram

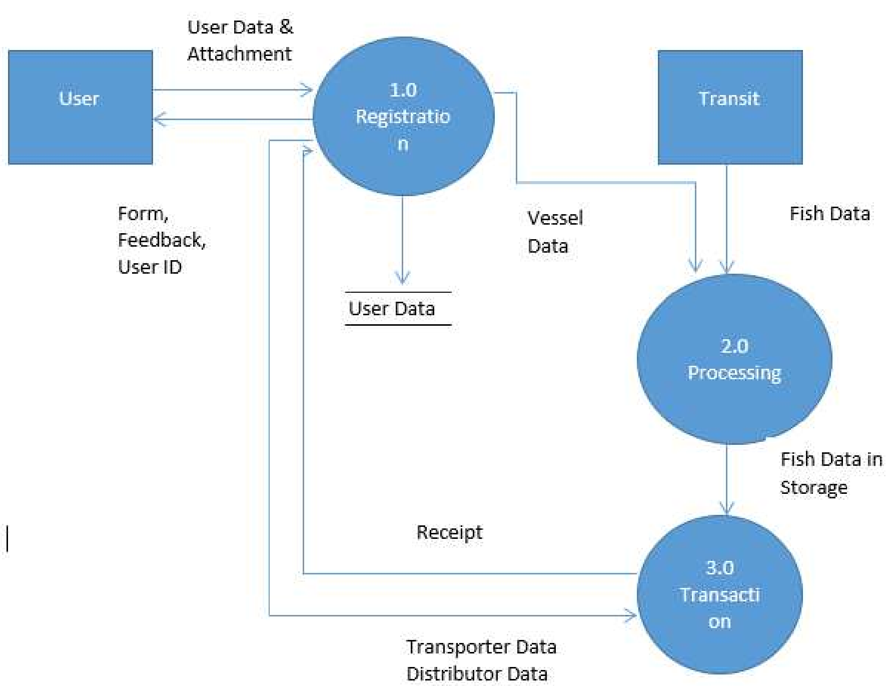


Figure 4. DFD Level 1 Tuna Quality Management System

DFD Level 2 consists of three diagram which each process of level 1 diagram is decomposed into a more explicit DFD [21]. Diagram 1 Level 2 shows the decomposed of registration system which explains the flow of user registration and how system saved the data. Three step of registration are registration form, verification, and approval. Registration form is the step which the actor candidate fill in the form in the system. Then the administrator will verify the data in verification step and approve the actor with the certificate to the actor in approval step. Diagram 2 shows the decomposed of processing stage. The processing stage consists of many steps to process tuna from raw material into the product. It consists of raw material receiving, weighing, cutting, skinning and trimming, retouching, freezing, packaging, storage, and laboratory. Every step is documented in specific digital form. Diagram 3 shows the decomposed of transaction process which explains how the transaction of tuna is doing. Transaction process, which is called order system, link the information exchange from system and two entities, which are government and distributor. DFD Level 2 shows in figure 5, figure 6, and figure 7.

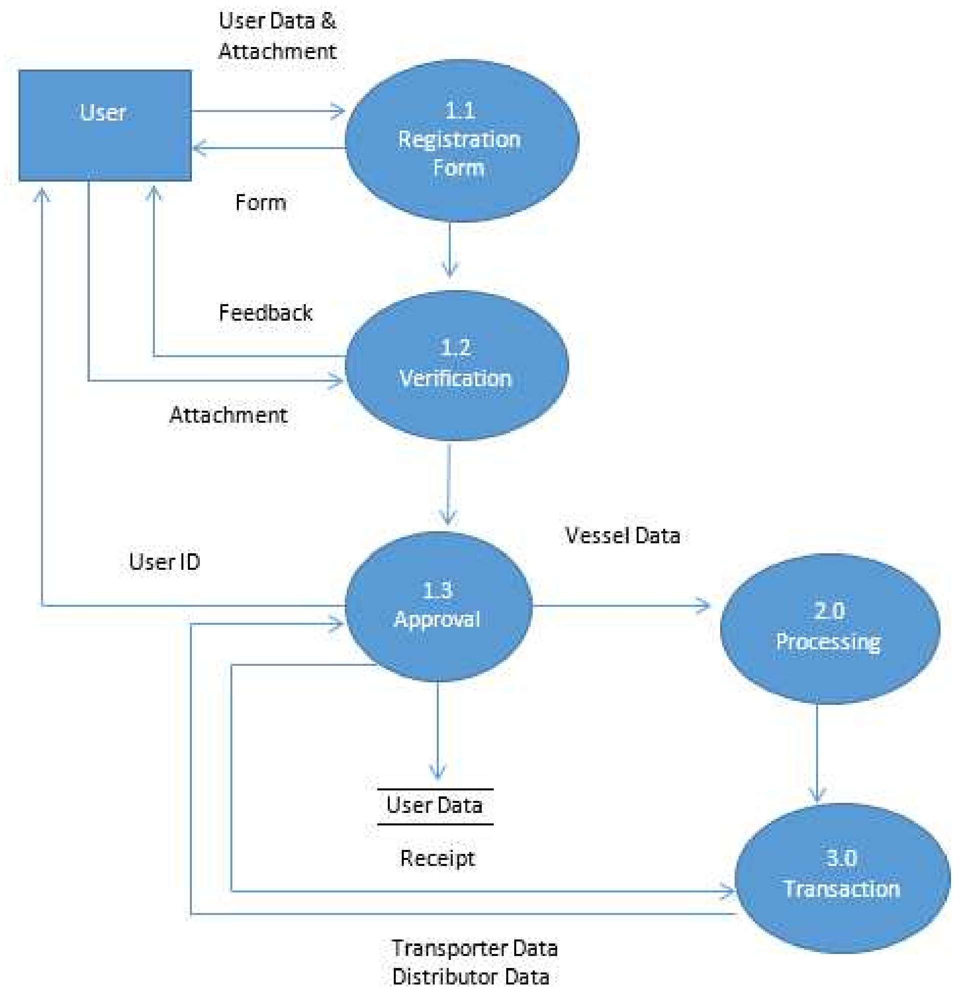


Figure 5. Diagram 1 Level 2 Registration Stage

Int. J Sup. Chain. Mgt Vol. 6, No. 3, September 2017

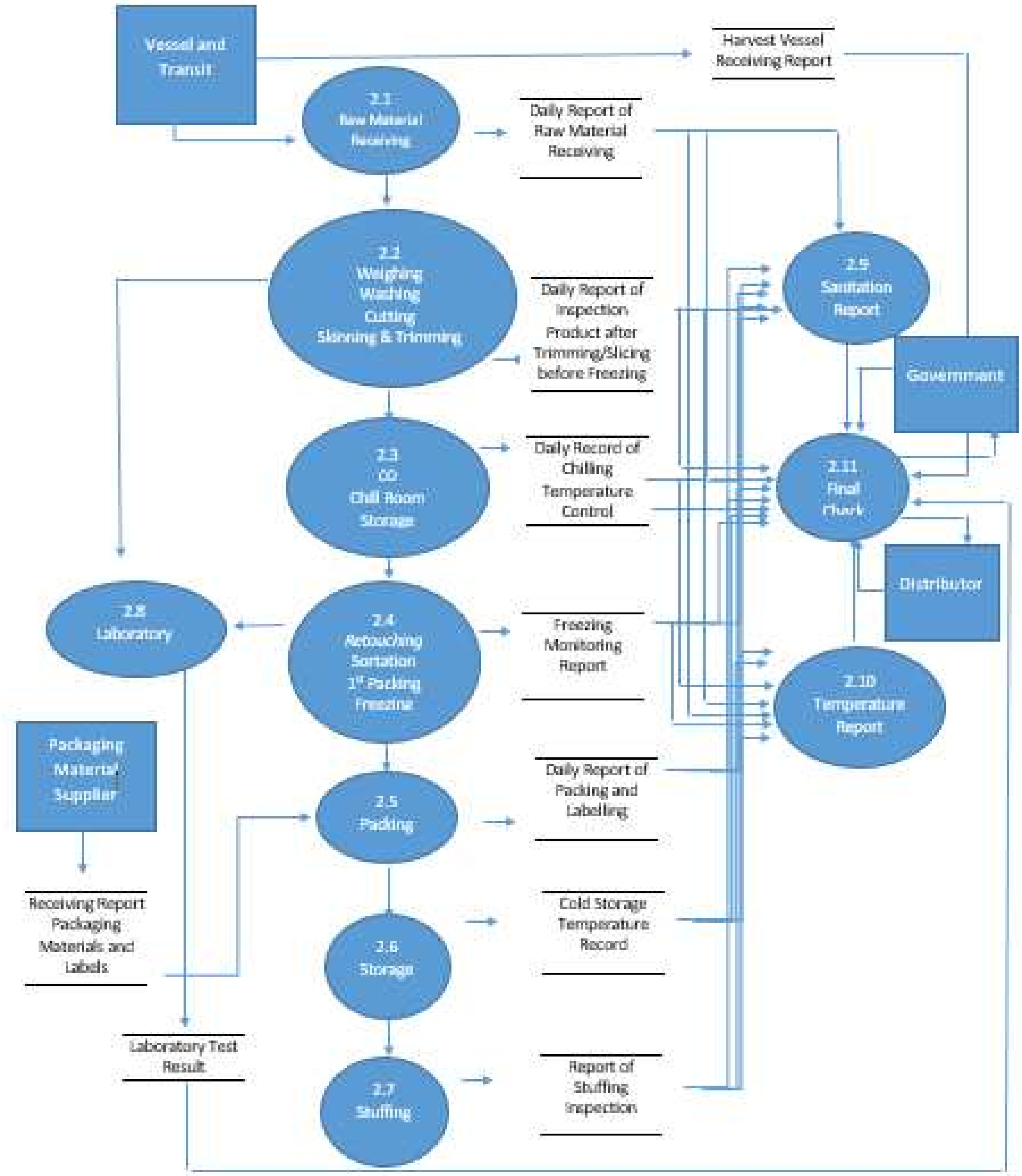


Figure 6. Diagram 2 Level 2 Processing Stage

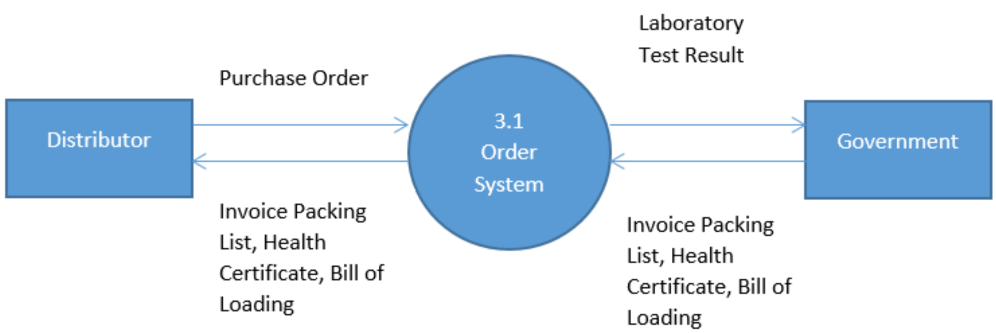


Figure 7. Diagram 3 Level 2 Transaction Stage

DFD Level 3 consists of two diagrams which is a decomposed of laboratory process (Diagram 2.8) and final check process (Diagram 2.11). Diagram 2.8 shows the decomposed of laboratory process which explains the steps in laboratory tests. The laboratory process made up by three tests, which is called histamine test, Total Plate Count (TPC) test, and pathogen bacterial test, namely *E.coli* and *Salmonella* test from raw material sample or ice and water sample. Diagram 2.11 shows the decomposed of final check process. It explains the final stage of tuna production in fish processing unit which is the coordination process with the government to get the certification to export the product. DFD Level 3 shows in figure 8 and 9.

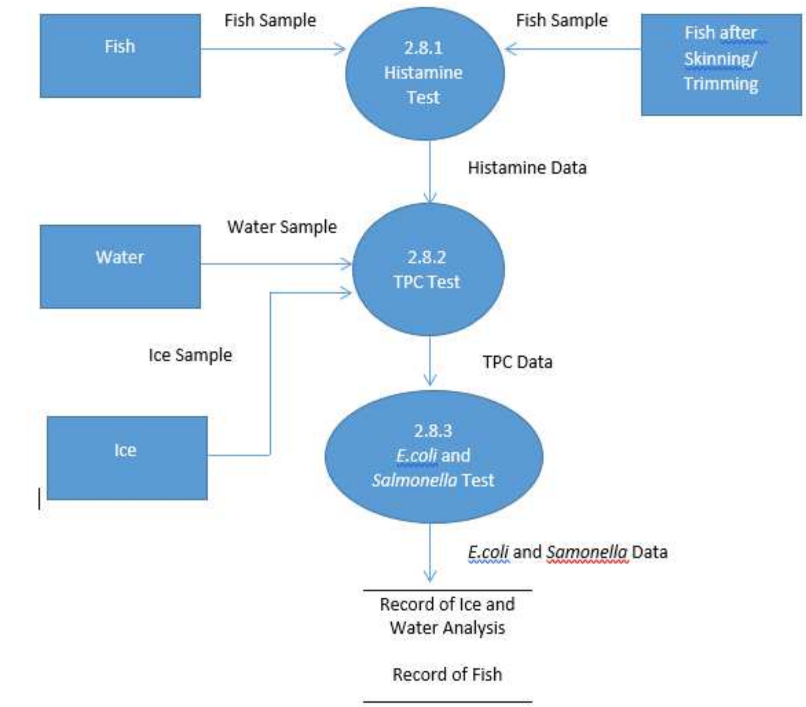


Figure 8. Diagram 2.8 Level 3 Laboratory Process

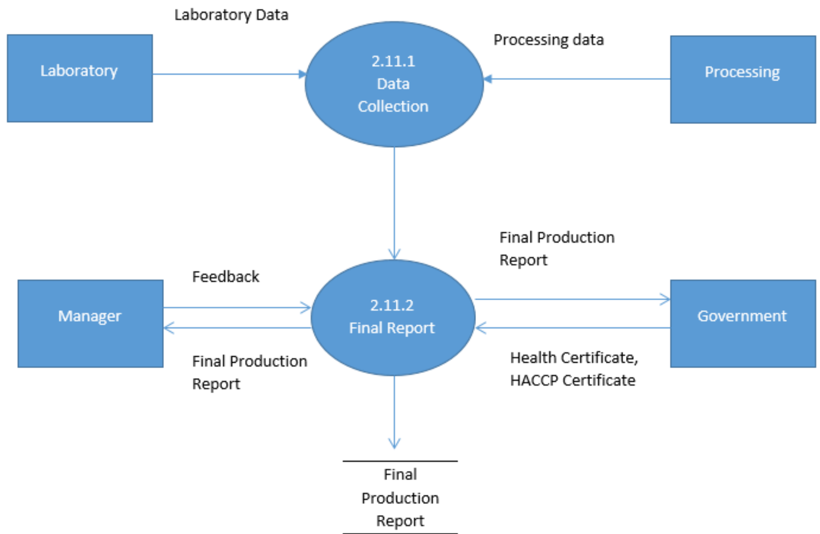
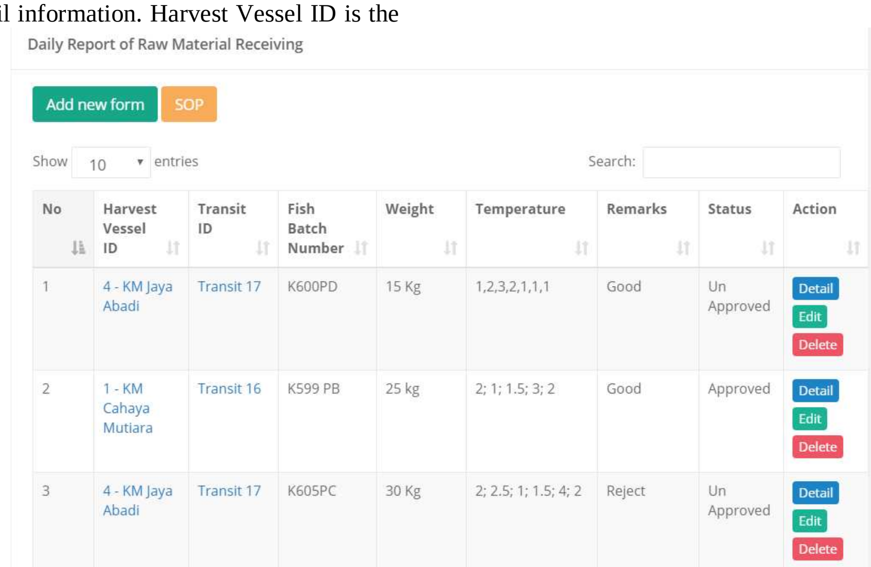


Figure 9. Diagram 2.11 Level 3 Final Check Process

4 Implementation Issues

The prototype system allows the actors to interconnect with the web platform model and real time data acquisition. Every actor can access and monitor the system but they required to be registered in the system. This system will be managed by administrator in fish processing unit and shows the documentation for every process in tuna supply chain, simultaneously fish condition since in the fishing vessel up to retailer. The documentation system will replace the paper based traceability form. The documentation system will have an integrated system and can link with the other page to describe the condition in every process properly. Two most critical part in processing stage will be showed as the examples. There are receiving raw material step and microbiological analysis step. Figure 10 shows the Daily Report of Raw Material Receiving. It is the report for daily raw material (tuna fish) received in fish processing unit. It consists of Harvest Vessel ID, Transit ID, Fish Batch Number, Weight, Temperature, and remarks. This page can link with to Harvest Vessel ID page and Transit ID page to get the detail information. Harvest Vessel ID is the ID of harvest vessel that catch the fish. It shows in figure 11. Transit ID is the ID of transit that unloading fish from vessel and checked the grade of tuna. It shows in figure 12. In addition, the system has the Standard Operating Procedure (SOP) as a guideline to receive the raw material. The SOP is based on the temperature and sensory analysis. It refers to Indonesia National Standard. The SOP page shows in figure 13. The system enable the user to access and manage the data easily and support to make quick and accurate decision. Figure 14 shows the microbiological analysis report. It is the report for result of microbiological analysis from raw material sample. It consists of ID raw material, date taken, date evaluated, TPC, *E.coli*, Salmonella, result, and status. Additionally, the microbiological analysis report has the SOP as a guideline of microbiological analysis result. It refers to Indonesia National Standard. The SOP page shows in figure 15.

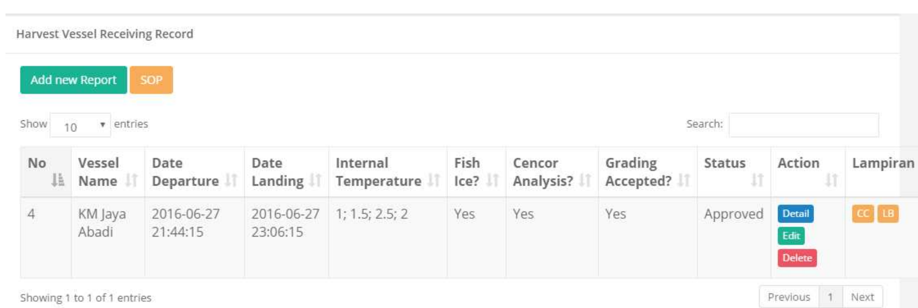

Daily Report of Raw Material Receiving

Add new form SOP

Show 10 entries Search:

No	Harvest Vessel ID	Transit ID	Fish Batch Number	Weight	Temperature	Remarks	Status	Action
1	4 - KM Jaya Abadi	Transit 17	K600PD	15 Kg	1,2,3,2,1,1,1	Good	Un Approved	Detail Edit Delete
2	1 - KM Cahaya Mutiara	Transit 16	K599 PB	25 kg	2; 1; 1.5; 3; 2	Good	Approved	Detail Edit Delete
3	4 - KM Jaya Abadi	Transit 17	K605PC	30 Kg	2; 2.5; 1; 1.5; 4; 2	Reject	Un Approved	Detail Edit Delete

Figure 10. Daily Report of Receiving Raw Material


Harvest Vessel Receiving Record

Add new Report SOP

Show 10 entries Search:

No	Vessel Name	Date Departure	Date Landing	Internal Temperature	Fish Ice?	Cencor Analysis?	Grading Accepted?	Status	Action	Lampiran
4	KM Jaya Abadi	2016-06-27 21:44:15	2016-06-27 23:06:15	1; 1.5; 2.5; 2	Yes	Yes	Yes	Approved	Detail Edit Delete	CC LB

Showing 1 to 1 of 1 entries Previous 1 Next

Figure 11. Harvest ID

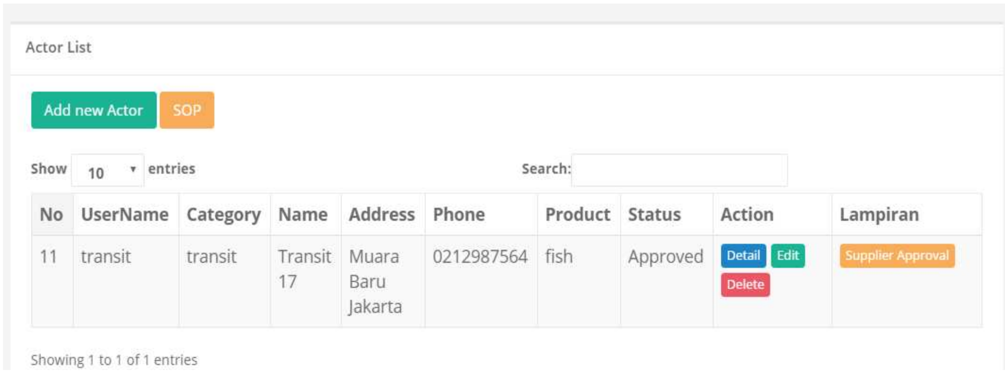


Figure 12. Transit ID

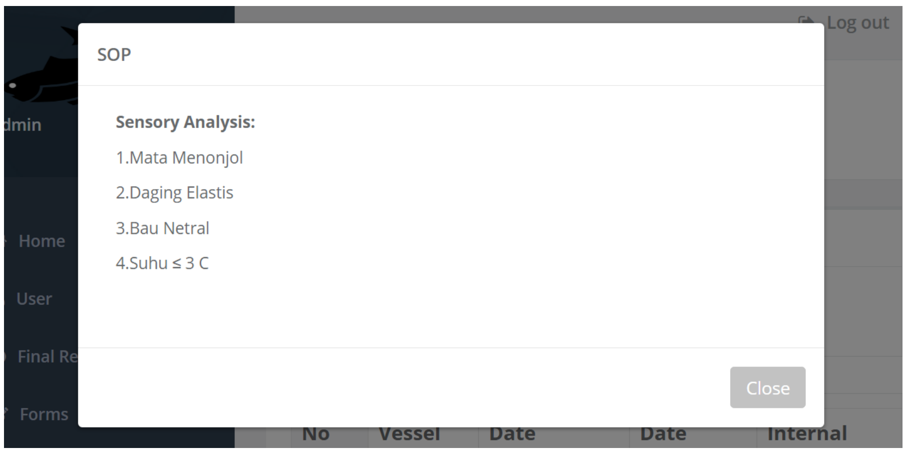


Figure 13. SOP for Raw Material Receiving

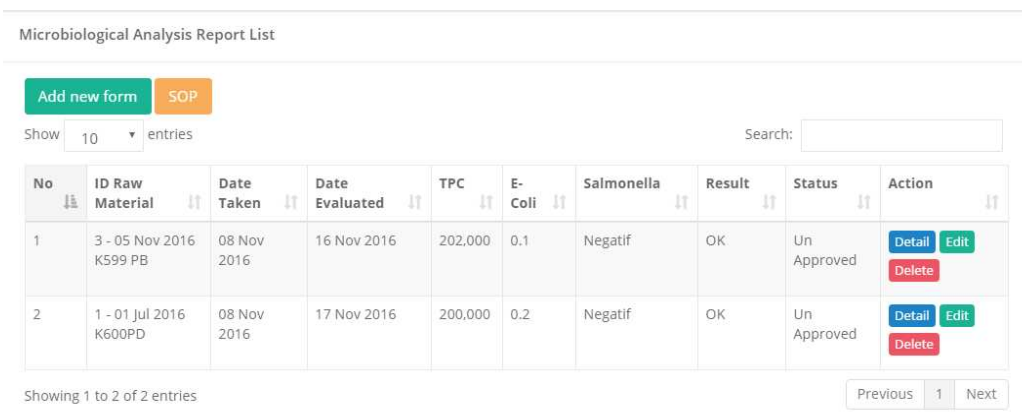


Figure 14. Microbiological Analysis Report

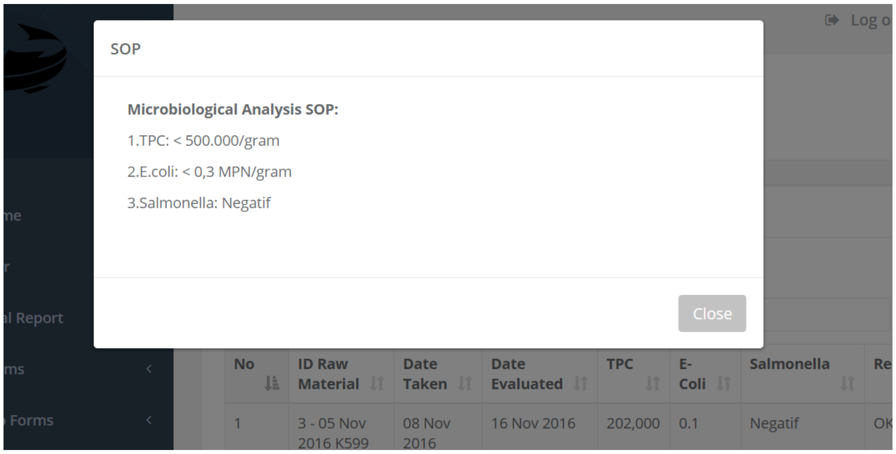


Figure 15. SOP for Microbiological Analysis Report

5 Conclusion

A traceability system architecture and prototype for tuna supply chains has been developed demonstrated for its functionalities to provide backward and forward tracing of tuna fish transformation and movement along the chain involving many actors (from fishing vessels to retailers). The system also permits the monitoring of processes and products based on microbiological analysis and on existing SOPs owned by some actors in a tuna supply chain. I has been shown that the ICT-based traceability system prototype allows all registered actors of the tuna supply chains to access pertinent information for monitoring and decision making purposes.

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