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Supply Chain Analysis and Design of An Android Based Robusta Coffee Traceability System

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Abstract

Robusta coffee is the most widely cultivated coffee commodity in Indonesia. In the East Bolaang Mongondow Regency, the problem at the supplier level is limited market information, which makes the coffee beans' quality inconsistent, impacting the price and product quality image. This research aims to identify supply chain structure models and members, added value, and design a traceability system to support product quality validation. Robusta coffee supply chain participants and their interactions were identified at the Modayag coffee plantation in East Bolaang Mongondow. The data were collected through observations, interviews, and field studies. Supply chain analysis was performed using the Vorst method and the added value was calculated using the Hayami method. The traceability system design follows the system development lifecycle method. The findings indicate that the Robusta coffee supply chain in East Bolaang Mongondow Regency includes farmers, collector traders, processing plants, the retail industry, coffee roasteries, and consumers. Farmers profit from selling perfectly ripe wet coffee beans 42-43%, wet mixed coffee beans (8%), and dry mixed coffee beans 63-71%. A traceability system named Kinton was successfully developed and integrated with the Firebase database to store all information.

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1. Introduction

Robusta coffee is one of the coffee varieties with strong disease resistance; therefore, it is the most widely cultivated in Indonesia, covering 79.4% of the total coffee plantation area (MOA 2022). North Sulawesi Province is an area in eastern Indonesia with topographic conditions that are ideal for the growth and development of coffee commodities. East Bolaang Mongondow Regency is currently still listed as a robusta coffee center in North Sulawesi Province. According to the data from the Agriculture Office (2022), East Bolaang Mongondow Regency has two sub-districts that have potential

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for the robusta coffee industry, Modayag and West Modayag, encompassing a total area of 2,047 hectares and yielding 453 tons in production.

Sales data from the East Bolaang Mongondow Regency Agriculture Office (2022) reveal significant price differences between farmers and other Robusta coffee supply chain members. This disparity results in a marketing margin of 81-85%, leaving farmers with a relatively low share at the supplier level. Sutrisno et al. (2015), found that the greater the marketing margin, the less efficient the marketing process. Price fluctuations are often a major issue for farmers, who, as the lowest tier in the supply chain, have the least influence over setting field prices. Supply chain management and traceability systems play important roles in overcoming these problems to support the sustainability of the Robusta coffee industry. According to Kot (2018), supply chain management plays a key role in providing good resource management, maximizing profitability, increasing competitiveness, and minimizing costs. A strong traceability system is needed in an industry whose driving force is the consumer, where the system can provide assurance of product authenticity as well as quality and safety levels (Razak et al., 2021).

In Indonesia, research related to supply chain analysis and traceability system design has been conducted separately (Septarianes 2020; Suyuthi 2023); however, there has not been much research combining these two aspects. This study aims to analyze the supply chain mechanism, which includes aspects of the supply chain model, added value, and design an Android-based Robusta coffee traceability system to facilitate stakeholders in accessing information about the product using an Android smartphone device.

2. Research Methods

2.1 Data Collection

Data were collected from August to November 2023 in Sumber Rejo Village, Purworejo Village, Liberia Village, Modayag Sub-district, and the East Bolaang Mongondow District. This study used two types of data: primary and secondary. Primary data was obtained through in-depth interviews with Robusta coffee supply chain members, surveys, and field documentation. These data include supply chain activities, postharvest handling, transaction prices, and information related to the traceability system needs. Interview respondents were selected using two sampling techniques. First, purposive sampling classified respondents based on farm size and domicile. Second, snowball sampling is used to trace the transaction channels in the supply chain. Meanwhile, secondary data were gathered from literature reviews, journals, and documents from relevant agencies, enhancing the validity of the primary data.

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2.2 Research Procedure

This research involves two stages. The first stage analyzes the mechanisms within the supply chain to identify conditions and relationships among its members. The second stage focuses on designing a traceability system, informed by an assessment of the system's requirements within the supply chain.

2.3 Robusta Coffee Supply Chain Analysis

Supply chain analysis was conducted using the Vorst method (Septarianes 2019), where the supply chain was analyzed based on four basic variables: network structure, business processes, resources and supply chain management. The analysis was conducted on 3 core members of the supply chain; farmers, collector traders, and processing plants through in-depth interviews and literature reviews using documents from relevant agencies.

2.4 Added Value Analysis of Robusta Coffee

Added value was calculated using the method described by Hayami et al. (1987), which includes the calculation of added value at each stage of the supply chain based on several variables such as production output, raw material input prices, labor productivity, and other input contributions, as presented in Table 1.

Table 1. Analysis of the Added Value of the Hayami Method.

No	Variable	Value
	Input, Output and Price	
1	Output or total production (Kg/day)	(1)
2	Raw material input (Kg/day)	(2)
3	Direct labor	(3)
4	Conversion factor	(4) = (1) / (2)
5	Direct labor coefficient (hour/kg)	(5) = (3) / (2)
6	Output price (IDR/kg)	(6)
7	Direct labor wage (IDR/hour)	(7)
	Revenue and profit	
8	Raw material input price (IDR/kg)	(8)
9	Price of other inputs (IDR/kg)	(9)
10	Product Value (Rp/Kg)	(10) = (4)*(6)
11	a. Value added	(11a) = (10)-(8)-(9)
	b. Added Value Ratio	(11b) = (11/10)*100
12	a. Direct labor income (IDR/kg)	(12a) = (5)*(7)
	b. Direct labor section (%)	(12b) = (12a/11a)*100
13	a. Profit (IDR/Kg)	(13a) = (11a)-(12a)
	b. Profit Level (%)	(13b) = (13a/10)*100

2.4 Development of Traceability System

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The development of the traceability system refers to Lastanto (2022), using the system development life cycle (SDLC) method and modified to suit the research needs (Figure 1). System development goes through several stages: investigating the needs of the system based on respondents, designing the traceability system, coding, and testing to ensure that the system runs according to its development objectives.

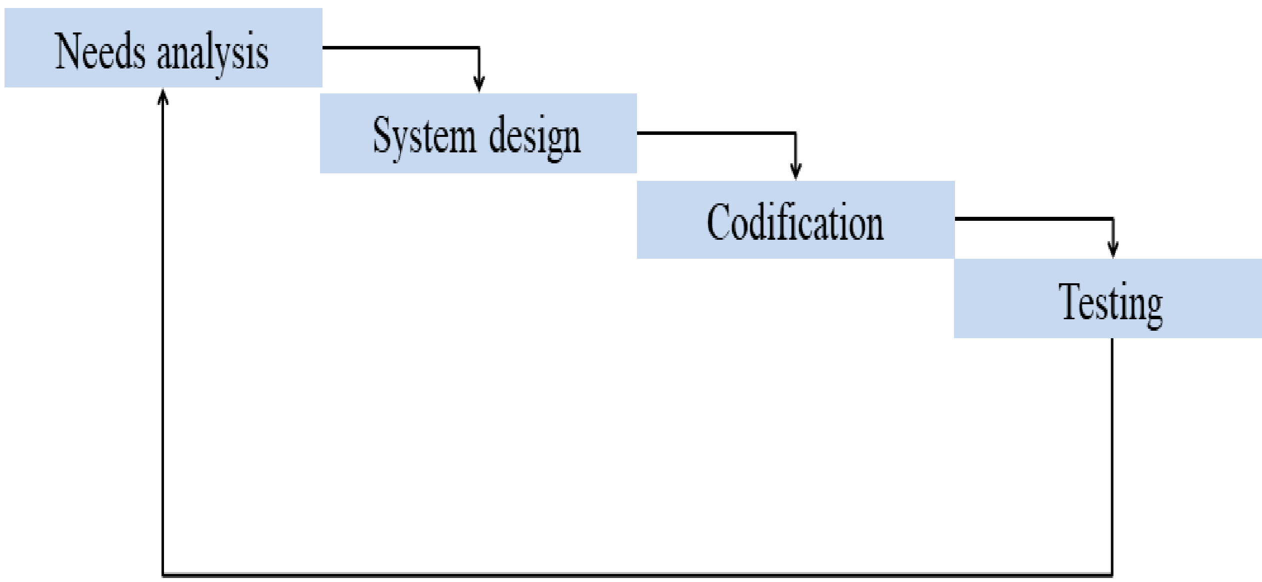

Figure 1. System Development Life Cycle Method (Modified from Susanto 2021).

3. Results and Discussion

3.1 Robusta Coffee Supply Chain Identification

The supply chain model was obtained through interviews with each member following a series of transactions in the field. The robusta coffee supply chain structure in East Bolaang Mongondow Regency consists of several actors, such as farmers and collector traders as raw material suppliers, processing place, coffee roasteries as a producer to process coffee beans, and the retail industry as a facilitator for individual consumers through the grinding and brewing process. Because of the limited processing equipment, collective traders only act as intermediaries between farmers and consumers outside the province. The robusta coffee supply chain model for the East Bolaang Mongondow Regency is shown in Figure 2.

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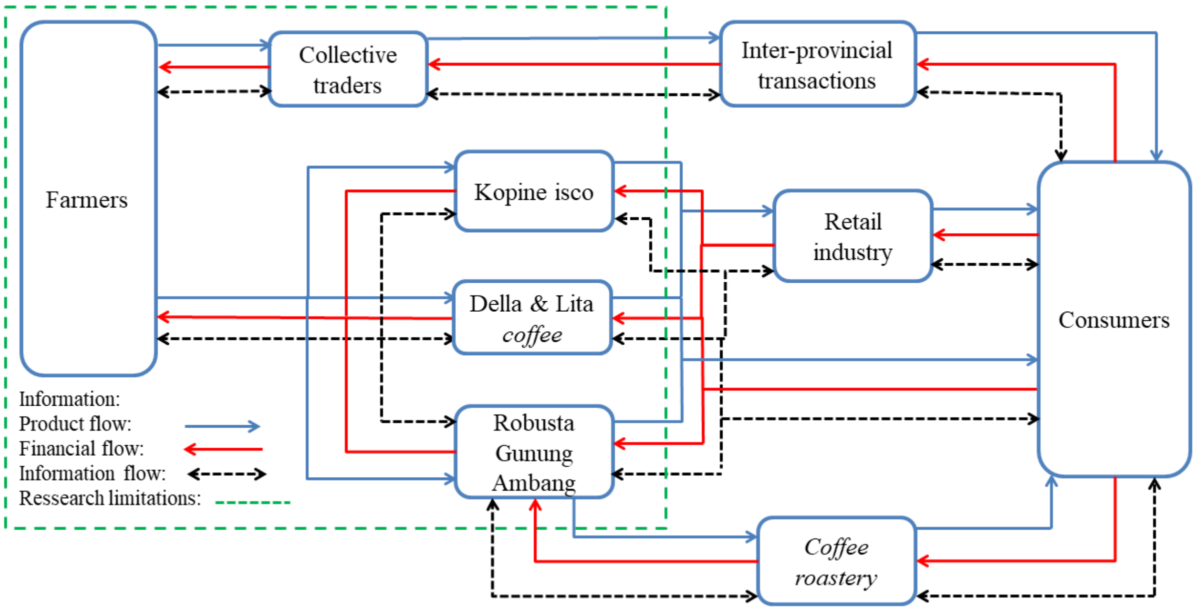

Figure 2. Robusta coffee supply chain model in East Bolaang Mongondow Regency.

Figure 2 shows several marketing patterns in the robusta coffee supply chain in Modayag Sub-district: 1) Farmer-processing place-consumer, 2) Farmer-collector trader-processing place-consumer, 3) Farmer-processing place-coffee roastery-consumer, and 4) Farmer-processing place-retail industry-consumer.

3.2 Robusta Coffee Supply Chain Business Process

The robusta coffee supply chain involves multiple stages of business processes, with specific criteria at each stage tailored to meet the needs of each supply chain member, as illustrated in Figure 3. Based on the field survey results, transactions between supply chain actors mostly involve coffee beans, with the first and third criteria. This is because of the economic considerations, time efficiency, and the existing traditions or habits of harvesting and processing the coffee beans.

The criteria for coffee beans with the best economic value in the robusta coffee supply chain in the East Bolaang Mongondow Regency are wet coffee beans with the second criteria while in dry form it is the fourth coffee bean criteria (Figure 3). The results of this study align with the research conducted by Septarianes (2019). Robusta coffee beans that are round, green/grassy in color, and have a high level of caffeine content are most in demand. This can only be obtained by processing coffee beans at the maximum harvest age.

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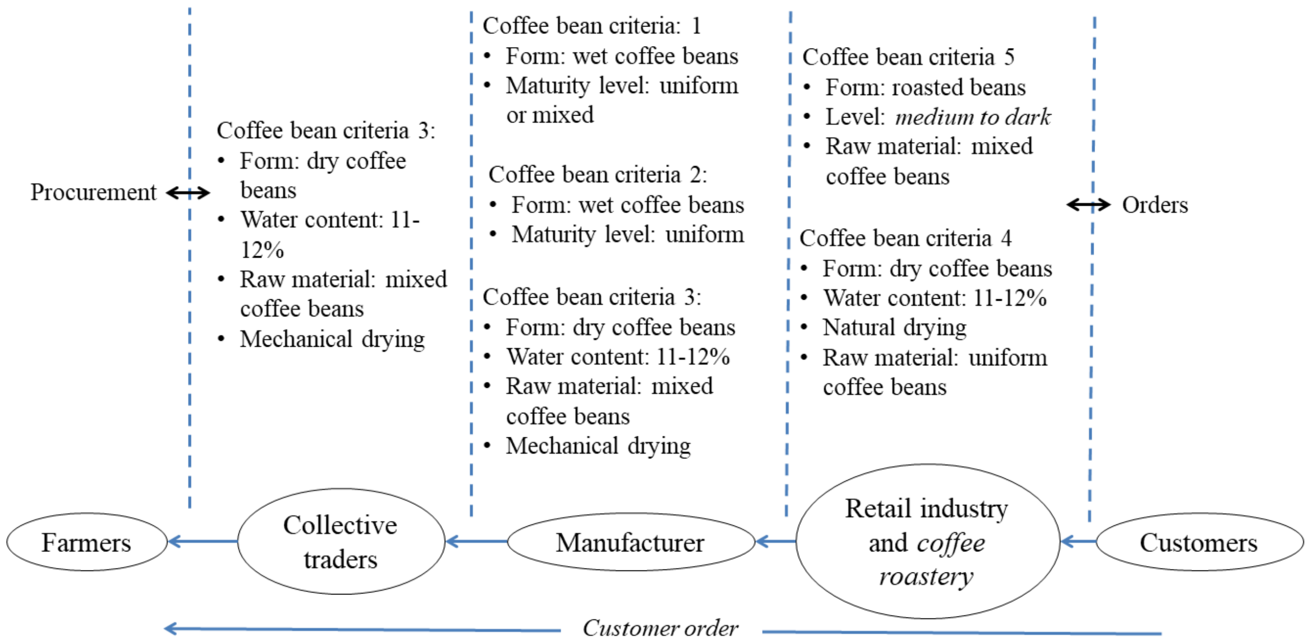

Figure 3. Criteria at the business process stage based on the needs of supply chain members.

Coffee farmers in Modayag District plantations generally use dry processing techniques. The process begins with harvesting. The local farmers harvest coffee beans with varying degrees of maturity, resulting in mixed beans. This habit was also found in Yulian's research (2019). This harvesting method was often carried out by farmers because it is quick and does not require a sorting process. The postharvest handling of robusta coffee commodities, adjusted based on production output, is shown in Table 2.

Table 2. Post Harvest Handling of Each Robusta Coffee Supply Chain Actor.

Actor	Output	Activity
Farmers	Red/mixed wet coffee and Greenbean	Harvesting, sorting, drying, dry coffee skin stripping
Collective traders	*Greenbean*	Storage and Packaging
Processing Place	*Greenbean, Roasted bean* and Coffee powder	Sorting, Drying, Pulping, Roasting, Milling and Packaging

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3.3 Resources and Supply Chain Management

The resources in the robusta coffee supply chain in East Bolaang Mongondow Regency include physical resources such as agricultural land, dry land, and storage warehouses. Human resources comprise workers/daily laborers, farmers, collector traders, and processing facility owners. The last technological resources consist of tools that support the harvest and post-harvest stages of robusta coffee commodities. The local government, through the 2024 Provincial Budget, provided assistance in the form of shoot-grafting of coffee seeds and fertilizers to support the expansion of coffee plants.

There has been no structured management for the implementation of supply chains so far. The selection of farmer work partners still based on the highest price offer or the distance between the partner's location and the farmer. Whereas for collective traders and processing place, it is still based on transaction experience. Contractual agreements between coffee farmers, collective traders, and processing places are formed only verbally/informally; therefore, they do not have strong attachments to the business process. This finding is consistent with the research conducted by Fajar (2014).

3.4 Added Value Analysis

The results of the added value calculation in Table 3 indicate that farmers obtain the smallest profit if they sell wet coffee beans with mixed maturity levels. The profit ratio obtained by farmers is 8%, whereas the profit ratio of coffee beans with uniform maturity levels averages 43-47%. This is in line with Anggrawati et al., 2022. Coffee beans with good economic value are those with a perfect level of maturity or have entered the maximum harvest age. Farmers will get more benefits from selling dried mixed coffee beans than wet beans, with an average profit of 63-71%. Mechanically dried coffee beans have a slightly higher price than sunny dried coffee beans.

Table 3. Farmers Added Value Based on Objective Criteria.

Criteria	Profit (%)			
	Collective Traders	Kopine Isco	Dela & Lita *Coffee*	Robusta Gunung Ambang
Wet coffee beans				
a. Red coffee beans			47.4	43.4
b. Mixed coffee beans				8.0
Dry mixed coffee beans				
a. Sun drying	63.2	67.3		
b. Mechanical drying	67.3	70.6		

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3.5 Robusta Coffee Traceability System Design

The system development life cycle (SDLC) method was used for software development. The development of the traceability system in this research was carried out in several stages as follows.

3.5.1 Traceability System Needs Analysis

Traceability system needs analysis is conducted through interviews with several potential users. These potential users have a better understanding of technological development. The results of the interviews can be used to develop the system that is expected to provide satisfaction to customers, ease the activation process, and the system could record the production and personal data.

3.5.2 Traceability System Design

The conceptual design of the traceability system refers to Lastanto (2022), which has been modified to suit the needs of the study. The conceptual framework of the system is illustrated in Figure 4.

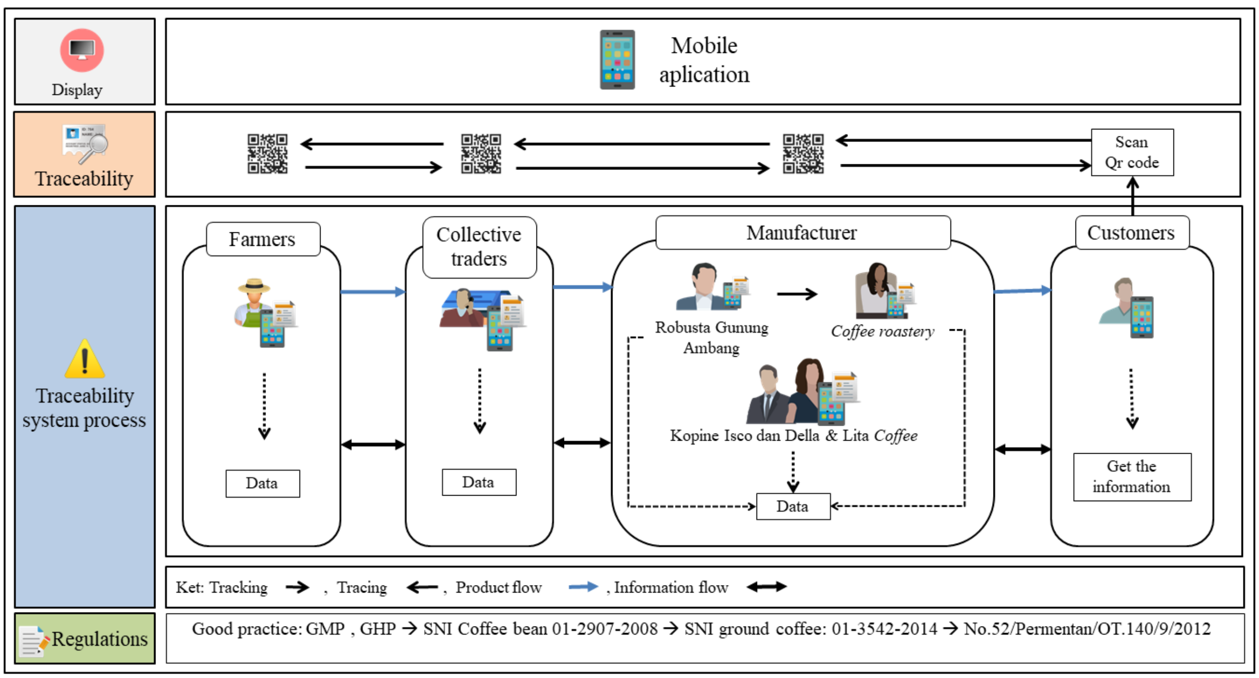

Figure 4. Conceptual framework of traceability system (Modified from Lastanto 2022).

The conceptual framework of the system consists of 4 layers, the first layer is the applicable rules or regulations, the second is the process that must be recorded by the traceability system, the third is the product search scheme based on the information stored in the QR code and the last is the system display adapted into a mobile application. The system is similar to a decentralized ledger, in which information is not controlled by a central entity. Data entered directly by each member in the traceability system can connect all of the actors that involved (Suyuthi, 2023).

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3.5.3 Functional Design of Traceability System

The Robusta coffee bean data in the traceability system were adjusted to the output of each actor (Table 4). The data included the cultivation process for technical processing of robusta coffee beans. The data stored in a unique QR code. This can makes consumers easier to access the information by scanning the QR code.

Table 4. Information in The Traceability System.

No	Actor/*user*	Output	Data
1	Farmers	Wet coffee beans and Greenbean	Farmer ID, Wet coffee ID, Greenbean ID, Farmer name, Coffee variety, Maturity level, Drying type, Moisture content, Fertilizer used, Harvest date, Plantation region, Processing type and Total weight
2	Collective traders	*Greenbean*	Collective trader ID, Greenbean ID, Collective trader name, Coffee variety, Maturity level, Drying type, Receipt date, What fertilizer, Total weight and Plantation area.
3	Processing Place	*Greenbean, Roasted bean* and ground coffee	Place Processing ID, Greenbean ID, Roasted bean ID, Ground Coffee ID, Owner's name, Coffee variety, Maturity level, Drying type, Received date, What fertilizer, Total weight, Plantation area, Product type, Roasting level, Temperature and Mill size.

The easy mobilization of traceability system information that can be accessed at any time makes the presence of third parties, such as certification board in charge of validating product quality, unnecessary. Based on the study by Seiferman et al. (2022), technology that applies the blockchain method can overcome weaknesses such as lack of trust, risk of manipulation, and eliminate the need for product certification service providers.

3.5.4 Structural Design of Traceability System

The system was built using firebase services as an information repository, referring to Lastanto (2021). Some firebase services used in the system include authentication, cloud firestores, and firebase storage. Firebase authentication verifies registered users, cloud firestores as a place to store profile and product information, whereas the firebase storage stores images. The main menu consists of four features: profile, management data, QR code menu, and about the application. The structural design of the traceability system is illustrated in Figure 5.

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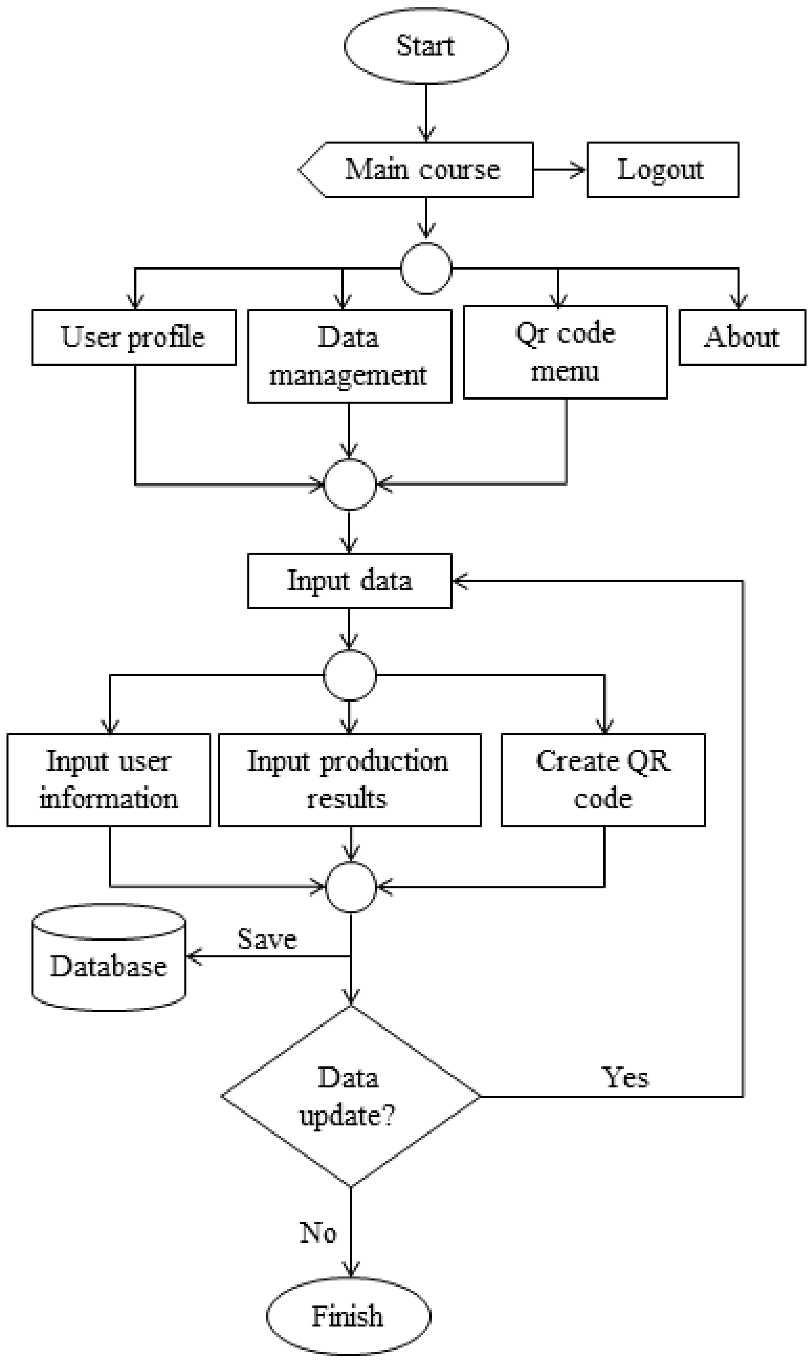

Figure 5. Structural design of traceability system (Modified from Amadea et. al 2024).

3.5.5 User Interface Design and Conding

The traceability system was successfully created using Android Studio software and named Kinton. The system coding process uses the xml programming language in managing the frontend

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system while for the backend using the java and kotlin programming languages. Kinton can be run on android smartphones that have a minimum operating system of 4.1 (kitkat). Kinton consists of 15 layouts to support the performance and display of the stored information. The user interface design of the traceability system is shown in Figure 6.

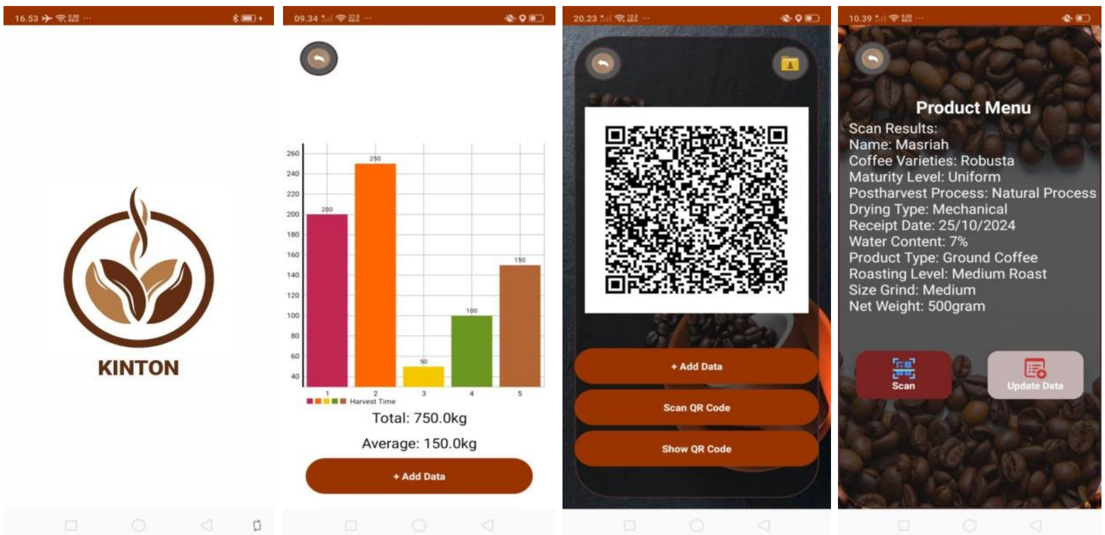

Figure 6. Splash Screen, Management Data, QR Code Menu and Scanning Results

3.5.6 Traceability System Testing

The system testing was conducted, including alpha and beta tests. Alpha testing was conducted to identify the triumph of the coding, whereas beta testing was conducted to evaluate the triumph of the system that comply the user needs. The test results showed positive results. The coding was success and could be implemented by the users. The system has some additional notes for further development from users, such as the addition of location features affiliated with Google Maps, which can attach locations.

4. Conclusion

The robusta coffee supply chain network structure in the East Bolaang Mongondow Regency consists of farmers, collective traders, processing places, the retail industry, coffee roastery, and individual consumers. The calculations of added value indicate that farmers could achieve greater benefits by selling wet coffee beans with a uniform maturity level of 43-47% and if they want to sell mixed coffee beans, they should be sold in dry form (green beans) with a profit ratio of 63-71%. The traceability system was successfully built and named Kinton, which is integrated with Firebase services as a database to store all user activities.

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The suggestion from this research is it is necessary to carry out socialization about the traceability system that has been successfully built for stakeholders, especially consumers. Coaching the supply chain stakeholders to provide transparent and accurate data so that the traceability system can produce accountable information.

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