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MORALITY BEFORE KNOWLEDGE

Optimization of agricultural supply chain through a crop distribution center for economic empowerment towards a smart city

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ABSTRACT
Background: The agricultural sector is vital to Indonesia's economy, yet farmer welfare remains low due to long, inefficient distribution chains that limit their income and create dependency on intermediaries. High poverty rates and a lack of formal protection plague farming households, preventing them from receiving fair economic value for their products. This study aims to design and develop a digital solution that positions farmers as key players in the agricultural supply chain, breaking their dependence on conventional systems. **Methods:** This research utilized a combined methodological approach, integrating Research and Development (R&D) to design the innovation and the Waterfall model for the structured development of the digital system. Data collection was performed using a mixed-methods approach, involving quantitative surveys to assess farmers' needs and qualitative interviews to understand supply chain challenges. **Findings:** The primary outcome is an integrated digital marketplace and physical crop distribution center. This system enables direct B2C (Business-to-Consumer) sales from farmers to consumers, with proceeds transferred immediately to their accounts. The application prototype was tested with target users, achieving a high success rate of 83.33% based on the System Usability Scale (SUS), which validates the design's effectiveness and intuitive user experience. **Conclusion:** The integrated platform represents a feasible solution to improve farmers' market access and agricultural distribution. The high usability score demonstrates its potential to support an inclusive and sustainable smart economy. **Novelty/Originality of this article:** The novelty of this research lies in its integrated ecosystem approach, which combines a physical distribution hub (for logistics, storage, and quality control) with a direct-to-consumer digital marketplace. This holistic model directly addresses both the logistical and market access barriers for farmers, offering a comprehensive solution that distinguishes it from existing platforms focused solely on digital transactions.

KEYWORDS: farmers; smart city; supply chain.

1. Introduction

Agriculture is the backbone of the economy in many developing countries, including Indonesia. As an agrarian nation, Indonesia relies on agriculture not only as a food provider, but also as a driver of economic growth and social resilience. In 2023, the total number of agricultural enterprises in Indonesia is reported to reach 29.36 million units, consisting of 29.34 million Individual Agricultural Enterprises (*Usaha Pertanian Perorangan*, UTP), 5.7 thousand Incorporated Agricultural Company (*Perusahaan Pertanian Berbadan Hukum*,

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UPB), and 12.96 thousand Other Agricultural Enterprises (*Badan Pusat Statistik* (BPS), 2023). Furthermore, a report from the Institute for Development of Economics and Finance (INDEF) highlights the strong performance of the agricultural sector in labor absorption. Based on data from Statistics Indonesia as of February 2025, the sector employs 28.54% of the national workforce. Additionally, Indonesia's Quarterly Gross Domestic Product (GDP) Report for the period 2020–2024 indicates that the Agriculture, Forestry, and Fisheries sector remains one of the largest contributors to GDP at 12.98% and experienced significant growth of 23.43% in the second quarter of 2024 (BPS, 2024).

However, other data reveal a misalignment between the strategic role of farmers in national food provision and their persistently unprosperous conditions. Statistics Indonesia reports that the average net income of farmers is around IDR 1.45 million per month, the lowest compared to other sectors, such as the industrial sector 27% higher and the service sector 50% higher. When compared to the national average provincial minimum wage (*Upah Minimum Provinsi*, UMP) which reached Rp 2.7 million, farmers' income only reached 50% of the minimum standard. Furthermore, it is recorded that more than 40% of poor households have farming as their primary occupation (BPS, 2023). From the table below, it can be seen that, of the total poor population in 2021, around 40.71% or 11.21 million people are members of agricultural households (*Rumah Tangga Pertanian*, RTP) and 14.73% or 4.06 million people are members of farm workers, then in 2022 it will decrease to 39.59% (RTP) and 13.31% (farm labor). However, in 2023, it is seen to increase slightly to 39.92% or 10.34 million people (RTP) and 13.93% or 3.6 million people (farm laborers) of the total poor population in Indonesia (BPS, 2023).

Table 1. Number and share of Indonesia's poor population from agricultural households, 2021–2023

No.	Description	2021	2022	2023	Growth (%)
1	Indonesian Population	271,584,775	274,204,096	276,786,794	0.95
2	Total Poor Population	27,542,772	26,161,298	25,898,546	-3.01
3	Total Members of Agricultural Households (RTP)	73,145,268	74,491,896	73,902,076	0.52
4	Total Poor Members of RTP	11,213,159	10,358,416	10,339,940	-3.9
5	Total Farm Laborers	24,852,248	24,289,788	24,555,624	-0.58
6	Total Poor Farm Laborers	4,058,078	3,480,943	3,608,240	-5.28
7	% of Indonesian Poor Population	10.14	9.54	9.36	-3.93
8	% of Poor RTP Members to Total Poor Population	40.71	39.59	39.92	-0.96
9	% of Poor RTP Members to Total RTP Members	15.33	13.91	13.99	-4.34
10	% of Poor Farm Laborers to Total Poor Population	14.73	13.31	13.93	-2.49
11	% of Poor Farm Laborers to Total Farm Laborers	16.33	14.33	14.69	-4.85

(BPS, 2023)

Statistics Indonesia reported that the Farmer Exchange Rate (*Nilai Tukar Petani*, NTP) in May 2025 was recorded at 121.15, above the minimum Farmer Exchange Rate, which is 100 (BPS, 2025). It does not necessarily reflect the welfare of farmers as a whole. Farmer Exchange Rate is a proxy indicator that measures the ratio of the price index received by farmers from selling their agricultural products to the price index paid by farmers for household consumption and agricultural production costs. While Farmer Exchange Rate indicates the economic ability of farmers to cover production and consumption costs, holistic welfare must be seen from other indicators such as access to education, health, and quality of life (Siregar, 2004). The narrow scale of business makes it difficult for farmers to achieve economic efficiency, especially in the face of volatility in fertilizer and seed prices, as well as climate uncertainty. Meanwhile, food industrialization tends to place farmers as price takers instead of price makers (Gilbert et al., 2024). This situation reflects the disparity between the vital role of farmers and the protection they receive.

Apart from land ownership, land size, and pressures from climate change, one of the most influential factors is the long distribution chain, which results in low farmer incomes compared to market selling prices and ultimately traps farmers in dependency on middlemen (Dedi, 2024). Based on data analysis from 61 countries covering 90% of the global economy, farmers receive only an average of 27% of consumer expenditure, while the remaining 73% is absorbed by post-harvest value chains (Yi et al., 2021). In general, this dependency is very prevalent among smallholder farmers who lack broad market access and sufficient capital. Farmers tend to borrow capital from middlemen because the process is easier and faster. Typically, such loans come with an agreement that farmers must sell their harvest to the middleman at prices lower than the market rate (Dedi, 2024). This paradox indicates that the fundamental problems lie not only in income levels but also in market structure, supply chain efficiency, and access to modern economic systems.

The existing gap in the current literature is the lack of an integrated solution model that simultaneously addresses financing, post-harvest handling, and market access. Most research remains fragmented, discussing marketing digitalization separately from logistics optimization or capital solutions (Terera et al., 2025). Yet, data show that inefficiencies in post-harvest and distribution stages cause enormous economic losses. Globally, about one-third of total food production is lost or wasted. In Indonesia, the economic losses due to food loss and waste (FLW) are estimated to reach IDR 213 to 551 trillion per year, equivalent to 4-5% of national GDP (Food and Agriculture Organization (FAO) & BPS, 2025), while other studies even report losses reaching IDR 484 trillion. The highest FLW occurs in strategic commodities such as cereals (especially rice) and horticulture, with production and processing/packaging stages each contributing 28% of total losses (Taufiqi et al., 2025).

Research in West Kalimantan reinforces these findings, estimating food losses in rice commodities at approximately 101,579.7 tons per year, equivalent to an economic loss of around IDR 1,010,717.88 billion annually. Losses occur at every stage of the supply chain: harvesting (9.52% yield decline), threshing (1.90%), drying (2.89%), milling (2.19%), and distribution (1.61%). The greatest losses occur during harvesting, largely due to inadequate harvesting technology and poor post-harvest practices. At the distribution stage, losses arise from rice spillage, damage during transport, and improper handling and storage (Ningsih et al., 2024). This case demonstrates that the suboptimal agricultural logistics system is a major cause of farmers' suboptimal income.

A logistics system capable of enhancing industrial competitiveness depends on four interrelated pillars: infrastructure, institutional framework, services, and logistics actors (Banomyong et al., 2008). Within the agricultural context, these factors must work synergistically to achieve cost efficiency, service reliability, and supply chain responsiveness. In the modern context, these four factors must be supported by technological advances, most notably the digitalization of all stages of the agricultural supply chain, including logistics systems and distribution chains. Digitalization plays a crucial role in enhancing supply chain efficiency, improving the quality of agricultural outputs, accelerating information exchange, and strengthening coordination among supply chain stakeholders, including farmers, distributors, and final consumers (Keefe et al., 2024).

While agricultural digitalization has progressed through platforms such as TaniHub (Suhermanto et al., 2021), a notable deficiency persists within the current ecosystem. The leading platforms have strategically redirected their efforts mainly towards Business-to-Business (B2B) transactions and peer-to-peer lending services, which often emphasize large distribution networks and financial accessibility. As a result, smallholder farmers frequently find themselves without a direct retail avenue to consumers (B2C). Moreover, these platforms predominantly function as digital aggregators yet fail to incorporate essential physical infrastructure that could help reduce post-harvest losses at the source. Consequently, there is an absence of solutions that merge a consumer-targeted marketplace with on-site facilities for quality control and cold chain logistics, ultimately hindering farmers from becoming independent price-setters. ultimately hindering farmers from becoming independent price-setters. Comparable platforms in other developing countries face a similar limitation, connecting farmers directly to buyers without integrated physical distribution infrastructure (Gomathy & Boopathi Kumar, 2025), a gap also reported among e-commerce platforms serving smallholder farmers in other developing regions (Morepje et al., 2024).

Based on this identified gap, an innovation is needed that not only shortens the distribution chain but also builds an integrated ecosystem to empower farmers as primary actors. This research aims to fill this void by proposing a smart economy platform named TANImart. This platform is designed to resolve the issue of unequal market structure through a digital marketplace model connected to distribution centers, while equipping farmers with digital economic instruments. Unlike conventional approaches, TANImart integrates supply chain shortening with logistics optimization and digital financial inclusion within a coherent system. Therefore, an innovation that integrates all aspects of the agricultural supply chain in Indonesia is urgently needed, and this system must position farmers as the main actors within the chain.

2. Methods

2.1 Research design

The mixed approach has been applied through the use of Research and Development (R&D) methods and the Waterfall model. The rationale for the use of the R&D method was mainly because the focus of the research was to design, develop, and test a new digital system. In Sugiyono (2017), the development model is appropriate to be used to produce a product while at the same time testing the effectiveness of the product being produced. Thus, this model produces not just a product design but also a prototype of the product used in the field. The research and development (R&D) design of the study used five main stages. These five stages include the first stage, the analysis stage, to identify the needs and issues of the farmers and marketplaces by conducting surveys, literature studies, and field observations of agricultural players. The second stage is design, which involves creating flowcharts, user interface prototypes, and system features that cater to farmers and marketplaces. The third is development, which involves creating a working prototype of the TANImart system, with iterative improvement and limited pilots leading to on-field implementation. Fourth is the product implementation stage. This is when the design is tested with end-users on a limited scale in a test environment to investigate the system in a real-world setting. The fifth and final stage is the evaluation stage, which tests the system's usefulness, usability, advantages and disadvantages as a basis for further improvement and validation.

2.2 System development

The development stage followed the Waterfall model. Pressman (2015) describes the Waterfall model as a classic, sequential software development model in which each phase must be fully completed before the next phase is initiated. In addition, this model was selected because it provides a systematic way to ensure that the quality of the system is checked through each of its phases. The Waterfall model phases of the system requirements analysis, architecture design, implementation (coding), testing, and final system deployment were strictly adhered to at each stage of system construction.

The R&D model embedded in Waterfall design model acts as a good foundation for the rest of the process. The R&D model allows a product to be developed based on a firsthand knowledge of user needs. The Waterfall design model allows the software development process to be systematic and managed. Through this methodological symbiosis, the theory and practice of the design process was maintained at every stage - through problem definition to prototype review - close to user needs and evidence. The R&D component to the design process informed system requirements and priorities iteratively in terms of relevance and utility to the agricultural sector. The Waterfall component ensured traceability and documentation throughout the development of the system.

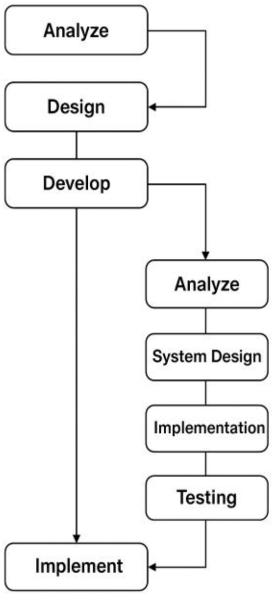

Fig.1. Flowchart R&D combined with waterfall model

This combination of methods was required to ensure the reliability and efficiency of the research. The R&D process provided a structured way to address a need and to continue iterating the product with the specific customer group. The iterative quality checking process meant that any issues with functionality or usability could easily be fixed at an early stage, resulting in both technical and contextual correctness of the end product. Checks also ensured that the design and user requirements were being met after each phase of the Waterfall process. The Waterfall model, on the other hand, allowed for a predictable, risk-averse software development process that resulted in a more reliable and strong digital working system. The systematic nature of the development process along with its transparency and repeatability, made it easier for the project to serve as an example of two pillars of high-quality empirical research.

Thus, the whole process can give a valuable contribution to the body of knowledge of the software engineering and innovation fields, not just in terms of the technical rigor that has gone into the process but also in terms of delivering a product with social value. It exemplifies how the research and development chain can be used to deliver innovative solutions for smart city transformation, with a specific focus on the agricultural ecosystem in Indonesia.

2.3 Data collection and usability testing

The primary data collection methods for the study were a farmer survey and farmer interviews, which were conducted using a mixed-method approach. The quantitative data were collected from the farmer survey to identify the economic status of farmers and the technology they required. In-depth interviews and observations of the agricultural supply chain were used to collect qualitative data to understand the issues and opportunities in the sector. This dual approach provided data to help both the design and evaluation of the prototype, and to get a more complete view of the problem, and the effectiveness of the proposed solution.

The usability test was conducted by convenience sampling (Etikan et al., 2016) by taking 7 participants who were selected from the Informatics Engineering and Agriculture departments, who were judged to have sufficient computer literacy skills and knowledge of agricultural supply chains. This small group of non-representative users constitutes a proof of concept to enable us to test the main functionality of the prototype and the general user flow of the application before it is used by a larger and more heterogeneous population of farmers. Feedback from this 'native user' group is important as it helps to identify the major usability issues.

3. Results and Discussion

3.1 SWOT analysis

TANImart represents a digital breakthrough in the agricultural sector that is developed to address long-standing challenges within the agricultural supply chain. By using SWOT analysis (Benzaghta et al., 2021), the project's internal strengths and weaknesses, along with external opportunities and threats that may affect its performance and sustainability, can be identified. The results of this analysis then serve as a strategic reference in formulating development plans that are adaptive to market changes and the socio-economic context of Indonesian farmers.

3.1.1 Strength

One of the main strengths of TANImart lies in its ability to break long and inefficient supply chains in traditional agricultural systems. So far, farmers have often been the party that has benefited the least because there are too many intermediaries between producers and consumers. Through TANImart, farmers can sell their crops directly to end consumers and business actors, so that the profit margins they get become larger. In addition, TANImart builds an integrated digital ecosystem that connects various elements in the agricultural sector, ranging from the production process, distribution, to consumption. This integration is realized through two main components, namely the digital marketplace and the Distribution Hub. The synergy between the two allows the logistics process to run more efficiently, reduces distribution costs, and improves the quality and timeliness of delivery of agricultural products, consistent with prior supply chain management models developed to strengthen food distribution and security in staple-crop production (Kurniawati et al., 2020).

From a social perspective, TANImart has a strong empowerment value. The platform not only focuses on the commercial aspect, but also encourages the transformation of farmers from "price taker" positions to "price makers." Farmers have greater control over the selling price of their products, as well as gain more transparent access to market data. With a technology-based and empowerment-based approach, TANImart has the potential to increase the digital literacy, bargaining power, and independence of Indonesian farmers (Zhang et al., 2025).

3.1.2 Weakness

On the other hand, TANImart still faces some weaknesses that need to be anticipated from the beginning. One of them is the challenge of technology adaptation by farmers. Not all farmers have an adequate level of digital literacy to operate online-based applications. Many farmers in rural areas are also still constrained by limited internet access and inadequate digital devices, so the adoption of digital systems can be slow. Furthermore, TANImart's business model still needs to be validated on a broader operational scale. Despite its strong potential, practical implementation still requires ongoing testing to reveal possible obstacles in logistics, data processing, and payment operations. In addition, the project faces a key weakness in the form of high initial investment costs. The development of infrastructure such as Distribution Hubs, storage warehouses, cooling systems, to software development and data security requires large costs. Without strong and sustainable funding support, TANImart's expansion could be hampered.

3.1.3 Opportunity

The agricultural sector is the backbone of Indonesia's economy, with a large contribution to the Gross Domestic Product (GDP) and wide labor absorption. However, the welfare of farmers is still a fundamental issue due to the low exchange rate of farmers and limited access to modern markets. These conditions provide a favorable context in which TANImart can expand its potential and relevance. By digitizing distribution and marketing processes, TANImart has the potential to enhance farmers' income, broaden market reach, and lower distribution expenses. As public awareness of local products and sustainable farming increases, TANImart can strengthen its role as a platform that supports an inclusive and eco-friendly economy, in line with sustainability indicators increasingly used to evaluate staple-crop supply chains (Chandan & John, 2025). In addition, the government's support for the digital transformation of the agricultural sector and smart city development policies opens up space for strategic collaboration between TANImart and public, private, and financial institutions. As awareness of local products and sustainable farming continues to rise, TANImart has the potential to further reinforce its position as a platform that promotes an inclusive and environmentally friendly economy.

3.1.4 Threat

However, the success of TANImart cannot be separated from a number of external threats that have the potential to disrupt its operational stability. One of the main threats is the high risk of food loss due to suboptimal post-harvest handling, inadequate storage, or late distribution. If these issues are not anticipated appropriately, they may lead to reduced operational efficiency and a decline in consumer trust. In addition, fluctuations in the price of agricultural inputs such as fertilizers, seeds, and fuel can affect the selling price of products in the market, thus impacting TANImart's competitiveness. Extreme climate change also adds uncertainty to crop yields and product quality. On the other hand, competition with other agritech platforms that offer similar business models can be a threat in itself. If TANImart does not have a strong differentiation strategy for example in terms of service, price, or quality of technology then its attractiveness in the eyes of farmers and consumers can decrease.

3.2 Proposed infrastructure: Smart distribution hub

The TANImart Distribution Hub is more than just a way for farmers to connect to the market. It serves as the central pillars that ensure the agribusiness ecosystem is fair and honest. As a solution we think this building should be turned into a "Smart Hub" that is fully connected. We make sure that the whole supply chain, from the first upstream collection to the last downstream dispatch, always has accurate data, fast operations, and strict quality control by putting Internet of Things (IoT) protocols directly into the infrastructure.

Fig. 2. Distribution Hub

3.2.1 Information kiosk

In the business world, we need an administrative control center that regulates our business so that it runs smoothly. The information kiosk is not just an administrative desk. It is the main command center for the building. It is the operational core because it uses a Warehouse Management System (WMS) to turn all the flows of goods into digital data. A Barcode or Radio-Frequency Identification (RFID) sticker gives each crate from farmers a unique ID right away. This WMS implementation ensures that the entire supply chain is transparent and easily tracked (Rahman & Hasan, 2025). When staff members scan these tags as they come in, the computer automatically saves important information like the farmer's name, the type of commodity, the starting weight, and the exact time of reception.

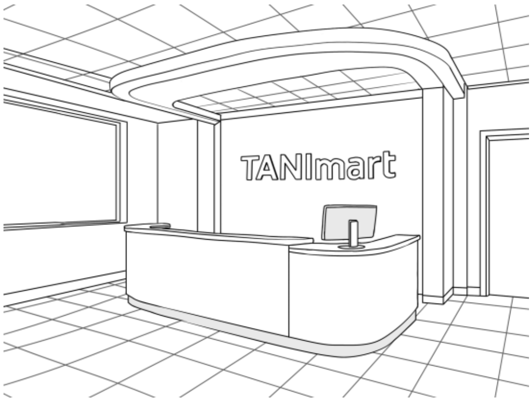

Fig. 3. Information kiosk

The WMS can also predict what will happen next in a purchasing flow, which makes logistics work better. It optimizes storage allocation to accelerate the loading process. A real-time Analytical Dashboard also shows all the levels of stock, the patterns of sales, and the risks of items going bad. This information lets workers use a First-In, First-Out (FIFO) strategy, which makes sure that food is given out before it goes bad (Sembiring et al., 2019). This makes the supply chain very clear and reliable.

3.2.2 Transaction kiosk

The transaction kiosk is a digital terminal that you can use on your own. It has a touchscreen that lets you interact with it. Farmers who sign up get a Digital Identity Card with either QR Code or Near Field Communication (NFC) technology built in. This makes sure they can get in safely. By scanning this card, users can log into their own dashboards and keep an eye on crucial supply chain KPIs like stock levels and real-time sales data.

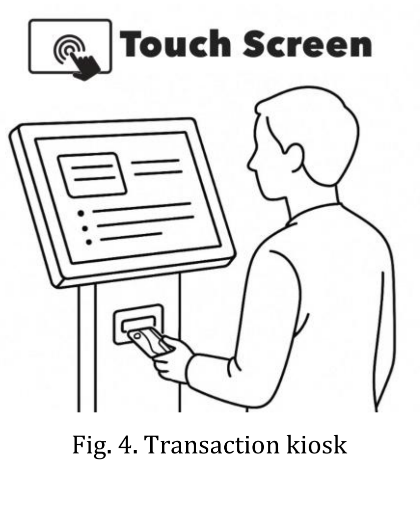

Fig. 4. Transaction kiosk

Other than that, the transaction kiosk also encourages openness by getting and displaying up-to-date market price information from central databases. A digital payment system that works with QRIS (a QR code-based digital payment system) can help people become more financially independent. Farmers can now take their money straight to their bank accounts or e-wallets, so they don't have to rely on middlemen who only deal in cash. So, this method not only lets farmers fully control their income, but it also leaves a digital trail of their money that can be checked to make it easier for them to get formal banking services in the future.

3.2.3 Hygienic Control Module

We're changing the Hygienic Control Module from a place where people test things by hand to a piece of quality control equipment that works on its own. The main goal is to make sure that all incoming produce meets strict standards. This will help the company stay competitive in high-end markets. Initially, the system employs non-destructive IoT sensors to assess internal quality parameters, including ripeness, moisture content, and sugar levels, without damaging the produce, consistent with the growing use of IoT-based sensing for smart precision agriculture (Ahmed et al., 2018). Subsequently, the commodities undergo visual inspection via a Smart Grading Machine equipped with high-resolution computer vision. This technology autonomously categorizes items based on size, shape, color, and surface defects, achieving a level of speed and objectivity that far surpasses manual human inspection.

Each product gets a digital passport that keeps track of all of its quality history after passing this hard test, ensuring transparency and traceability in the supply chain (Azis et al., 2026). This approach mirrors blockchain-based architectures that support real-time, verifiable traceability across supply chain tiers (Helo & Shamsuzzoha, 2020; Gonçalves et al., 2025). This automation makes sure that the customer only gets goods that are of high quality and are always the same. Farmers can easily enter modern markets like hotels, restaurants, and supermarkets that need the same quality by offering products that meet those standards. In the end, this use of technology makes agricultural goods worth a lot more on the market and makes TANImart look like a reliable provider.

3.2.4 Storage warehouse

We are making the storage warehouse into a smart facility with controlled cold chain technology so that things don't go bad. The main goal is to keep farm goods fresh and make them last a lot longer in the store, which is a critical standard for modern food cold chain logistics (Mustafa et al., 2024), as consistent time-temperature control is widely recognized as the main determinant of quality retention along the cold chain (Mercier et al., 2017). We put temperature and humidity sensors that use the Internet of Things (IoT) in all of the Cold Storage Rooms to do this (Elegbeleye et al., 2025). They work all day and night to make sure everything is just right. The temperature in these rooms is set based on what the goods inside need. For instance, horticultural products must stay between 0 °C and 10 °C.

This system is different because it takes action before something happens. It doesn't just sit there and watch, but also sends an alarm to the manager's phone right away if it sees something strange, like a door being left open and the temperature going up. You can use this tool to stop quality from getting worse right now. Because of this, vegetables can last for two to three weeks instead of just a few days. This longer life not only cuts down on losses, but it also helps with exports and getting things to people in other countries. It also gives you a new way to make money by renting out storage space to other businesses.

3.3 Implemented prototype: TANImart marketplace

The TANImart marketplace platform is the main digital part of this new idea. It connects farmers and consumers directly. The platform's design has gone through a number of modeling and testing stages to make sure that it works, is effective, and is easy for everyone to use.

3.3.1 Flowchart

The flowchart delineates the sequential steps and core processes within the TANImart mobile application, mapping the user journey from initiation to transaction completion. During the preliminary design phase, this diagram functions as a vital communication bridge between the development team and key stakeholders. It ensures that the application's logic strictly aligns with the intended functional requirements. Each node representing specific actions such as login, product selction, or order finalization serves to identify potential inefficiencies or logical errors prior to system deployment.

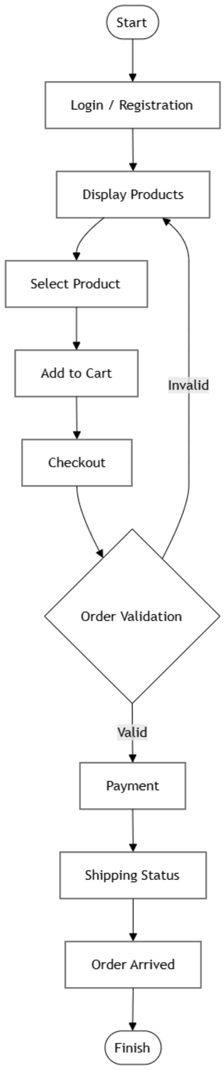

Fig. 5. Flowchart

3.3.2 Usecase diagram

The Use Case Diagram shows all the functional interactions that the main actors in the TANImart system have with each other. This diagram is meant to help you understand how each user interacts with the system and what features they can use. There are three main roles: User (the person who buys something), Farmer, and Admin. The diagram shows the system's limits and range by showing a series of use cases or functions, like "Place Order" for the User, "Manage Products" for the Farmer, and "Verify Order" for the Admin. This modeling is very important during the requirements analysis phase because it makes sure that the development team correctly identifies and understands all of the functional requirements for each user role.

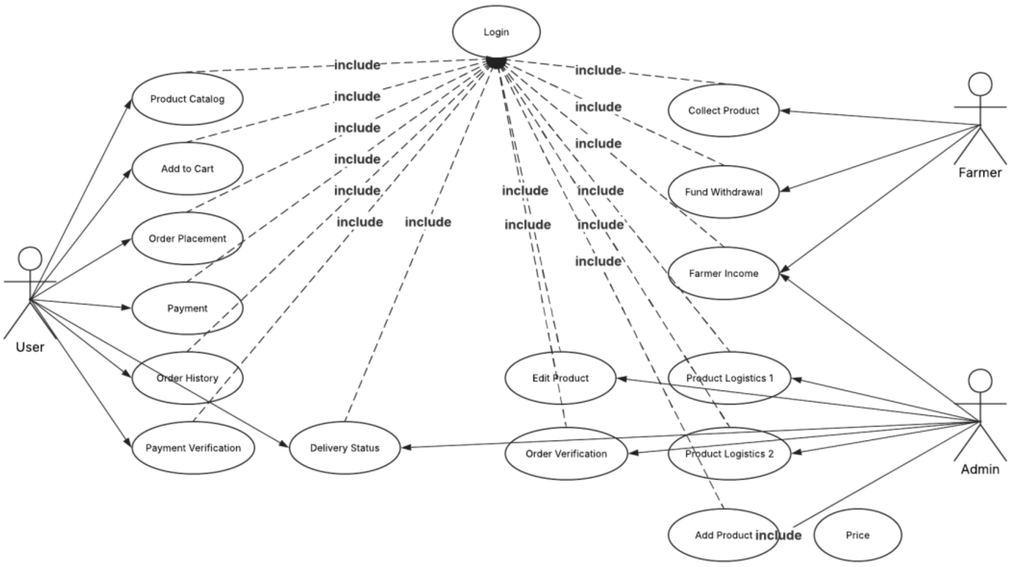

Fig. 6. Usecase diagram

3.3.3 Activity diagram

The activity diagram shows in detail the order in which tasks are done in a business process. An activity diagram can show more complicated flows than a flowchart, which usually show linear flows. For example, it can show parallel paths and branches with different actors or system components. The TANImart diagram shows the ordering workflow with several swimlanes that show what each actor is responsible for. For example, the User, System, Admin, and Farmer. The diagram shows that an activity starts when the user logs in, the system checks the information, and the Admin checks the payment. This starts the shipping process by the Farmer. This picture is very helpful for figuring out how different parts of the system work together to get a job done and for finding possible delays or bottlenecks.

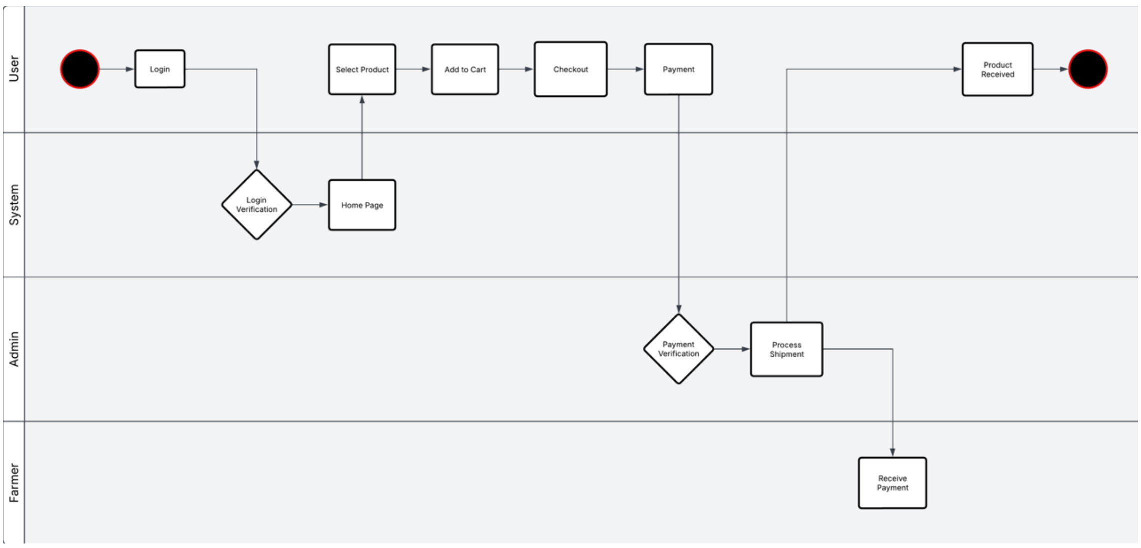

Fig. 7. Activity diagram

3.3.4 UI/UX Prototype

Designed as a visual and interactive simulation of the UI/UX framework, the prototype incorporates essential modules such as the splash screen, product listings, and item detail views. This early validation stage is critical for testing interaction flows with actual users before committing to substantial software engineering costs. Consequently, obtaining immediate feedback reduces the risk of structural design flaws and allows for agile adjustments, ultimately guaranteeing a final solution that effectively meets user needs.

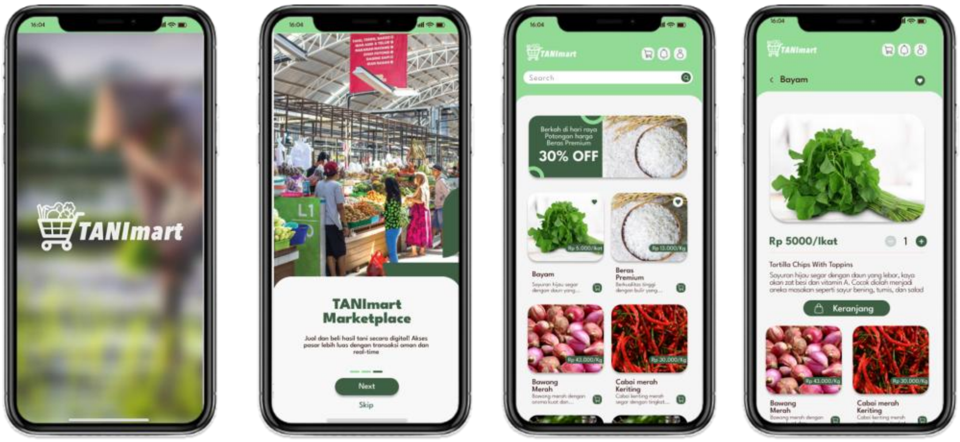

Fig. 8. TaniMart UI/UX prototype

3.3.5 System Usability Scale (SUS)

A task-based test was done with a group of native users to see how well the application prototype worked and how many people were able to use it successfully. When we say "native user," we mean people who are exactly like the people TANImart wants to reach. Their interaction and success in completing task scenarios accurately reflect the application's performance in a real-world context.

Table 2. Task scenario

Task	Scenario
New Account Registration	You are a new consumer wanting to buy fresh vegetables directly from farmers. Register an account on TANImart using your email or phone number.
Product Filtering	You are looking for food with a maximum price of IDR 50,000/kg. Use the search and filter features to find it.
Understanding Product Information	You want to check the quality of tomatoes before buying. Review the product details including the farmer's origin, farming method (organic/non-organic), and review ratings.
Checkout and Payment	Add 2 kg of Malang corn to your cart, then proceed to checkout. Choose the same-day delivery method and pay via a digital wallet.
Product Return (If Damaged)	You received broccoli that was wilted. Report this issue and request a refund.
Logout	You want to log out of the TANImart application.

In this test, each native user had to finish six task scenarios that showed how the main application works. We looked at how well they did in each situation and gave them three ratings. Success means that the user finished the task without any help; Partial Success means the user finished the task but had some trouble or took longer; Fail means the user couldn't finish the task at all.

Table 3. Success rate

Task	S1	S2	S3	S4	S5	S6
R1	S	P	S	S	S	S
R2	S	S	S	P	F	S
R3	P	S	S	S	P	S
R4	S	P	S	S	P	S

R5	P	S	S	P	P	S
R6	S	S	P	S	P	S
R7	S	S	S	S	P	S

R = Respondent (Native User), S = Success, P = Partial Success, F = Fail

To get a number that shows how well the application was designed, we used the following formula to figure out the overall task success rate. The data showed that out of 42 tasks (7 users × 6 scenarios), 29 were rated as Success, 12 as Partial Success, and 1 as Fail. The success rate is calculated using this information:

$$Success\ rate\ = \frac{Successful\ tasks}{Total\ attempts} \times 100\% \qquad \text{(Eq. 1)}$$

The result shows a success rate of 83.33%, which means that the TANImart application prototype works very well. This means that most users will be able to finish the main tasks that the app was made for. The high success rate shows that the workflow and interface design are easy to understand and work well for the people who will be using them. The overall success rate is high (83.33%), but there were 12 "Partial Success" and 1 "Fail" ratings, mostly for the "Product Return" and "Checkout" tasks. This was mostly because each task had a strict 60-second time limit. Some participants needed a little more time to get used to the interface on their first try, which caused timeouts. This limit was put in place on purpose to put the interface's efficiency to the test. The results show that the workflow makes sense, but the visual cues for important action buttons need to be more obvious so that users can find them and finish their tasks faster.

3.4 Evaluation

Based on the entire design and testing process, the TANImart smart economy innovation shows immense potential to address fundamental problems related to inefficiencies in Indonesia's agricultural supply chain. A more in-depth analysis and evaluation can be broken down as follows.

3.4.1 Design potential and strengths

Supported by a Distribution Hub and a digital marketplace, this innovation aims to reposition farmers as price-setters rather than mere price-takers. The structural impact of this design is significant by cutting out 2-3 layers of middlemen (collectors, large traders, retailers), it is projected that farmers can increase their profit margins by approximately 15-25% per kilogram of produce, while still offering competitive prices to consumers. To guarantee that this sophisticated economic model is accessible to its target demographic, the prototype underwent rigorous testing, yielding a System Usability Scale (SUS) score of 83.33% (Lewis, 2018). This result confirms that the technology is highly effective and easy to learn, thereby accelerating the transition from traditional to digital agricultural systems.

3.4.2 Implementation and scalability challenges

While the conceptual framework is robust, the tangible implementation of TANImart must navigate significant hurdles, ranging from uneven internet connectivity and varying digital literacy in rural zones to the substantial capital expenditure required for the Distribution Hub's infrastructure. As the ecosystem scales, it must also manage increasing logistical complexity while contending with entrenched conventional distribution networks. To address these competitive pressures and ensure economic sustainability without burdening the farmers, TANImart adopts a transparent 'Commission-Based Model' rather than a high-margin intermediary system. Farmers are charged a fixed service fee of 5% solely upon successful transactions. This rate is significantly lower than the typical margins retained by conventional middlemen, ensuring that farmers still enjoy a higher net income. Furthermore, to maximize adoption rates, registration and access to the analytical dashboard are provided free of charge, effectively removing upfront financial barriers for smallholder farmers.

3.4.3 Recommendations for further development

To guarantee the long-term viability and amplify the impact of TANImart, several future iterations should be emphasized. First, the platform can be augmented with personalization features for consumers, such as product suggestions rooted in purchase history or individual preferences. Second, a specialized analytics dashboard for farmers should be established to deliver comprehensive insights into sales trends, price fluctuations, and market demand, empowering them to make more calculated planting decisions. Third, the platform's alignment with IoT technology (specifically storage sensors) should be strengthened to offer more transparent and real-time quality data to buyers. Finally, broadening the network of logistics partners and payment channels, including the adoption of optimized vehicle routing for perishable, temperature-sensitive deliveries (Awad et al., 2020), will expand service flexibility and accessibility. Through ongoing assessment and incremental development, TANImart can transform into a comprehensive and robust digital agricultural ecosystem.

3.4.4 Alignment with the sustainable development goals (SDGs)

Beyond its technical and economic merits, TANImart's design reflects a deliberate alignment with the United Nations 2030 Agenda for Sustainable Development. Each functional module of the system addresses a specific structural barrier faced by Indonesian smallholder farmers barriers that are directly mapped to priority SDG targets. Table 4 presents a systematic alignment matrix that links each TANImart feature to its corresponding SDG target, the mechanism through which the feature contributes to that goal, and the anticipated socio-economic impact.

Table 4. TANImart feature SDG alignment matrix

TANImart feature/module	SDG target(s)	Mechanism of contribution	Expected socio-economic impact
TANImart Digital Marketplace (B2C direct sales)	SDG 1 (No Poverty) SDG 8 (Decent Work & Economic Growth)	Cuts 2-3 middlemen layers, farmers receive direct payment via e-wallet, increasing net margin by an estimated 15-25% per kg	Higher household income, greater financial independence for smallholder farmers
Smart Distribution Hub (physical logistics & FIFO cold storage)	SDG 2 (Zero Hunger) SDG 12 (Responsible Consumption & Production)	IoT cold-chain extends vegetable shelf life from days to 2-3 weeks. FIFO inventory prevents spoilage reduces post-harvest food loss	Reduction of food waste along the supply chain improved food availability and stability
Hygienic Control Module (IoT sensors + computer-vision grading)	SDG 2 (Zero Hunger) SDG 12 (Responsible Consumption & Production)	Automated quality sorting and 'digital passport' traceability enables entry into premium markets (hotels, restaurants, supermarkets)	Higher product value, reduced consumer health risk, and access to export markets
Transaction Kiosk (QRIS digital payment + real-time price	SDG 1 (No Poverty) SDG 10 (Reduced Inequalities)	Farmers access transparent market prices and receive	Financial inclusion of rural farmers, reduction of price

display)		digital payment directly. Digital transaction history facilitates formal banking access	exploitation by cash-only intermediaries
Kios Informasi / Farmer Dashboard (WMS + analytics + cultivation guide)	SDG 4 (Quality Education) SDG 8 (Decent Work & Economic Growth)	Data-driven cultivation recommendations, sales-trend analytics, and weather data support informed planting decisions and productivity growth	Improved agricultural literacy transition from subsistence to market-oriented farming
Operational Management Module (production & stock tracking)	SDG 8 (Decent Work & Economic Growth) SDG 17 (Partnerships for the Goals)	Structured workflow documentation increases operational efficiency; integration with third-party logistics enables market reach beyond local regions	Scalable supply-chain management foundation for cooperative and multi-stakeholder platform governance
Digital Identity Card (QR/NFC e-wallet for farmers)	SDG 1 (No Poverty) SDG 10 (Reduced Inequalities)	Acts as a digital identity and payment gateway enables receipt of government subsidies and incentives electronically	Formalization of smallholder farmers in the digital economy access to social protection programs

The matrix reveals that TANImart most direct SDG contributions are concentrated in SDG 1 (No Poverty), SDG 2 (Zero Hunger), and SDG 8 (Decent Work and Economic Growth) goals that are critically underserved in Indonesia's current agricultural system, where average farmer incomes remain at roughly 50% of the national minimum wage (BPS, 2023). SDG 1 and SDG 10 (Reduced Inequalities) are addressed structurally through the elimination of cash-only intermediary dependencies by providing QRIS digital payment and transparent price data at the Transaction Kiosk, TANImart ensures that the economic gains of agricultural transactions flow directly to farmers rather than being captured by middlemen. Equally significant is the contribution to SDG 2, achieved through the Smart Distribution Hub's cold-chain technology, which extends vegetable shelf life by up to three weeks and reduces losses that research estimates at over 101,000 tons of rice annually in West Kalimantan alone (Ningsih et al., 2024).

From an educational and capacity-building perspective, the Kios Informasi and farmer analytics dashboard address SDG 4 (Quality Education) by converting market and cultivation data into actionable guidance for farmers who have historically operated without access to real-time information. This transition from reactive subsistence farming to proactive, data-informed decision-making directly supports SDG 8's vision of productive employment and decent work. Finally, the platform's integration with third-party logistics providers and potential for public-private partnership (PPP) financing positions TANImart as a vehicle for SDG 17 (Partnerships for the Goals), enabling multi-stakeholder collaboration between government agencies, cooperatives, technology providers, and financial institutions. Taken together, these alignments demonstrate that TANImart is not merely a commercial platform but a policy-relevant instrument for inclusive and sustainable agricultural transformation in Indonesia.

4. Conclusions

TANImart provides a comprehensive, technology-driven response to the systemic challenges afflicting Indonesia's agricultural sector. By integrating a physical distribution hub with a digital marketplace, TANImart effectively addresses the inefficiencies caused by multiple intermediary layers and limited farmer access to end consumers. The system's design combines IoT sensors, automated quality-control modules, smart cold storage, and farmer information kios to ensure produce quality, reduce post-harvest losses, and maintain freshness through an efficient First-In-First-Out (FIFO) inventory management system. This holistic integration not only improves logistics efficiency but also ensures that farmers retain more of the economic value generated from their produce. As a result, TANImart embodies the transformation of agriculture from a traditional, fragmented supply chain into a data-driven and transparent ecosystem aligned with modern smart farming principles.

The development and testing of the TANImart prototype demonstrate its technical feasibility and strong potential for real-world impact. Through a structured Research and Development (R&D) approach combined with the Waterfall software development methodology, the system was built, tested, and iteratively refined based on user feedback. Evaluation using a task-based usability test involving seven representative users yielded an impressive 83.33% success rate across key activities such as registration, product search, ordering, and digital payment. This high usability score confirms that TANImart's user interface and interaction flow are well-aligned with the practical needs and digital capabilities of local farmers. Such evidence-based validation highlights the system's scalability potential, particularly in rural communities where ease of use and reliability are crucial factors for technology adoption.

Beyond its technical merits, TANImart holds broader socio-economic implications by empowering farmers both economically and socially. The introduction of a secure Digital Access Card, which also functions as a payment wallet, enhances farmers' participation in the digital economy while ensuring secure and direct financial transactions. Real-time access to market prices allows farmers to make informed selling decisions and avoid exploitation by middlemen. Additionally, the platform's data-driven cultivation recommendations support sustainable agricultural practices by optimizing crop selection and yield planning. By centralizing logistics and market data, TANImart strengthens farmers' bargaining power and transparency across the value chain. This transformation helps farmers transition from being passive producers to informed agripreneurs with improved control over pricing, marketing, and supply strategies ultimately increasing income stability and fostering long-term rural resilience.

Nevertheless, scaling TANImart across Indonesia requires strategic attention to several implementation challenges. Limited internet connectivity in remote areas and varying levels of digital literacy among farmers present significant barriers to widespread adoption. Moreover, constructing and equipping distribution hubs with IoT infrastructure, cold storage, and digital kios involve substantial capital investment. Addressing these issues will necessitate strong collaboration among government institutions, cooperatives, private investors, and technology providers. Public-private partnerships (PPP) and targeted subsidies can accelerate infrastructure readiness, while community-based digital literacy programs can empower farmers to fully utilize TANImart's features. Through these iterative improvements, TANImart offers a replicable model for digital agricultural transformation one grounded in evidence, aligned with Indonesia's SDG commitments, and designed to convert farmers from passive price-takers into active, empowered participants in the national food economy.

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Author Contribution

Conceptualization, D.S.M., A.M.V., and V.C.P.; Methodology, V.C.P.; Software, D.S.M.; Validation, A.M.V., and V.C.P.; Formal Analysis, A.M.V.; Investigation, D.S.M., A.M.V., and V.C.P.; Data Curation, V.C.P.; Writing – Original Draft Preparation, A.M.V.; Writing – Review & Editing, D.S.M.; Visualization, D.S.M.; Supervision, D.S.M; Project Administration, A.M.V.; and Funding Acquisition, V.C.P.

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Ethical Review Board Statement

This study did not require formal ethical approval because the data collection involved interviews with government institutions, namely the Food Security Office of Southeast Sulawesi Province, the Food Security Office of Kendari City, and the Agriculture Office of Southeast Sulawesi Province. The interviews focused on institutional and policy information rather than personal or sensitive data. The interviews were conducted with an official introduction letter from Halu Oleo University, and all procedures adhered to general research ethics principles, including voluntary participation, informed consent, and confidentiality of responses.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study. Participants in the usability testing, who are alumni with expertise in UI/UX, provided their consent before participating in the prototype evaluation.

Data Availability Statement

The data supporting this study were obtained from interviews with the Food Security Office of Southeast Sulawesi Province, the Food Security Office of Kendari City, and the Agriculture Office of Southeast Sulawesi Province. As the data contain institutional information collected with official permission from Halu Oleo University, the full data set cannot be shared publicly to respect confidentiality agreements with the participating institutions. However, a summarized version of the interview results and key findings is available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflict of interest.

Declaration of Generative AI Use

During the preparation of this work, the authors used Gemini Pro to assist in improving grammar and clarity for the English language sections of the manuscript. After using this tool, the authors reviewed and edited the content as needed and took full responsibility for the content of the publication.

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