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KOREA GREEN GROWTH TRUST FUND

Digital Technology for Traceability in Vietnam's Fruit and Vegetable Value Chains

DECEMBER 2022

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ACRONYMS AND ABBREVIATIONS

AB	Agribusiness
ANCC	Article Numbering Center of China
AOSC	Accreditation Office for Standards Conformity Assessment Capacity
API	Application Programming Interface
ASEAN	Association of Southeast Asian Nations
BFT	Byzantine Fault Tolerance
BRC	Bureau Veritas
CAB	Conformity Assessment Body
CCP	Critical Control Point
CODEX	Codex Alimentarius
CTE	Critical Tracking Event
DARD	Department of Agricultural and Rural Development
DLT	Distributed Ledger Technology
DPOS	Delegated Proof-of-Stake
EC	European Commission
EPCIS	Electronic Product Code Information Services
ERP	Enterprise Resource Planning
EU	European Union
EY	Ernst & Young Vietnam Ltd.
F&V	Fruit and Vegetable
FBO	Food Business Operator
FDA	US Food and Drug Administration
GCP	Global Company Prefix
GDPR	General Data Protection Regulation
GIAI	Global Individual Asset Identifier
GlobalGAP	Global Good Agricultural Practice (formerly EuropeGAP)
GLN	Global Location Number
GPS	Global Positioning System
GRAI	Global Returnable Asset Identifier
GSIN	Global Shipment Identification Number

GSM	Global System for Mobile Communication
GSRN	Global Service Relation Number
GSO	General Statistics Office
GTIN	Global Trade Item Number
HACCP	Hazard Analysis and Critical Control Point
HCMC	Ho Chi Minh City
ICT	Information and Communication Technology
IoT	Internet of Things
ISO	International Organization for Standardization
IT	Information Technology
KCCI	Korea Chamber of Commerce and Industry
KDE	Key Data Element
MAFFTP	Ministry of Agriculture, Foodstuff and Forestry Policies and of Tourism (
MAFRA	Ministry of Agriculture, Food and Rural Affairs
MARA	Ministry of Agriculture and Rural Affairs
MARD	Ministry of Agriculture and Rural Development
MES	Manufacturing Execution System
MFDS	Ministry of Food and Drug Safety
MOH	Ministry of Health
MOIT	Ministry of Industry and Trade
MOST	Ministry of Science and Technology
M2M	Machine-to-Machine
NBC	National Numbering and Barcode Center
NFC	Near-Field Communication
OCOP	One Commune-One Product
OMS	Order Management System
PDA	Personal Digital Assistant
PHI	Pre-harvest Interval
PII	Personally Identifiable Information
PLU	Price Look-Up Code
POS	Point of Sale
PoS	Proof-of-Stake
PoW	Proof-of-Work
PoWeight	Proof-of-Weight
PUC	Production Unit Code

QdC	Quaderno di Campagna
QR	Quick Response
RFID	Radio Frequency Identification
RTO	Registro Telematico Olio
RTV	Registro Telematico Vino
SaaS	Software as a Service
SGTIN	Serialized GTIN
SMEs	Small and Medium Enterprises
SSCC	Serial Shipping Container Code
STAMEQ	Directorate for Standards, Metrology and Quality
TCVN	Tiêu Chuẩn Việt Nam (Vietnam National Standard(s)
TRACES	Trade Control and Expert System
UPSS	Unsafe Product Screening System
VCA	Vietnam Cooperative Alliance
VietGAP	Vietnam Good Agricultural Practice
VinaSME	Vietnam Association of Small and Medium Enterprises
VNTP	Vietnam National Traceability Portal
WMS	Warehouse Management System

PREFACE AND ACKNOWLEDGMENTS

This study assessed the use of digital technologies to improve traceability in fruit and vegetable (F&V) value chains in Vietnam. It is supported by the Korea Green Growth Trust Fund (KGGTF), a partnership between the World Bank Group (WBG) and the Republic of Korea. As a technology-driven and implementation-focused trust fund, the partnership supports countries in their innovative and sustainable growth strategies and investments. KGGTF is fully committed to greening the post-COVID recovery and supporting multi-sectoral initiatives for Green, Inclusive, and Resilient Development (GRID). The study was undertaken by a World Bank team comprising Binh Thang Cao (Senior Agricultural Specialist, SEAAG, and Task Team Leader), Hardwick Tchale (Senior Agricultural Economist, SEAAG), and John G. Keogh (Senior Food Traceability Consultant). The study received assistance from Hoa Phuong Kieu (Program Assistant, EACVF). The report was prepared with guidance from Dina Umali-Deininger (Practice Manager, SEAAG).

The primary research and the analysis underpinning this report were conducted by an interdisciplinary consulting team (the research team) of Ernst & Young Vietnam Ltd., including Long Viet Nguyen (Economist and Policy Expert), Jimmy Ong (Blockchain and Enterprise Resource Planning Expert), Giuseppe Perrone (Agri-food Traceability and Digital Expert), Richard Katter (Agri-food Traceability and Digital Expert), Hongjoon Jeon (Korea Subject Matter Resource), Vy Ha Tran (Agriculture Value Chain and Digital Transformation Analyst), Charlene Uy (Digital Technology Analyst), Cherie Gao (China Subject Matter Resource), Thanh Thi Tieu (Policy and Regulation Analyst), Phong Anh Nguyen (F&V Value Chain and Policy Expert), Phuong Bich Bui (Policy and Regulation Analyst), and Anh Thi Phuong Nguyen (Analyst).

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The burden on the world's food supply networks is growing because of climate change and

EXECUTIVE SUMMARY

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the increased demand for food that is safe, nutritious, and traceable. Environmentally friendly and sustainable farming, food processing, and distribution methods are essential for a nation to achieve economic success and help combat hunger, malnutrition, and poverty.

Foodborne diseases pose serious health risks and can have significant economic and financial impacts on economies, so there is little room for complacency. Food safety outbreaks cost developing economies an estimated US$110 billion in lost productivity and medical costs in 2016, according to the Safe Food Imperative, a 2018 World Bank research report. An incident involving food safety can harm a nation's export reputation as well as the reputation of a food brand, necessitating more investment in programs designed to foster confidence and rebuild trust. If food safety management is handled systemically and with an emphasis on prevention, the risk of food safety incidents can be minimized. Effective traceability systems underpin food safety management and reduce the risk that unsafe foods will reach consumers, thereby reducing foodborne illness and positively affecting human health (Dessureault 2007) and safety. Businesses with stringent food safety management systems and a food safety culture that encourages consistent behaviors are more likely to expand and draw investment.

In Vietnam, stakeholders in the agri-food sector, as well as government agencies, incur high transaction costs due to manual and labor-intensive data collection, recording, and sharing. Along the food supply chain, information asymmetry is the norm. Digital transformation of the agri-food sector can help drive efficiencies from primary producers to consumers by reducing transactional costs; eliminating information asymmetries; and acting as an agricultural policy design, delivery, monitoring, and reporting mechanism. Furthermore, implementing traceability in food supply chains also helps reduce uncertainty, improve enforcement of agreements and coordination, and reduce the risk to human health and safety (Banterle and Stranieri 2008).

Digital transformation of the agri-food sector

While it may be challenging to precisely describe digital transformation, in the narrower food supply chain context, it involves switching from manual or paper-based data collection, storage, and retrieval techniques to digital technologies. In the World Bank's What's Cooking series on Digital Transformation of the Agrifood System (2021), they note "...digital technologies will increase farmers' access to upstream and downstream markets by drastically lowering information-related transaction costs. That could allow them to tap into a larger, thicker set of markets through improved price discovery, buyer-seller matching, lower transport costs, and digitally enabled collective action to increase farmers' inclusion and bargaining power in agri-food value chains. Already farmers are seeing new incentives for quality improvement, changes in the way they allocate resources, and higher incomes and profits."

Despite the broad nature of potential applications of digital transformation across the entire spectrum of the agri-food sector, this report narrows its focus to the digital transformation required for agri-food traceability as a key foundational principle in food safety management.

Traceability is foundational for food safety management and global trade

Traceability of agri-food products and the ability to quickly recall unsafe products are mandatory requirements domestically and for exporting to most countries. Traceability management in global food supply chains is complex and has attracted significant societal, business, and policy attention because of numerous foodborne illness outbreaks and high-profile food fraud incidents. In 2011, an *Escherichia coli* O104:H4 bacteria (*E. coli*) outbreak in Germany infected 3,950 people and caused 53 fatalities and cost an estimated US$2.84 billion (Ringsberg 2014). Between January 2017 and July 2018, a listeriosis (*L. monocytogenes*) outbreak in South Africa infected 1,060 people and caused 216 fatalities and cost an estimated US$260 million. Food fraud incidents, such as the 2008 China melamine scandal resulted in the deaths of six children and sickened 300,000 more (Gossner et al. 2009; World Health Organization 1990). Additionally, melamine-contaminated milk from China was discovered in a range of dairy products exported to 47 countries, underscoring the potentially catastrophic and cascading effects of poor governance of food safety as well as the importance of robust traceability and recall solutions.

Around the world, various technologies and solutions for food traceability are being used. Some are as simple as an Excel workbook and others use advanced technologies, which may include a combination of blockchain, internet of things (IoT) sensors, and artificial intelligence. In Vietnam, traceability is a vital underpinning for food safety governance in Vietnam's exports. In 2021, Vietnam exported[1] US$5.5 billion in edible fruits, nuts, peel of citrus fruit, and melons. Coffee, tea, mate, and spice exports were US$3.72 billion while vegetable, fruit, and nut food preparation totaled US$1.19 million. Edible vegetables including roots and tuber amounted to US$486.4 million. Strengthening robust and resilient supply chains with food safety governance and traceability solutions will boost the reputation of Vietnam, enhance standards and quality compliance, and facilitate market access.

Global supply chain standards

To facilitate global trade and ensure that stakeholders apply universal naming conventions that facilitate food traceability and interoperability between digital systems and platforms, industry-driven supply chain data standards are crucial. For example, the industry standards from GS1,[2] the global, not-for-profit supply chain standards organization and the International Organization for Standardization (ISO) are reliable and interoperable industry standards for traceability and recall solutions that can be used to protect company interests while reducing threats to consumer health and safety. Both standards organizations have aligned on using the Electronic Product Code Information Services (EPCIS) standard to enable interoperability. The EPCIS standard is GS1's flagship data sharing standard for enabling visibility, within organizations as well as across an entire supply chain of trading partners and other stakeholders. It helps provide the "what, when, where, why, and how' of products and

1 https://tradingeconomics.com/vietnam/exports-by-category.

2 A neutral, global supply chain standards body.

other assets, enabling the capture and sharing of interoperable information on the visibility of a shipment, its current status, its location, its movement, and chain of custody."[3]

Traceability defined

There are several similar definitions of traceability used by standards bodies, academia, and inter-governmental agencies, including the international food standards agency Codex Alimentarius (CODEX), which defines traceability as "the ability to follow the movement of a food through specified stage(s) of production, processing and distribution." However, for this research paper, traceability is defined in accordance with the joint GS1 and ISO 9001:2015 standards:

> "Traceability is the ability to trace the history, application, or location of an 'object' (e.g., a product). When considering a product or a service, traceability can relate to: (1) origin of materials and parts; (2) processing history; (3) distribution and location of the product or service after delivery."

Traceability, by this definition, serves two primary functions: *tracing* a food item's origin (and history) and *tracking* its forward movement throughout its distribution.

Food safety regulations, technical standards, and identified gaps

In both the domestic and export markets, food safety is still a major concern in Vietnam. With continued assistance and capacity building from numerous bilateral and multilateral organizations, Vietnam is steadily improving its ability to meet the criteria of major trading partners for food safety management. Despite enduring challenges, capacity-building initiatives have helped Vietnamese processors and exporters reduce the rejection rate of food exported to Organisation for Economic Co-operation and Development markets and increase agri-food commerce in commodities with higher values and more sensitive food safety standards and traceability requirements.

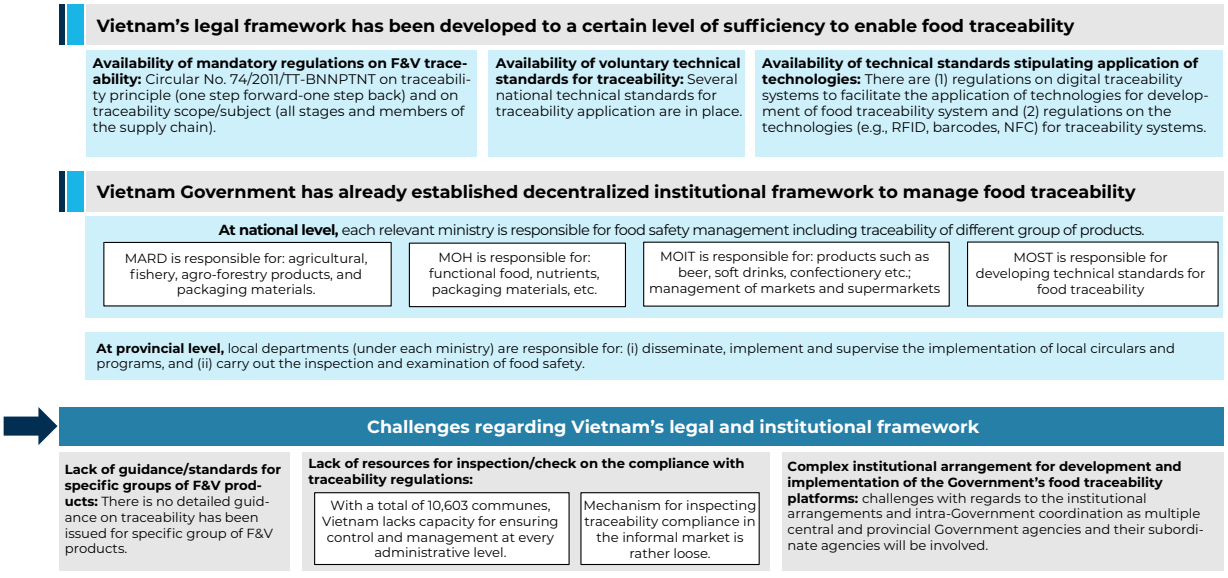
Figure 1 highlights the institutional framework in Vietnam and its gaps. At the national level, three ministries enforce food safety regulations: the Ministry of Health (MOH), the Ministry of Agriculture and Rural Development (MARD), and the Ministry of Industry and Trade (MOIT). Furthermore, numerous regulatory activities are decentralized and managed at the provincial or local level, resulting in a growing number of municipal and provincial food traceability systems. Traceability is mentioned in the Food Safety Law enacted by the National Assembly of Vietnam on June 17, 2010, as one of the risk management tools (along with food recalls, labeling, and response capacity).

Concerning technical standards, the Directorate for Standards, Metrology, and Quality (STAMEQ) is a governmental agency within the Ministry of Science and Technology (MOST) responsible for advising the government and MOST on the state management of

3 https://www.gs1.org/standards/epcis.

standardization, metrology, and quality. Within STAMEQ, the National Numbering and Barcode Center (NBC) hosts the Vietnamese office of the global, not-for-profit industry standards body GS1 Vietnam. NBC is the adviser for developing the national standards, technical regulations, circulars, and decrees for traceability systems in the supply chain, including barcoding, product, party (business), and location identification codes and interoperability, all of which are essential components of digital food traceability systems. Most of the GS1 global standards have been adapted and adopted as voluntary national standards (Tiêu Chuẩn Việt Nam or TCVN), including the GS1 Global Traceability Standard and the GS1 Fresh Fruit and Vegetable Traceability Guideline. This latter document provides details on how to achieve traceability for both packaged and loose fruits and vegetables. Furthermore, NBC is the focal point to engage all provinces and ministries in Vietnam and assist with their traceability systems as well as develop and implement the Vietnam National Traceability Portal (VNTP).

Figure 1: Vietnam's legal and institutional framework for food traceability

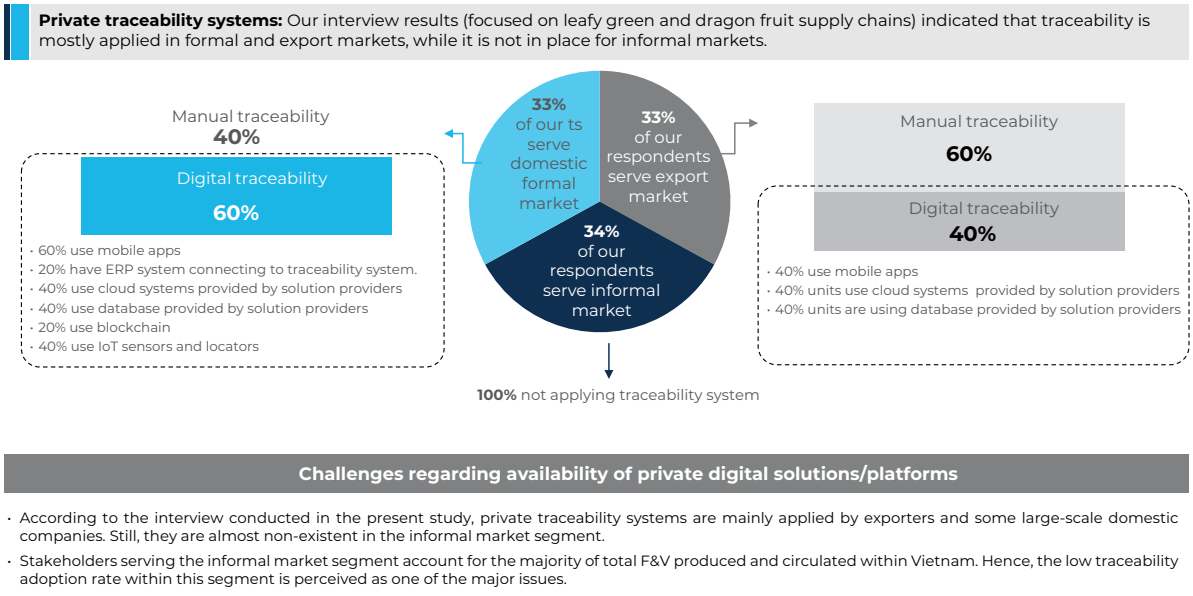


In Vietnam's fruit and vegetable (F&V) supply chains, especially in the formal market, digital traceability is not a novel idea. GS1 Vietnam has more than 30,000 active business members and about 50 percent are involved in the food industry. Its national product catalog is growing and contained 860,000 registered products in September 2022, half of which are food related. There are numerous published case studies and success stories in the food sector that demonstrate the value of using GS1 standards for traceability and process efficiencies in the agri-food sector.

Further, several provincial and municipal traceability portals have been developed that provide affordable, quick fixes for the vast majority of market participants. Some industry participants perform traceability manually, while others use digital traceability solutions, depending on their needs and financial resources. As seen in figure 2, compared to 40 percent of exporters who utilize digital traceability solutions, 60 percent of interview participants who work in the formal domestic market (retailers) have digital traceability systems in place. Informal market participants who were interviewed said they did not apply any digital traceability systems, mainly due to their limited technical knowledge and financial constraints. In addition,

consumers who frequently come to informal markets are mostly of low and middle income. They tend to trust the traders and/or producers they know well rather than having strong demand for food traceability.

Figure 2: Current state of traceability in the private sector



Those performing manual traceability in Vietnam frequently use farm books (or farm diaries) or Excel spreadsheets. Those deploying digital traceability solutions frequently use quick response (QR) codes to link to a website with static information. Mobile applications and cloud-based systems are common among those deploying digital traceability solutions. Additionally, there are traceability applications using blockchain technology and IoT sensors. Still, these technologies are not widely used because of their complexity, necessary technological maturity, and capital requirements.

Identified gaps

Vietnam's rapidly expanding information technology (IT) infrastructure can support the implementation of digital traceability systems in large cities, owing to the country's high internet and mobile penetration rates. Nonetheless, rural and mountainous areas continue to face challenges in accessing the internet and mobile phone services (Cameron et al. 2018).

Despite the excellent progress made, stakeholder interviews and desk research identified gaps between the regulations, enforcement, industry capability, and implementation.

- In traditional wholesale and retail wet marketplaces, there is a significant gap identified through suppliers' opposition to any additional expenses for packaging or labeling and customers' lack of need for traceability solutions. This is concerning because conventional markets sell around 90 percent of fresh fruits and vegetables. It is critical to promote the importance of traceability at both the supply and demand ends of the supply chain to assist food safety management and reduce the risk to consumer health and safety.

  - Recent literature helps better understand the lack of need for traceability on the demand side (consumers in conventional markets). In a survey (Ha et al. 2022) on consumer purchase intention and consumption (n = 463) of conventional vegetables in Hanoi wet markets in 2022, researchers discovered that trust in local government, farmers, and traders was relatively low. As a result, purchasing conventional vegetables was perceived as high risk. Despite the elevated risk, consumers formed relationship bonds with farmers who are knowledgeable and transparent about their methods of production and the food origin. As a result of these bonds, a form of *blind trust* develops over time between the consumer and the farmer that strengthens the trade-off in food safety risks/benefits. Trust was linked in this study to perceived hedonic benefits, such as the pleasure of eating traditional and culturally relevant vegetables purchased in a culturally acceptable environment (wet markets).
  - In similar research of traditional wet markets in China, the transparency or information visibility of where and how the food was produced (its origin) and how it was processed was historically based on the trust established between the buyer and seller during their face-to-face transactions (Mol 2014). This type of face-to-face relationship bonding is also the case in Vietnam's informal trade in wholesale and retail wet markets, according to recent research cited earlier.

- Vietnam lacks specific food traceability-related policies, industry guidance documents, and training materials for F&V products.
  - Although NBC/GS1 Vietnam has published a TCVN called the 'Fresh Fruit and Vegetable Traceability Guideline', which was adapted from the GS1 global guideline and sets out in granular detail what industry stakeholders must do to capture, record, and share traceability data, there are no traceability requirements and guidelines for certain high-risk and high-value F&V products, especially for export markets.
- There is a lack of human resources for regulatory inspection for compliance with food safety regulations and food traceability requirements specifically.
- Digital food traceability has limited deployment as agriculture in Vietnam is highly decentralized, relying heavily on small-scale households that lack the financial resources and technical expertise to adapt and use new technologies. The informal distribution channels, which account for approximately 90 percent of the total quantity of agricultural product consumption (Vu 2020), also pose a challenge for food traceability. According to our interviews with selected F&V supply chain stakeholders, traceability is not used in the informal markets. In contrast, 100 percent of interviewed firms that are export-oriented or distribute their products through formal distribution channels have implemented either manual or digital traceability systems. As discussed in a meeting with the management board at a Ho Chi Minh City (HCMC) wholesale wet market in August 2022, the informal market situation results from a lack of a regulatory framework on food traceability, limited financial resources and technical capacities, and the absence of market need for traceability. Labeling, as an enabler of traceability, is perceived as adding unnecessary costs and packaging (which may have traceability labels) is reused many times.

- Many of the existing traceability systems in the public and private sectors are proprietary and do not follow the technical guidance published in the TCVN (which are adapted from GS1 standards). This limits their ability to share information electronically and may pose a risk to the required interoperability requirements for the national and provincial traceability portals. It should be noted that the national traceability portal is based on published TCVN, adapted from GS1 standards and includes the joint GS1/ISO EPCIS standard for interoperability.

International experiences on food traceability and lessons learned for Vietnam

Sections 5 and 6 of this report discuss the characteristics of an effective food traceability system and the technologies that can be used and review the application of digital technology-based traceability in specific markets. A review of international practices from the European Union (EU) and selected advanced countries, including Italy, China, and the Republic of Korea (Korea), shows that successful adoption of digital technology-based traceability systems requires a robust legal framework with detailed traceability provisions, a well-defined institutional framework, and strong (and active) government support in developing national traceability systems that can incorporate traceable data from supply chain stakeholders. Numerous lessons can be drawn from international practices, including the following:

- **Industry guidance and standards**: These are available for specific categories of F&V products. The EU, Italy, Korea, and China, all have regulatory requirements for high-risk, high-value, or signature F&V products.
- **Trained personnel**: It is essential to have qualified personnel available to conduct inspections, monitor compliance with traceability regulations, and provide training programs for government inspectors. For example, Italy conducts thousands of inspections yearly to ensure that food operators adhere to traceability requirements, in which its inspectors are well versed. China, despite its massive scale and scope of operations, holds regular training programs for its food inspection personnel.
- **National and regional traceability systems**: Promoting the use of interoperable national or regional traceability systems helps manage risk, enables resource efficiency, reduces costs associated with product recalls, and increases product information transparency. National and regional traceability systems are also considered appropriate for participants in informal markets who lack the required resources (both human and financial) to implement and operate their own traceability systems. Participation in China's national traceability system is low cost and affordable.
- **Increasing public awareness**: For the past two decades, the Ministry of Food and Drug Safety (MFDS) has held an annual Food Safety Day in Korea to raise public awareness about food safety and to promote safety awareness among food-related workers.

A review of international practices also reveals that mature businesses employ private traceability systems to ensure the link between input and output following each internal processing stage. The present study identifies the following technologies applicable to

Vietnam's context: label-based data carriers such as GS1 barcodes and the QR code; electronic data carriers such as radio frequency identification (RFID) and near-field communication (NFC) tags; and applications based on distributed ledger technology (DLT) such as blockchain, mobile applications, and IoT sensors. Each technology has its advantages and disadvantages as well as a distinct scope and stage of application.

- Numerous industry standards-based barcodes are used to encode an object's identification and permit electronic scanning.[4] In the packaged F&V context (for example, a bag of 10 apples or an organic cauliflower individually packaged) or with high-value unpackaged fruits and vegetables (for example, a pineapple or organic, premium apple or orange), the identification code embedded into the barcode is called a global trade item number (GTIN). It is scannable at point of sale (POS). Loose items, such as an individual organic apple or orange, are often labeled with a GS1 2D data bar, whereas a bag of 10 apples will be labeled with the linear 1D barcode.
- At a higher level of aggregation, the barcodes on shippable cartons, containers, or totes containing bulk fruits and vegetables may include information about the processor's name and address, referred to as a global location number (GLN). A pallet of goods shipped from a processor to a retailer can be labeled with a unique shipping barcode, which is called a serial shipping container code (SSCC), and this code is used for traceability.
- The various industry standards-based barcodes enable electronic scanning of the encoded data and tracking of the objects' movement (for example, pallet, carton, tote, and packaged product) at all stages of the supply chain, including the POS in organized trade. Barcodes ensure greater accuracy compared to manual traceability; they are relatively inexpensive and easy to use and facilitate interoperability. However, barcodes have some limitations, including the cost to register the company with GS1, recurring annual fees, the ease with which they can be counterfeited, the time required to scan each code, the necessity of a line of sight between the scanner and the barcode, and a small risk of scanning error if multiple items are in proximity. QR codes are often attached to products and used primarily to link to a website to access additional product information.
- A proprietary QR code does not replace the GS1 barcode and its embedded GTIN as the formally recognized product identifier for trade items.
- *Note:* In organized retail trade, a label with a price look-up code (PLU) is often used for bulk fresh fruits and vegetables that are sold loose and are of variable weight (for example, loose tomatoes). Usage of the PLU is not a regulatory requirement and is an industry-specific initiative. The Canadian Produce Marketing Association's website[5] is a good source of information on PLU codes and how they integrate into the GS1 system of standards.
- RFID and NFC tags can be used in place of barcodes in supply chains (but not at retail POS) and can help capture the movement of physical objects such as a pallet of goods without the need for line-of-sight scanning, as with the barcode. Onboard functionality on IoT-

4 https://www.gs1.org/docs/freshfood/Fresh_Food_Implementation_Guide.pdf

5 Canadian Produce Marketing Association: https://cpma.ca/industry/supply-chain-efficiencies/coding-identification-in-canada/plu-codes/plu-faq

based sensors may include the ability to detect movement or record temperature in a cold chain. Compared to barcodes, these sensors provide faster and more reliable data capture and can help avoid the risk of intentional data modifiability. However, these technologies are expensive and complex to implement, and their performance may be compromised by environmental factors such as extreme heat or cold, humidity, or electrical/electronic interference.

- Blockchain technology is used to record and share transaction data. It has several advantages over other transaction databases, including improved data provenance, enhanced transparency, and data immutability. However, blockchain technology has not been widely adopted as it is considered resource intensive and technically complex. Additionally, blockchain is a relatively immature technology, beleaguered by the negative association with cryptocurrencies and increased energy consumption.
- Mobile applications are primarily used in supply chains to capture, record, and share data. The extent of mobile application usage is vast, and it can be customized and tailored to the needs and financial capacities of agribusinesses (ABs).

Recommendations on the approaches

While traceability is adopted and well implemented in the formal retail and export markets, it almost does not currently exist in the informal market. The following approaches are recommended for informal and formal markets.

1. Supporting small food business operators (FBOs) in the informal market and the role of the government

As no digital or manual traceability systems are currently in place in the informal market, there is a need to create greater demand for F&V traceability among domestic consumers, merchants, traders, and producers. To make it happen, both public and private sectors should make more efforts to raise public awareness about the need for food safety and the risks of consuming unsafe and untraceable food. There is a big role for the government to provide technical and material assistance to small producers and traders in the informal market to reduce their investment and operating costs of adopting food traceability. In terms of implementation arrangements, the government should assist individual small-scale farmers and vendors at community wet markets or street vendors in joining cooperatives or producer/trader organizations, where appropriate. The management boards of these entities will represent the groups and are responsible for registering and managing traceability data and tools, as well as training and supervision.

- **Phase 1 (the transition phase)**: Since the informal market's stakeholders have limited technical and financial capabilities and operate on a smaller scale, it is recommended that they perform manual data collection and recording for internal traceability. Under the guidance of cooperatives, traders who collect vegetables from farms and farmers who operate as traders can keep track of their batches or lots using existing farm books or Excel files.

- Once farmers have been determined to be compliant using manual methods (farm diaries), capacity building is recommended to enable the transition to e-farm diaries using smartphones as data input devices. Several e-farm diary solutions are presently being piloted and deployed in the Vietnamese market.
- Capacity building might extend to market traders who collect vegetables from farmers, allowing them to connect to an e-farm diary in a one-step-up/one-step-down traceability functionality. To ensure that vegetables from different farms are not commingled, this external traceability mechanism would necessitate cooperative management controls and training at the trader's stall.
- External traceability is critical, and it can be handled and monitored by the cooperative's management board, which oversees registering all traders with the municipal or provincial traceability system. Several towns and provinces have already built traceability systems that allow enterprises and cooperatives to register for QR codes that link product and provenance information. In the absence of a municipal or provincial traceability system, farmers should be assisted in forming production partnerships with ABs to market their farm output, with the ABs handling traceability for all farm produce. Similarly, the wholesale market's management board is advised to assist traders and distributors in securing signage and QR codes for their food stalls. This methodology is similar to the HCMC-based pork traceability pilot plan, in which the management board registers pork sellers and provides them with QR codes to display at their food stalls.

- **Phase 2 (the mature stage)**: At a later stage, these stakeholders can deploy labeling with a barcode, QR code on consumer packaging, and a simple mobile application based on a global standard such as GS1 and Vietnamese technical standards or TCVN. These technologies are significantly less expensive and easy to use.

2. Formal retail and export markets and the leading role of the private sector

Stakeholders in the formal retail market and export-oriented markets must leverage GS1 Vietnam's industry standards, which were adapted and published as TCVN. Additionally, firms with strong technical and financial capabilities and larger-scale operations are urged to consider deploying more advanced technologies, such as IoT-based sensors, blockchain, and customized mobile applications, to improve traceability and recall of unsafe foods. Automatic data collection and recording will assist in minimizing human error and time. These stakeholders may continue to use manual systems if they meet their current needs, but digital technologies are recommended for larger-scale processes involving much more complex processes. Apart from the minimum data required to comply with the 'one-step-back and one-step-forward' traceability principle, internal traceability should be applied to ensure a stronger connection between food products received and processed internally to identify potential vulnerabilities in internal stages. The decision to invest in common technologies and simpler systems versus advanced technologies and complex systems is entirely dependent on the needs and budget of the individual stakeholder. To encourage the adoption of digital traceability in the formal market, the government could draw on Korea's experience, beginning with larger companies and then rolling out to medium and small businesses (details are presented in Section 6).

Note: In research conducted in Italy on voluntary traceability in vertically integrated supply chains, the researchers contended that while supplier monitoring costs may increase to ensure compliance, implementing traceability was shown to reduce uncertainty among economic actors, enhance chain transparency and accountability, improve chain coordination, and reduce transaction costs and risk (Banterle and Stranieri 2008).

3. Government's role in facilitating and managing food traceability

The government has a crucial role in facilitating and managing food traceability, especially in helping small FBOs participate in food traceability and ensuring traceability systems developed by provinces and private sector companies are interoperable. At the provincial level, it is recommended that MOST issues guidance and standards on establishing provincial traceability systems to ensure data can be shared and traced for food safety management purposes. For the existing provincial portals, it is necessary to conduct a comprehensive review and assessments for recommending solutions to improve them to meet the national required standards, especially in data sharing and privacy protection, and apply the solutions to high-risk, high-value, and signature products. The government should have incentive policies to encourage small FBOs to join their provincial traceability portals, preferably through their groups or organizations. The government should also build competent and trained local teams with clear institutional arrangements to manage and perform regular inspections on traceability data provided by stakeholders.

At the national level, it is recommended that the government accelerates the implementation of the national traceability portal. The main function of the national traceability system is to connect public and private traceability systems, aggregate data and information, and manage food safety risks and traceability at the country level. It also serves as the platform for FBOs in provinces whose provincial traceability portals have not yet been developed.

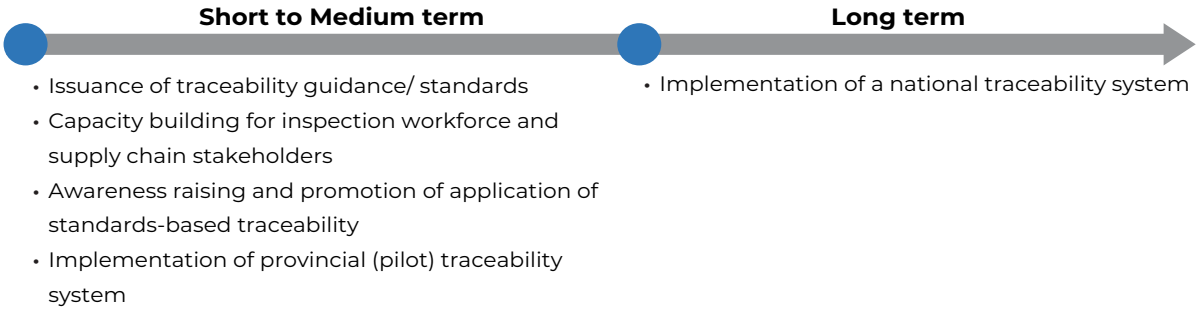
4. Private sector's role in investment and implementing traceability

The private sector plays the primary role in investment and implementation of traceability in both export and domestic markets. Its investments are usually motivated by consumer demands, risk mitigation, standards compliance, efficiency gains, or some combination of these incentives. In fragmented informal value chains such as in Vietnam, the private sector's cost-benefit analysis does not always add up to a strong enough business case for investment. To provide incentives for the private sector to invest more in food traceability, besides creating an enabling environment, the government should also assist in training and organizing small producers and small traders into groups to link them with private sector firms that have the capacity to implement and supervise food traceability across entire food value chains. It is important for private producers and traders to recognize traceability as an excellent tool to showcase their adherence to food safety standards, differentiate themselves in the market, safeguard from trade disputes, and better engage their consumers. These benefits would help enhance their competitiveness in the market, especially when there is increased demand for information and transparency about the sources of products.

Recommendations on intervention areas

Based on the review of good international practices, the following intervention areas are recommended: (a) issuance of traceability guidance/standards, (b) capacity building for inspection workforce and supply chain stakeholders, (c) awareness raising and promotion of the application of standard-based traceability, and (d) implementation of the provincial (pilot) traceability system.

Figure 3: Proposed short-term to medium-term intervention areas



- **Issuance of traceability guidance/standards:** It is recommended that MOST and its subordinate unit (for example, STAMEQ) collaborate with MARD and its subordinate units at the national level and with the Department of Agriculture and Rural Development (DARD) and its subordinate units at the provincial level to develop specific traceability guidance for high-value and high-risk products and those with geographic indicators.

  Note: Voluntary technical standards exist as TCVN and are encouraged to be developed further for specific high-value, high-risk, and signature products, including provincial specialties and those awarded geographic indications. Specific guidance for activities that are heavily featured in F&V supply chains and have the potential to apply digital technologies is also encouraged.

- **Capacity building for inspection workforce and supply chain stakeholders:** Central ministries and their provincial units should mainstream and conduct training on traceability requirements and enforcement of food safety regulations for the inspection workforce. Capacity-building activities may include holding national, regional, and provincial events and training courses for F&V supply chain stakeholders to enhance general technical knowledge, promote digital traceability technologies, and adopt national standards/ guidance.

- **Awareness raising and promotion of the application of standard-based digital traceability:** It is essential to raise awareness of all concerned government agencies and supply chain stakeholders, especially those involved in the informal sector with limited financial capacity.

- **Gender:** From farming to selling in informal marketplaces to preparing and cooking meals in street cafes and restaurants, women play a critical part in Vietnam's agri-food ecosystems. Women are also the leading buyers of fruits and vegetables in households. It

is recommended that the public awareness program should also include specific training for women on food safety and food safety handling awareness at home, in food service, and at markets, plus worker safety and food traceability.

- **Implementation of provincial traceability systems:** Provinces should develop their traceability portals targeting high-risk, high-value, and signature products and those with geographic indicators.

- **Implementation of the national traceability portal:** MOST is currently cooperating with all concerned central agencies and 63 provinces to accelerate the implementation of the national traceability portal with consideration for common and easily adopted technologies (such as barcodes, QR codes, and mobile applications). The following should be considered by the Vietnamese government:

    - Implementing a national traceability portal depends heavily on Vietnam's current technical resources, cross-ministerial collaboration, and capacity building with both the public and private sectors. For example, the public sector traceability system(s) implemented in China offers users both mobile applications and web dashboards to enter data into the system, which most supply chain stakeholders can easily obtain. In Vietnam, cooperatives, large-scale food companies, formal distribution channels, and so on, can adopt such technologies, but small-scale farmers will require training and technical support.
    - Implementing a national traceability system would require the government to build competent and trained teams with clear institutional arrangements to manage and regularly inspect traceability data provided by stakeholders.

      Note: Digital transformation is often incorrectly discussed as the diffusion of new and disruptive technologies. However, preparing *people* and *organizations* for the transformation to digital business model is essential as successful digital transformation lies at the intersection of technology, organizations, and people (Queiroz and Fosso-Wamba 2022).
    - Raising awareness of related government agencies and supply chain stakeholders regarding the national traceability portal is essential to increase the adoption rate. As GS1 Vietnam is tasked with implementing the VNTP, this significantly benefits capacity building with industry players, including food cooperatives, organized retail trade, food processors, and solution providers, as many firms are already members of GS1.
    - Consumer education on F&V safety and traceability is highly recommended, as they will be primary users of the VNTP, once it is operational. Recent research (Tran et al. 2022) in Vietnam has positively indicated that consumers are willing to pay a premium for products with labels (including Vietnam Good Agriculture Practice [VietGAP]) and traceability data accessible via QR codes. However, further studies are needed to better understand the historical, cultural, and socioeconomic relevance of wet market purchasing traditions and willingness to pay for traceability.

- It would take time to fully implement a traceability system at the national level. In the short term, pilot traceability systems should be implemented at the provincial level targeting signature products, including those that are provincial specialties (including products under the one commune-one product [OCOP] program), those awarded geographic indications by the government of Vietnam or other countries, or those that are of high risk and high value.
- It is highly recommended that the national and provincial traceability systems be based on interoperable industry standards that facilitate compliance with regulations and data exchange between different systems. Ultimately, the national system must connect to multiple regional traceability systems, and the EPCIS standard adopted by the national traceability portal facilitates this data exchange. For example, a shopper in Hanoi can use a single-user interface (such as a mobile phone application or web interface) linked to the national system to scan and query a product grown in the Mekong and seamlessly access traceability data from local or regional systems.

SECTION 1. INTRODUCTION

Photos: @ART STOCK CREATIVE/Shutersctock

1.1. Background

For years, food safety has been a critical issue in Vietnam. Food safety and hygiene play an important role in daily life of society, and ensuring food safety is now an urgent task to improve people's health, promote socioeconomic development, and expand international relations. From January to November 2021, Vietnam recorded 81 cases of food poisoning, infecting 1,942 people and causing 18 fatalities (MOH 2021). The analysis results of food poisoning cases recorded from 2010 to 2020 by the Department of Food Safety (under the Ministry of Health [MOH]) showed that the main causes of poisoning were microorganisms (accounting for 38.7 percent of the cases), natural toxins (accounting for 28.4 percent of the cases), and chemicals (accounting for 4.2 percent of the cases) (MOH 2020). One of the major challenges of food safety management in Vietnam is the dominance of small-scale production, which is accompanied by many risks due to the practices of farming, production, distribution, and consumption as well as the habit of overusing pesticides. Besides, the prevention of smuggled and counterfeit food is still limited. One important element in managing food safety is food traceability, which involves the capacity to trace (back) food, feed, and food ingredients to their origins and to track these elements forward into final products and distribution channels.

The purpose of this study was to assess the current state of existing traceability systems in Vietnam's fruit and vegetable (F&V) value chains, examine pertinent policies and regulations, share international good practices and explore their potential applicability to Vietnam, and examine the current legal and institutional framework governing agri-food traceability in Vietnam and some major export markets (for example, the European Union [EU], Italy, China, and the Republic of Korea [Korea]). The study identified potential intervention areas and made recommendations to policy makers and food business operators (FBOs) in Vietnam regarding the implementation of digital traceability systems and the regulatory environment that facilitates their use. The interventions aim to contribute to lowering the incidence levels of specific hazards in perishable products in the F&V value chains, increasing FBOs' compliance, enhancing consumer awareness of food safety, and strengthening the food safety regulatory system. Additionally, the interventions would contribute to re-establishing public confidence in the quality and safety of Vietnamese agri-food as well as its current food safety oversight regime.

1.2. Objectives and scope

1.2.1. Objectives and focus of this study

The study's objectives were to evaluate the current state of traceability systems in Vietnam's F&V value chains and recommend ways to strengthen them. Additionally, the study will inform the World Bank on how to strengthen its dialogue with the government on food traceability and food safety issues.

This report focuses on promoting digital food traceability in F&V value chains in Vietnam because (a) they are perishable and of high food safety risks and (b) they have significant potential for both domestic consumption and exports but face several challenges in creating added value. Vietnam has favorable natural conditions in terms of land, soil, and diverse climate for the cultivation of fruits and vegetables. As of 2020, the country has 854,000 ha of vegetables of all kinds, with an annual output of about 14.5 million tons and 910,000 ha of fruit trees of all kinds, with an annual output of about 9.5 million tons (MARD 2020). However, the current production, processing, and preservation of F&V products have not fully utilized their potential (for example, the rate of processed fruits and vegetables is only 10 percent, poor preservation and post-harvest losses are over 20 percent, and food safety is still a significant issue). The Ministry of Agriculture and Rural Development (MARD) has developed a policy[6] decision document for the development of the F&V processing industry in 2021–2030, which identifies traceability as one of the key solutions to enhance and ensure the quality and food safety of F&V supply chains in Vietnam.

1.2.2. Scope of work

Three major tasks were accomplished during this study:

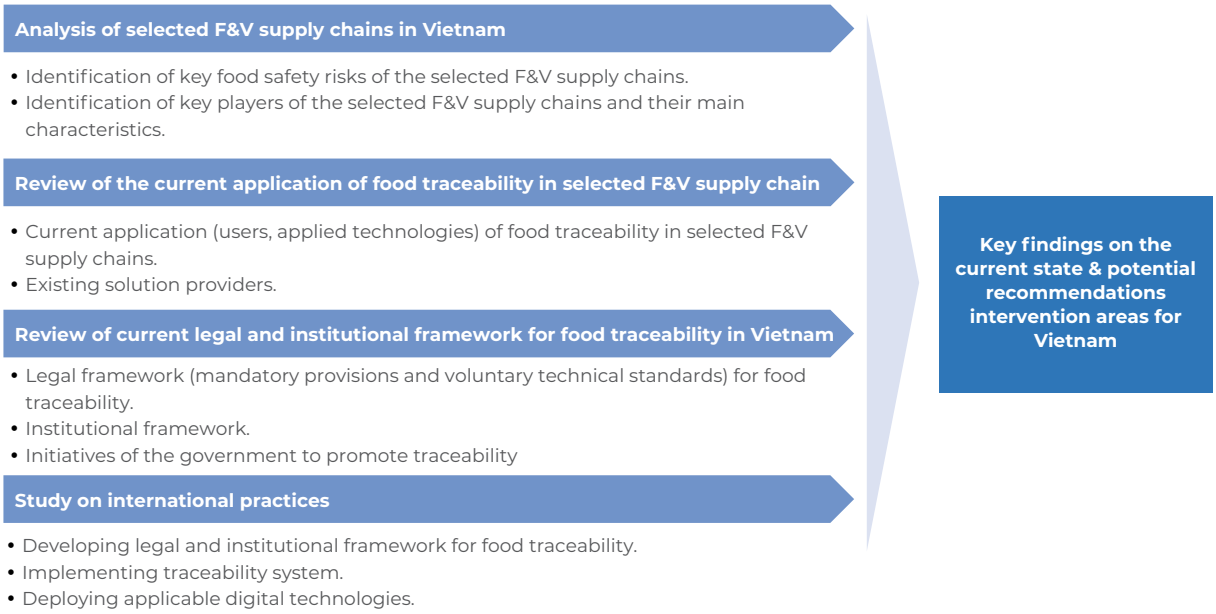
- Task 1: Review the current state of existing traceability systems in Vietnam's F&V value chains and relevant policies and regulations.
- Task 2: Review international experiences and their potential applicability to Vietnam and make recommendations and intervention areas for Vietnam.
- Task 3: Disseminate knowledge and link technology providers with potential clients and policy makers.

1.3. Methodology

Data and information were collected via desk research; interviews with stakeholders; consultations with local experts and subject-matter resources from Ernst & Young Vietnam Ltd. (EY); and feedback received from participants during two national workshops and three focused training courses with local government agencies, research institutions, and food operators.

6 https://thuvienphapluat.vn/van-ban/Thuong-mai/Quyet-dinh-417-QD-TTg-2021-phat-trien-nganh-che-bien-rau-qua-giai-doan-2021-2030-468479.aspx

Figure 4: Methodology



The report is structured as follows:

- Overview of F&V supply chains in Vietnam, including key players and key food safety risks
- Current application of food traceability in select F&V supply chains
- Current legal and institutional framework for food traceability in Vietnam
- Gaps identified and challenges faced by Vietnam F&V supply chain stakeholders when performing food traceability
- International experiences (EU, Italy, China, and Korea) in (a) developing a legal and institutional framework for food traceability, (b) implementing traceability systems across Vietnam and some export markets, and (c) deploying applicable digital technologies into traceability systems
- Proposed recommendations and intervention areas for Vietnam.

SECTION 2. TRACEABILITY

Photos: @MONOPOLY919/Shutersctock

2.1. Introduction to traceability

Traceability is a foundational requirement of a robust food safety management system and is mandated by regulatory frameworks to ensure consumer health and safety. Furthermore, a traceability system underpins numerous common food product claims, such as organic, halal, and grass-fed (Caveen et al. 2021).

2.1.1. Drivers of traceability

There are many drivers of traceability in the food industry, and they vary by product and market. The broad categories of drivers are captured by Aung and Chang (2014) in figure 5. In addition to these drivers, demand for enhanced traceability in global food chains is increasingly driven by environmental, social, and governance concerns, commonly referred to as the ESG factors. Regarding competitive advantage and brand protection as drivers in the Aung and Chang framework, firms apply and promote traceability of food origin (also called food provenance) and transparency of worker conditions and processing methods to differentiate their products and supply chains from those that are at risk of modern slavery, including forced labor and child labor.

Food importing firms must also comply with their domestic laws and regulations on supply chain due diligence. The United Kingdom, New Zealand, and the US state of California have antislavery supply chain legislation. In Europe, Germany passed a supply chain due diligence act in June 2021 mandating that large firms (defined as German-based firms with 3,000 employees) must prove that no slave or child labor, deforestation, or habitation loss occurred at any tier in their product supply chains. The act is effective from January 1, 2023, and mandates that firms establish governance processes to identify, assess, prevent, and remedy various human rights and environmental risks and their impacts on their global supply chains and internal business operations.[7]

Figure 5: Drivers of traceability

Source: Aung and Chang 2014.

7 German supply chain due diligence act: https://www.sedex.com/germanys-new-supply-chain-due-diligence-act-what-you-need-to-know/

2.1.2. Traceability definitions

There are many definitions of traceability provided across industry, academia, international standards agencies, and regulations.

- ISO 9001:2015 "Traceability is the ability to trace the history, application, or location of an 'object' (e.g., product). When considering a product or a service, traceability can relate to: (i) origin of materials and parts; (ii) processing history; (iii) distribution and location of the product or service after delivery."[8]
- Vietnam Law on Food Safety Clause 28, Article 2: Traceability is defined as "tracing the process of forming and circulating food."
- National technical standard TCVN 12850:2019: "Traceability is the ability to identify a product/service unit throughout each stage, time, location of production, processing, storage, transportation, distribution, and selling processes."

Table 1 by Aung and Chang (2014) compares several definitions of traceability.

Table 1: Comparison chart for selected definitions of traceability

Define in	Traceability?	Trace what	Trace how	Trace where	Trace why	Trace when
ISO 8402	Ability to trace	An entity (origin/ history/location)	By means of recorded identification	-	-	-
ISO 9000	Ability to trace	An entity under consideration (origin/history/ location)	-	-	-	-
EU Regulation (178/2002)	The ability to trace and follow	A food (or ingredients of food)	-	All stages of supply chain	-	-
CAC	The ability to follow	A food	-	All stages of supply chain	-	-
Wilson and Clarke (1998)	Information necessary about a product	A food crop (i.e. Agri-food)	-	From the grower to the consumer's plate	-	-
Dalvit et al. (2007), McKean (2001)	A system able to maintain records about products	Animal or animal products	-	From farm to retailer	-	-
Olsen and Borit (2013)	The ability to access any or all information	A food	By means of recorded identification	Entire life cycle of food	-	-
Bosona and Gebresenbet (2013)	Part of logistics management that capture, store, and transmit adequate information	A food, feed, food-producing animal or substance	-	At all stages in the food supply chain, traced upward, and tracked downward	For safety and quality control	At any time required.

Source: Aung and Chang 2014.

8 Digitalisation of Conformance and Accreditation Processes (2022), p. 8. https://nata.com.au/supplychain/

2.1.3. Traceability standards: GS1

GS1 is a global, not-for-profit standards body headquartered in Brussels, Belgium, with federated, independent offices in more than 115 countries.[9] GS1 is assigned by the International Organization for Standardization (ISO) as the single global issuing agency for object identifiers in supply chains. Objects include trade items (products), shipping containers, returnable assets (for example, totes, pallets, and containers), and locations. GS1's role as the issuing agency is to digitally manage and control all numeric identifiers within a range of 0–9 and to ensure there is no possibility of collision between object identity systems.

Note: If a proprietary code is embedded in a non-GS1 standards based quick response (QR) code or radio frequency identification (RFID) or near-field communication (NFC) tag, it does not replace the GS1 object identifier (global trade item number, GTIN) as the globally recognized product (object) identification.

GS1 Vietnam is a sub-department of the Directorate for Standards, Metrology, and Quality (STAMEQ) within the Ministry of Science and Technology (MOST) and manages the assignment of GS1 global company prefixes (GCPs) to Vietnamese companies, starting with the digits '893'. GS1 Vietnam has 30,000 active members (August 2022, 50 percent are in the food industry). Based on the assigned identifiers (GCPs), companies formally registered with GS1 Vietnam can allot globally unique and interoperable identifiers to products, assets, locations, and services. As of August 2022, the GS1 Vietnam national product catalog contained 860,000 registered products, 50 percent of which are from the food industry.

2.1.4. Key traceability concepts

According to GS1 standards, a robust traceability system includes a series of tools and technologies to (a) identify products, locations, and services; (b) capture and record the data; and (c) share the data and information.

These functions are performed with the support of

- Documented rules, procedures, and processes; and
- Software, hardware technologies, and human resources.

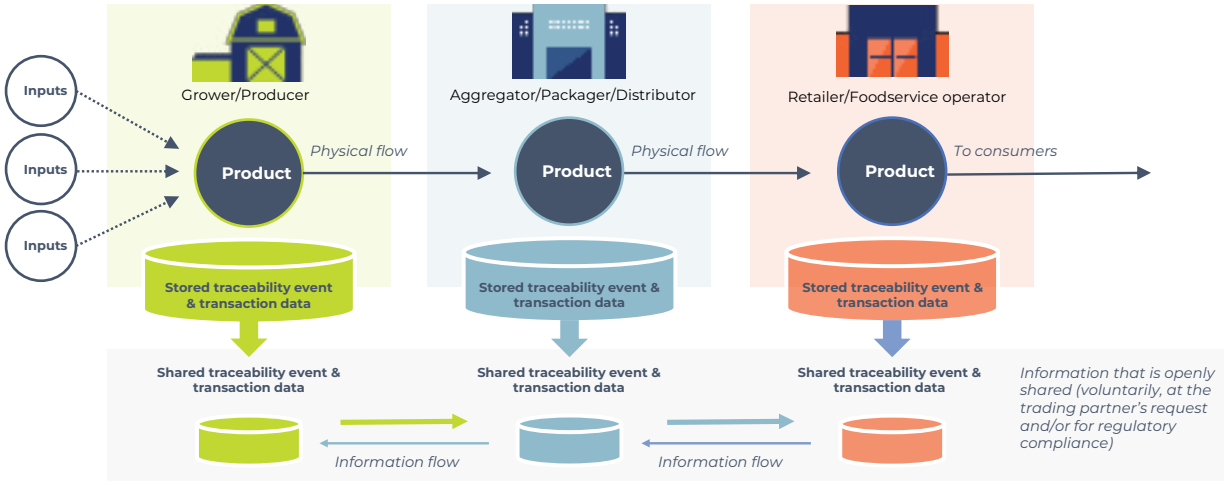
2.1.5. Full chain traceability

Full chain traceability applies digital, physical, and mobile technologies to achieve higher levels of granularity and transparency in a product supply chain. The GS1 linear barcode contains the product identity (GTIN) and is used for business-to-business and point-of-sale (POS) purposes. A secondary data carrier (for example, a QR code) is often applied to a traceable object, such as a carton of milk. Subsequently, a consumer may scan the QR code using a mobile device (or engage through a website) and trace the history of the product including its origin (often referred to as the product provenance), method of production and harvest,

9 Note: GS1 is not an acronym and is often misrepresented as Global Standards One.

labor conditions, and a wide range of other attributes that the brand owner may find helpful to differentiate the brand to consumers. Figure 6 represents an overview of the physical product flow and information flow in a typical food chain.

Figure 6: F&V product and data flows for end-to-end traceability



Source: GS1.

2.1.6. Internal and external traceability

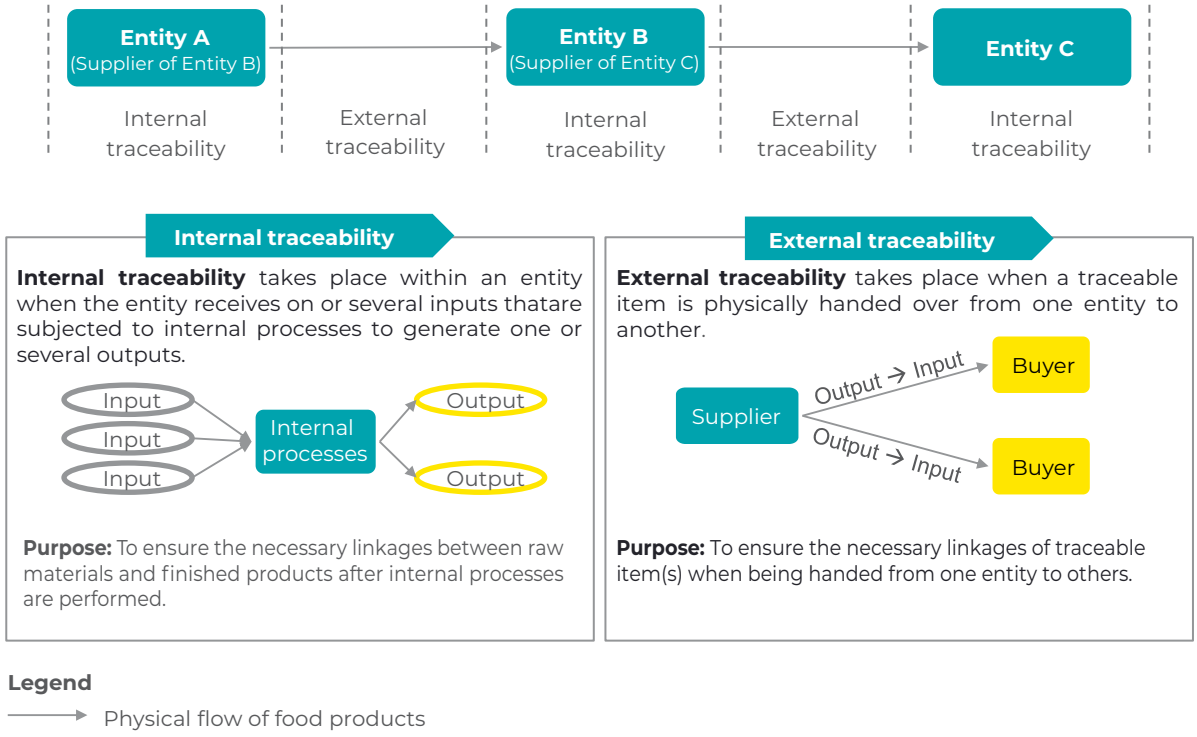
At a more granular level, internal traceability takes place within an entity when the organization receives inputs (for example, raw materials) that are subjected to internal processes to generate outputs (for example, finished product).

External traceability requires that all traceable items are globally and uniquely identified when physically distributed between trading partners. Figure 7 provides detailed descriptions.

Note: An important aspect to consider is the potential sensitivity of the traceability data that an organization may choose to share with other parties. A distinction can be made between internal data —data not suitable for sharing with other parties, for example, due to commercial or privacy reasons—and external data—data suitable for sharing with other parties if certain predefined conditions are met.[10]

10 GS1 Fresh Fruit and Vegetable Traceability Guideline. Release 2.0 Ratified Feb. 2021

Figure 7: Internal and external traceability



Source: EY and GS1 Global 2021.

2.1.7. Traceable objects

At the most fundamental level, the GS1 system of standards can be thought of as a set of industry-developed standards that help organizations identify, capture, and share information about traceable objects and comply with regulatory requirements for traceability and recall. Organizations gain efficiencies and interoperability across disparate technology platforms when industry standards are applied consistently.

A traceable object is a physical object in a supply chain whose traceability needs to be documented and recorded. Every firm operating in a supply chain must determine what needs to be traceable. This is commonly referred to as the 'traceable item'. From a GS1 standards perspective, a traceable item can be either

- A product or other trade item (for example, case/carton);
- A logistic unit (for example, pallet and transport container); and
- An asset (for example, reusable tote, crate, and bin).

Trading partners generally agree on what the traceable item is, how it should be traced, and what information is to be captured and shared. This ensures that trading parties are tracking the same elements and the one-step-up/one-step-down traceability concept called for in regulations and standards can be met.

2.1.8. Critical tracking events for the fresh produce industry

For Vietnamese exporters, it is important to note that the US Food and Drug Administration (FDA) adopted a new traceability rule mandating the capturing and sharing of critical tracking events (CTEs) and key data elements (KDEs) for certain domestically produced and imported fresh produce. The traceability rule will be effective from January 20, 2026, for firms from Vietnam exporting to the US. For an overview of the rule and additional resources, see https://www.fda.gov/food/food-safety-modernization-act-fsma/fsma-final-rule-requirements-additional-traceability-records-certain-foods.

This section is mainly replicated from the GS1 traceability guideline for fresh fruits and vegetables to retain its accuracy and consistency:

- Since the strategic concept of CTEs was first introduced in 2009, there has been growing consensus on its utility in documenting the path of a product through the supply chain. CTEs are activities in the supply chain that should be documented by the capture of key information for each event to accurately track and trace product movement up or down the supply chain. Introduced by the Institute of Food Technologists, CTEs are defined as "those instances wherein the product is moved between premises, is transformed, or is determined to be a point where data capture is necessary for effective tracing." Typically, these events involve a product's transformation, transportation, or depletion.
- To ensure that the chain of traceability is not broken, each trading partner responsible for one of these events should record key information about each event and be prepared to share it with their trading partners or government authorities upon request. The information to be captured and shared at each CTE is known as KDEs and consist of the who (the party involved), what (product ID or lot number), when (date/time), where (location), and why (business process such as shipping).
- There are six CTEs for parties in the fresh produce supply chain and these events are organized into four types as shown in table 2.

Table 2: Definitions of CTEs

CRITICAL TRACKING EVENT DEFINITIONS		
Beginning of life – type event *Events that typically support the introduction of an item in the supply chain*	Beginning of life (B)	An event where a new item is introduced into the supply chain (e.g. Harvesting a specific batch/lot of apples).
Transformation – type event *Events that typically support internal traceability within the four walls of a supply chain company*	Transformation (T) Input/Output	An event where one or more materials are used to produce a traceable product that enters the supply chain. Note: materials used to produce products for immediate consumption by consumers are reported as consumption events
Transportation – type event *Events that typically support external traceability between supply chain companies*	Shipping (S) event	An event where traceable product is dispatched from a defined location to another defined location
	Receiving (R) event	An event where traceable product is received at a defined location from another defined location
Depletion – type event *Events that capture how traceable product is removed from the supply chain*	Consumption (C) event	An event where a traceable product becomes available to consumers (point of sale or prepared)
	Disposal (D) event	An event where a traceable product is destroyed or discarded or otherwise handled in a manner that the product could no longer be used as a food ingredient or become available to consumers.

Source: GS1 guideline.

2.1.9. Farm to Fork

Traceability is frequently misunderstood and interpreted in a variety of ways by diverse stakeholder groups (Olsen and Borit 2013). For instance, some technology solution providers may assert that their solution enables farm-to-fork or sea-to-plate traceability. This is difficult to accomplish, and in many cases, it may be impossible to achieve without the collaboration of all stakeholders to share data. For this report, traceability must encompass both the ability to trace back to a product's origin and to track forward through its distribution (for example, to retail POS or food service consumption). Traceability of food products to a consumer's home address should not be the aim of traceability solutions and is not a regulatory requirement. Further, it is generally not permitted to capture personally identifiable information (PII) under personal data privacy protection laws, unless the consumer opts for a retailer's or wholesaler's loyalty program or bought the food product through e-commerce channels that legally capture and store their PII.

Note: US-based wholesaler Costco is an example of a firm that can claim farm-to-fork traceability due to its loyalty-based business model that permits it to legally capture and store PII and rapidly warn its loyalty members if a product they bought is unsafe and being recalled.

To elaborate on the above points, when a consumer buys a food product using cash or a debit card, the transaction and his/her identity is anonymous, his/her home address is unknown, and thus, traceability stops at the retail POS. However, when a consumer is a member of a loyalty program or purchases the food online, the 3Ps necessary for traceability are legally stored and may facilitate effective farm-to-fork traceability. The 3Ps are 'Product Identification' (P1), such as the GS1 product identity or GTIN which is the number embedded in a barcode; 'Party identification' (P2) in industry standard language or the consumer's name in the farm-to-fork concept; and 'Premises identification' (P3) or forwarding location, such as the consumer's home address. Without the 3Ps, traceability stops at the retail POS. It should be noted that the application of a QR code on a food product does not solve the traceability or farm-to-fork concern. Although a QR code may permit the trace-back function (fork to farm), which is one component of the traceability function, it simply links a consumer to a website and does not capture the 3Ps needed for traceability. In this regard, it may be more useful for industry stakeholders to promote farm-to-fork transparency, where the trace-back function can provide access to the product history and its journey versus farm-to-fork traceability. However, for this process to be successful, all parties in the supply chain must agree to make the information available and discoverable and this drives the need for industry standards such as the GS1 system of standards which enables interoperability.

2.2. Characteristics of a good food traceability system

This section provides a description of an effective/ideal food traceability system, which is assessed based on the following six characteristics: (a) components that fully cover traceability functions, (b) operational ease, (c) interoperability, (d) ability to access and protect stakeholder Information, (e) reliability, and (f) compatibility with regulatory provision.

2.2.1. Functions of the traceability systems

A complete traceability system covers all the following functions:

- Identifying traceable objects, parties, and locations
  - A traceable object is an object for which there is a need to record and retrieve information about its history, application, or location. Examples of traceable objects include products (for example, consumer goods, packaged food, and electronic devices), logistic units (for example, palletized goods and shipping containers), and returnable assets (for example, pallets, totes, and containers).
  - A party (hereafter referred to as a supply chain stakeholder) is an entity involved in the handling, temporary custody (for example, logistics or shipping firm), or ownership of the objects moving through the supply chain.
  - Physical locations are critical to understanding the path an object takes across a supply chain. It may be a manufacturing site, a specific production line, a warehouse, a farm, field within a farm, and so on.
- Automatically capturing (through a barcode scanner or RFID reader) the movements or events involving an object
- Recording and sharing the traceability data, either internally or with members in a supply chain, so that visibility of what has occurred may be achieved.

For example, a strawberry traceability system generates a GS1-128 barcode label for a case level (box or tote) with a GTIN, lot number, harvest date or pack date or best if used by/best before date, name and variety of product, grade, packaging size, and origin. When the case is moved through a logistics system, the information embedded in the barcode can be scanned and captured using a barcode reader. The information is uploaded to a database from which information can be shared within the organization or with other stakeholders in the supply chain. An example of an updated industry-wide agreement (from 2021) on case labeling for fresh fruits and vegetables can be seen in figure 8 from the North American Produce Traceability Initiative. In this situation, cases are labeled with a GS1-128 label.

Figure 8: Sample case label

Source: GS1 US 2021.

2.2.2. IT infrastructure architecture of the traceability system

A typical traceability system architecture comprises four layers: the front-end layer, the middleware layer, the data and protocol layer, and the infrastructure layer. Multiple technology components interact to perform traceability functions beneath each layer. Different technology components will be used depending on the organization's size and the purpose of the traceability system.

Everything that the users see and interact with is considered the front-end layer. For example, stakeholders can use mobile apps to input relevant data in the production processes or to scan the traceability codes for required information processing. Additionally, they can use web-based dashboards to monitor and track supply chain performance by tracking critical events, such as the movement of pallets between facilities.

The middleware layer is the software between an operating system and the applications running on it. It provides common services and capabilities to applications beyond those provided by the operating system. For example, stakeholders might implement enterprise resource planning (ERP) and information and communication technology (ICT) cloud systems to enable the transmission of data and databases between the front-end layer and the data and protocol layer. They also can utilize the decision support systems to support the decision-making activities based on their input data.

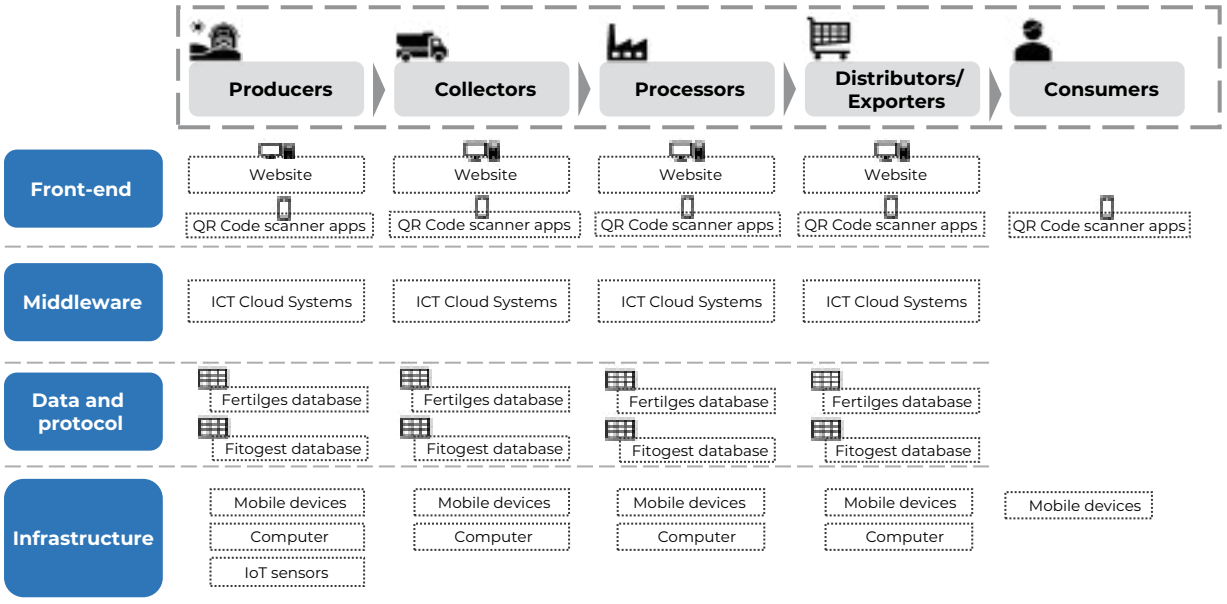
The data and protocol layer provides a framework for data storage, retrieval, and sharing. For example, supply chain stakeholders can store their data using blockchain technology with a defined framework of the blockchain (a blockchain is one example of distributed ledger technology [DLT] and it should not be implied as critically necessary in the food chain as its usage is dependent on the use case).

The infrastructure layer provides the platform that supports the entire traceability system. It includes either physical or virtual components that allow the flow, storage, processing, and analysis of data. It is the basis of the foundation for the first three layers mentioned above.

- Nodes and blocks are part of the blockchain infrastructure.
- Mobile devices (for example, cell phones) are needed for the download and usage of mobile applications.
- Internet of things (IoT) sensors could also be part of an infrastructure for a traceability system that supports an automatic collection of data.
- RFID scanners are a physical component that supports the use of RFID tags/labels.

Figure 9 presents an example of a digital traceability system architecture with the type of system/technology referred to and its corresponding infrastructure layer.

Figure 9: Architecture and components of a traceability system



2.2.3. Operational ease

Operational ease describes how easily users can use the system to deliver the three functions of a traceability system (mentioned in Section 2.2.1). Specifically, the system will have to make it simple for its users to perform the following activities:

- **Set up the system**: The system and its information technology (IT) components need to be set up before operation. It may contain mobile applications installation, registration for barcodes, RFID system installation, and so on. Some IT components can be set up by the users, while others require technical support from experts. However, to ensure the ease of setting up, these IT components should provide users with detailed guidance for installation, make the set-up process as simple as possible, or provide users with support from the IT technical team.
- **Identify the traceable objects**: The traceability system needs to provide each object with a globally unique identifier. To make the process easier, the system should provide a form containing data fields (that record the information) and identifiers that are automatically generated. It should be noted that there is a difference between a serialized identifier in highly regulated sectors such as pharmaceuticals and one in food items. In the pharmaceutical supply chain, regulations require that every product has a unique serial number. In the food industry, there is no regulatory requirement to serialize; hence, the industry assigns the same GTIN to a class of products. For instance, every can of Coca-Cola of the same size and flavor will have the same GTIN (object class identifier) and will be distinguished from other cans of Coca-Cola by its batch or lot number or other code such as a use-by date.
- **Capture the information**: Some movements or events involving an object will be captured by electronic scanners or readers. These devices should be easy to use.

- **Record the information when objects are moved through the supply chain**: At each stage, information from the previous party needs to be recorded and updated. This recording process will be easier if technology such as a barcode or IoT sensors is applied. Product information is encoded by the barcode and then recorded using a scanner.
- **Upload the information to a platform that enables data storing and sharing**: For manually recorded data, an example of an easy upload process is that after filling information into a form, users only need to click a 'Save' button and everything is uploaded to the database, from which it is shared with related stakeholders.
- **Search for information in the platform**: A traceability system provider can make the information search functionality convenient by designing a user-friendly front-end, ensuring that the search function works well, and by providing guidance for users.

2.2.4. Interoperability

Interoperability refers to the ability of two or more technology platforms or systems to share information, such as the exchange and transfer of relevant traceability information to the next stage of the supply chain.

According to GS1 standards, three requirements should be met to enable interoperability between different systems: identification requirements, automatic data capture requirements, and data sharing requirements. The GS1 Electronic Product Code Information Services (EPCIS) standard for data interoperability has been adopted by many large global solution providers and was adopted in 2015 by ISO as its data interoperability standard.

2.2.5. Identification requirement

Stakeholders must recognize the traceable objects, parties, and locations using globally unique identifiers to identify a product throughout the supply chain.

A traceable object, party, or location with a unique identifier can be distinguished from others of different systems. Widely used standardized identifiers enable the information to be shared with other systems. These are the key enablers to allow tracing back and forward.

a. Identification of traceable objects

To enable tracing back and forward in a supply chain, there must be an agreement between supply chain stakeholders to identify the traceable object.

In the fresh fruit and vegetable supply chain, GS1 provides several 'keys' including a GTIN (product ID such as on a can of soup), a serial shipping container code (SSCC), global shipment identification number (GSIN), global individual asset identifier (GIAI) for assets, and global returnable asset identifier (GRAI) on pallets, cases, or totes to identify the traceable objects. Details are included in appendix C and at https://www.gs1.org/standards/id-keys.

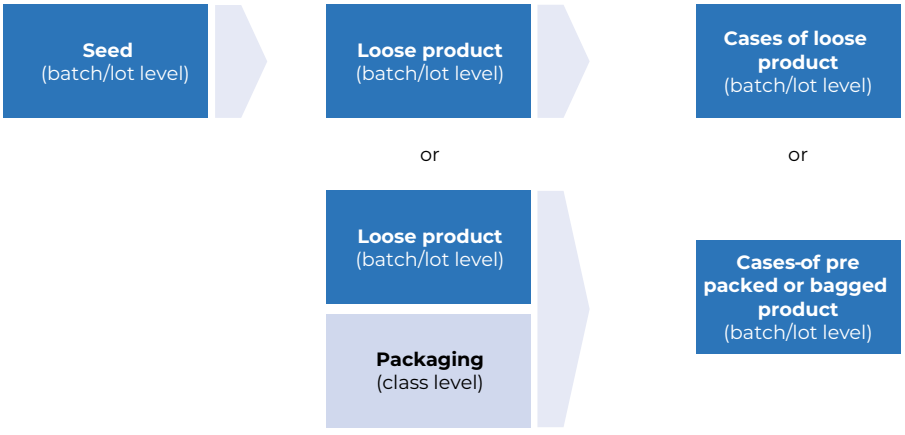
GS1 standards also provide a choice regarding the identification level of trade products, leading to varying degrees of precision of traceability that can be achieved, including grower-

specific trade item level (GTIN), batch/lot level (GTIN + batch/lot number), and instance level (GTIN + serial number - a combination also known as serialized GTIN or SGTIN). Details are provided in appendix C.

Based on the objective of the traceability system and the characteristics of the supply chain, the supply chain members determine the right level of identification. For example, products associated with high food safety risks will always be identified at batch/lot or instance level.

In F&V supply chains, companies often apply a combination of identification levels. For example, in a fresh vegetable supply chain, there are several types of traceable objects at different processing stages, including seed, loose produce, and packed produce. Each type of traceable object has an identification level as presented in figure 10.

Figure 10: Identification levels in a fresh vegetable supply chain



Source: Fresh Fruit and Vegetable Traceability Guideline, GS1.

b. Identification of traceable parties

Examples of parties in the supply chain might include a manufacturer, distributor, logistics carrier, or retailer. To understand the full context of traceability, knowing who played a role and their relationship with each other in the chain is essential.

Under GS1 standards, identification of trading parties (for example, businesses) can be accomplished with the registration and issuance of a unique GCP. In some cases, especially when identifying individuals involved, the global service relation number (GSRN) can also play a role. Under GS1 standards, physical locations defined by an organization for its business operations can be identified using the global location number (GLN). For instance, if a farmer has three fields with crops, each field can be assigned a different GLN to capture the uniqueness of seeding, cultivation, and harvesting related to a variant of a crop in one of the fields. Similarly, a GLN can be assigned to a facility or warehouse and to locations within a facility or warehouse. Details are provided in appendix C.

2.2.6. Automatic data capture requirements

Data should be encoded using a common language, such as the GS1 barcode or GS1 EPC/RFID, so it is readable when shared among different systems. The system should use scanners/readers that can read or scan industry standard barcodes/RFID/NFC tags. When these common languages are applied, information can be recorded and shared easily between systems. For example, when a company receives a product batch from its supplier, a barcode containing product information updated by the supplier can be captured easily using an appropriate scanner.

2.2.7. Data sharing requirements

For data sharing requirements, the traceability system needs to allow traceability data to be provided to other parties and to be received from other parties within the required time frame using effective and secure mechanisms. Moreover, traceability data need to be retained and remain accessible to authorized parties to meet the traceability requirements of all industry stakeholders and regulators.

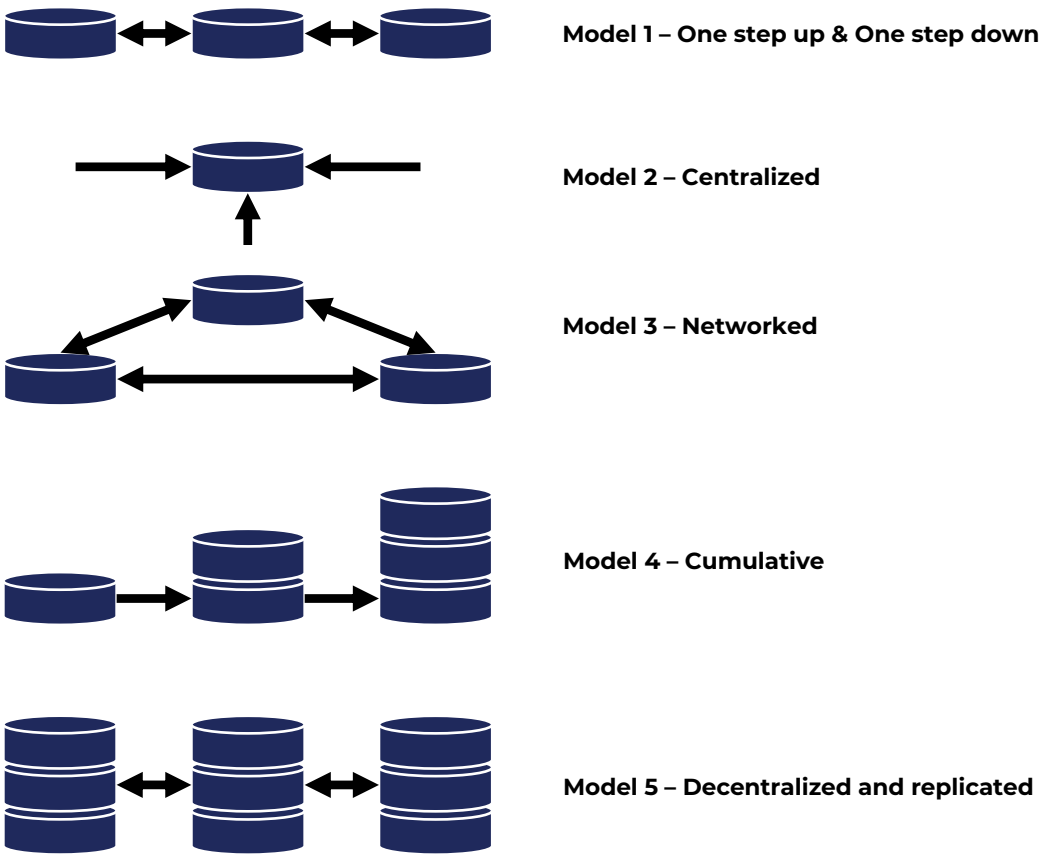
2.2.8. Access and protection of stakeholder information

Access and protection of information refer to securing the data to prevent unauthorized access that could lead to data loss, data theft, or unauthorized data modification.

2.2.9. Different models of stakeholder information storing and sharing

According to GS1, there are five different models of data storing and sharing in which stakeholders can access and protect information in different ways. All the models can selectively restrict access to the data exchanged so that it can be accessed only by people demonstrating a reasonable need to know. The five models are shown in figure 11 and briefly described below.

Figure 11: Different types of traceability databases



Source: GS1 global traceability standard - sharing of traceability data.

- Model 1 – One-step-up and one-step-down: Parties store traceability data in their own systems. Information requests are exchanged between immediate trading partners upstream or downstream.
- Model 2 - Centralized: Parties share the traceability data in a central repository and send their requests for information access.
- Model 3 - Networked: Parties store traceability data in their own systems and stage it in a way that enables all stakeholders (not only immediate trading partners) to query the data.
- Model 4 - Cumulative: Traceability data are systematically enhanced and pushed forward to the next party in the chain in parallel with the product flow. It enables sharing of upstream data with parties further downstream, but not the opposite. This model applies to highly regulated sectors such as pharmaceuticals, tobacco, and others.
- Model 5 - Decentralized and replicated: All stakeholders involved in the network keep a local copy of all data. This model is typical for blockchain technology.

2.2.10. Requirements to ensure the ability to access and protect stakeholder information

a. Prevent unauthorized access from other parties

The choice of model is determined by the objective of implementing the traceability system and the stakeholders involved in a particular supply chain. Regardless of the model used, the system must ensure the accessibility and security of stakeholder data.

- For models 1 to 4, which involve bilateral communication between an information requesting party (querying party) and an information providing party (which may be the original contributor of the data or a shared repository holding the data), privacy must be ensured via different measures. For example, mutual authentication is a secure process in which both parties authenticate each other's identities before communication occurs (Techopedia 2014). Another measure is the use of secure communication channels, which provides an encrypted form of communication between parties.
- Model 5 can hide the meaning of sensitive data either by encrypting such data or by storing a 'hash' value in the ledger. This 'hash' value is a series of characters that present the data uniquely without disclosing its meaning.

Of these five models, model 5, the decentralized and replicated model, is the most robust in terms of data security. According to GlobalSign, a leading provider of trusted identity and security solutions, to enhance data security, a system should be able to limit the number of parties with access, limit access to sensitive data, and update and back up data regularly to prevent data loss (Buttler 2017). Model 5, which often accompanies blockchain technology, can fulfill these three functions. It limits access to sensitive data by storing data in a hashed or encrypted manner, provides automatic data updates, and ensures data backup by allowing all stakeholders in the network to keep a local copy of all data. The four remaining models cannot perform these functions.

b. Commit to preventing unauthorized usage of users' data

The system provider must comply with data privacy regulations and commit not to disclose or use users' data for their own purposes without permission.

For example, if an organization processes the personal data of EU residents or citizens or offers goods or services to such people, it must comply with General Data Protection Regulation (GDPR)—Europe's data privacy and security law (EU GDPR 2018).

Vietnam has regulations for personal data protection. Article 17, the law on cyber information security, states that personal information processing organizations have the following responsibilities: (a) collecting PII after obtaining consent on the scope and purpose of such collection and use; (b) using the collected personal information only for a stated purpose obtained by the subject's consent; (c) not providing, sharing, or distributing PII that they have collected to a third party, except with the consent of the subject or upon requirements of the competent state authority.

2.2.11. Reliability

Reliability is a term that refers to the degree of data integrity that ensures the accuracy and availability of data. It refers to the degree of precision with which a system can track the movement of a traceable object. To ensure reliability, GS1 mandates that the system meets three requirements, which are detailed in the subsections below.

Complete identification

The system should be capable of identifying all three of these components, including objects, parties, and locations. With such comprehensive identification, the system can track the movement of a specific product, increasing its reliability. A traceable object is a physical or digital object that can and must have its supply chain path determined. A manufacturer, a broker, a distributor, a carrier, or a retailer are all examples of supply chain parties. To fully grasp the context of traceability, it is critical to understand who played a role and, in some cases, their relationship with one another along the chain. A traceability location is a physical area that has been designated for being included in the scope of a traceability system.

Automatic tools for capturing and recording data

When data are captured and recorded manually, there is a risk that the person in charge will enter incorrect information, resulting in the recording of an incorrect product (and/or quantity). However, with automatic data capture and recording tools such as sensors or barcode/RFID tags, scanners automatically capture information about the production stage or the products. There is little chance that it will be incorrectly recorded.

Data availability

The system should ensure that data are accessible whenever it is required. Data should be securely stored in the data and protocol layer as well as in middleware. Additionally, the front-end website and applications should be stable, with little or no chance of collapsing and disrupting user interaction.

2.2.12. Compatibility with regulatory provision

A traceability system must adhere to the regulations of the country in which it is operated. Among the regulations that a system must adhere to are the following: (a) privacy and data sharing, (b) data protection, and (c) cybersecurity. Additionally, policies and regulations aimed at a specific group of users and technologies should be followed.

2.3. Digital technologies for food traceability

Based on the research of both international and domestic case studies under the present study, the following technologies have been identified as being frequently applied in traceability systems, including (a) barcodes, (b) RFID tags, (c) NFC tags, (d) blockchain technology, (e) IoT

sensors, and (f) mobile applications. Some can be used interchangeably and others jointly to form a complete traceability system.

As indicated in section 2 of this report, a complete traceability system covers all the following functions:

- Identifying traceable objects, parties, and locations.
- Automatically capturing (through a scan or read) the movements or events involving an object.
- Recording and sharing the traceability data, either internally or with members in a supply chain to ensure visibility.

Table 3: Functions of a complete traceability system covered by four selected technologies

Technology	Functions of a complete traceability system		
	Identification	Capturing	Recording and sharing
Barcode	Barcode	Barcode scanner	—
Sensors (including NFC, RFID, and IoT sensors)	RFID/NFC tag	RFID reader and antenna/NFC reader	IoT sensors
Software including blockchain	—	—	Blockchain database
Mobile application	[a]	Mobile application (if acting as tag/code reader)	Mobile application

Note: a In some cases, the mobile application may also act as a barcode (code emulation form), but this is not common as it incurs much higher costs than the printed one.

2.3.1. Barcode

Components and functions

A barcode is a machine-readable optical representation of data associated with the object to which it is attached. By varying the widths and spacing of parallel lines (1D) or rectangles, dots, hexagons, and other geometric patterns in two dimensions, barcodes represent data for identification in a systematic manner (2D). Originally, barcodes were scanned using specialized optical scanners called barcode readers. Later, scanners and interpretive software became available for automatic data capture on devices such as desktop printers and smartphones.

Scope of application

The barcode is used to identify products, make data capture faster and more accurate, and enable the sharing of product information across the supply chains. Barcodes are extensively used for packaged food and POS scanning. Packaged products with barcode labels may be accompanied by batch or lot codes, harvest date, expiry, or other handling information. Examples of their usage for fresh fruits and vegetables and the evolution toward various 2D

barcodes can be found in the GS1 implementation guide. It should be noted that the transition to include 2D barcode scanning at POS is a multiyear process and may not be widely available in developing countries.

a. Strengths

- **Accuracy**: Using barcodes ensures better accuracy than manual recording. When a product moves between stages, its movement needs to be recorded. If the recording is done manually, there is a risk that the person responsible may input the wrong numbers, leading to a different product being recorded. However, with an attached barcode, the product code is captured by scanners, and there is little chance that it is recorded incorrectly.
- **Low cost of establishment, operation, and maintenance**:
  - *Cost of obtaining barcodes:* Before a company can use GS1 identification keys and barcodes, it must first register with GS1 and pay a registration fee that covers the assignment of a globally unique company prefix (GCP) and product codes. Companies need to renew their membership annually to continue using the barcode. Detailed pricing for GS1 Vietnam is described in table 4.

Table 4: Cost of obtaining barcodes in Vietnam

No.	Type	Fee (VND)	Fee (US$)
I.	**Fees for issuing and giving instructions to use codes and barcodes (per code/barcode)**		
1.	Using GS1 company prefixes (regardless of registered codes)	1,000,000	43.82
2.	Using GLN codes	300,000	13.15
3.	Using 8-digit GTIN (GTIN-8)	300,000	13.15
II.	**Fees for registration (certification) of foreign codes and barcodes**		
1.	Processing an application for 50 product codes or fewer	500,000 per application	21.91 per application
2.	Processing an application for more than 50 product codes	10,000 per code	0.44 per code
III.	**Annual fees for maintenance of codes and barcodes (per year)**		
1.	Using GS1 company prefixes		
1.1	Using 10-digit GS1 company prefixes (a company is allowed to use 100 item numbers)	500,000	21.91
1.2	Using 9-digit GS1 company prefixes (a company is allowed to use 1,000 item numbers)	800,000	35.06
1.3	Using 8-digit GS1 company prefixes (a company is allowed to use 10,000 item numbers)	1,500,000	65.73
1.4	Using 7-digit GS1 company prefixes (a company is allowed to use 100,000 item numbers)	2,000,000	87.64
2.	Using GLN codes	200,000	8.76
3.	Using 8-digit GTIN (GTIN-8)	200,000	8.76

Source: Circular No. 232/2016/TT-BTC issued by the Ministry of Finance dated November 11, 2016, providing fees for issuance of codes and barcodes, and collection, transfer, management, and use thereof.

- *Cost of barcode scanners:* There are three distinct categories of barcode scanning devices at different price points (Harrison 2016). The first category is a mobile computer with integrated scanners. These devices are typically equipped with Windows or Android operating systems, screens, flexible memory/storage, and support for a full range of barcode symbology. Their prices range from US$1,500 to more than US$2,500. The second category is the handheld barcode scanner. It is the most common type of barcode reading device. Handheld scanners are ergonomic and simple, but they need an interface cable or built-in networking signal to transfer data in real time, and they cost between US$100 and US$200. The third category is smartphones and tablets. Today, there are many barcode scanning applications that can be used on smartphones and tablets without additional hardware costs. Most of these applications are free; some require monthly or annual subscriptions.

- **Ease of use:** To receive registered barcode identifiers, which uniquely identify the products, the company must register for GS1 membership, and the company is granted a globally unique code that identifies the company (a company prefix or GCP). Based on the company prefix, identification codes can be assigned to locations (GLN) or products (GTIN) that uniquely identify them. There are simple and easy-to-follow guidance documents on GS1 member organization websites.
- **Interoperability:** As with RFID, the interoperability of barcode systems relies on the standardization process. First, for each type of barcode, the data are encoded using a global standardized language so that it can be read by common barcode scanners. Then, the scanners are configured to transfer these encoded data to computer-readable data by standard methodologies of analog signal generation.

Limitations

- Ease of counterfeiting or reuse of a barcode label (reuse of packaging is widespread in Vietnam).
- The time needed to scan each barcode and the risk of product omission: Barcodes can only be scanned one by one; therefore, when many products need to be scanned, the risk of product omission increases.
- Susceptibility to damage: Barcodes are much more susceptible to damage than RFID tags because they must be printed directly or stuck on the surface of goods, therefore prone to being easily scratched or deformed.

Suitability for Vietnam

Most parties participating in the F&V supply chain are small to medium in size. These parties have limited financial resources and knowledge of technologies. Hence, barcodes' low price and ease of use make them a suitable option for these parties. Fruits and vegetables can be tracked in bulk by a lot or batch number or by tote or container.

2.3.2. Sensors (RFID, NFC, and IoT sensors)

RFID

Components and functions

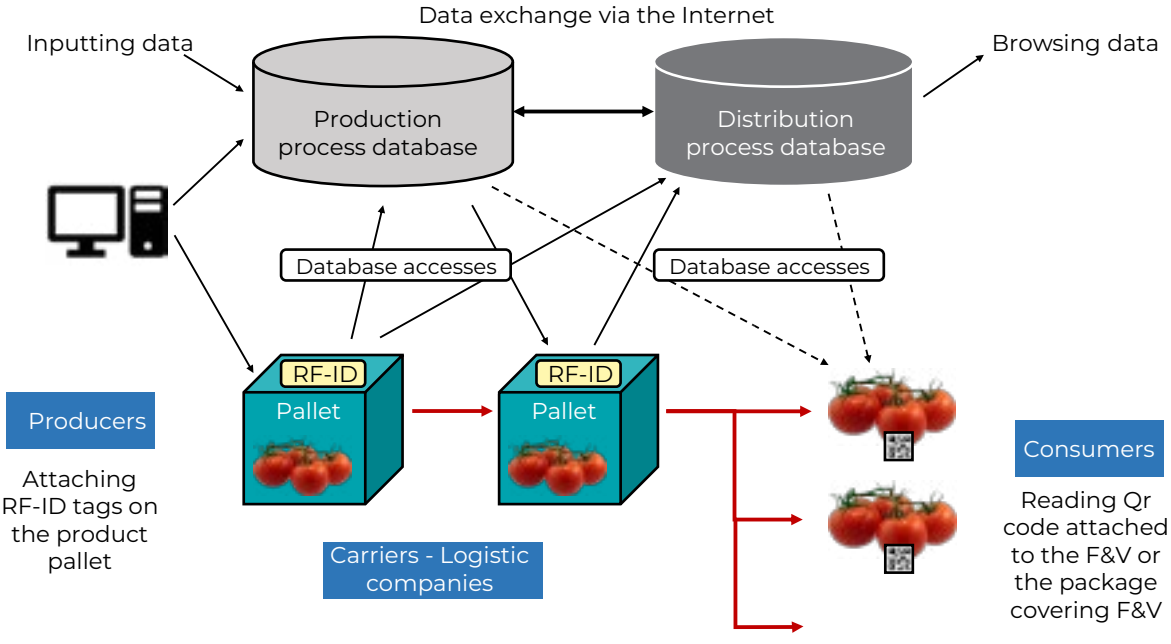
RFIDs are chips or tags capable of being read through radio waves. Certain RFID devices have a memory function to store data and a battery, which enables greater information transmission. RFID devices are either active, which means they carry a battery and are considered 'always on' transmitting a signal, or passive, meaning only read when interrogated by a signal from an antenna in proximity.

Tagging items with RFID tags allows users to automatically and uniquely identify and track inventory and returnable assets (such as totes and pallets). An RFID tag may comprise two parts: an antenna for transmitting and receiving signals and an RFID chip which stores the tag's ID, and depending on the type of tag, may contain other information. RFID tags may be embedded into a traceable object such as a tote or pallet or attached under a label on a traceable item.

Scope of application

- **Stage of application**: RFID technology can be applied for all stages of supply chains where there is need to capture movements or changes of an object, but RFID is typically attached to pallets containing fruits and vegetables during upstream processes.

Figure 12: Example of RFID application in a traceability system



Strengths

- RFID systems offer a fast and reliable way to track objects without having to scan individual items separately (such as the barcode or QR code). With RFID applications in logistics operations, the system can recognize object identity by using antennas and readers

strategically positioned throughout a process. For instance, the automatic receipt into the inventory of multiple totes full of bulk fruit or vegetables being unloaded at a receiving dock and automatic deduction from inventory when reloading onto a truck for customer delivery. RFID can also help find items that are on site but have been misplaced. Because data are collected and uploaded electronically, RFID also avoids transcription errors, duplication of data, and 'missed items' when used to collect data on large numbers of items simultaneously. As such, RFID technology reduces the need to check, audit, or verify that the correct product and quantity are available. In addition, most read/write tags can be locked to prevent further writing over specific data blocks in the tag's internal memory; hence, users cannot intervene to change the data stored there. Another important element of RFID is its data storing capacity, which is higher than that of barcodes. This allows for increased data volume, which means more information is captured and available.

- In contrast to barcodes, data stored with an RFID tag can be changed or modified.
- The interoperability of RFID with other systems results from the process of standardization. Once standardized, RFID can interoperate with networks, cloud-based platforms, and IT systems.

Limitations

- Using radio waves as its transmission medium makes the technology vulnerable to eavesdropping, with a risk of data manipulation. RFID can be susceptible to hacking because the interaction between the RFID chip and the reader can be done without authentication, leaving the system open to attacks and spoofing. However, over the years, many protocols have been proposed for RFID security using the symmetric key and public key cryptography (Das 2013), mitigating the risk of data leakage.
- There are high costs for establishment, operation, and maintenance:
    - Establishing an RFID system may vary due to differences in size, scope of application, type of equipment and tags, and so on. It requires an initial investment for testing and working with several types of equipment and tags.
    - The cost of RFID tags ranges from US$0.10 for basic passive RFID tags to US$15–US$20 for active RFID tags that contain a battery and have storage capacity. Basic passive tags can be applied to most surfaces under a label or may have more ruggedized plastic housing for extreme environmental or working conditions where there is a risk of damage. Active RFID tags are usually in a ruggedized plastic housing and require no human intervention since they are entirely automated. While a passive tag remains 'quiet' until it is interrogated by a signal from an antenna, an active tag may send a signal once every minute or may be activated when the asset is moved. In the latter case, a high-value asset on a remote site may be programmed to signal movement, which may indicate theft. Beyond passive and active tags, firms may use real-time global positioning system (GPS) tracking devices on high-value assets such as forklifts and delivery trucks.
    - Handheld RFID readers can cost anywhere between US$1,250 and US$20,000 each, depending on the level of automation offered. Active RFID readers are the least

expensive option at US$1,250 to US$1,500 each. Passive and handheld RFID readers are more expensive, ranging from US$3,000 to US$20,000 each (Advancedmobile Group 2016).

  - Passive RFID installation must be done by experts who are well versed in tuning the equipment, directing the antennas, running the necessary connectivity tests, and configuring settings and networking details. The readers are connected via a local area network to a central server, which is typically on site and processes all the RFID data. Specialized antennas are used for passive RFID and must be installed and calibrated to ensure appropriate performance. For these reasons, the installation costs of passive RFID are high. By contrast, many active RFID systems such as AirFinder can be installed by an IT team member, making the process simpler and much less cost prohibitive. Generally, the exact placement of an active reader is not important. However, ultra-wideband active RFID systems have installation costs that can exceed those of passive RFID (Ray 2020).
  - Passive and active RFID tags used on assets require asset management software, the complexity and specialization of which drive the cost. Basic tag reading software could be an open source project, whereas an integrated RFID-to-ERP enterprise application could cost hundreds of thousands of dollars to implement and operate. While active RFID licensing costs are typically bundled with software, passive RFID technologies often require ongoing licensing costs for support and software upgrades (Ray 2020).
  - The ongoing maintenance costs address issues with equipment that is unplugged or goes offline for another reason. Passive readers are more complex than active readers due to their extensive cabling, antennas, and so on, and because the passive readers are large, they are at a greater risk of being damaged in a warehouse operation, which could lead to costly maintenance and repair. Active RFID systems are less complex, but their tags include batteries. This means the tags will need to be maintained anywhere from every few months to every few years, depending on their life expectancy (Ray 2020).

- RFID systems are complex and difficult to install and integrate. RFID technology requires a certain level of technical knowledge, adequate time, and effort to successfully establish, operate, and maintain. From the physics of the hardware installation to the challenges of integrating RFID-generated data with existing business processes, a broad base of expertise is required for successful implementation. Professionals working in RFID installations, operations, and maintenance must have proficiency in areas such as radio frequency technology; RFID hardware (antennas, tags, and readers); how to properly tag pallets, cartons, and products; and RFID standards (Sommer 2019).

Suitability for Vietnam

To successfully implement RFID, businesses must consider two factors. First, businesses must have sound financial resources and ensure the business case can guarantee a return on investment, as RFID technology is relatively expensive to implement. Firms must ensure a sufficient revenue stream and conduct cost-benefit analyses (not only considering the procurement costs but also the long-term maintenance costs). Second, businesses must assemble an RFID-savvy team to develop and deploy the RFID system throughout the supply

chain. RFID implementation necessitates extensive testing and piloting with various types of equipment and tags prior to final system configuration, including antennas, readers, and software. Additionally, with the implementation of the RFID system, the volume of product data will change by ±30 percent (Shah and Murtaza 2010), necessitating enhanced capabilities for data analysis and interpretation. The real-time transmission of data adds another layer of complexity to managers' ability to process information on time. Many routine tasks will need to be automated, as managers will be required to handle alerts and exceptional cases, and they will need to develop the ability to make decisions quickly in a fast-paced environment.

In Vietnam, although F&V production areas are increasing, agricultural production is decentralized and depends largely on small-scale households (PSAV 2017). These households have limited financial resources, produce and handle small product volumes, and have insufficient technical knowledge. Hence, RFID may exceed the needs and capacity of most small producers. However, this technology is feasible for large cooperatives and large-scale farming companies. It should also be noted that the Vietnamese government has already issued several technical regulations and standards regarding the implementation of RFID, which provide support and guidance for users and align with GS1 standards.

NFC

Components and functions

NFC is a wireless, close-range (a few centimeters) connectivity technology derived from RFID. It allows data to be transmitted between two devices (for example, a debit or credit card 'tap' to pay on a POS device). The main difference between NFC and RFID is that NFC tags have been widely integrated with mobile devices, such as smartphones, tablets, and notebooks, as well as embedded into passports, drivers' licenses, and credit and debit cards. This allows the development of applications directly addressed to the end users.

NFC has limited applications in the food supply chain (production, processing, distribution, and retail and consumer). Some applications may be conceivable, such as embedding into materials of expensive packaged food as a method for authentication and detecting counterfeits.

Scope of application

NFC technology has limited applications in F&V supply chains.

Strengths

- Users do not have to perform complex operations to read NFC tags. They can simply place a smartphone near the tag. This facilitates the use of non-expert users of smartphones. Compared with the barcode (QR code), the use of NFC is much more immediate than the barcode. However, the NFC tag must be much closer to the reader (usually within 1 to 3 cm).
- Data stored within NFC tags are automatically captured by NFC readers in real time, which significantly reduces human error and delays in manual capturing. The NFC application can be regarded as a secure wireless technology due to its short range of operation.

- Unlike the barcode, NFC technology allows for the rewriting of data several times and can protect the rewriting of data with a password.
- The short-range wireless technology limits communication to within a short distance and helps reduce the opportunities for an attacker to eavesdrop on communications, adding security and privacy compared to RFID (Lemos 2015).
- The inclusion of NFC in smartphones and tablets is propelling the global NFC market forward. NFC is now an integral part of every smartphone and tablet. Smartphones, tablets, and notebooks can read NFC tags, and the data can be shared with a cloud database or blockchain ledger. Additionally, unlike barcodes, NFC technology enables multiple rewrites of data and can protect each rewrite with a password.

Limitations

- NFC is not considered suitable for F&V supply chains in Vietnam.
- NFC tags are costly and are not commonly used in the F&V industry.

Suitability for Vietnam

Users must have both technical and financial resources to implement the technology. Existing infrastructure, such as cloud storage systems, is also required to support the implementation of NFC. Implementing NFC is possible for large cooperatives and large-scale farming companies with sufficient labor skills and financial resources. Agricultural production in Vietnam, on the other hand, is decentralized and heavily reliant on small-scale households with limited financial resources and little technological knowledge (PSAV 2017). As a result, NFC may exceed its requirements and capacity to implement.

IoT sensors

Components and functions

IoT sensors consist of hardware and software that can communicate without human intervention and can be considered machine-to-machine (M2M) communication.[11]

Scope of application

IoT sensors are applied for automatically collecting data from the physical state of the products. They help reduce users' work by providing a tool to automatically capture various forms of data. All the data can then be input directly onto the database without human interference.

Strengths

- Farming tasks such as irrigating and pesticide and fertilizer application can be automated, saving time and effort. For example, farmers in Don Duong use drip irrigation and nutrition systems. Instead of physically opening and closing the pump system up to eight times per day, farmers can now operate them using remote controls.

11 Pokorni, Slavko 2019)

- Sensors can provide data at a granular level. As a base technology for a sensor management system, a cloud server can function as a repository for the data produced from each sensor. These data can easily be managed and controlled from a distance by a remote device operating on a network.
- IoT sensors are composed of a variety of devices which are called 'smart objects/things' that support the process of collecting information and data at the fields/production areas. Thus, they can integrate with smart devices to collect and digitalize data to be stored in a *cloud-based system*.

Limitations

- The battery is a concern for IoT applications because the application layer is often unaware of the remaining battery left on the device, thereby making it difficult to determine when the device requires a battery replacement. This battery life concern is further compounded when devices may be in places that are physically difficult or dangerous to reach and replace.
- The sensors and actuators that are used in the IoT system are often deployed in remote and distant locations. They can often be subject to harsh environmental conditions such as heat, freezing temperatures, mechanical wear, noise and vibration, and moisture. The life of a device may shorten if the device is employed in an extremely harsh environment. As a result, we could expect to see variances in lifetime for identical devices deployed in different environments, which results in the system reliability being difficult to manage.
- Most farms in Vietnam are in remote locations where the existing infrastructure of the farms cannot ensure strong or stable internet connectivity to facilitate fast transmission speeds needed to stream the data sets from the sensors to the cloud-based system for further analysis. Poor internet connectivity in farms can disrupt connectivity to the cloud-based system.
- There may be significant up-front investment costs of IoT systems that make farmers hesitant to deploy them. For example, a limited set of sensors can cost up to US$8,000, resulting in farmers continuing to rely on less advanced farming technologies, which limits their productivity (Chandra 2018). In addition, implementing such complex systems require training for farmers to operate and maintain.

  Note: Some solution providers sell various IoT solutions for farming, including hardware, software, and maintenance, on a more affordable cost per acre basis or an operating expense (opex) versus a capital expense (capex) model.

Suitability for Vietnam

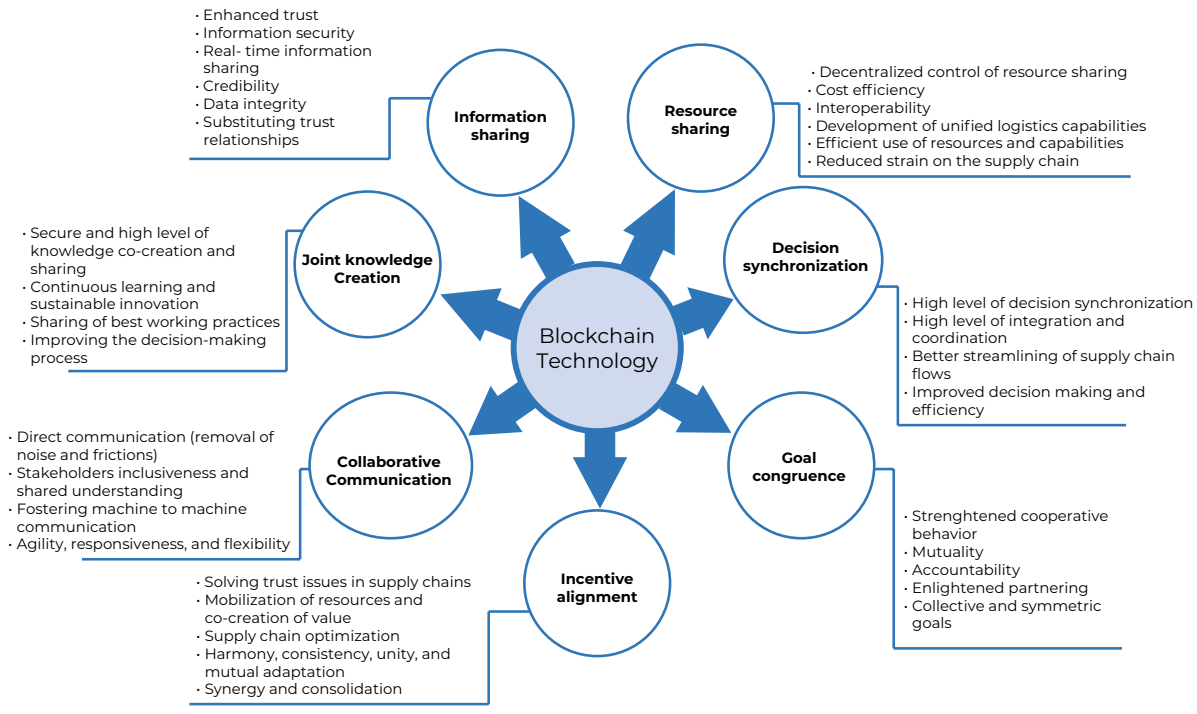
Applying IoT systems in Vietnam is not considered complicated or out of reach. One of the most critical factors is to provide support and guidance to users, especially farmers, and ensure that the system is operated in a simple and user-friendly manner. The application of IoT in Vietnam is still relatively limited (Choudhary and Fock 2020). However, with the cost of IoT sensors dropping in recent years and the global expansion of IoT solution providers with opex-based solutions, deployments in Vietnam can be expected to grow.

2.3.3. Software (distributed ledger applications such as blockchain)

Food traceability software systems enable firms to monitor their supply chains and record data about the composition and traceability of food ingredients, batches, and finished items. These technologies enable the recording of data related to their input sources (for example, ingredients and suppliers) and shipments (for example, customers) aligned with regulatory requirements for one-step-up and one-step-down traceability. One of the most common drivers for traceability solutions is the ability to assist firms in adhering to human health and safety regulations. Numerous food traceability solutions exist and may include tools for optimizing recipes or formulations, creating labels with nutrient profiles and allergy alerts, and providing supply chain and product data to consumer-centric mobile apps. In a peer-reviewed research paper on the potentials, challenges, and future research directions of blockchain in the food industry, Rejeb (2020) argued that *"Blockchain technology has emerged as a promising technology with far-reaching implications for the food industry. The combination of immutability, enhanced visibility, transparency, and data integrity provides numerous benefits that improve trust in extended food supply chains (FSCs). Blockchain can enhance traceability, enable more efficient recall, and aids in risk reduction of counterfeits and other forms of illicit trade. Moreover, blockchain can enhance the integrity of credence claims such as sustainably sourced, organic, or faith-based claims such as kosher or halal by integrating the authoritative source of the claim (e.g., the certification body or certification owner) into the blockchain to verify the claim integrity and reassure business customers and end consumers."*

In a separate research paper on business-to-business collaboration, blockchain technology emerges as one of the most promising technologies with the ability to enhance collaboration (Rejeb et al. 2021). It provides a useful collaboration framework highlighting the potential roles of blockchain technology in collaborative supply chains.

Figure 13: Blockchain technology



Source: Rejeb et al. 2021.

Nonetheless, blockchain is not the only applicable technology for a good traceability system. Indeed, it is important to note that blockchain solutions are transaction-based ledgers that may be built on top of existing systems and as-is processes, thus not excluding the usage of traditional systems with an added layer of security and transparency guaranteed by blockchain.

2.3.4. Blockchain components and functions

An asset can be a physical object such as a returnable asset (a pallet or tote) or a digital object such as patents, copyrights, or land ownership deeds. Virtually anything of value can be tracked and traded on a blockchain network, reducing risk (IBM 2018).

Public blockchain: A public blockchain is a network where anyone is allowed to join and participate. It is a decentralized system where there is no one single entity that controls the network. Even though anyone can read or write into the blockchain, data on this public blockchain are still secure because it is not possible to modify the data once validated.

Private blockchain: In this type of blockchain, there are restrictions on who can access and participate in the network. Therefore, only the people who are part of the transaction will have access to the data.

In both public and private blockchains, there is a data validation process where most of the participants reach a common agreement. Data will not be modifiable after validation, thus, reducing data tampering and increasing data reliability.

2.3.5. Blockchain scope of application

Blockchains are used to verify and store transaction data. Its scope of application exceeds that of its predecessors, which initially helped protect, certify, and distribute data. Furthermore, it is possible to use blockchain-oriented methods without intermediary clearing houses. For instance, payment movement on the financial market, contracts, certifications, attestations, copyrights, patents, and registries can theoretically be administered without the need to involve banks, notaries, custodians, or any state institutions. The increasing interest in blockchain technology is evident not only in the banking sector but also in the real estate, insurance, and health industries, which can also benefit from blockchain's wide range of potential uses. Supporters of this technological concept predict its expansion to judicial systems, energy industries, and public administration.

Blockchain is important for agricultural supply chain as it supports transparency and accountability, traceability, fraud prevention, cybersecurity, and authentication (Phan Thi Huong Giang 2021).

Strengths

- Reliability of data (data provenance, transparency, and immutability) helps reduce inspection and verification costs. Members of a private network can be assured that they receive accurate and timely data. Their confidential blockchain records will be shared only with network members who have specifically been granted access. Regarding data accuracy, consensus on data accuracy is required from all network members, and all validated transactions are immutable and recorded permanently. No one, not even a system administrator, can delete a transaction. All network participants have access to the distributed ledger and its immutable record of transactions. With this shared ledger, transactions are recorded only once, eliminating the duplication of effort that is typical of traditional business networks. In addition, no participant can change or tamper with a transaction after it has been recorded to the shared ledger. If a transaction record includes an error, a new transaction must be added to reverse the error, and both transactions are then visible (IBM 2018).
- Consensus protocols create an irrefutable system of agreement between the devices in a distributed network, thereby preventing system exploitation. One can choose from a wide variety of consensus protocols available for the blockchain. Some of them are Proof-of-Work (PoW), Proof-of-Stake (PoS), Delegated Proof-of-Stake (DPOS), Byzantine Fault Tolerance (BFT), Proof-of-Weight (PoWeight) (Sharma 2022).

Limitations

- A public blockchain is viewable by anyone with access, which means that the confidentiality of any data stored here is null. However, in the business world, there are many sound reasons for not making data public. In the case of food traceability, this is a great advantage in ensuring the transparency of data collected (Martin 2016). Firms may not be capable of setting up blockchain systems internally and may require the help of solution providers. However, the number of developers may be limited by the niche status of the blockchain (Vasylchykov 2018).

- The cost to build a blockchain app depends on various factors, including its deployment phases, its complexity, and the specialized development resources needed. The deployment phases usually include proof of concept, one or more pilots, then system development and operation. The system's complexity depends on its purpose and the specific use case. Table 5 represents the cost percentage with respect to a specific development phase. For example, deployment and third-party costs for a private blockchain are around US$1500 per month and for a public blockchain are around US$0.01 per transaction, with a cost of US$750 for a third-party solution. From EY's expert experience, the establishment cost can range from US$15,000 for micro solutions up to US$1 million for big enterprises. The average is around US$100,000 per solution, with 15 percent added for maintenance and cost of transactions (gas fees needed to pay for transactions in the blockchain).

Table 5: Cost percentage in a development phase

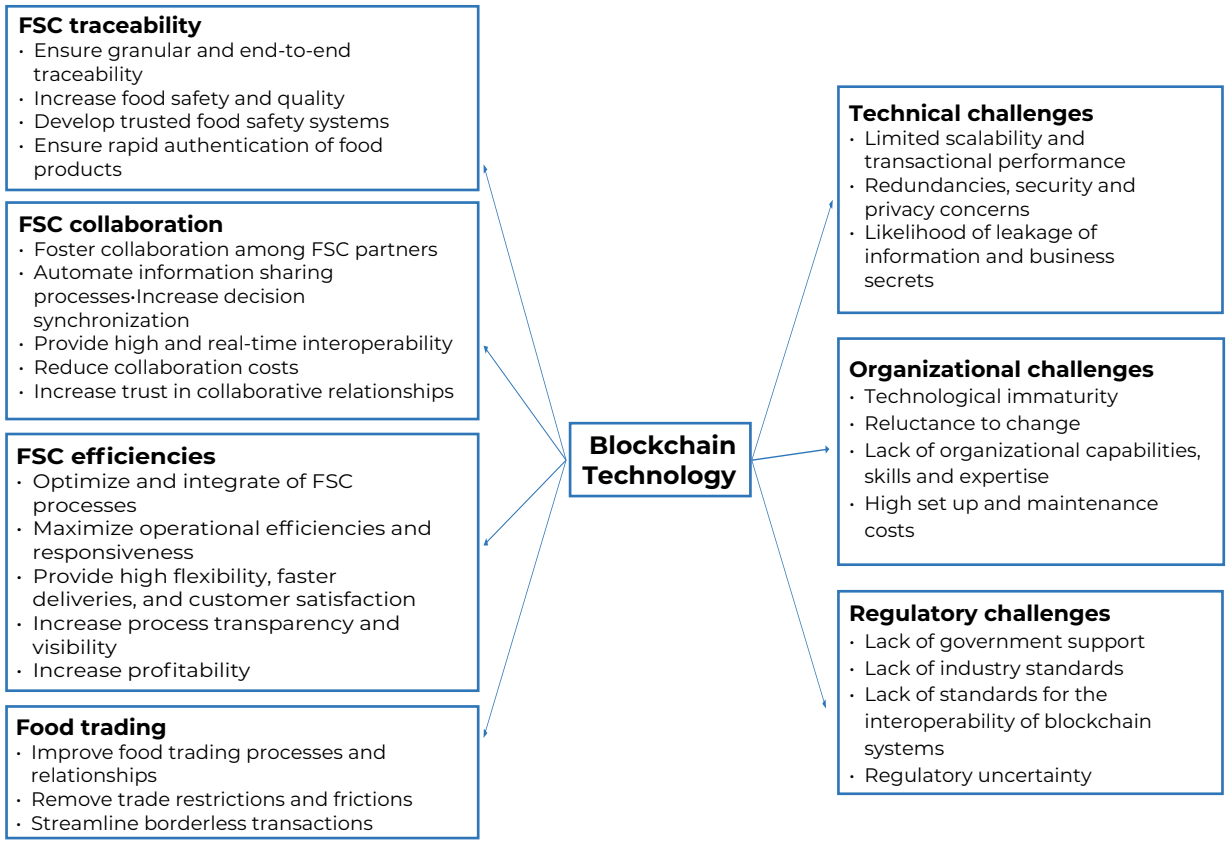
No.	Types of expense	Percentage
1	Consulting expense	10
2	Designing expense	15
3	Development expense	50
4	Quality assurance	25
5	Maintenance	15–25 of the overall project cost (Takyar 2019)

- Scalability can be considered a major barrier in implementing public blockchains. The issue arises with the increasing number of nodes and transactions in the blockchain. This issue is particularly prevalent in major public blockchain applications because each node is required to store and execute a computational task to validate each transaction. As a result, public blockchains are always in need of massive computational power, a high bandwidth internet connection, and massive storage space.

2.3.6. Suitability of blockchain for Vietnam

- To implement blockchain in Vietnam for food traceability, there are specific challenges that organizations may face including technological, operational, and regulatory factors. Rejeb (2020) summarizes the potential benefits and challenges of blockchain technology in figure 14. While the opportunities are consistent for Vietnam, the challenges, particularly the regulatory uncertainty, may slow or delay blockchain deployments in Vietnam.

Figure 14: Potential benefits and challenges of blockchain



Source: Rejeb et al. 2020.

Note: FSC = Food supply chain.

Furthermore, with the abovementioned operational challenges, a reluctance to change (by management primarily) and a lack of organizational skills, capabilities, and resources are seen as significant hurdles to overcome.

2.3.7. Mobile application

Components and functions

A mobile application is a software program that users can download and access directly using their phone or other mobile devices, such as a tablet or music player. Mobile applications used in traceability systems can be classified into two categories: barcode scanning applications and data input applications. As the name implies, barcode scanning applications enable users to scan barcodes and access information about the products encoded within them. The embedded information may take the form of a product code or include a link to a website where users can obtain more information about the product. Users only require a smartphone with an integrated camera to capture the image of barcodes and are then presented with human-readable information or transferred to a website. Barcode scanning applications on

smartphones offer a more affordable alternative to traditional (industrial) barcode scanners. Some are subscription-based applications with a low fee, while others are free. They do, however, have limited capabilities. Barcode scanning applications are unable to store data and scan one item at a time and transfer data at a slower rate than traditional scanners. From these characteristics, they are generally used by the last link in the supply chain—the end customer. Barcode scanning applications on smartphones are listed as one of three types of barcode scanners in the preceding section.

Scope of application

Data input applications are used to record and share data between parties. They can be applied at any stage of the supply chain where there is a need to record and share information.

Strengths

Data input applications are easy to set up and use and ensure better data accuracy than manual records. Besides data recording, they also allow data to be shared with other parties in the supply chain.

Limitations

The cost of developing a mobile application can be high. Developing a mobile application also requires sufficient time and skilled developers to test and pilot.

Suitability for Vietnam

There are three critical factors to implementing the mobile application. The first one is the availability of smartphones. If a smartphone is easy to obtain at an affordable price, it is much easier for supply chain parties to apply mobile apps to their traceability system. The second factor is the country's internet coverage because the internet is needed to set up the app and share data between parties. The third factor is users' knowledge and skills in applying the technology.

In the Vietnamese F&V supply chain, most players are small-scale farmers. Many do not have a smartphone to install the data input applications and are not familiar with using mobile devices to record data. Therefore, it is difficult for them to use the mobile application. However, data input applications can be widely used in large-scale farming companies or modern retailers because they have adequate infrastructure, financial resources, and technical knowledge.

SECTION 3. ANALYSIS OF FOOD SAFETY RISKS IN F&V SUPPLY CHAINS IN VIETNAM

Photos: @Paula Cobleigh/Shutersctock

3.1. Current food safety situation in F&V supply chains in Vietnam

Food safety is a concern for F&V supply chains in Vietnam. In the domestic market, the main hazards detected from F&V products include pesticide residue, nitrate, heavy metals, and microorganisms. Vegetables, fruits, and meat were considered to be the top three riskiest items, with the mean risk perceived at a high level (7.14, 6.74, and 6.70, respectively) (Ha et al. 2019). Inspection results conducted by importing countries indicate that F&V ranked second for the number of safety violation cases, most of which were detections of biological hazards and residues of agricultural inputs (antibiotics, pesticides, and fungicides) (World Bank 2017). According to details shared by the Vietnam Sanitary and Phytosanitary Notification Authority and Enquiry Point, within the first six months of 2022, there were 40 agricultural products from Vietnam that received a warning from the Rapid Alert System for Food and Feed of the EU due to unsatisfactory import test results (ASEAN Vietnam Information Portal 2022). Subsequently, the EU has issued a warning against nine fresh and processed fruits and vegetables from Vietnam due to food safety risks (VCCI 2022).

3.2. Key players in the F&V supply chain

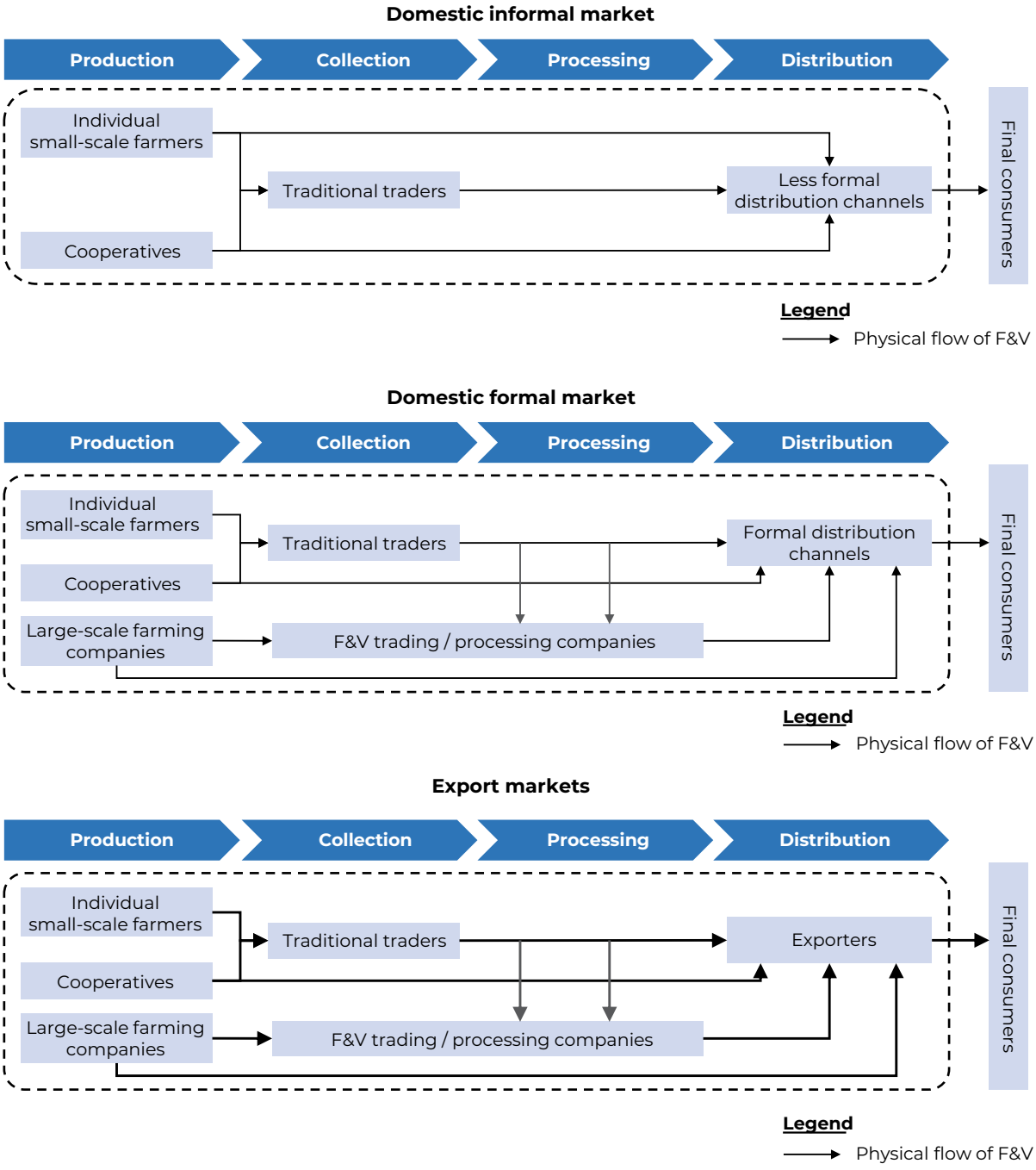
Participants in the informal market are mainly individual small-scale farmers and cooperatives, in which small-scale and fragmented farmers contribute the majority of total F&V production, traditional traders (referred to as aggregators by the Ho Chi Minh City [HCMC] wholesale wet market management board), informal distribution channels including traditional markets (wholesale markets and community markets), and vendor or small food stalls. This market accounts for the majority of total F&V circulated in the Vietnam domestic market.

The formal market has participants mostly from large-scale farming companies and cooperatives; F&V trading and processing companies; and formal distribution channels including supermarkets, minimarts, restaurants, and so on. Traditional traders and individual small-scale farmers account for the minority of total F&V distributed to formal distribution channels since this market has more stringent requirements.

The export-oriented market is dominated by participants from large-scale farming companies and cooperatives, F&V trading companies, and exporters (mostly in the form of companies). Individual small-scale farmers and traditional traders also participate in this market (for example, dragon fruit).

Figure 15 depicts the main value chains, and appendix A presents a detailed description of the key players in the F&V supply chain in Vietnam, with data and figures describing the two specific supply chains: the Hanoi vegetable supply chain and the Binh Thuan dragon fruit supply chain.

Figure 15: Types of value chains



3.3. Key food safety risks associated with F&V supply chains

Table 6 presents key food safety risks associated with F&V supply chains in Vietnam with some real-world examples. It should also be noted that each supply chain has its own characteristics in terms of commodity nature, involved members, and handling practices. Hence, the probability of incurring risks regarding food safety hazards associated with the same factor may vary among supply chains.

Table 6: Key food safety risks associated with F&V supply chains in Vietnam and examples

No.	Hazard	Sources	Risk description	Level
1.	Heavy metal amount (for example, copper, and arsenic)	Contaminated production soil	F&V products which are chemically contaminated with excessive residues of heavy metals can potentially harm human health	**Medium** **Usage of unapproved pesticides was reported to happen.** *A 2018 study in Hoai Duc district of Hanoi indicates that the soil was contaminated with excessive amounts of arsenic and cadmium that were 1.11 to 1.49 and 1.07 to 1.13 times higher than the allowable limits, respectively* (Ha Nguyen 2018). *In Bac Ninh province, from 35 soil samples, two were polluted with lead (Pb), cadmium (Cd), and copper (Cu); two samples contained excessive amounts of Cu (with 71.78 mg/kg and 71.12 mg/kg) while the remaining were close to the allowable limits* (Pham 2020).
2.	Harmful pesticide residues (for example, insecticides, fungicides, herbicides, or even banned ingredients)	Pesticides (caused by over-usage and usage of unapproved pesticides or non-compliance with pre-harvest interval [PHI])	Excessive residual amounts of pesticides in F&V products would significantly harm human health	**High** **Usage of unapproved pesticides was reported to happen.** *According to the MARD inspection department, in 2020, several plant protection products are smuggled into Vietnam each year, including those of unknown origin, or excluded from the permissible list, some of which contain extremely high levels of toxicity* (Thao 2020).

No.	Hazard	Sources	Risk description	Level
				Over-usage of pesticides was reported as a common practice. *Assessment results reported in 2019 by the Agricultural Food Safety Supervision Team of Loc Ha district, Ha Tinh province, showed that 76% of samples (32 of 42), comprised mostly of cabbages, cauliflower, and dragon fruit collected from wet markets, contained excessive amounts of pesticide residue* (Tan 2019). *Vietnam's exported dragon fruit is frequently rejected due to contamination with excessive pesticide residue. For example, from 2015 to 2018, there were 17 warnings issued due to excessive amounts of carbendazim, dithiocarbamates, carbofuran, permethrin, dimethroat, iprodione, and azoxystrobin.* **Non-compliance with the PHI before harvesting was reported.** *The standard PHI specifies that no pesticide and fertilizer applications are allowed for a certain number of days before the harvest date to minimize chemical residues. However, there were cases in which producers did not comply with the standard PHI* (Tuoi tre e-news 2017).
3.	Harmful chemical residues (for example, chlorine and trisodium phosphate)	Processing water and packages	Excessive residual amounts of chemical residues in F&V products would harm human health	Low

No.	Hazard	Sources	Risk description	Level
4.	Harmful microorganisms (*E. coli*, coliforms, *Salmonella*, and so on)	Contaminated production soil/ organic fertilizer/ contaminated irrigation water/ unhygienic workers, equipment, facility/ inappropriate temperature control	F&V got contaminated with harmful microorganisms	**Medium** **Production soil and irrigation water containing excessive harmful microorganisms or excessive usage of unprocessed organic fertilizer can cross-contaminate vegetables.** *A 2019 investigation by the HCMC Plant Protection Department found that 70% of morning glory samples collected from production areas in HCMC contained excessive amounts of E. coli bacteria* (HCMC Plant Protection Department 2019a). *Another study conducted in Vinh Long and Can Tho to assess the risk of biological contamination (with coliforms, Salmonella, Shigella) associated with the use of organic fertilizers in leafy green cultivation revealed that fecal samples were contaminated with microorganisms at moderate to high levels. Coliforms and E. coli had densities ranging from 3.84 to 5.26 log (mpn/g), while Salmonella had a density of 3.08 log (cfu/g), indicating that improperly processed or unprocessed organic fertilizers are likely to contain intestinal bacteria* (Nguyen 2013). **Biologically contaminated F&V products were reported in the domestic market.** *There was a case when 58 students were infected with E. coli and coliform bacteria in 2020 after eating cabbage soup* (Dan Tri News 2020). *A 2020 investigation conducted for Khanh Hoa province by Khanh Hoa Science and Technology Council reported that 102 of 620 vegetable samples tested positive for E. coli, with lettuce having the highest contamination rate* (Cam Ranh government portal 2020). *According to a 2019 assessment conducted by the HCMC Plant Protection Department, 70% of morning glory samples collected directly from their production areas and 55% of morning glory samples collected from circulation areas (for example, markets) contained an excessive amount of E. coli* (HCMC Plant Protection Department 2019b).
5.	Harmful parasites (worms, flukes, pinworms, and so on)	Contaminated production soil/ organic fertilizer/ contaminated irrigation water	F&V got contaminated with harmful parasites	Low

SECTION 4. CURRENT STATE OF FOOD TRACEABILITY IN VIETNAM

Photos: @Hananeko/Shutersctock

4.1. Regulations on food traceability in Vietnam

This section presents key summaries of regulations on food traceability in Vietnam in terms of regulations on food traceability, voluntary technical standards (Tiêu Chuẩn Việt Nam or TCVN) enabling the application of technologies, and institutional framework for food traceability. While three different ministries (MARD, the Ministry of Industry and Trade [MOIT], and MOH) have various responsibilities for food safety governance in Vietnam, they also issue decrees or circulars related to food safety, traceability, and recall. National Numbering and Barcode Center (NBC - GS1 Vietnam) is the adviser for developing the national standards, technical regulations, circulars, and decrees for traceability systems in the supply chain including barcoding; product, party (business), and location identification codes; and interoperability, all of which are essential components of digital food traceability systems. Most of the GS1 global standards have been adopted as national standards or TCVN including the GS1 Global Traceability Standard and the GS1 Fresh Fruit and Vegetable Traceability Guideline. This latter document provides foundational details on how to achieve traceability for both packaged and loose fruits and vegetables. Furthermore, NBC (GS1 Vietnam) is the focal point to engage all provinces and ministries in Vietnam and assist with their traceability systems as well as develop the Vietnam National Traceability Portal (VNTP).

4.1.1. Regulations on food traceability requirements

MARD has issued mandatory requirements for traceability for plant-based food products, based on the widely used traceability 'one step back-one step forward' principle as well as voluntary food traceability technical standards (TCVN) based on GS1 and ISO standards. Regarding the mandatory provisions, MARD regulates (a) the scope/subjects of application and (b) the compulsory traceability principle to be compliant with. Regarding the scope/subjects of application, per Circular No. 74/2011/TT-BNNPTNT dated October 31, 2011, food of plant origin has mandatory traceability for all stages of the value chain. In particular, the circular provides the traceability, recall, and handling of unsafe agri-foods and the responsibilities of organizations and persons engaged in food production, trading, and related agencies. Subjects of application include all stages and the value chain of agricultural products.

Regarding food traceability technical standards, each national technical standard (TCVN) touches on distinct aspects of food traceability, including traceability requirements for (a) traceability systems, (b) supply chain of fresh fruit and vegetable, (c) bodies providing audit and certification of traceability systems, and (d) compliance criteria. Table 7 presents the mapping between issued TCVN and equivalent GS1 standards.

Table 7: Vietnam's technical standards on traceability and equivalent GS1 standards

No	Number of technical standards	Name of applicable regulations/ technical standards	Equivalent to
1	TCVN 12850:2019	Traceability - General requirements for traceability systems	GS1 Global Traceability Standard (Ver 2.0)
2	TCVN 12827:2019	Traceability - Requirements for the supply chain of fresh fruits and vegetables	GS1 Traceability for fresh fruits and vegetables - Implementation guide (2015)
3	TCVN 12851:2019	Traceability - Requirements for bodies providing audit and certification of traceability systems	—
4	TCVN 13167:2020	Traceability - Compliance criteria for food traceability systems (checklist for food traceability system divided into 12 groups with 72 control points)	GS1 Global traceability compliance criteria for food. Application standard (2016)

4.1.2. Regulations enabling the application of technologies

The Vietnamese government has established (a) technical standards (TCVN) on digital traceability systems to facilitate the application of technologies for the development of food traceability systems and (b) regulations on the technologies (for example, RFID, barcodes, and NFC) for traceability systems. Regarding the technical standards of digital traceability systems, the government has issued several technical standards for the identification of products, parties, and locations under the digital traceability systems. MOST (through STAMEQ/NBC) issued technical standards for the identification of item numbering, trade item identification (TCVN 6939:2007, TCVN 6940:2007), global location numbering (TCVN 7199:2007), SSCC (TCVN 7200:2007), logistics labeling (TCVN 7201:2007) for uniform mark, and TCVN 13274:2020 traceability guidance for formatting tracing codes. These technical standards provide the foundation for the digitalization of logistics activities and set a general standard of identification code to support organizations in need.

Table 8: Technical standards for identifying products, parties, and locations under digital traceability systems and equivalent GS1 standards

No	Number of technical standards	Name of applicable regulations/technical standards	Equivalent to
1	TCVN 13274:2020	Traceability - Guide for formatting tracing codes	—
2	TCVN 13275:2020	Traceability - The format of data carriers	—
3	TCVN 6939:2007	Article Number - The Global Trade Item Number of 13-digit - Specification	GS1 General Specification
4	TCVN 6940:2007	Article Number - The Global Trade Item Number of 8-digit - Specification	GS1 General Specification
5	TCVN 7199:2007	Automatic identification and data capture - GS1 Global Location Number - Specification	GS1 General Specification
6	TCVN 7200:2007	Article Number and Barcode - Serial Shipping Container Code (SSCC) - Specification	GS1 General Specification
7	TCVN 7201:2007	Automatic identification and data capture - GS1 Logistics Label - Specification	GS1 General Specification

Technical standards for technologies are defined in TCVN 13275:2020 for traceability relating to the technical format of data carriers, which promotes the use of QR codes and RFID for traceability. For other technologies, stakeholders can refer to the existing standards included in table 9.

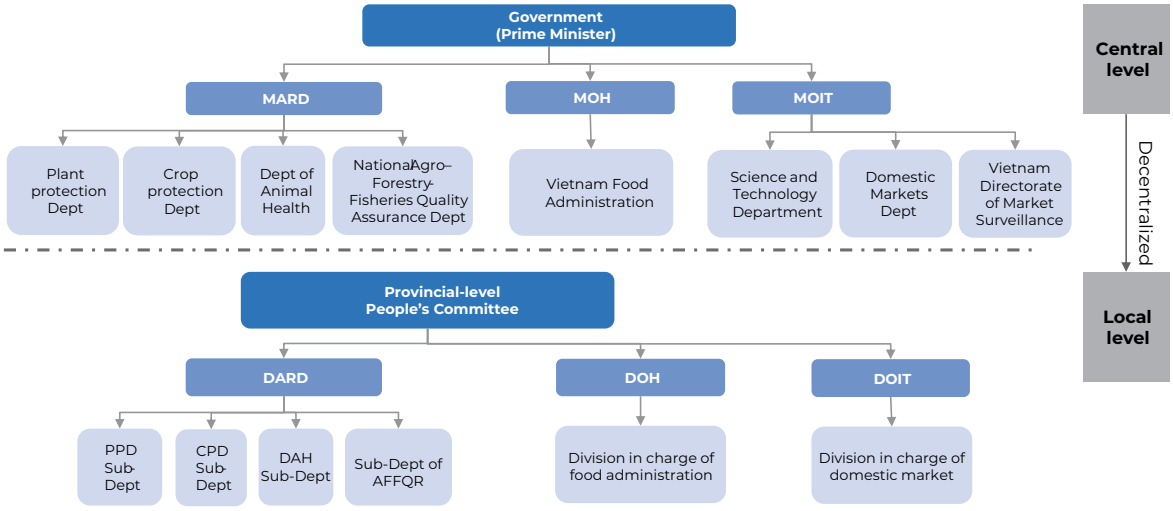
Table 9: Regulations and technical standards on select digital technologies for traceability systems

No	Name of technology	Name of applicable regulations/technical standards
1	Barcode	• Decision No. 45/2002/QD-TTg of the Prime Minister on state management of barcode codes and barcode state management agencies. • Decision No. 15/2006/QĐ-BKHCN (23/08/2006) of MOST on the issuance, use, and management of barcodes. • TCVN 7322:2009, Information technology - Automatic identification and data capture techniques - QR code 2005 bar code symbology specification.
2	RFID	• Mandatory national technical regulations: QCVN 95:2015/BTTTT on Radio Frequency Identification Equipment (RFID) operating in the band 866 MHz to 868 MHz • National technical standards: In September 2020, MOST issued Decision no. 2421/QD-BKHCN on the announcement of national technical standards relating to RFID. In particular, the following six voluntary national technical standards were published: o TCVN 12977:2020 - ISO 17363:2013: Supply chain applications of RFID - Freight containers. o TCVN 12978:2020 - ISO 17364:2013: Supply chain applications of RFID - Returnable transport items (RTIs) and returnable packaging items (RPIs). o TCVN 12979:2020 - ISO 17365:2013: Supply chain applications of RFID - Transport units. o TCVN 12980:2020 - ISO 17366:2013: Supply chain applications of RFID - Product packaging. o TCVN 12981:2020 - ISO 17367:2013: Supply chain applications of RFID - Product tagging. • TCVN 12982:2020 - ISO 4178:1980: Complete, filled transport packages — Distribution trials — Information to be recorded.
3	NFC	• Mandatory national technical regulation QCVN 74:2020/BTTTT on short-range device - Radio equipment to be used in the 1 GHz to 40 GHz frequency range.
4	Blockchain	• There is no specific law/policy in Vietnam regarding the requirements for blockchain technology for food traceability.
5	IoT sensors	• There is no specific law/policy in Vietnam regarding the requirements for blockchain technology for food traceability.
6	Mobile applications	• There is no specific law/policy in Vietnam regarding the requirements for blockchain technology for food traceability.

4.1.3. Institutional framework for food traceability

According to the Vietnamese food safety law, three ministries are responsible for food safety: MOH, MARD, and MOIT (figure 16). Each ministry has control over the products it manages throughout the supply chain, from production to processing, collection, and distribution. MOH is responsible for food safety in Vietnam as a whole and for a variety of products, including functional foods, nutrients, and packaging materials. MARD oversees food safety for the agricultural, fishery, agroforestry, and packaging materials. MOIT is responsible for certain products and retail food marketing, as well as market and supermarket management.

Figure 16: Decentralization of roles and responsibilities of state management on food safety control



Locally, the provincial people's committees and city people's committees are responsible for organizing and implementing food safety post-inspection plans through inspection and supervision. Additionally, local departments such as Departments of Agriculture and Rural Development (DARDs), Departments of Health, and quality management sub-departments will disseminate, implement, and monitor the implementation of local circulars and programs, while also conducting food safety inspections and examinations, including food traceability.

Table 10: Responsibilities of line ministries for traceability and recall of unsafe products under their management

Ministry	MARD	MOH	MOIT
Scope of management	Agricultural products, fishery products, agroforestry products, packaging materials	Products including functional food, nutrients, packaging materials, and so on	Products and retail marketing of food, management of markets, and supermarkets

Ministry	MARD	MOH	MOIT
Focal point under the ministry	• National Agro-Forestry-Fisheries Quality Assurance Department • Department of Crop Production • Directorate of Fisheries	• Vietnam Food Administration	• Science and Technology Department • Domestic Markets Department
Roles and responsibilities	• Issue regulations on traceability for products under their management • Issue procedures for recall and handling of unsafe products under their management • Take charge and cooperate with relevant agencies to inspect the implementation of traceability • Report on results of monitoring the implementation of the traceability system, proposing solutions and measures to ensure food safety.		

In addition to the above three ministries, MOST is responsible for developing technical standards for food traceability. Within MOST, STAMEQ is the directorate responsible for standardization, metrology, and the quality of products. Regarding the traceability system, MOST issued national standards (TCVN 12850), which harmonize with the international standards (for example, GS1 standards).

Inspection mechanism

Circular No. 38/2019/TT-BNNPTNT and Circular No. 17/2018/TT-BNNPTNT regulate the management scheme for food manufacturing and trading business, including small-scale businesses. As for the food manufacturing and trading business, the competent state agencies will conduct periodic assessments on the compliance of the businesses with food safety regulations (including compliance with food traceability requirements). Table 11 provides details of the assessment criteria.

Table 11: Assessment criteria

Content	Details
Basis for assessment	• National technical regulations and national standards • Legal documents relating to food safety
Rating forms	• **Rank A**: good, fully conforming to requirements on food safety • **Rank B**: satisfactory, basically meeting the requirements on food safety • **Rank C**: unsatisfactory, not yet conformed to food safety regulations
Assessment frequency rate	• **Rank A business**: 1 time/18 month • **Rank B business**: 1 time/12 month • **Rank C business**: assessment time varies based on the degree of defect.

For small-scale businesses, the inspection mechanism is not as strict as for formal businesses. They are only required to sign minutes on the commitment to follow food safety regulations (including traceability requirements) with the state management agencies.

State management agencies will only conduct inspections as per the plan approved by the provincial people's committee or in case of food safety incidents.

In terms of inspection personnel, MARD is one of the most important agencies responsible for food safety and traceability management throughout the F&V supply chain. However, 15 inspectors are assigned to relevant MARD departments (NAFIQAD, DPP, and DCP, see MARD departments in Figure 16), with an average of 10 to 15 inspectors assigned to each province. Between 1,000 and 1,500 inspectors are assigned to crop production management at MARD and local levels (World Bank 2017). Sub-NAFIQAD was established in several provinces with limited investment in facilities and equipment as well as limited personnel (only 12 to 15 permanent officers). Apart from MARD, MOIT (which is responsible for monitoring and inspecting all products sold in markets and supermarkets—except wholesale wet markets) employs approximately 7,000 market inspectors who are tasked with controlling and monitoring all types of markets throughout the country as well as performing traceability checks (World Bank 2017).

Role and responsibilities of the conformity assessment organization

According to the Law on Product and Goods Quality, the conformity assessment organization will conduct auditing and certification activities to ensure that the enterprise's traceability system complies with the enterprise's standards. MOST has published TCVN 12851:2019, defining the requirements for organizations that evaluate and certify traceability systems.

4.2. Initiatives by the Vietnamese government promoting traceability

4.2.1. Initiatives at the national level

Vietnam recently approved the 'National Digital Transformation Programme, with orientation toward 2030'. The initiative will help accelerate digital transformation through changes in awareness, enterprise strategies, and incentives toward the digitalization of businesses, administration, and production activities. The program will target businesses, cooperatives, and business households that want to adopt digital transformation to improve their production, business efficiency, and competitiveness. As part of the plan, a national digital traceability system was considered one of the government's priorities.

On January 19, 2019, the Prime Minister issued Decision No. 100/QD-TTg approving the scheme on the implementation, application, and management of the traceability system (Decision 100). The scheme's objectives include the following:

- Reviewing the institutional and legal framework on traceability
- Raising awareness on traceability of the society and related parties
- Promoting socialization of traceability activities

- Ensuring information disclosure and transparency
- Issuing the national technical standards, regulations, and guidance on traceability
- Piloting traceability systems for specific groups of products.
- Establishing a national portal for tracing the origin of products and goods.

4.2.2. Institutional arrangements

The Prime Minister assigned MOST to take the lead in implementing and controlling the project. Within MOST, STAMEQ is the agency assisting in state management of traceability activities and taking the lead in the planning and implementing Decision No.100. Within STAMEQ, the NBC hosts the GS1 Vietnam offices and is the focal point to engage all provinces and ministries in Vietnam and assist with their traceability systems as well as develop and implement the VNTP.

MOST and MOIT have both approved plans to implement the national traceability portal. As of December 2020, STAMEQ has established a guiding document for the implementation of Decision 100 in 63 provinces/cities throughout the country.

To raise awareness, NBC/GS1 Vietnam has been collaborating with local governments to host seminars and training sessions on standards-based identification codes and related barcodes, which include content on food traceability. In 2020, GS1 conducted capacity-building activities in several provinces, including Binh Dinh, Thua Thien Hue, Nghe An, Thai Nguyen, Dong Thap, Binh Thuan, Tay Ninh, Ba Ria - Vung Tau, Kien Giang, Thai Binh, Cao Bang, Gia Lai, Bac Ninh, and Son La.

Note: MOST/STAMEQ/NBC adapted GS1 global standards and technical specifications and issued several national technical standards (TCVN) that support food chain traceability.

In preparation for the launch of the national portal for tracing the origin of products and goods, STAMEQ is currently developing a set of technical standards that will enable agencies, organizations, and enterprises to connect and align their traceability systems with the planned national portal.

Regarding other tasks, GS1 is implementing a series of traceability applications as a service to be provided to industry, including one for agricultural products. These applications include digitizing farm diaries and connecting all information in the food supply chain, enabling consumers with a mobile device to scan a QR code to review the history of the product's production and distribution. Additionally, there is an application of a Vietnamese fruit map to aid in the promotion of local fruits via e-commerce. This application was created to track and update data on fruit production, price trends, and consumer demand.

4.2.3. Capacity-building initiatives at the provincial level

In alignment with Decision 100, by April 2021, 54 of 63 provinces/cities had carried out several activities.

- 48 provinces have approved decisions to implement the scheme.
- 41 provinces have organized workshops, events, and training courses to disseminate knowledge relating to traceability to relevant stakeholders.
- 23 provinces have been preparing IT infrastructure enabling digital food traceability, including Tra Vinh, Ca Mau, Gia Lai, Tay Ninh, Khanh Hoa, Ba Ria Vung Tau, Soc Trang, Kien Giang, and Quang Ninh.
- 25 provinces have implemented traceability systems and applied traceability stamps for specific products (for example, one commune-one product [OCOP] products and specialties).
- In response to capacity-building events, some provinces have been actively seeking consultation from GS1 relating to food traceability matters, including Son La, Quang Ninh, Nghe An, Gia Lai, Phu Yen, Thua Thien Hue, and Binh Thuan.

4.3. Application of food traceability in Vietnam's F&V supply chains

This section describes the current application of food traceability in selected F&V supply chains and introduces digital traceability solution providers in Vietnam.

4.3.1. Digital traceability solution users

As consumer concerns about food safety and transparency of product information intensify in Vietnam and throughout the world, many stakeholders in selected supply chains in Vietnam recognize the business value of traceability in terms of increasing product transparency, increasing the penetration of Vietnamese-made products into high-demand markets, and introducing premium pricing in the domestic market. According to the results of the present study's interviews, many F&V firms (leafy greens and dragon fruit) already have traceability systems in place that are based on digital technology. However, the extent to which traceable data and traceability systems are complete varies according to stakeholders and their target markets. Table 12 summarizes the interview results of the current application of food traceability in selected F&V supply chains (leafy greens and dragon fruit).

Table 12: Current state of traceability systems by stakeholders in the F&V supply chain[12]

Target market	Export-oriented firms - 33%	Firms distributing products through formal distribution channels - 33%	Farmer households distributing products only through informal distribution channels - 34%
1. No traceability	• Not applicable	• Not applicable	• 100%
2. Manual traceability	• 40%	• 60%	• Not applicable
3. Digital traceability	• 60%	• 40%	• Not applicable
3.1. Front-end	• 60% use mobile apps to record traceable data	• 40% use mobile apps to record traceable data	• Not applicable
3.2. Middleware	• 20% have an ERP system connecting to the traceability system and use their own cloud system • 40% use cloud systems provided by solution providers	• 40% use cloud systems provided by solution providers	• Not applicable
3.3. Data and protocol layer	• 40% are using the database provided by solution providers • 20% have their own database using blockchain technology	• 40% are using the database provided by solution providers	• Not applicable
3.4. Infrastructure	• 40% have IoT sensors and locators • 60% equip mobile devices for farmers to record traceable data	• 40% equip mobile devices for farmers to record traceable data	• Not applicable

Source: Interview results by EY, 2021.

Traceability systems have been implemented by export-oriented firms and firms that distribute their products through formal channels, as indicated by the interview results in table 12. By contrast, businesses that distribute their products through informal channels lack a traceability system and associated data. They are mostly small-scale farmer households that are not members of cooperatives.

Manual data collection tools and data storage and sharing systems, such as mobile apps, electronically readable codes (QR code, barcode), and ERP, are currently used in the F&V value chains. Blockchain-based systems and automated data collection tools such as sensing devices, real-time image processing, and camera detection are currently in limited use and are only available to large-scale enterprises.

Export-oriented firms are most likely to use digital traceability (for example, mobile apps to record and monitor traceable data), followed by firms that distribute their products through

12 Based on stakeholder interviews and analysis by the research team.

formal domestic distribution channels. Most of these applications are developed and implemented by technology solution providers. Additionally, solution providers offer cloud-based systems for storing and analyzing traceable data. To monitor product storage at a large-scale enterprise, an ERP system is typically integrated with a traceability application. Additionally, companies may have sensor devices and geolocators in the production fields to enable real-time information gathering. Around 40 percent of export-oriented firms and 60 percent of firms distributing products through formal domestic distribution channels continue to manually record traceable data in farm books and Excel files.

To achieve traceability compliance for the EU markets, importers must document the sources of their products and be able to provide proof of origin for all fruits and vegetables. Proof of origin is also necessary for importers to receive beneficial tariffs that are common for imports from developing countries with a Generalized Scheme of Preferences (CBI 2020).

Note: In scientific terms, a food product's source or origin is referred to as its provenance or scientific origin. It is important to note that product labels (including seals/stamps/stickers/QR codes) are not a guarantee of origin and digital traceability systems, including blockchains, but only provide a guarantee of data provenance or when the data entered the system, whereas the scientific analysis of the product through laboratory testing can verify the true geographic source or origin using the ascertainable and verifiable characteristics of the product (for example, DNA fingerprint analysis or other chemical analysis). As an example, a Vietnamese trader could buy fruits and vegetables from cheaper sources in neighboring countries and then add them to a Vietnamese-based blockchain traceability solution and export them to Europe with a false claim of Vietnamese origin. This is an example of confusing data provenance in a blockchain with scientific provenance of the physical product. An interview conducted in August 2022 with the management board of a HCMC-based wholesale food wet market indicated that false claims of provenance are common in Vietnam. They shared numerous examples, including potatoes from China repackaged and sold as potatoes from Da Lat province and mangoes from various areas sold as premium mangoes from Can Tho.

The Chinese market has tightened its food safety and traceability requirements. China's General Department of Customs issued a notice to customs on December 10, 2018, outlining specific requirements for the quarantine of fruit exports and imports between China and Vietnam. Quarantine procedures for fruit exports and imports must include the production unit code (PUC), acreage, estimated yield, and a quarantine certificate for plants. From January 1, 2019, fruit exported to China must come from inspected and certified farms and packing plants, see this link.[13] This requirement is applicable to both official quota and border trade products exported from Vietnam to China. On the other hand, beginning on the same date, when fruit exported from China to Vietnam is quarantined, it is necessary to confirm that the fruit originates from a registered orchard and packing plant (a list of which can be obtained from the China General Administration of China Customs website) and to include the name or code of the registered packing plant in the 'additional declaration' column of the phytosanitary certificate issued. All Chinese customs offices should inform relevant Chinese export enterprises of the Vietnamese side's requirements.

13 https://trungtamwto.vn/file/18361/Chinh%20sach%20nk%20rau%20cu%20qua%20cua%20Trung%20Quoc.pdf

In the domestic market, businesses/cooperatives that sell their products through formal distribution channels frequently have more sophisticated traceability systems than those that sell their products through informal channels. To comply with tightened regulations and modern consumers who demand more information and assurances about the safety of their purchases, formal distribution channels such as supermarkets have stricter requirements for agricultural products. Products must be traceable, compliant with domestic and international standards (such as Vietnam Good Agriculture Practice or VietGAP and Global Good Agricultural Practice or GlobalGAP) and labeled in accordance with applicable state labeling requirements. Thus, a traceability system enables businesses/cooperatives to sell their products through formal distribution channels. In comparison, a sizable proportion of small-scale farmers continue to sell their products through informal distribution channels (such as traditional markets). The products sold are extremely diverse in terms of type, quality, and quantity, but frequently lack a label on the packaging and an apparent origin (Dung 2020). Farmers frequently sell their products at traditional markets or to wholesalers. No traceable data are required for these products from wholesalers or consumers through informal distribution channels. As a result, farmers and wholesalers frequently fail to record traceable data about their products or implement a traceability system.

Another previous study also presented the same result. A series of surveys was conducted (Cameron et al. 2019) to assess the digital awareness and readiness of 500 enterprises and 200 households in the agriculture sector and found that about 70 percent of agriculture firms participating in the survey had access to digital technologies to support their business. It was much less for household farmers at only 18 percent, although more than half of the survey participants considered Industry 4.0 as important. Moreover, the trend of investing in technologies in the upcoming years among survey takers was not significant. More than 80 percent of agriculture households and 60 percent of enterprises did not have any plans for technology investment in the next 12 months. Only about 5 percent of small households intended to invest in technology in the next year, one-fourth of the figure for enterprises.

Experiences in applying traceability systems companies in Vietnam

Private food traceability systems

Lavifood

The company produces, distributes, and exports fresh, dried, pureed, and frozen (individual quick freezing) F&V products. The company directly exports using Lavifood's trademarks as well as an original equipment manufacturer. Its target markets are high-end domestic markets and export markets including Russia, the US, Japan, Korea, and Eastern Europe.

- As a large export company with high-value products, Lavifood deploys complex technologies to serve its management purposes (including traceability), including
    - Front end: Website and mobile application.
    - Middleware: ERP, ICT cloud system, and artificial intelligence.
    - Data and protocol layer: Blockchain.

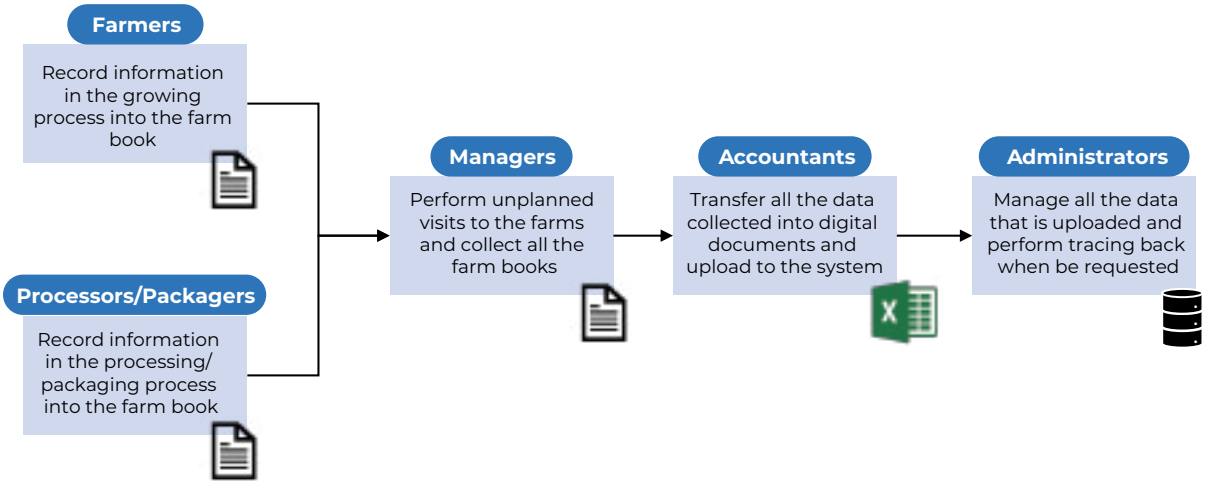
  - Infrastructure: QR code system, IoT sensors, mobile devices, and blockchain nodes.
- The system is quite complex for those participating in informal markets: farmers might have difficulties accessing technology and not be familiar with using mobile devices to record daily diaries.
- The system facilitates interoperability and can integrate and synchronize with the factory's systems, applications, and products system and smart cold storage system.
- The system is reliable: (a) blockchain technology ensures data reliability (no change can occur without notifying other stakeholders in the supply chain) and (b) IoT sensor technology reduces human errors.
- Stakeholder information is protected: the cloud-based system helps to back up and store all the data and information for traceability of any product.
- Lavifood's products are certified by global quality evaluation organizations, such as ISO 22000, hazard analysis and critical control point (HACCP), Bureau Veritas (BRC), Halal, and Kosher.

Queen Dragon Fruit

Queen Dragon Fruit is the largest dragon fruit grower and exporter in Vietnam. Their business activities range from growing, processing, and packaging to directly distributing. The company develops the traceability system itself and uses it internally. Its target markets are export markets, including Russia, the EU, China, and Thailand.

- Differing from Lavifood, Queen Dragon Fruit deploys a much simpler system:
  - A traceability code is stamped on each box of dragon fruit according to the market requirements with information such as exporter name, batch, and internal tracking code.
  - All information is recorded manually and entered in Excel files.
  - Data are pushed into their database (as described in figure 17) for tracing back when needed.

Figure 17: Queen Dragon Fruit traceability flow



- The system is quite simple and can be applied to both formal and informal market players: It is easy to set up and does not require much training since it needs only an Excel file and an internal database.
- Although recording data manually, the system is quite reliable since the verification process is ensured as managers help control all the possible risks that may occur during these phases.
- Data protection is ensured: the database is only accessed by the administrators; no other outside sharing of data is allowed.
- The system complies with all the data requirements of GlobalGAP.

Vietnam Cooperative Alliance (VCA)

VCA is a socioeconomic organization regulated by the law. The alliance supports its members in applying technology to perform traceability. The system was developed by VCA with the goal of being accepted by Vietnamese and Chinese customs. Its target markets are export markets, including the EU and China.

- The system deploys both common and advanced technologies applicable for food traceability, including
  - Front-end: website and mobile application;
  - Middleware: ICT cloud system;
  - Data and protocol layer: blockchain database; and
  - Infrastructure: QR code system, mobile devices, and blockchain nodes.
- The system is quite complex for those participating in informal markets: The usage of a smart mobile device is still difficult for many farmers, so they cannot fully utilize all its applications. Blockchain is also viewed as advanced for these players.
- The system is quite reliable since
  - Data complies with the GS1 Global Standards on Traceability and will be tested by VCA's system management personnel; and
  - Blockchain technology ensures data reliability (no changes can occur without notifying other stakeholders in the supply chain).

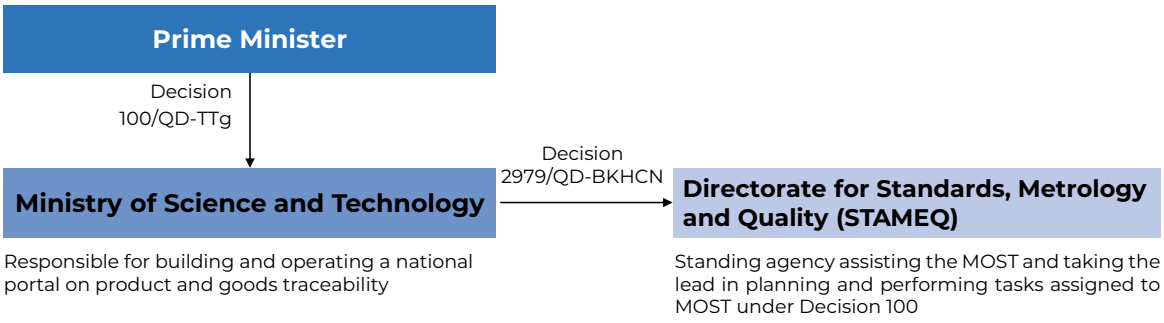
Other cases: Details are provided in appendix B.

Public food traceability systems

Responsible government bodies

The national portal on product and goods traceability under MOST will play a central role in the traceability system in Vietnam, with the participation of all parties in the supply chain, such as manufacturers, packers, transporters, distributors, and retailers, traceability solution providers, and state management agencies.

Figure 18: Responsible government agencies



Current implementation progress

- STAMEQ is developing a set of standards to ensure the traceability systems of agencies, organizations, and enterprises are connected to the national portal.
- According to STAMEQ, the national portal was expected to be put into operation in the fourth quarter of 2021. As of August 2022, the portal is undergoing scalability testing for 60,000 concurrent users with a scheduled completion in November 2022. By 2025, the platform will be scalable for 100,000 concurrent users, according to GS1 Vietnam.

National traceability system under MOIT

Under Decision 1978/QD-BCT, MOIT plans to build and operate a traceability system for products and goods under the direct management of the ministry—by 2025.

According to NBC/GS1 Vietnam executive leadership, the MOIT traceability system will function as a module within the VNTP. Additionally, MOIT is responsible for reforming the legal system, developing guidance documents on product and goods traceability, promoting the socialization of traceability activities to facilitate international integration, and enhancing state management efficiency, thereby ensuring the quality and safety of products and goods.

Provincial traceability systems

Some provinces/cities such as Hanoi, Quang Ninh, Hung Yen, and Hoa Binh have implemented provincial traceability systems with the participation of a wide range of agri-food products, including fresh fruit and vegetable to processed and packaged foods (for example, confectionery, cooked food, and frozen food).

- These systems deploy common, low-cost, and easy-to-use technologies such as QR codes and mobile application solutions. By scanning these codes, consumers will then be directed to a portal that displays some basic information about the products and places of production.
- These systems integrate all the products managed under provincial DARDs, Departments of Industry and Trade, and Departments of Health to provide a combined portal serving traceability within these cities/provinces.

  Note: According to GS1 Vietnam, many of the existing traceability systems do not follow the national technical standards (TCVN) and GS1 standards on traceability which limits

their ability to connect (or facilitate interoperability) with existing/future systems of other provinces as well as with the future national traceability portal (NBC 2021).

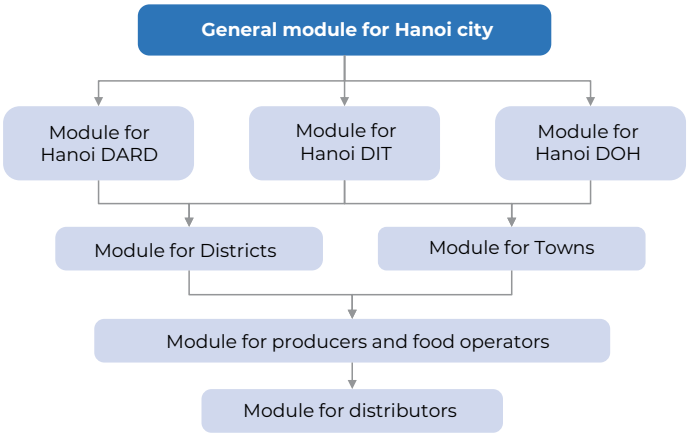
Traceability system implemented by Hanoi city

In 2018, Hanoi city launched an electronic information system aimed at helping consumers trace the information regarding the origin of Hanoi's safe agricultural products (http://hn.check.net.vn) as well as improving food safety in the city.

Figure 19: Hanoi's city food traceability system

The system was set up with administrative layers, including layers for the city's departments, districts, towns, and consumers, to allow it to provide transparent information about products while effectively connecting producers and manufacturers with consumers.

Figure 20: General module for Hanoi city



To obtain QR codes, producers/suppliers must register with the Center for Development and Integration of Enterprises (under the Vietnam Association of Small and Medium Enterprises - VinaSME), after which they will be provided with a registered code to access the system and obtain a QR code.

By 2020, the system had stored information on 2,854 enterprises and cooperatives producing safe agricultural, forestry, and fishery products with nearly 8,702 QR-based product traceability codes.

Traceability system implemented by Hoa Binh

While implementing Plan No. 151/KH-UBND dated November 27, 2018, of the People's Committee of Hoa Binh province, in 2019, Hoa Binh DARD collaborated with the CheckVN technology platform to build an anti-counterfeiting authentication traceability system (https://hb.check.net.vn/).

Figure 21: Hoa Binh's provincial food traceability system

The traceability system aims to improve the efficiency of the state management of food safety, strengthen management capacity, control quality, trace the origin of agricultural products and food, and improve the competitiveness of products. Consumers can use the code scanning app on smartphones or through the website of the traceability system to access traceability information about the legality of the business, safety certificates, and so on. The traceability system allows consumers to communicate directly with food operators about product quality, purchase and sale transactions, order information, and other elements.

In the future, the authentic anti-counterfeiting traceability system in Hoa Binh province aims to integrate more advanced technologies to better perform traceability functions while continuing to trace the origin of products, ensuring safe agricultural products and food production in chains and focusing on key fruit products and products with high risks, such as vegetables, meat, and seafood, in the provincial area.

Traceability system implemented by Quang Ninh province

The database system for traceability of safe agricultural, forestry, and fishery products in Quang Ninh province was established in 2019, with the website address https://qn.check.net.vn/.

Figure 22: Quang Ninh's provincial food traceability system

By 2020, 164 products from 23 enterprises and cooperatives were eligible to issue traceability stamps. There are two types of traceability stamps: one contains one QR code and traceability information and the other performs the anti-counterfeiting function. The system has printed 90,000 traceability stamps. According to information attained from the Quang Ninh portal, the implementation of the provincial traceability system will help the province improve the effectiveness of the state management of food safety, strengthen management mechanisms and product quality control, as well as contribute to administrative digital transformation. In addition, the provincial digital traceability system allows the city administration to enhance its supervision and inspection capabilities, easily verify product origins, detect counterfeit goods on time, and contribute to protecting the legitimate rights and interests of consumers' health.

4.3.2. Digital traceability solution providers

Table 13 presents an overview of five digital traceability solution providers in Vietnam with further details on their services (for example, technologies deployment) and the pros and cons. The selected solution providers are some of the most prominent and committed to the Vietnamese market. TE-FOOD, for example, has strong alignment with the government in areas such as pork traceability and is a strong supporter of GS1 standards.

Table 13: Introduction to digital traceability solution providers in Vietnam

No.	Provider	General information	Digital traceability solution offered	Pros	Cons	Conclusions
1.	VCA	VCA was established in 1991. Its overall function is to represent and protect its members' legitimate rights and interests. Website: https://hoptacxa.vn/vn	VCA develops a blockchain-based traceability system for the full end-to-end agriculture supply chain. The solution conforms to national and global standards and helps VCA's members gain the trust of consumers as the source of high-quality and safe products, enhance information transparency, and provide buyers with necessary information related to food safety. The system includes all four layers: • Front-end layer: Website (hoptacxa.vn), an application (hoptacxa.vn) for both Android and iOS • Middleware layer: ICT cloud systems • Data and protocol layer: Blockchain • Infrastructure layer: Mobile devices, blockchain nodes, and QR code printer	VCA deploys Agri360 solutions. Assessments can be found below.		

No.	Provider	General information	Digital traceability solution offered	Pros	Cons	Conclusions
2	iCheck (Agri360)	Website: https://icheck.com.vn/ Traceability product: Agri360	iCheck (icheck.vn) was formed in 2015 and funded by VNLife, and is now a member of VNLife's ecosystem, including VNPay - one of the most popular mobile payment platforms in Vietnam. iCheck is known for its anti-counterfeiting traceability system. In 2019, iCheck launched Agri360, an end-to-end traceability system for agriculture. Agri360 is now one of the major players and cooperates with VCA to promote thousands of farmers and small and medium enterprises (SMEs). The system includes all four layers: • Front-end layer: Web app and mobile app • Middleware layer: Local cloud • Data and protocol layer: On provider's system • Infrastructure layer: Mobile app and QR code	iCheck has dominated the market for anti-counterfeiting labels and has a large customer base iCheck provided support and consultancy and has a large resource pool. It is backed by an investment fund (VNLife) as well as supported by VNLife's ecosystem. iCheck also partners with VCA which supports many cooperatives nationwide.	iCheck is well known for its anti-counterfeiting solution. However, it has only recently initiated the traceability solution. Currently, it does not support marketing and sales activities, for which traceability data can be useful. iCheck is still in the process of enriching its traceability features. The system has been deployed by some big corporates and by hundreds of SMEs. Proprietary anti-counterfeiting solutions lock the company into one provider and are often confused with the formal product identifier from GS1.	iCheck has a strong base with millions of active users who are using 'iCheck' mobile application. iCheck may be suitable for the local market. However, it will take more time for the system to be completed and to serve a massive number of clients. Proprietary anti-counterfeiting solutions are not a formal supply chain traceability solution and have a narrow niche market.
3	Trace Verified	Website: https://traceverified.com/	Started in 2011 by a project funded by Greed Climate Fund, Trace Verified was officially formed in 2016. Trace Verified has successfully built a few solutions related to traceability. However, market adoption and customers' spending on traceability are still low. The system includes all four layers: • Front-end layer: Mobile app and, web app • Middleware layer: Local cloud • Data and protocol layer: on provider's system • Infrastructure layer: Mobile app and QR code	Trace Verified is not well known; however, it has been in Vietnam agri-food for over 10 years and its services contain not only traceability systems but a wide range of related services, including consultancy with clients listed such as Big C, Vineco, and Co-op mart	Trace Verified is not a big organization and resources for consultancy and implementation are limited.	As part of the ecosystem and a top player in the market, Trace Verified can be a candidate for integration and adoption for any system to be promoted in Vietnam, although its technical and human resource scalability to support large-scale projects is unknown.

No.	Provider	General information	Digital traceability solution offered	Pros	Cons	Conclusions
4	TE-FOOD	Website: https://te-food.vn/	Launched in 2016, TE-FOOD is a subsidiary of a Hungarian company, now headquartered in Germany. It reportedly serves over 6,000 business customers and performs 400,000 traceability-related transactions each day. The team claims food products tracked with TE-FOOD are available for more than 150 million consumers around the world. TE-FOOD aims to improve consumer trust and brand exposure, gain deeper supply chain insight to improve its operational efficiency, comply with export regulations, protect its brands against counterfeiting, and perform quicker product recalls. As an end-to-end solution, TE-FOOD offers many components for the complete supply chain to identify tracked items and batches, capture the data, store it on a blockchain (the Foodchain), process the data, and present it to the consumers. TE-FOOD in Vietnam has a strong presence in the pork sector. The system includes all four layers: • Front-end layer: Web app and mobile app • Middleware layer • Data and protocol layer: Block-chain • Infrastructure layer: QR code and mobile app	TE-FOOD traceability solution is not only strong in fruits and vegetables, but also in meat value chains. It also provides features to promote business-to-business transactions and interactions (such as notification on receiving goods). TE-FOOD is strong in technology and architecture; it makes use of a strong blockchain (Trustchain), which is the target for the global food supply chain. TE-FOOD is a German company built in Vietnam, supporting many farmers in Vietnam and servers globally, especially in Germany and Hungary. TE-FOOD also provides both an Enterprise version and Lite version, which are customized for big enterprises and SMEs, respectively. TE-FOOD designed its solution based on GS1 standards.	Offering high-tech solutions, the cost to deploy such systems would be quite high compared to informal market players.	TE-FOOD has a good vision and technology platform and has strong leadership in Vietnam and globally. It is a successful and suitable solution set. And since it targets the global market, it does create an opportunity for Vietnamese farmers to export to other markets, especially Europe.

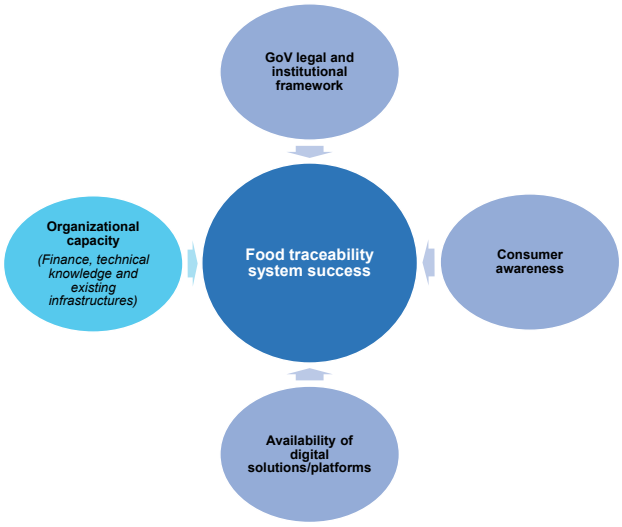
No.	Provider	General information	Digital traceability solution offered	Pros	Cons	Conclusions
5	KIAG Vietnam	Website: https://www.ki-ag.com/	Founded in 1999, KIAG offers IT solutions and advisory services for public and private sector partners. KIAG is based in Bonn and Darmstadt, Germany, with an office in HCMC. KIAG has provided solutions which have been implemented in 14 countries with thousands of farms and other users of its systems. Its 'WeTrace; branch focuses on agricultural value chains in Africa and Asia. KIAG combines ICT and traceability solutions with Geodata, big data, business intelligence, and blended learning. Its system includes all four layers: • Front-end layer: Web app and mobile app • Middleware layer: ICT cloud and business intelligence • Data and protocol layer: Geodata, big data • Infrastructure layer: Mobile devices, computer systems, ICT infrastructures, QR codes, and QR code printers.	KIAG has experience working with provincial government authorities to develop traceability solutions for the F&V supply chains (for example, Tay Ninh, Dong Thap). The company is strong in technology and architecture and can offer a wide range of high-tech solutions that are reliable and facilitate interoperability and automation, with strong data protection.	Offering high-tech solutions, the cost to deploy such systems would be quite high compared to informal market players.	It is suitable for the Vietnamese market, and since it targets the global market, it does create an opportunity for Vietnamese farmers to export to other markets, especially Europe.

SECTION 5. CHALLENGES IN IMPLEMENTING FOOD TRACEABILITY IN F&V SUPPLY CHAINS IN VIETNAM

Photos: @Lamyai/Shutersctock

This section discusses challenges in implementing food traceability in F&V supply chains under the four main themes: (a) legal and institutional framework, (b) availability of digital solutions/platforms, (b) organizational capacity, and (d) consumer awareness (figure 23). The challenges are summarized based on a review of (a) key players in the F&V supply chain and their characteristics, (b) current food traceability implementation in a few selected F&V supply chains, and (c) food traceability regulations in Vietnam.

Figure 23: Enabling environment for food traceability systems success



5.1. Challenges in Vietnam's legal and institutional framework

5.1.1. Lack of guidance/standards for specific groups of F&V products

Vietnam has mandatory provisions for traceability for all agricultural products and recommended national technical standards on traceability of general F&V products. However, no detailed guidance on traceability has been issued for specific groups of F&V products. Furthermore, as discussed in section 4.1, labeling is not required for fresh, raw, or processed food without packaging, although a TCVN was adopted with detailed guidance on how to manage traceability for packaged and non-packaged fresh fruits and vegetables. For example, TCVN 12827:2019 adopts the GS1 global traceability guidelines for fresh fruits and vegetables and highlights the foundational requirements necessary for the traceability of loose and unpackaged fruits and vegetables. See the discussion on traceability and GS1 standards.

Note: In a post-project discussion (August 2022) with the management board of a HCMC-based wholesale wet market, it was noted that 95 percent of the 2,500 tons of bulk fruits and vegetables received daily is untraceable. It stressed a regulatory gap exists for traceability, and bulk shipments do not have full traceability to the source/origin. Approximately 250 trucks arrive daily with registration papers such as 'potatoes from Da Lat region', and the

trucks comprise commingled products from various farms and cooperatives. As a result, the wholesale traders in the wet market may have no visibility of the actual source/origin of the fresh produce they buy and resell. Further, if a cooperative or farmer is VietGAP certified, this information is lost in the buying/selling process and the wet market trader is unaware of the certification.

5.1.2. Lack of resources for inspection on the compliance with traceability regulations

Human resources

Regulatory enforcement action is one of the key challenges that Vietnam is facing.

- Vietnam lacks sufficient qualified state officials to ensure control and management at every administrative level. MARD has 1,000 to 1,500 inspectors for local crop production management, and there are only 7,000 market inspectors from MOIT for all products sold in markets and supermarkets. These resources are considered insufficient to manage and inspect a total of 10,603 communes.
- Some provinces and cities have recently reported that they face constraints in conducting inspections on food safety, including the lack of funding and qualified technical staff (Son La 2021; Vinh Phuc News 2017).

Inspection mechanism

The mechanism for checking traceability compliance in the informal distribution channels, such as traditional wet markets, is unclear. The management board of a HCMC wet market highlighted a regulatory gap in mandating and enforcing traceability.

5.1.3. Complex institutional arrangement for development and implementation of the government's food traceability platforms

The development and implementation of the government's food traceability platforms may face challenges with regard to the institutional arrangements and intra-government coordination as multiple central and provincial government agencies as well as their subordinate agencies will be involved in hosting integrated public traceability platforms.

5.2. Challenges from available digital solutions/ platforms

5.2.1. Application of public traceability systems

National traceability systems

The national traceability portal is still under development, although the government initially planned to launch it in late 2022.

Provincial traceability systems

As previously mentioned, some provinces/cities such as Hanoi, Quang Ninh, Hung Yen, and Hoa Binh have implemented provincial traceability systems. However, the following observations are made:

- The current numbers of users and issued codes are small compared to existing agribusinesses (ABs) in those cities.
- According to GS1 Vietnam, most of the systems only record and display basic information about the products and places of production. Furthermore, GS1 noted that most of the systems do not follow the national technical standards (TCVN) on traceability which limits their ability to connect with existing/future systems of other provinces as well as with the future national traceability portal.

5.2.2. Application of private traceability systems

According to the present study's interviews, private traceability systems are primarily used by exporters and a few large domestic companies. They are, however, virtually non-existent in the informal market segment.

As stated in section 3.2 (key players of the F&V supply chain), stakeholders serving the informal market segment account for the majority of total F&V produced and circulated within Vietnam. Hence, the low traceability adoption rate within this segment is perceived as one of the major issues.

5.3. Challenges from organizational capacity of F&V supply chain stakeholders

The lack of financial and technical resources from supply chain stakeholders to implement digital traceability systems is a major constraint.

5.3.1. Financial resources

Vietnam's F&V sector still largely depends on small-scale and fragmented production areas and distribution channels that face a shortage of finance for new technologies.

- According to the interview results, 100 percent of cooperatives and small-scale farmers stated that they do not have the financial resources to acquire or pay fees for high-tech solutions to support the traceability of products. In addition, F&V products produced by farmers are mostly of low value and low quality; hence, the total sales cannot offset the initial investment costs or recurring fees.
- Many secondary sources also found that the shortage of finance is one of the top worldwide considerations for the implementation of high-tech solutions in supply chain traceability (Demestichas et al. 2020; Kamble et al. 2020; Xu et al. 2020). This challenge is more significant

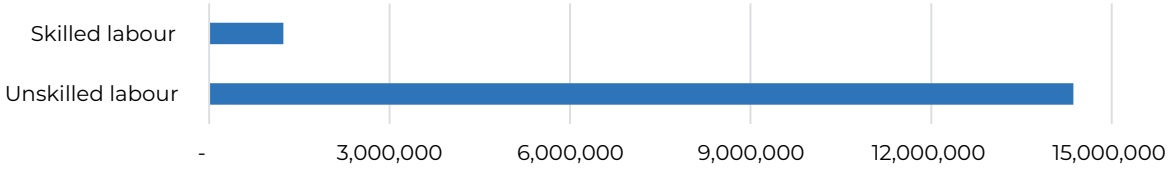
for small-scale farmers since the average cost of data collection for small-scale farmers is higher than that for larger producers (Xiong et al. 2020). Particularly for Vietnam, the lack of financial resources is one of the most significant barriers to the adoption of agriculture technology (Cameron et al. 2019). For small-scale farmers, financing is the second most common obstacle to adopting technology; meanwhile, for agriculture enterprises, this is the most common challenge encountered by more than 40 percent of firms (Cameron et al. 2019).

5.3.2. Technical resources

Vietnam's F&V sector still largely depends on small-scale and fragmented production areas, and informal distribution channels lack the technical resources to implement traceability systems:

- The extent to which participants possess technical knowledge and experience has a significant impact on their attitudes toward the adoption of high-tech solutions. Businesses with greater expertise and understanding derive greater benefits from the use of blockchain in supply chain management and are thus more likely to adopt the technology (Hackius and Petersen 2017). However, technological knowledge among various stakeholders, particularly farmers, in Vietnam's F&V supply chains is limited. Additionally, Vietnam's education has not kept up with the rapid development trend of the digital economy and the creative economy of the Industrial Revolution 4.0 (Bui 2020). Despite the high demand for skilled workers, the General Statistics Office (GSO) of Vietnam reported that unskilled labor constitutes the largest occupational group, accounting for more than 90 percent of total employment in agriculture households in Vietnam (General Statistics Office 2016).

Figure 24: Employment in agriculture by qualification group (thousands of persons)



Source: EY calculation based on data provided by General Statistics Office 2016.

Additionally, Vietnam is dominated by individual households engaged in small-scale agriculture; however, they lack the time and resources necessary to keep up with advanced agricultural technologies (Kamilaris, Fonts, and Prenafeta-Bold 2019). As a result, many stakeholders in the F&V supply chain struggle to comprehend the full potential of blockchain technology to improve the traceability system.

- Current infrastructure in rural/mountainous areas poses a great challenge for Vietnamese participants in digitizing traceability systems. In particular, farmers in rural/mountainous areas still face obstacles in accessing the internet and mobile phone services (Cameron, Pham, and Atherton 2018), while both the household farmer group and enterprise group encounter difficulties in setting up the infrastructure required (Le, Tran, and Ta 2014). In

addition, in Vietnam, microenterprises and SMEs are the two most dominant types of business in the agriculture sector, accounting for about 74 percent and 25 percent of total enterprises, respectively (General Statistics Office 2019). According to Cisco's report, Asian SMEs are in the digital indifferent state (first state) of maturity with the shortage of necessary technologies as one of the top three challenges to enable the digital transformation (Cisco 2020).

5.3.3. Interoperability

There is a lack of interoperability among existing traceability systems being implemented in Vietnam. While interoperability is a critical component of full-chain digital traceability, it is virtually non-existent in the supply chains studied. Dealing with heterogeneous data is a major concern for interoperability. The stakeholders in the selected supply chains are diverse. Organizations collect data in a variety of ways, including manual farm books, ERP systems, and high-tech devices such as sensors. Additionally, they have disparate interests, system protocol specifications, and data format/structure requirements for tracing information's origins. They do not, however, have any standards for the use of technology in agricultural traceability systems, which would facilitate interoperability between different systems (Schatsky, Arora, and Dongre 2018). Without agreed-upon methods of working toward digital traceability, different technology companies may develop traceability systems using incompatible software/hardware or programming languages. GS1 Vietnam reports 60,000 members who use GS1's interoperable standards. However, they caution that many of Vietnam's current traceability systems (public and private) are largely unable to integrate with other systems due to the use of proprietary product identifiers that are incompatible with global and national standards (GS1 and MOST). Typically, these existing systems utilize proprietary identification codes that are structured for internal use only. Additionally, because there is no centralized management and coordination of the structure of identification codes, code duplication and cyber collisions (as a result of coincidental duplicate numbering schemes) between different traceability systems is likely to occur, eroding consumer confidence (GS1 Vietnam 2021). As a result, data may be difficult to exchange and interpret consistently across multiple systems.

5.3.4. Security and privacy

Security and privacy concerns are becoming more prevalent as technology is implemented in agriculture. The global data flow has been increasing in recent years and has increased by a factor of 45 since 2005 (McKinsey & Company 2016). This increases Vietnam's vulnerability to cyberattacks as more information is made available online, and hackers from anywhere in the world can access Vietnamese data. Additionally, cyber-attacks are evolving and becoming more dangerous to the world of technology, as they can affect multiple technologies simultaneously. (Cameron et al. 2019). Although Vietnam is increasing the number of secured internet servers, which is critical for e-commerce because it fosters trust among stakeholders to engage in online transactions, it still has significantly fewer secure internet servers per million people (3,105 secure servers) than the global average (16,421 secure servers). Additionally, the total damage caused by computer viruses to internet users in Vietnam in 2019 was VND 20,892 billion, or US$902 million, nearly 40 percent higher than in 2018 (BKAV

2020). Additionally, according to the Vietnam Computer Emergency Response Team there were over 6,000 instances of cyberattacks on Vietnam's websites between January and July 2019, more than double the figure for the same period in 2018.

5.3.5. Challenges regarding consumer awareness

Consumers today, particularly in the domestic market, are increasingly concerned about food safety and transparency. However, consumers are not always attuned to the need to verify the legitimacy of traceable data. TE-FOOD noted that only 1–2 percent of all QR codes it assigns to pork products get scanned by consumers. Most consumers are still unconcerned about where goods are produced or manufactured, who evaluates their quality, and so forth (Minh 2018); instead, they focus on other attributes, such as the brand, with the perception that recognized brands imply high-quality products. According to VECO Vietnam, 93 percent of consumers in Hanoi express concern about food safety; however, only 3.2 percent of total vegetables consumed are labeled as safe vegetables, owing to consumer distrust of safe agriculture product certifications (Vietnam Economic and Cultural Office, 2016). Additionally, more than 80 percent of survey respondents who are concerned about food safety evaluate products based on their personal experiences rather than relying on traceability technologies (Lam et al. 2020). Thus, demand for traceable products is insufficient to incentivize producers to implement effective traceability systems, particularly for stakeholders focused on the domestic market.

SECTION 6. INTERNATIONAL EXPERIENCES ON TRACEABILITY AND LESSONS LEARNED FOR VIETNAM

Photos: @Joe Techapanupreeda/Shutersctock

6.1. Developing a legal and institutional framework for food traceability

For this analysis, the research team investigated institutional frameworks for food safety related traceability required by key markets for Vietnamese F&V such as the EU, China, and Korea. Italy was included in the analysis as it has national traceability criteria for high-value food with more than 870 registered geographical indications, which are a fundamental factor for a strong reputation in safe and traceable food products. Italy has implemented a number of actions to safeguard its 'Made in Italy' claims.

Traceability is critical for export markets, and a greater emphasis on growing the Vietnamese market for safe and traceable food with geographic indicators could lead to expanded global trade and lower port rejections of F&V products. The US government published the results of an import rejections report from 2002 to 2019 in December 2021. The US reported 22,000 pathogen and toxin violations totaling 5,115 import refusals from India (22.9 percent), followed by Mexico at 3,338 import refusals (14.9 percent), and Vietnam at 1,929 import refusals (8.6 percent). Fish had the most import refusals with 9,857 incidents; followed by spices, flavors, and salts (5,886); fruit and fruit products (1,388); nuts and edible seeds (1,149); and vegetable and vegetable products (925). The value of Vietnam's import rejections globally is unknown, but rejections place Vietnam in a higher-risk category for additional scrutiny and inspections prior to export from Vietnam and again upon arrival in ports.

Vietnam's vegetables and fruits imported into the EU in the first four months of 2022 totaled 24,000 tons with a net value of US$63 million. While this statistic was up 7.6 percent in volume and 29 percent in value over the same period in 2021, it represented 0.01 percent of overall EU F&V imports. To enhance trade with the EU, the Vietnamese F&V sector must develop strict hygiene controls, better quality standards, and reliable traceability solutions.[14]

6.1.1. European Union

The EU embarked on a major reform of food safety regulations to ensure a safer and more trustworthy food supply across its Member States after the outbreak of BSE (also known as 'mad cow disease') in the 1980s and 1990s (Arienzo, Coff, and Barling 2008). Traceability provisions were viewed as an effective measure to supply consumers and control authorities with relevant information for a faster recall of products in emergencies.

Regulations on food traceability

Regulation (EC) No 178/2002, dated January 28, 2002, also known as the General Food Law (EC 2002), is the legal basis of EU food control. EU legislation for the traceability of all food and feed products applies not only to domestic but also imported products of all Member States.

14 https://vietnamagriculture.nongnghiep.vn/vietnams-vegetables-account-for-only-01-of-the-eus-total-imports-d331597.html.

Article 18 of the General Food Law establishes requirements for food traceability, beginning with the establishment of food traceability at all stages of production, processing, and distribution. Second, business operators must be able to identify suppliers of raw materials for their products and firms to which their products have been shipped, and this information must be made available to the competent authorities on demand. Third, food placed on the market or likely to be placed on the market in the EU Member States shall be adequately labeled and identified to facilitate traceability via relevant documentation or information. Like the Vietnamese market, the General Food Law is based on the 'one step back-one step forward' principle, which means the data confirming the source and destination of a product or ingredient are recorded (up to the POS only). However, Article 18 is non-prescriptive and does not specify the type of information that must be kept by the food and feed business operator or a minimum period for keeping records. Therefore, businesses must determine the data to capture and record, bearing in mind that failure to produce adequate records would constitute a regulatory or legal offense.

Detailed requirements for specific products

The EU imposes mandatory requirements on several product categories, including (a) products of animal origin and (b) high-risk agri-products (for example, sprouts and seeds intended to produce sprouts). For food of animal origin, Regulation (EU) No. 931/2011 provides detailed guidance on traceability requirements established by Regulation (EC) No. 178/2002. The regulation establishes the information that FBOs must make available to their customers and the competent authorities regarding consignments of food of animal origin. In 2013, the EU issued Regulation (EU) No. 208/2013 on the traceability requirements for sprouts and seeds intended to produce sprouts. This regulation was enacted in response to a Shiga toxin-producing *E. coli* outbreak in May 2011 in the EU, in which consumption of sprouts was identified as the most likely cause of the outbreaks. At all stages of production, processing, and distribution, sprout business operators shall ensure information about batches of seeds intended for sprout production or the batches of sprouts is kept on records using the 'one step back-one step forward' principle. The information referenced above shall be updated daily and maintained for a sufficient time after the sprouts are assumed to have been consumed.

Regulations enabling the application of digital food traceability technologies

While the European Commission (EC) requires prescription medicines and some over-the-counter medicines for human use supplied in the EU to have a unique GS1-centric serialized identifier (a two-dimension barcode) and an anti-tampering device on their outer packaging, there is no mandatory requirement for serialization of food items and no guidance on digital technologies for food traceability. GS1 standards are consistently and widely used by FBOs across the EU as they enhance efficiency and reliability and ensure interoperability across EU supply chains.

Institutional framework

The food production chain frequently entails numerous steps, from the importation or primary production of a product to its sale to final consumers. Food businesses, competent authorities

in Member States, and the EC, all have clearly defined roles and responsibilities and must respond appropriately when a risk is identified. Food law holds that the operators in the feed and food business bear primary responsibility for food safety. The competent authorities then monitor, enforce, and verify this responsibility through the operation of national surveillance and control systems throughout the production, processing, and distribution processes. Additionally, Member States are required to establish rules governing the enforcement of food and feed law safety. They must be proportionate, effective, and dissuasive. The EC focuses on assessing competent authorities' ability to deliver these systems through audits and inspections conducted at the national level (in each Member State).

The EC established several organizations to assist in food safety management, including food traceability. The two noteworthy organizations that play important roles in assisting food safety management are the Food and Veterinary Office and the European Food Safety Authority.

- The Food and Veterinary Office controls the compliance with EU food regulations and standards and contributes to the development of EU legislation through the results of annual inspection programs.
- The European Food Safety Authority deals with General Food Law.

EU member state level

In addition to the legal implementation of EU legislation, many Member States have put a national performance policy in place and explained the meaning of this policy to the public. The EU Member States have established a National Food Safety Authority to contribute to higher food safety standards and more effective food safety control. These authorities comply with the requirements of the General Food Law, with additional or different controls based on local context and requirements. The responsibilities and tasks of these organizations may vary according to the Member State. In some countries, their mandate is limited to risk assessment and scientific advice to their government. In other cases, their mandate includes risk communication and enforcement of food control regulations. Risk management tasks are usually left in the hands of the responsible ministries.

Initiatives of the EC to promote traceability

To ensure food safety and particularly traceability, the EU has established the Rapid Alert System for Food and Feed and the Trade Control and Expert System (TRACES) to track the movements of livestock for preventing the spread of livestock diseases:

- The alert system was established in 1979 and was enhanced in 2002 when the General Food Law was issued (EC, 2002). The system has the participation of 26 member countries, the EC, the European Food Safety Authority, Iceland, Liechtenstein, and Norway. This alert system supports the traceability system by allowing the sharing of critical information when there is a food or feed safety hazard identified by the member countries. If a member country identifies a food safety risk, it may notify the EC and then, the Commission will pass on this information to other members for timely actions.

- TRACES system: In 2004, the EC introduced TRACES (EC, 2004), a multilingual online platform for sanitary and phytosanitary certification required for the importation of animals, animal products, food, and feed of non-animal origin and plants into the EU and the intra-EU trade and EU exports of animals and certain animal products. Its main objective is to streamline the certification process and all linked entry procedures and offer a fully digitized and paperless workflow in line with the Commission's communication on Shaping Europe's Digital Future (EC 2020. TRACES provides a central database for tracking the movement of animals and animal products both within and outside the EU. TRACES also allows for the quick detection of fake certificates and therefore contributes to enhancing trust and better collaboration. In the event of a disease outbreak, TRACES ensures that all potentially affected animals can be quickly identified and that authorities can respond appropriately. When a decision or a measure is taken on a consignment, the involved parties are notified and have access to the relevant documents.

6.1.2. Italy

Italy is characterized by its strong identity and the exacting standards of its agri-food production. A country with 870 registered geographical indications, which are the key element for a good reputation of food and products, has implemented a series of measures to protect its 'Made in Italy' agri-food, including the control system for traceability. In particular, the Italian government has put significant efforts to set up the traceability database for key products—of which some actions can be observed and learned by the Vietnam government. Italy has

- Followed the General Food Law and set forth mandatory traceability requirements for all commodities, which ensures its cross-border tradability among countries with the most challenging markets;
- Followed specific requirements (issued by the EU) regarding traceability of high-risk products: sprouts and seeds intended to produce sprouts;
- Developed the national traceability system for high-value and signature products including wine and olives; and
- Implemented control activities against frauds and misuses: the government performs thousands of checks on the compliance of food operators with traceability every year. Inspectors are well trained on traceability requirements.

Regulations on food traceability

Italy follows the EU's regulations on mandatory traceability as discussed in section 6.1.1. However, if the EU law is incomplete or absent, Italian law applies. The main principle of the single market concept is to ensure that all food products, whether produced in the EU or imported from a third country, can move freely throughout the EU if they comply with the uniform requirements.

In addition, Italy applies its own requirements on labeling (as prescribed by Decree No. 145 dated September 15, 2017). Pre-packaged food products intended for the final consumer must indicate the location of the production plant or packaging plant on the packaging or labeling.

It makes information relating to the product more transparent for the consumer and allows tracing back in the supply chain.

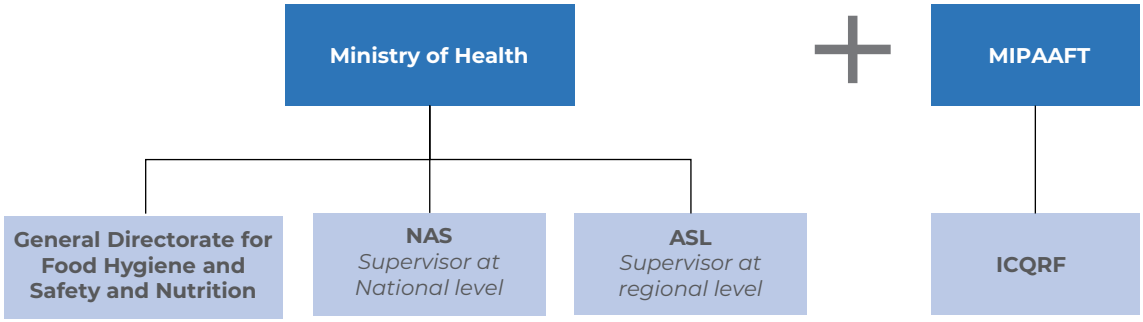
Regulations enabling the application of digital technologies for food traceability

Italy promotes the use of GS1 standards through GS1 Italy, and GS1 standards are the common language for identifying, capturing, and sharing information along the supply chain and ensuring that essential information is accessible, correct, and easily understandable.

Institutional framework

Like Vietnam, Italy manages food traceability using a decentralized model (from the national to the provincial level). At the national level, food safety and food traceability are regulated and controlled by both MOH and the Ministry of Agriculture, Foodstuff and Forestry Policies and of Tourism (MAFFTP). Because food safety directly affects human health, MOH manages almost all food categories while MAFFTP is responsible for some specific categories, including fruits and vegetables.

Figure 25: Decentralization of roles of state management bodies in food safety control



Source: EY's consolidation from Italian legal and institutional framework.

At the provincial level:

- The Local Health Unit is a supervisory body under MOH at the local level. It performs periodic and occasional controls on site to ensure the compliance of agri-food operators with HACCP procedures, which among the others, oversee the traceability of products.
- The inspectorate for fraud repression and quality protection of the agri-food products and foodstuffs (ICQRF), operated under the MAFFTP, is responsible for the defense of the 'Made in Italy' designated products in all European countries and for combating counterfeiting outside the EU borders. ICQRF successfully conducted thousands of checks every year on national agri-food production and on those marketed in Italy. Additionally, to carry out the activity of control and protection of quality Italian productions on the web, ICQRF cooperates with main e-commerce players in the world, such as eBay, Alibaba, and Amazon.[15]

15 Article 4 - D.P.C.M. No. 179 of 05/12/2019 - Reorganization of the Ministry of Agriculture, Foodstuff and Forestry Policies and of Tourism.

- Regions and autonomous provinces are responsible for planning, coordination, guidance, authorization, and verification within their territories. Operational implementation of controls is handled at the local level by 123 Local Health Units with a high degree of managerial autonomy.

Role and responsibilities of the conformity assessment organization

The Italian government has appointed the National Accreditation Body (Accredia) to attest to the competence, independence, and impartiality of Conformity Assessment Bodies (CABs), which verify the conformity to the standards of goods and services, including requirements on traceability of food products. All European countries have an accreditation body that operates in line with Regulation EC 765/2008 and with the international standard ISO/IEC 17011.

In Vietnam, there is also an entity called the Accreditation Office for Standards Conformity Assessment Capacity (AOSC) under the management of MOST for conformity assessment of standards. However, most of its current work is related to the medical and testing fields (for example, accreditation of testing/calibration and medical laboratories).

Initiatives by the government of Italy to promote traceability

The government of Italy has established national traceability systems for its high-value and specialty products, olive oil and wine, both of which are currently managed by MAFFTP.

Electronic olive oil register (Registro Telematico Olio - RTO)

The electronic olive oil register (RTO) is a system managed by the ICQRF under MAFFTP that enables accurate traceability of the national olive oil supply chain. It allows the official control bodies to monitor the supply chain movement of olives, olive oil, pomace oil, and pomace for each plant/warehouse online. Additionally, it enables the identification of domestic and foreign operators responsible for the movements. RTOs must be maintained for each established warehouse by olive dealers, oil mills, packaging companies, bulk oil traders, refineries, and olive-pomace traders. Operators who hold oil solely for personal consumption, non-food purposes, or for use in specific food products, as well as operators who hold only pre-packaged and labeled oils, are exempt from the RTO requirements. There are approximately 21,000 active electronic registers as of December 31, 2020. Since 2018, the ICQRF has aggregated RTO data in a report called 'Frantio Italia' that is available on its website every two weeks.

Electronic wine register (Registro Telematico Vino - RTV)

The electronic wine register (RTV) has been operational in Italy since 2017. The wine supply chain operators are required to register the movement and processing of wine products online. Along with enabling official state management authorities to monitor and verify each operation and movement made by all operators online, the register provides critical data for understanding the wine market.

As of December 31, 2020, nearly 17,000 operators are registered on RTV, with approximately 10 percent producing 1,000 or more hectoliters per year. There are approximately 615,000

registered wine storage containers, and over 30 million operational transactions are recorded annually. Since 2018, the ICQRF has aggregated RTV data in a report called 'Cantina Italia' that is available on its website every two weeks.

6.1.3. China

Like GS1 Vietnam, the GS1 organization in China—also known as the Article Numbering Center of China—ANCC, was founded in 1988 under the authorization of the State Council of the People's Republic of China as an affiliate of General Administration of State Administration for Market Regulation. GS1 China oversees the organization, coordination, and administration of article numbering and Auto-ID work throughout China.

As a result of numerous food safety and food fraud scandals, the Chinese government has recognized the critical role of food traceability in food safety governance. Numerous government-supported traceability initiatives have been launched over the past two decades, focusing on various types of risks in food and agricultural products, specific IT standards, and specific municipalities and provinces. For example, GS1-centric "barcode applications have been extended to the food safety area with great efforts and a number of food safety tracking and tracing system demonstrations have been established on a range of products such as Shandong seafood, Xinjiang cantaloupe, Yunnan pork, Sichuan tea, and the Hetian chicken of Fujian, this consolidates the critical role the barcode plays in our national food safety tracking and tracing system."[16]

The current legal and institutional framework in China for food traceability is defined by the following key points that the Vietnamese government should consider:

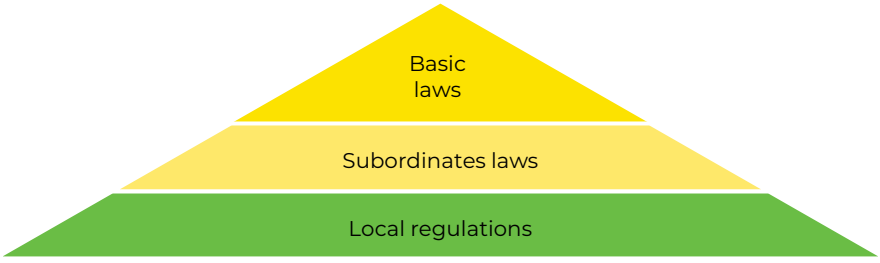
- China has set out several mandatory requirements in regulations on food traceability for all commodities and voluntary technical standards for traceability systems.
- The Chinese government has prioritized high-risk and signature products and particular supply chains by issuing detailed traceability requirements:
    - High-risk/signature products: meat and tea.
    - Supply chains in cold chain activities and e-commerce.
- Capacity building for inspection workforce: after the recent issuance of national technical standards on traceability, the government plans to conduct training for its inspection workforce.
- Issuance of national and provincial traceability systems: (a) a national system for agricultural products and (b) provincial systems for meat and vegetable products.
- China encourages food producers and traders to use IT to collect and retain production and trading information and establish food safety traceability systems. In China, QR codes are widely used by both major retailers and street markets. As a result, the food traceability sector highly depends on this technology due to its widespread and easy to use nature.

16 http://ancc.org.cn/GS1ChinaEN/GS1ChinaENTest/foodsafety.aspx.

Regulations on food traceability

China's domestic legal framework comprises three tiers of national laws. These laws are often set with minimal requirements and are mandatory for all food producers and traders of all kinds of food. Figure 26 demonstrates three key tiers of the legal framework regulating food traceability in China. Detailed information is presented in appendix D.

Figure 26: Legal system hierarchy in China



Source: EY's consolidation from the Chinese government's legal framework.

Regulations enabling the application of digital technologies for food traceability

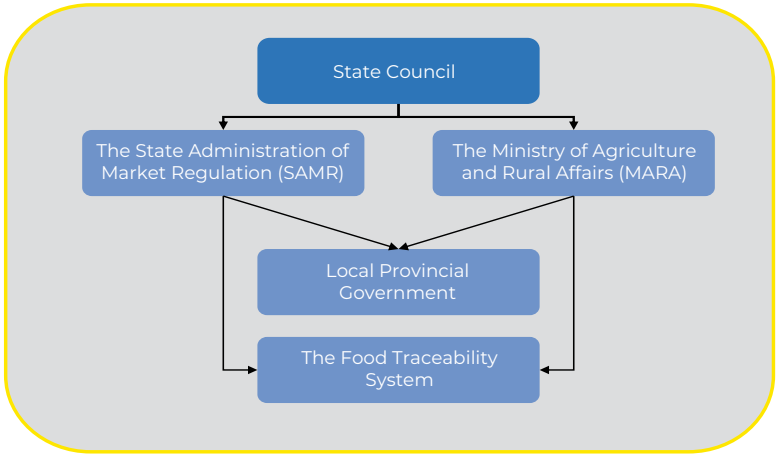
The regulations and technology standards listed below are voluntary regulations that businesses are recommended to follow for the following:

- Barcode/QR code: General technical requirement for QR code of food traceability (GB/T 38574-2020) and food traceability two-dimensional code technical specification (under Plan No. 20171121 T-469).
- IoT: The province of Jiangsu has a plan to implement the 'Food Safety Electronic Traceability and Data Sharing' standard, which disciplines the use of IoT devices in food traceability (Berti and Semprebon 2018).

Institutional framework for food traceability

Like Vietnam, the Chinese government manages food traceability using a decentralized model (from the national to the provincial level), which includes the State Administration of Market Regulation, MARA, and relevant local government authorities. Figure 27 illustrates the institutional framework for food traceability in China.

Figure 27: Institutional framework for food traceability in China



National level: There are two competent ministries responsible for food traceability management:

- The State Administration of Market Regulation is responsible for the coordination of China's food safety system; development of major food safety related laws, policies, and regulations; and implementation of market inspections and registration of special foods.
- MARA is responsible for regulating the quality and safety of domestic agricultural products (at pre-processing stages).

Provincial level: Apart from overseeing and administering food safety and traceability, provincial authorities (provincial food and drug administrations) will be responsible for developing measures and conducting pilot projects tailored to local conditions.[17] In China, food traceability is managed at three levels of local government: provinces, cities, and counties. The relationship between various food safety authorities at all levels is structured similar to that of the central government. Each level reports to the authority of the preceding higher level (Jia and Jukes 2012). Due to the size of the country and the numerous provinces, cities, and counties to manage, inspections conducted in local areas rely heavily on the quality and quantity of inspection workforces. Following the recent publication of national technical standards on traceability, the Chinese government intends to train its inspection workforce.

Initiatives by the Chinese government to promote food traceability

The Chinese government has invested in and established both national and provincial traceability systems.

The National Agricultural Products Quality and Safety Traceability Management Information Platform

17 Chapter 7 of the Provisions for Establishment of Food Safety Traceability Systems by Food Production and Trading Companies issued by the China Food and Drug Administration.

In June 2017, MARA launched the 'National Agricultural Products Quality and Safety Traceability Management Information Platform'. The system is a government-led effort to integrate all traceability systems into a single centralized database for improved control and oversight by regulatory agencies. Provincial traceability platform data can be exchanged and shared with the national platform, allowing the consumer to query detailed traceability information from a single interface to the centralized database.

This system is used by four primary stakeholders: agricultural product producers, law enforcement agencies, testing facilities, and regulatory agencies. The platform places a premium on government involvement, as the system's primary objective is to assist these agencies in ensuring food safety. Additionally, the system provides the public with a single unified query portal for rapidly accessing the traceability data of agricultural products. The system utilizes a variety of technologies, including 2D barcodes, mobile apps, and ICT cloud systems.

Other provincial traceability systems

- **Pilot Project for a System to Trace the Quality of Beijing Vegetable Products (2004):** The Beijing Municipal Agriculture Bureau and the Hebei Province Department of Agriculture launched the 'Pilot Project for a System to Trace the Quality of Beijing Vegetable Products' in 2004. It was the first project in China to establish a food traceability system. Six counties in Hebei were chosen as a base for vegetable production to implement standardized packaging and product traceability labels (Tang et al. 2015).
- **Beijing Olympics Food Traceability System (2008):** Beijing authorities developed a pilot food traceability system in 2008 to track all food for the 2008 Olympic Games in Beijing. This system integrated a variety of technologies—RFID, GPS, automatic temperature recording and control, humidity control, and encrypted communication—to track and record a wealth of information about food, including its production, processing, transportation, and storage (Tang et al. 2015).
- **Meat and Vegetable Distribution Traceability System (2010–Present):** Since 2010, the Ministries of Commerce and Finance have funded a pilot program to establish a Meat and Vegetable Distribution Traceability System in 50 cities in four batches. The central government spent CNY 1.86 billion (approximately US$300 million/VND 6,600 billion) to promote the system. The Ministry of Commerce program seeks to have the traceability system cover all cities with a population greater than 1 million, and the traceability system should include meat, vegetables, livestock, marine products, fruit, edible fungi, and soy products, among other foods (Tang et al. 2015).
- In May 2022, the Chinese province of Zhejiang (population 65 million) signed an agreement with GS1 China to migrate the province's food traceability and organized retail to 2D barcodes. In total, 7,000 food companies and 200 retail stores will take part in the initiative. It is expected that by the end of 2023, 80 percent of food producers in the province will have 2D barcodes on their products.[18]

18 https://www.gs1.org/articles/gs1-2d-barcodes-gain-momentum-china.

6.1.4. Korea

Korea's government has made significant investments in food traceability to improve national food safety. Korea has done the following:

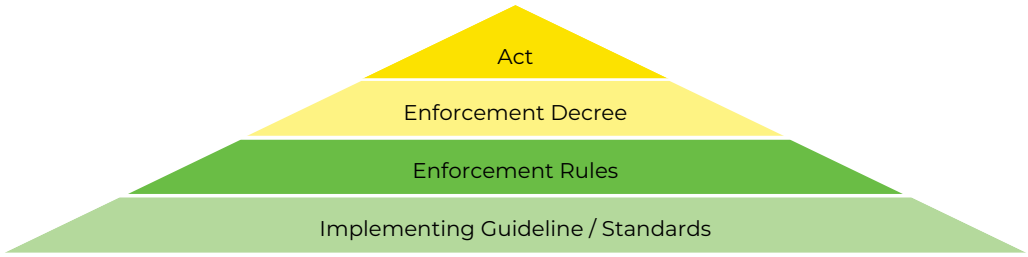
- Established specific regulations covering several aspects of traceability that may apply to business entities (for example, producers, collectors, processors, and sellers of food products) that wish to register (or are required to) for traceability in Korea. The legal framework regulates, among other things, the set of information required for traceability purposes, data recording and data storage, indication display, prohibited actions relating to traceable products, inspection and examination mechanisms for traceability standards compliance, and sanctions for non-compliant cases. These regulations compel registered entities to implement a standardized traceability system. Additionally, it assists the Korean government in monitoring and supervising the country's food safety.
- Developed mandatory traceability requirements for specific categories of products, including (a) high-risk products such as baby formula, livestock products, and functional health food; (b) large-scale operator products; and (c) government-related products.
- Implemented a national traceability system that includes (a) systems for prohibiting the sales of non-compliant products and (b) agricultural traceability systems.
- Provided financial support for food traceability. Within budgetary constraints, related Korean government bodies may subsidize funds required for food traceability to registered entities.[19]
- Enhanced public awareness of the critical nature of food safety and food traceability. For the past two decades, the Ministry of Food and Drug Safety (MFDS) has held an annual food safety day in Korea to generate public interest in food safety and to promote safety awareness among food-related workers.

Regulations on food traceability

Korea has an advanced legal system based on a fixed hierarchy. The acts or laws enacted by the National Assembly establish the legal framework for government regulations. Under each act, an enforcement decree and enforcement rules are drawn up by the responsible ministry to implement. The competent ministry or agency promulgates notices, guidelines, or standards to provide more detailed guidance. Figure 28 provides a general view of Korea's legal system.

19 Item 6, Article 49 of the Act on Food Sanitation; and Item 6, Article 24 of the Act on Agricultural and Fishery Products Quality Control.

Figure 28: Legal system hierarchy in Korea



Source: U.S. Embassy Seoul's Office of Agricultural Affairs 2019.

The same hierarchy is applied to regulate food traceability in Korea.

Korean food traceability regulations are segmented into four major regulatory systems:

- Act on Food Sanitation with enforcement decree, rules, and standards.
- Act on Agricultural and Fishery Products Quality Control with enforcement decree, rules, and standards.
- Special Act on imported food safety management and enforcement decree and rules regulate food imported from foreign countries to Korea[20] and Act on cattle and beef traceability with enforcement decree and rules.[21]
- GS1 Korea, which follows GS1 Global Standards on Traceability.

The above regulations and standards regulate (a) entities involved in traceability, (b) requirements for a traceability system (including the scope of traceability data to be recorded, method of recording and storing that data, and submission of data when required), and (c) inspection and examination mechanisms on the compliance with traceability standards.

Entities included in subjects of traceability application

Traceability is mandatory in Korea under the regulations for specific groups of products,[22]

20 Special Act on Imported Food Safety Management, Law No. 17653, December 22, 2020, effective from January 1, 2021.

21 Act on Cattle and Beef Traceability, Act No.16536, August 27, 2019.

22 Act on Food Hygiene, Law No. 17809, December 29, 2020, effective from January 1, 2021.
Enforcement decree of Act on Food Hygiene, Presidential Decree No. 31472, issued on and effective from February 19, 2021.
Enforcement rule of Act on Food Hygiene, Prime Minister's Decree No. 1661, December 31, 2020, effective from January 1, 2021.
Act on Agricultural and Fishery Products Quality Control, Act No. 17037, February 18, 2020, effective from February 19, 2021.
Enforcement decree of Act on Agricultural and Fishery Products Quality Control, Presidential Decree No.29052, issued on and effective from February 19, 2021.
Enforcement rules of Act on Agricultural and Fishery Products Quality Control, Marine Fisheries Division No. 467, issued on and effective from February 19, 2021.
Special Act on Imported Food Safety Management, Law No. 17653, December 22, 2020, effective from January 1, 2021.
Act on Cattle and Beef Traceability, Act No.16536, August 27, 2019.

including (a) high-risk products (for example, baby formula, livestock products, and functional health food), (b) products from large-scale operators; and (c) products relating to government. Additionally, other food operators are encouraged to participate. Concerning the principle of traceability, full-chain traceability is compulsory for livestock and livestock products. The traceability system must cover the stages of breeding, slaughtering (or importing), distribution, and sale.[23]

Requirements for traceability systems

Both the Act on Food Sanitation and the Act on Agricultural and Fishery Products Quality Control contain specific provisions governing the scope of traceability data that must be recorded, the method of recording and storing that data (including a minimum period of storage), and the retrieval (and submission) of data when required. Additionally, both acts include the following prohibitions:[24]

- Placing any indication of traceability or indications like that on agricultural products which are not agricultural traceability products.
- Selling or keeping/displaying for sales purposes agricultural products which are not agricultural traceability products by mixing them with agricultural products carrying an indication of traceability.

Inspection and examination mechanisms on the compliance with traceability standards

Under the Act on Food Sanitation, MFDS conducts examinations and evaluations every three years on the compliance of producers, processors, and sellers with food traceability standards and other matters. During and after inspections, if non-compliance is found, further actions will be performed, including revocation of registration or issuance of an order to take corrective measures.[25]

Under the Act on Agricultural and Fishery Products Quality Control, the Ministry of Agriculture, Food and Rural Affairs (MAFRA) may, if necessary, have relevant public officials conduct the examination to maintain the level of quality of agricultural traceability products.[26] Details on the scope of investigations involving stakeholders are provided in section on the institutional framework for food traceability.

Regulations enabling the application of digital technologies for food traceability

The Korean government stipulates that those registered entities must record and store food traceability information electronically,[27] which can then be shared with the MFDS-established

23 Act on Cattle and Beef Traceability, Act No.16536, August 27, 2019, Article 23, item 1.

24 Ibid, Article 29, items 5 and 7.

25 Ibid, Article 49.

26 Ibid, Article 10, item 1.

27 Ibid, Article 49-2, items 1 and 2.

food traceability system.[28] However, the ministry does not regulate the application of specific digital technologies. Ear tagging is compulsory for livestock and livestock products,[29] but specific technology is not prescribed. The act only mentions a few technologies that facilitate ear tagging implementation, such as barcodes and RFID.[30]

Recommended technical standards

- GS1 Korea was formed in 1988 and has been actively promoting supply chain standards to improve supply chain management. As with almost all government regulations, apart from highly regulated sectors such as pharmaceuticals, specific industry standards are not prescribed, although some do make recommendations. GS1 Korea promotes the full range of GS1 standards that enable digital traceability and incorporate product identification codes, barcodes, data synchronization, and EPC/RFID technology.

Institutional framework for food traceability

The institutional framework for food traceability in Korea is shown in figure 29.

- At the national level, MFDS is responsible for the safety of foods and drugs within Korea (including food traceability)[31]. Regarding traceability management, MFDS and MAFRA are both responsible.
    - MFDS is responsible for monitoring the traceability of agricultural, livestock, and fisheries products, as well as processed foods.
    - MAFRA is in charge of the oversight of agricultural and livestock products.
- Currently, these two ministries are responsible for food traceability under two distinct acts. The distinction between these two acts is in the products that are being traced.
- At the provincial level, local government agencies operate under the two ministries and support them in performing detailed tasks.

28 Ibid, Article 49-2, item 3.

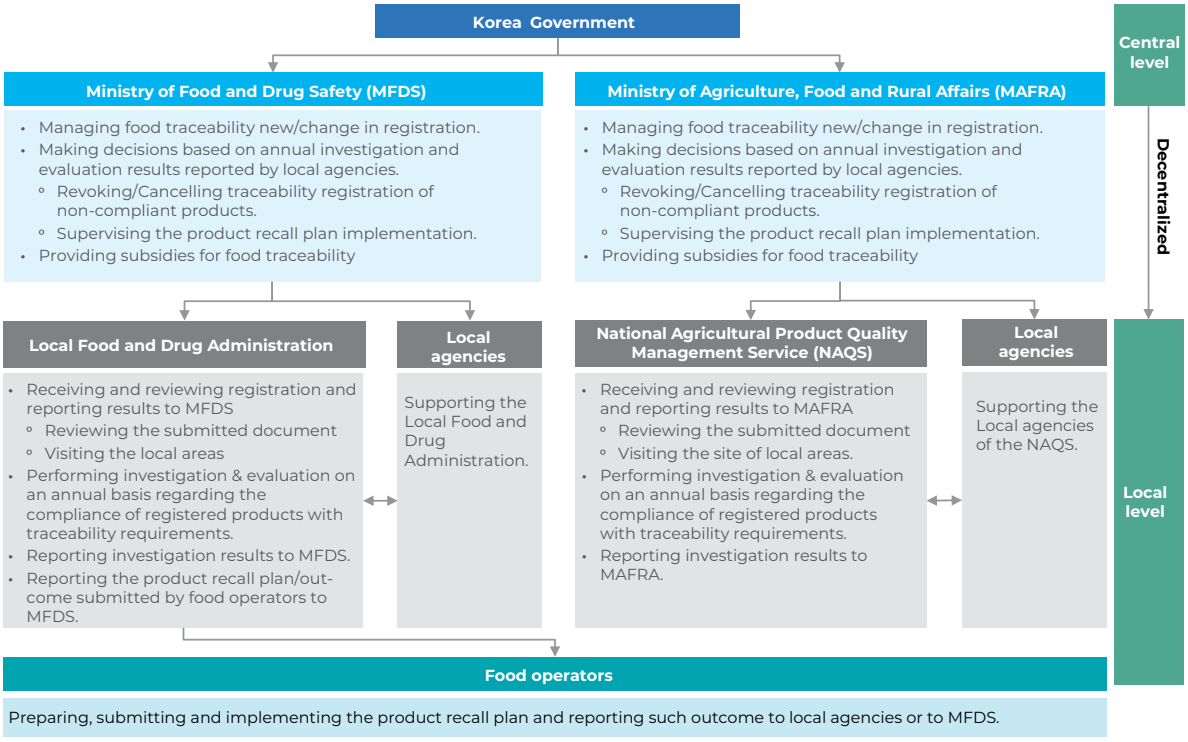
29 Article 9 of the Act on Cattle and Beef traceability no. 16536

30 Ibid, Article 2, item 10.

31 The Korean National Government Organization Act 2020, Article 25.

Figure 29: Institutional framework for food safety and food traceability management in Korea

(Under the Act on Food Hygiene and its enforcement decree and the Act on Agricultural and Fisheries Products Quality Control and its enforcement decree)



Initiatives by the Korean government to promote traceability

The Korean government observes a food safety day annually to raise public awareness and social consensus about the critical nature of food safety, to promote safety awareness among food-related workers, and to highlight the rapid progress made in recent years in Korea's food safety. The event is organized by MFDS and brings together global experts.

Additionally, both the abovementioned acts contain provisions allowing related Korean government bodies to subsidize funds required for food traceability to registered entities within budgetary constraints. Additionally, the government has invested in and implemented several traceability systems, including the following:

- The Agricultural History Tracking Management Systems (costing Korean ₩1.8 billion or approximately VND 37.2 billion in total investment): This system is managed by MAFRA but is not mandatory. Now, the system comprises voluntary participants from producers (individual farms, agricultural associations, and cooperatives), collectors (cooperatives, manufacturing companies, and exporters), and distribution channels (agricultural cooperatives, supermarkets, minimarts, exporters, and so on).
- The Unsafe Product Screening System (UPSS) is intended to improve consumer safety by effectively and efficiently utilizing information about unsafe products reported and shared

by government inspectors to prevent them from being sold in organized retail. The system is operated by GS1 Korea (under the auspices of the Korea Chamber of Commerce and Industry - KCCI) in collaboration with three relevant government agencies (including MFDS), and participation is voluntary. As of 2019, the UPSS was used by 173,708 locations (retail stores) throughout the country, ranging from large-scale retailers such as hypermarkets and department stores to small and medium businesses such as supermarkets and convenience stores. When an unsafe product is identified, an electronic message is sent to the retailer's headquarters using GS1 standards and the GS1 product identifier (GTIN). Within 30 minutes of receiving the notice, all cash registers (POS) will block the GS1 product ID (the GTIN) from being sold. The system is not a formal product recall process and is considered a 'stop sale' procedure.

6.1.5. F&V traceability challenges in Vietnam versus international practices

Table 14 is a summary of the challenges facing Vietnam in implementing traceability in the F&V sector. The table lists the identified challenges and reference mitigating factors/initiatives in international practices.

Table 14: Summary of challenges versus international practices review

Challenges in applying traceability for F&V supply chains in Vietnam		International practices review
Challenges from Vietnam's legal and institutional framework	Lack of guidance/ standards for specific groups of F&V products	EU, Italy, Korea, and China have requirements for high-risk, high-value, and signature F&V products. • **EU** has specific requirements on traceability of high-risk products: sprouts and seeds intended to produce sprouts. • **Italy** follows EU requirements regarding the traceability of sprouts and seeds intended to produce sprouts and focuses on the traceability of its signature and high-value products: olive oil and wine. • **Korea** has specific requirements on traceability for products relating to the government: agri-products purchased or imported or processed by/on behalf of the government. • **China** has specific national standards on traceability for its signature product: tea. The government of China also promotes traceability standards for cold chain activities and e-commerce transactions.
	Lack of resources for inspection/compliance check with traceability regulations	• **Italy** performs thousands of checks on the compliance of food operators with traceability every year. Inspectors are well trained on traceability requirements. • **China:** After the recent issuance of national technical standards on traceability, China has planned to conduct training for its inspection workforce.

Challenges in applying traceability for F&V supply chains in Vietnam		International practices review
Challenges from the availability of digital solutions/ platforms	Public traceability system: (a) national traceability system is planned but not yet implemented and (b) provincial systems are implemented but with limited users.	National traceability systems are implemented, which helps reduce the costs of product recall and enhance information transparency. • **EU:** (a) the system for animal products and (b) the system for sharing food safety information among EU members. • **Italy:** systems for (a) olive oil and (b) wine • **China:** (a) a national system for agricultural products and (b) provincial systems for meat and vegetable products. • **Korea:** systems for (a) banning sales of non-compliant products and (b) agricultural products.
Challenges regarding organizational capacity of F&V supply chain stakeholders	• Lack of financial and technical capabilities • Lack of ability to access international standards and export markets' requirements • Lack of interoperability between existing systems	**Regarding financial capacities:** Users lacking financial capacities may join the national traceability systems invested and implemented by the government that meet minimum requirements to perform traceability. In China, the fees are offered at low rates. **Regarding technical capacities** • These markets establish guidance/standards on the application of digital traceability systems and digital technology (for example, QR code) for users to apply. National standards have facilitated interoperability between existing systems as they employ technology complying with the same standards. In the case of China, the national system can connect with other systems. • In China, QR codes are widely promoted and used by major retailers and in street markets due to low implementation costs and ease of application.
Challenges regarding consumer awareness	Low public awareness	In Korea, for 20 years, the annual Food Safety Day has been held by MFDS to raise public interest in food safety and promote safety awareness for food-related workers. On the annual Food Safety Day, the Korean government presents the Orders of Merit, the Medals of Honor, and several Certificates of Commendation to the individuals, companies, or local governments that contributed to the improvement of food safety.

6.2. Implementing traceability systems

The review of international experiences in implementing food traceability systems shows two different systems in terms of scale and scope of application: (a) public traceability systems (at both national and/or regional levels) and (b) private traceability systems.

Public traceability systems (at both national and/or regional levels) are operated to support the management and supervision of food safety and often cover most stages of the supply chain. Information shared in this system is external traceability data.

Private traceability systems operate at the business level to ensure the link between input and output after going through each internal stage and ensure compliance with regulations and trading partner data exchange.

To assess the applicability of the traceability systems to Vietnam's market, the present study used a set of 10 criteria as shown in table 15. Additional surveys were carried out with selected international experts and national experts in Vietnam to get their opinions and to identify the importance of each criterion. A pair comparison approach was used to define the weightage for the assessment criteria. This exercise demonstrates a significant difference in three areas between the international experts and national experts in Vietnam. The international experts weighted criterion 1 (functionality) at 24.3 percent whereas their Vietnamese peers assigned a 3 percent weight. The significant differences reappear in criteria 9 and 10 where national experts weighted localization and local support and compliance to local laws and regulations as significant. It was interesting to note that criteria 5 (reliability) and 7 (affordability) were weighted lower by national experts than their international peers.

Table 15: Assessment criteria for a traceability system

No	Criteria	Weighting from international experts (%)	Weighting from national experts (%)	Explanation
1	**Functionality**	24.3	3	This criterion evaluates whether the system can provide traceability features, including (a) identification, (b) automatic data capture, and (c) recording and sharing of the traceability data for traceability purposes.
2	**Operational ease**	6.8	3	This criterion measures how easy it is to use the system. It is important for non-IT users, workers, and farmers to use the system easily.

No	Criteria	Weighting from international experts (%)	Weighting from national experts (%)	Explanation
3	**Interoperability**	6.1	3	This criterion measures the capability of the systems to share data and information. In most cases, traceability systems are required to receive or share data with modern or legacy systems. Sub-criteria to evaluate include • Standardization; • Data storing and sharing (with/without blockchain); and • Integration (application programming interfaces [APIs] for integration, ERP, warehouse management system [WMS] integration).
4	**Access and protection of stakeholder information**	5.7	4	This criterion measures the system's security so that stakeholder information/data are protected from unauthorized access that could lead to data loss, data theft, or unauthorized data modification.
5	**Reliability**	14.6	10	This criterion measures the degree to which stakeholders can rely on the system. It should include the security and availability of the system. Reliability can be proven by data or by architecture and implementation.
6	**Scalability**	2.1	3	The system can be scaled up to support more players (producers, collectors, processors, distributors, retailers, and exporters) and other end users. The criterion can be evaluated by one of two methods: • Proven by market adoption is widely adopted by many entities, which makes it easier to scale up. • Proven by strong architecture has the ability to scale up.
7	**Affordability**	11.3	6	The cost of implementation includes the costs of initiation, operation, maintenance, and support. The cost should be considered for implementation at a large scale with similar characteristics.

No	Criteria	Weighting from international experts (%)	Weighting from national experts (%)	Explanation
8	**Vietnam infrastructure compatibility**	16.6	19	The system should be compatible with local Vietnam infrastructure, which may include: • Front-end layer: Mobile apps and web app • ICT cloud: Ability to deploy at local cloud service providers (for example, CMC (Telecommunications Infrastructure Corporation), FPT (Financing and Promotion Technology), and Viettel) • Locally available network: Existing 3G/4G mobile network coverage, internet broadband, and types of the network provided by local authorities • Support popular types of identifiers: RFID, barcodes, QR codes, popular IT sensors, and handheld devices
9	**Localization and local support**	3.8	24	The system should have a feature for localization, and the vendor should provide local support in Vietnam (preferably through a partner) • Support Vietnamese language and currency • Provide local support • Rules and regulation compatibility
10	**Compatibility with Vietnam's policies/ regulations**	8.7	25	Comply with Vietnam's policies and regulations, standards, and other requirements.

Table 16 summarizes key characteristics of the systems in terms of the target market, initiative type, and technologies used. Details are presented in section 6.2.1.

Table 16: International experiences in traceability systems

Country	Name of system	Product	Initiative type			Market			Technology					
			Government	Private sector	Joint public-private	High-end market	Institutional procurement	Informal market	Barcode	RFID	NFC	Sensors	Blockchain	Mobile apps
A. National systems														
Korea	1. UPSS[32]	Food	—	—	√	√	—	—	√	—	—	—	—	—
China	2. National Agricultural Products Quality and Safety Traceability Management Information Platform	Agri-products	√	—	—	√	√	√	√	—	—	—	—	√
B. Private systems														
Italy	1. Quaderno Di Campagna	Agri-products	—	√	—	√	—	—	√	—	—	—	—	—
	2. xFarm	Agri-products	—	√	—	—	—	√	—	—	√	—	—	√
	3. SecureTrack	Agri-products	—	√	—	√	—	—	√	√	√	—	—	—
	4. Trackyfood	Food	—	√	—	√	—	—	√	—	—	—	√	√
Korea	5. Smart HACCP System	Food	—	—	√	√	—	—	√	—	—	√	√	√

32 UPSS is not a traceability system and is implemented to stop sale of hazardous food. The system is managed by the Korean government and a tool that the Vietnamese government could consider.

Country	Name of system	Product	Initiative type			Market			Technology					
			Government	Private sector	Joint public-private	High-end market	Institutional procurement	Informal market	Barcode	RFID	NFC	Sensors	Blockchain	Mobile apps
China	6. Hezhi Fresh Agricultural Products Anti-Counterfeiting Traceability System	Fruits, vegetables, seafood, processed food	—	√	—	√	—	—	√	√	√	√	√	√
	7. 'Reassure on Code' Fresh Food Traceability System	Food	—	—	√	√	—	—	√	—	√	—	√	—
	8. Shidong Product Traceability System	Food, medicine, farm products	—	√	—	—	—	√	√	—	√	√	—	—
	9. Sunshine Lunch—School Food Safety Traceability Management Platform	Food	—	√	—	—	√	—	—	—	—	—	—	√

6.2.1. Experiences from China in establishing the national agricultural products quality and safety traceability management information platform

MARA is responsible for the implementation of the National Agricultural Product Quality and Safety Traceability Management Information Platform (hereafter referred to as the National Traceability Platform) launched in June 2017. This system has four distinct functions: traceability, supervision, monitoring, and law enforcement. The objective is to strengthen the government's smart supervision capabilities, regulate general production and operation activities, and increase consumer trust by providing information services to agricultural product quality and safety regulatory agencies, testing agencies, law enforcement agencies at all levels, and most agricultural product producers and operators, as well as the public. It is a critical component of the intelligent supervision of agricultural product quality and safety, as well as the bedrock of China's national e-government system. It serves the government, businesses, and the public. First, it is a tool for managing information for government oversight.

The government can digitalize supervision activities and enhance decision-making, early risk detection, and crisis management capabilities through this centralized data management. Second, this is a centralized internal and external traceability platform that enables enterprises to standardize their manufacturing and operational processes. It enables source tracking, product flow tracking, risk warnings, product recalls, and agricultural product accountability. Finally, it provides the public with a centralized query portal for quickly, and in real time, identifying agricultural product traceability information.

As mentioned earlier, the government initiated the system. In terms of target markets and distribution channels, the system spans the entire country with the goal of consolidating all traceability system databases into a single monitoring and inspection platform. China's government intends to consolidate all traceability system databases into a single portal for improved control and monitoring of regulatory agencies.

Technology deployment

The system is designed to benefit four primary stakeholders: (a) agricultural producers and operators, (b) law enforcement agencies, (c) testing facilities, and (d) regulatory agencies. The feature that distinguishes it from most systems is that it places a premium on the involvement of government agencies, and its primary objective is to assist these agencies in ensuring food safety.

The national traceability system makes use of ICT cloud systems, mobile apps, and 2D codes (QR codes), which are composed of several IT components organized in four distinct layers: front-end, middleware, data and protocol, and infrastructure.

- **Front-end layer**: Stakeholders with different purposes will access different modules to use the database. User interfaces include the mobile application (available for both iOS and Android operating systems) and a web platform (figure 30).

Figure 30: Interface of the official website of the National Traceability Platform

- **Middleware layer**: The national traceability system requires the use of ICT cloud systems to create a digital database to back up and restore all the traceability input by users.

- **Data and protocol layer**: The system uses a database that can store all information collected from all provinces of China.
- **Infrastructure layer**: The detailed hardware configuration recommendations for different stakeholders about the various entities to run the national traceability platform are as shown in table 17

Table 17: National traceability platform infrastructure layer in China

Stakeholder	Device
Regulator	**Option 1**: Personal digital assistant (PDA) **Option 2**: Smartphone and bluetooth printer
Testing facilities	Smartphones, Ukey
Law enforcement agencies	**Option 1**: PDA **Option 2**: Smartphone and bluetooth printer
Producers and operators of agricultural products	Computer and code scanner, code printer
	Option 1: PDA **Option 2**: Smartphone and bluetooth printer

In terms of the network environment required to operate the system, the national traceability platform is an internet-based system, which means the terminal equipment must connect to the internet to operate. For staffing and account management, all departments should be adequately staffed. Access to the platform for regulatory agencies is determined by the regulatory agency's hierarchy model, which ranges from ministerial to provincial, prefecture, county, and institution levels. The regulatory agency will have its own account, and the administrators will grant access to the testing institutions and law enforcement agency's systems, as well as to the account users within that agency and subordinate regulatory agencies. The entire authorization process takes place on the national traceability platform.

Figure 31: Account authorization process of the national traceability system

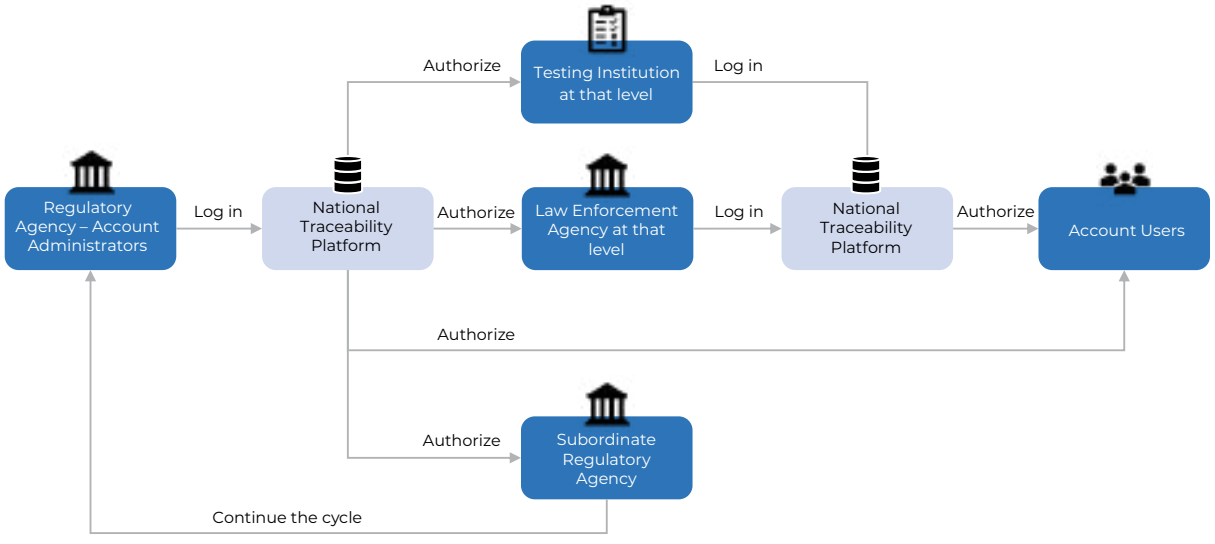


Table 18: Assessments of the system

No.	Criteria	Description of the system
1	**Functionality**	The system provides all functions, including identification, capturing, recording, and sharing traceability data. • Identification of the products: Use QR code • Information input: Use a PC to run the system software • Store and share data: Deploy a database that can store all information collected and shared with different supply chain stakeholders. The end consumers can scan a QR code using the mobile application or go to the website to retrieve the product information.
2	**Operational ease**	The platform provides two ways to enter or retrieve information through the website or mobile application. The system ensures the convenience of users by (a) support for granting and printing of the QR code for the product (three sizes available for the code to be printed on the label and posted on the products) and (b) support for entering the relevant information of the downstream entities using the pre-filled form.
3	**Interoperability**	This system can be linked with the provincial traceability platforms and the systems of 'three products and one standard', which is a certification system for pollution-free agricultural products, green agricultural products, and organic agricultural products.
4	**Access and protection of stakeholder information**	The system can be accessed by the supply chain stakeholders (agricultural producers and businesses), the end consumers, and the regulatory agency. The Software Development Department under the Ministry of Agriculture constantly improves the resilience and scalability of the data by reviewing the system code and improving the platform's availability and performance. It also performs database backup; establishes log tracking, records, and reviews; and performs timely discovery and resolution of security breaches.
5	**Reliability**	To ensure data completeness, the county-level regulatory agency checks whether agricultural producers and businesses collect and enter product information in accordance with the technical specifications to implement operations such as 'scanning code transactions' and performs retroactive checks for entering the market. The responsible regulatory agency also regularly checks the registration of the subject. To ensure data accuracy, the regulatory agencies at all levels check whether the work is carried out and executed smoothly and whether the data collection is proper and adequate. To ensure data availability, the testing facilities and law enforcement agencies at all levels regularly check whether the work is operating normally and whether data are collected and uploaded on time.
6	**Scalability**	This is a nationwide system that the Chinese central government and local government authorities use to manage agricultural product quality and safety. There is currently no information on whether the system is mandatory for all manufacturing companies and other supply chain partners.
7	**Affordability**	Companies can use the system in Jiangmen city of Guangzhou province free of charge.

No.	Criteria	Description of the system
8	**Vietnam infrastructure compatibility**	The system is well designed for the Chinese market and for state management of food quality and food safety. There is no evidence that it can be customized for Vietnam.
9	**Localization and local support**	
10	**Compatibility with existing policies and regulations in Vietnam**	The national traceability platform is a part of the e-government system in China, which provides smart supervision of agricultural product quality and safety. It can serve as a good reference for Vietnam.

Table 19: Key conclusions on the pros and cons of the China National Traceability Platform

Pros	Cons	Conclusion
The system provides an information platform for traceability management and supports common traceability technologies, including the QR code and mobile applications.	National platforms of traceability require a certain level of agreement by the government and the stakeholders. Coming to an agreement on the KDEs and protocol and ensuring implementation can be challenging.	This can be a reference model for Vietnam's authority in developing a public traceability system. However, the lack of personnel and a clear institutional arrangement will be a key constraint to ensuring effective control and management of the administrative levels.

6.2.2. Experiences from Korea in establishing the UPSS

In 2008, a serious food safety incident occurred with melamine-contaminated milk powders and related products imported from China. This deliberate food fraud incident resulted in the recall of 216 products in Korea. Product recalls of these dangerous products required considerable time and expense by competent government agencies, after which consumer confidence in Korean food products plummeted to an all-time low. According to a 2009 Gallup Korea customer survey, 65 percent of respondents stated that they "do not trust sellers," 77 percent stated that "unsafe goods are sold in stores," and 98 percent stated that "the government system does not work well" (Gallup Korea 2009). As a result, the Korean government recognized the critical need for a dependable national system capable of rapidly identifying and prohibiting the sale of unsafe products.

General information

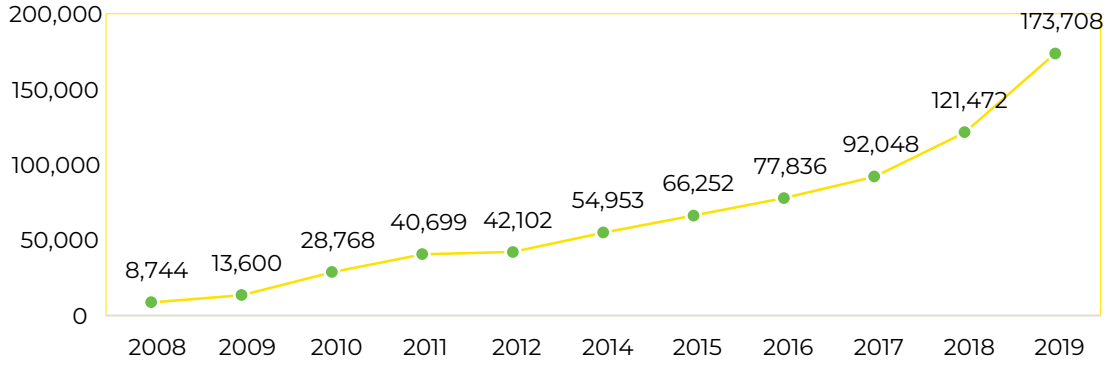
As consumer concern about food safety grows, the Korean government makes a concerted effort to protect consumers. The Korean MFDS implemented a food safety management system consisting of six subsystems: (a) Integrated Food Safety Information Network; (b) HACCP System; (c) UPSS (also known as Hazardous Food Sales Prevention System); (d) Food Traceability System (but mostly applicable to baby formula and health functional food); (e) Imported Food Control; and (f) Early Warning System for Foodborne Illness (Ministry of Food and Drug Safety 2017).

The UPSS is intended to improve consumer safety by effectively and efficiently sharing information about unsafe products that have been reported to government inspectors. It automatically prevents the sale of unsafe products, providing consumers with a sense of security and confidence. The system applies to all food commodities and products distributed by participating retailers.

The system was developed through collaboration between the public and private sectors. The UPSS was launched by the Ministry of Knowledge Economy and GS1 Korea in collaboration with three key government agencies: the Korea Food and Drug Administration, the Ministry of the Environment, and the Korean Agency for Technology and Standards (GS1 Korea 2019). GS1 Korea is managed by KCCI, the country's largest private economic organization, with 116 regional chambers and approximately 100,000 members representing all sectors of the Korean economy (KCCI 2015).

The UPSS is voluntary and primarily used in the organized retail sector. Major retailers stepped up efforts to implement the UPSS, resulting in a significant increase in the number of stores that use the system, including supermarkets, department stores, small and medium distributors, convenience stores, and home shopping channels (online stores). As of 2019, the UPSS was being used by 173,708 retail locations throughout the country.

Figure 32: Number of stores using the UPSS from 2008 to 2019



Source: GS1 Korea annual report 2020.

These stores may display the standard logo shown in figure 33 to announce that they are using the UPSS to prevent consumers from buying harmful products.

Figure 33: "UPSS in place" logo displayed in stores

Source: GS1 Korea annual report 2019.

According to GS1 Korea, it took a minimum of four hours before the system was implemented to stop the sale of unsafe products in retail operations. With the UPSS, the stop sale occurs within 30 minutes and all POS cash registers are blocked from selling the unsafe product. By 2021, the system successfully prevented the sale of over 1,700 dangerous products, allowing customers to shop with confidence (Ministry of Trade, Industry and Energy 2021).

UPSS's efficacy has been recognized and lauded by several participants. For instance, in the case of Hyundai Green Food, the deployment of the UPSS enables the corporation to (a) quickly receive product information disclosed about hazardous products, (b) easily determine whether the product is handled by Hyundai Green Food using the hazardous product information received, and (c) quickly cut off supply and take measures to return hazardous products (UPSS Korea 2018). The UPSS minimizes customer complaints and liability in the home and shopping sector by blocking hazardous products in advance (UPSS Korea 2018). For E-mart, the system simplifies the process of verifying detailed information about hazardous products (company details) (UPSS Korea 2018).

Technology deployment

The UPSS was developed to assist the government in prohibiting the sale of unsafe products through distribution channels. It implements several technologies, including locally installed applications that communicate with the local POS system and barcode technology. These technologies are distributed across four main layers: front-end, middleware, data and protocol, and infrastructure.

- **Front-end layer:** Users (cashiers) can interact with the UPSS interface displayed on the POS device to see the sales prohibition notifications with detailed information about the non-compliant products (including data of their origin, manufacturers/producers, and so on).
- **Middleware:** Each distribution agency participating in the UPSS must install the transmission/reception module to exchange information with the UPSS and receive hazardous product information from the inspection agency in real time. Additionally, developing the function to block the sale of harmful products in the POS system of each store is also required. Large-scale distributors use a different version of UPSS from that deployed by small and medium distributors. For chain stores, UPSS is installed at the head office, which then develops its own internal component to connect UPSS with the POS system of each of its chain stores. For small and medium distributors, UPSS is installed and connected directly to their POS system.
- **Data and protocol layer:** The system uses data from the following databases to generate sales prohibition notifications: (a) the database of the Non-compliant Food Emergency Reporting system regarding the inspection results of non-compliant products and (b) the database of the KorEANnet Server (GS1 Korea) regarding the product name, manufacturer name, and so on. KorEANnet offers an extensive service that allows GTIN users to create barcode symbols, manage their product information, and provide product information for users, particularly retailers. It also delivers new product information from manufacturers to retailers.

- **Infrastructure layer:** Barcode scanners are utilized from the POS system of the participating stores. The scanner is used to scan the barcode that is uniquely assigned to each traceable object. If the object is reported as non-compliant by the government inspectors, a sales prohibition notification will be displayed. The system utilizes the barcode issued by the KorEANnet system. The barcode is uniquely assigned to reduce the risk of banning the wrong products. The system also uses a POS device at the counter to display sales prohibition notifications.

Table 20: Assessment of the system

No.	Criteria	Description of the system
1	**Functionality**	It is mainly used to send notifications of unsafe food to millions of stores nationwide.
2	**Operational ease**	Distribution agencies may install a transmission/reception module in their POS system (including POS at the counter, a database of the distribution agency, and a barcode scanner) so that information can be exchanged with the UPSS.
3	**Interoperability**	The UPSS is one of six subsystems operated under the food safety management system established by MFDS to manage food safety through three stages: manufacturing, distribution, and consumption. In the manufacturing stage, interoperability happens when the UPSS can use data from the quality assessment results reported by manufacturers and inspection agencies for non-compliant food. In the distribution stage, food products are collected and inspected to strengthen safe food distribution. The inspection details/data are then entered into the non-compliant food emergency reporting system. The UPSS can use data from this system to issue a notification to retailers' headquarters, who then issue an internal notification to in-house POS cash registers at each store. In the consumption stage, false or exaggerated advertisements are monitored, and a consumer food sanitation guard system is activated. Interoperability happens when the 'false/exaggerated advertisement monitoring system' uses the sales prohibition notification to control advertisements relating to non-compliant food. The system provides notifications to millions of stores nationwide to inform and help block the selling of unsafe food once identified.
4	**Access and protection of stakeholder information**	The widespread use of the system requires security.

No.	Criteria	Description of the system
5	**Reliability**	1. Reliable tools to record data: • The inspection results of non-compliant food are reported by government inspectors and need to be reviewed carefully before being reported to the system. As such, it is considered reliable. • Information related to the products, such as their origins (producers, locations, and so on), is provided by manufacturers and distributors and is frequently inspected by the government, which improves the reliability of the information. 2. Availability of data: Regular checks are performed to prevent the server's failure.
6	**Scalability**	As of 2019, 173,708 stores were using the UPSS across the country, ranging from large-scale retailers, including hypermarkets and department stores, to small and medium businesses such as supermarkets and convenience stores and many other retail channels including groceries and online malls.
7	**Affordability**	Widely used by 100,000+ stores in Korea
8	**Vietnam infrastructure compatibility**	The system does not require special infrastructure. It sends notifications to retailer headquarters who issue an internal notification to block their POS from selling unsafe foods identified by the scannable GTINs (linear barcode)
9	**Localization and local support**	The system is well designed for Korea under a public-private partnership.
10	**Compatibility with existing policies and regulations in Vietnam**	The UPSS is the national system of Korea to prevent the sale of unsafe products. The system will be a good reference system for Vietnam to develop a similar food safety control/management system.

Table 21: Key conclusions on the pros and cons of the UPSS

Pros	Cons	Conclusion
The government's ability to use GS1 standards to structure an 'unsafe product' message to inform retailers and then for retailers to notify and block GTINs in their POS system at a large scale within 30 minutes is impressive and especially useful for a national food safety system.	The UPSS requires the cooperation of the state agencies (inspection agencies) and retailers. It is also implemented on a national/regional public scale. However, there may not be enough local capacity in Vietnam for this.	The system can be a good reference for Vietnam's authority to develop a national food safety control system that includes the feature to stop the sale of harmful products. The UPSS is a stop-sale process and not a recall solution. However, it is a critical first step in the process of protecting consumers until the unsafe products are recalled from stores.

6.2.3. Informal market: xFarm system in Italy

xFarm was founded in 2017 in Italy, as a software-as-a-service (SaaS) platform with the goal of facilitating farm digitalization. Its innovative platform accomplishes this by streamlining data

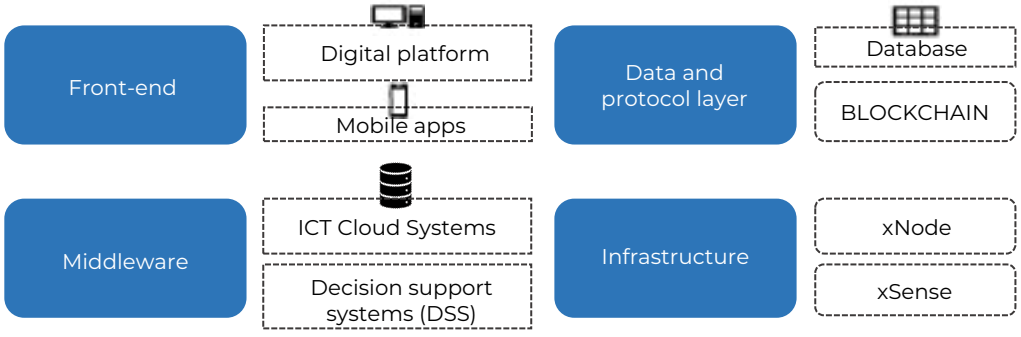
collection and analysis, reducing bureaucracy, increasing agricultural field efficiency and sustainability, and enabling the traceability of agricultural products. Their freemium business model is based on an open platform. It unifies a variety of functions into a single platform, including cloud-based management software, field IoT sensors, and a marketplace with high value-added services (such as irrigation optimization solutions, agri-meteorological forecasts, disease alerts, and precision farming services).

Matteo Vanotti founded xFarm as a private company in 2017 in response to the need for a digital service that would enable him and his brothers to manage their agricultural company digitally in a simple and efficient manner. xFarm's target market is the informal market. The system is primarily used by farmers.

Technology deployment

The ecosystem provided by xFarm includes an application that works both on mobile and desktop platforms, dashboard analytics to manage multiple farms, and a line of connected IoT sensors optimized for agricultural use that can directly communicate via the internet with users' accounts.

Figure 34: xFarm's component element



Source: xFarm.

xFarm incorporates several IT components distributed into four layers: front-end, middleware, data and protocol, and infrastructure.

- **Front-end:** xFarm has a digital platform for users to look up and manage their information. Users can access this platform via many different devices, such as mobiles, desktops, and tablets. Data collected by IoT devices and input data from users using a mobile app such as sowing, fertilizing, and harvesting will be displayed on a singular platform. This platform allows users to work and improve data management using a digital logbook that can be used to create essential documents to track activities and analyze their data using dozens of different modules.
- **Middleware:** xFarm also provides analytics and a decision support system to help farmers use data collected via sensors and interfaces to develop decision-making tools, maps, and forecasting models to give farmers personalized advice on irrigation, fertilization, plant protection, and machinery for their plots.

- **Data and protocol layer**: xFarm uses the cloud to store the data, which is only accessible by users.
- **Infrastructure layer**
  - xSense devices: Weather station connected. At the center of xFarm's solution is the xSense, an IoT device designed to monitor crops and protect them from adverse environmental conditions and the most common diseases. xSense is equipped with a camera and sensors for measuring environmental parameters such as air humidity, temperature, rainfall, and wind direction and speed, which constantly synchronize with xFarm's servers via global system for mobile communication (GSM). xSense's images and measurements are integrated into the xFarm's graphical interface, allowing 360° control of everything that happens on the farm. xSense measurements are combined with activities tracked in xFarm to provide targeted alerts for critical crop situations, such as drought or pest development. xSense stations are equipped with a sim card that allows you to send data via GSM to the platform. At the same time, all xNode modules use the LoRa wireless system, which allows minimal battery consumption up to a radius of 10 km (depending on environmental conditions) and can connect to 100 devices on the same network.
  - xNode devices: Farming IoT sensors. xNode devices are connected to xFarm and record important values relating to the surface (temperature, humidity, and conductivity) and the plants (for example, leaf moisture). xNode modules use the LoRa wireless system, which allows minimal battery consumption, up to 10 km radius (depending on environmental conditions) and can connect up to 100 devices on the same network.

To develop the best solution possible for farmers, xFarm collaborated with Spacesense to integrate satellite data to provide advanced crop information while remaining cost-effective, a critical factor for growers. These data are delivered via APIs, which are highly customizable. They provide the images and raw data as well as the statistics necessary to generate analytics. xFarm is notified whenever a new image becomes available and can create categories for each type of customer subscription. xFarm integrates satellite data to provide functions for monitoring crop health and performance (using indicators such as greenness and growth stage, water stress, plant biomass, chlorophyll content, and nitrogen content) as well as management tools for optimizing fertilization doses and seed input per zone based on the historical field productivity map.

Table 22: Assessment of the system

No.	Criteria	Description of the system
1	**Functionality**	The agri-food companies can connect with farmers to check records of treatment and field activities, update local environmental parameters to predict the production, organize in advance to buy from multiple suppliers, and trace the product movements.
2	**Operational ease**	All information is presented on only one platform dashboard, making it simple for users to monitor their farms' information. xFarm may be used on any device with a web browser and internet access, such as laptops, desktops, Android smartphones, iPhones, Macs, Android tablets, and iPads.
3	**Interoperability**	xFarm can be linked with the ERP and blockchain system and satellite data.
4	**Access and protection of stakeholder information**	xFarm's terms of service align with EU Regulation 679/2016 (Article 13), including data privacy policies to protect users' information. xFarm commits to never selling or transferring users' data to third-party companies without their consent. xFarm will not process advertising or for-profit functions without users' consent. It will not use users' data for activities or projects in collaboration with partners or customers without users' consent.
5	**Reliability**	xFarm aims to improve the automatic collection of information via IoT devices. xFarm also integrates satellite data for agronomic decision-making.
6	**Scalability**	Xfarm has been adopted by many farmers in Italy.
7	**Affordability**	xFarm offers four different packages with different features ranging from EUR 199 per year to EUR 2,690 per year (excluding VAT) (equivalent to VND 5,500,000 to VND 74,000,000 and US$240 to US$3,200, respectively). However, the system requires many IoT devices for advanced tracking and could be expensive to implement in Vietnam.
8	**Vietnam infrastructure compatibility**	xFarm supports IoT sensors and allows for users' manual input of data. xFarm integrates satellite data to provide advanced crop information.
9	**Localization and local support**	There is no information about whether the system can be localized to Vietnam.
10	**Compatibility with existing policies and regulations in Vietnam**	Xfarm uses IoT sensors to record the data regarding the production stage and the satellite data. The use of data shall comply with cybersecurity regulations.

Table 23: Key conclusions on the pros and cons of the xFarm system

Pros	Cons	Conclusion
xFarm has analytic features that help farmers track, monitor, analyze, and make decisions	The system is quite complex due to the technologies embedded in it. The xFarm sensors will be a new concept of technology that will require knowledge training. It is more focused on increasing the productivity of the farm rather than offering a traceability feature. xFarm is provided in a SaaS model with devices (camera, IoTs) and LoRa network, which requires authority's approval (likely to be approved for agriculture purposes). In addition, this system uses mobile apps to enter data relating to sowing, fertilizer, and so on. Currently, Vietnam traceability systems also include mobile apps; however, it has not been effective because of the stakeholders' level of knowledge and comfort in using the smartphone. This system does not have the feature of using the Vietnamese language and currency.	xFarm will be more suitable for larger agriculture corporates. It should be integrated with other traceability systems to support the full supply chain traceability.

6.2.4. Informal market: Shidong product traceability system (China)

This is a comprehensive e-commerce traceability platform for the integration of dependable, visible, credible, and sensible agricultural products (Shidong Centry, 2020). The farm to consumer e-commerce platform is a Vision Century-developed service platform that combines traceability and sales with agricultural industry characteristics. The platform makes use of technologies such as DNA identification of species, blockchain, real-time broadcast, one-to-one coding, and environmental monitoring. The core technology is the intelligent vending refrigerator. Additionally, it implements an integrated online e-commerce platform, a back-end traceability system (PC back-end), an operational-end management platform (planting/growing data collection, logistics transportation, production/sorting, e-commerce, and offline marketing platform integrating warehouse management, freezer tally, self-pickup, and cabinet management), and offline intelligent vending machine management. A private enterprise is developing the system. Vision Century (Beijing) Technology Co., Ltd is a provider of software development and solutions. The company is headquartered in Beijing, with a registered capital of more than CNY 10 million. In terms of market segmentation, the system targets informal sector stakeholders.

Figure 35: Shidong system's deployed traceability technologies

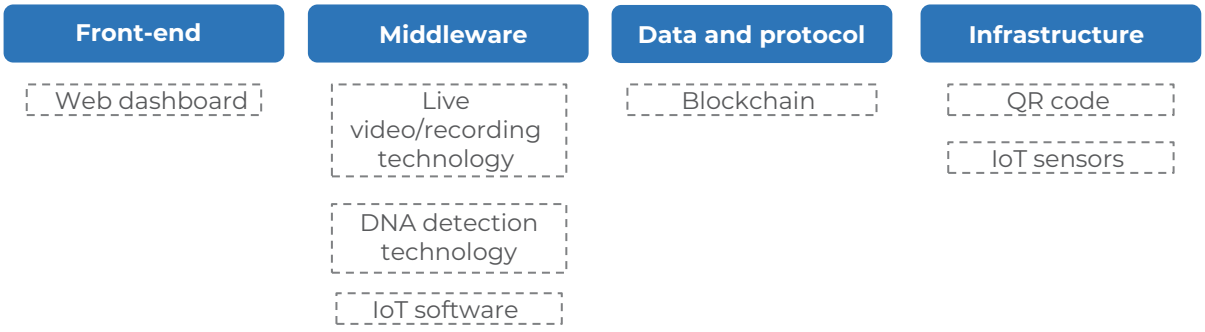


Table 24: Assessment of the system

No.	Criteria	Description of the system
1	**Functionality**	The system provides services to enterprises and allows health supervision bodies and industrial upstream and downstream agencies with blockchain technology to assess the database on traceability data. Through this system, users can monitor the life cycle of products they purchase (from production, sorting, storage, and logistics) or subscribe through live video/recording technology.
2	**Operational ease**	The system automatically generates the product traceability code, prints it through a handheld printer, and directly posts it on the product packaging. Users and consumers obtain such information through scanning.
3	**Interoperability**	The system can integrate with the client's ERP and WMS, which makes the transmission of information much faster.
4	**Access and protection of stakeholder information**	By using cloud computing and IoT, the system can collect and share information directly between stakeholders.

No.	Criteria	Description of the system
5	**Reliability**	The public inquiry platform can provide customers with convenient product tracking. The reliability of the information recorded by the system could be considered high due to the usage of video/live recording and DNA sensor technology.
6	**Scalability**	This system has been widely used.
7	**Affordability**	The system requires advanced technology components, including a 'vending refrigerator', that could make the system costly to implement on a large scale.
8	**Vietnam infrastructure compatibility**	The platform supports web dashboards, barcodes, and QR codes and provides the blockchain database and IoT sensor technology that are usable in Vietnam.
9	**Localization and local support**	There is no information available on whether the system can be localized to Vietnam.
10	**Compatibility with existing policies and regulations in Vietnam**	MOST of Vietnam has issued technical regulations governing QR code technology. However, there are no current technical standards for blockchain. If the Shidong system is implemented in Vietnam, it shall follow the national standards for barcode technology and traceability systems, including TCVN 12850:2019 on Traceability -General requirements for traceability systems as well as cybersecurity regulations.

Table 25: Key conclusions on the pros and cons of the Shidong system

Pros	Cons	Conclusion
Shidong aims to build an e-commerce solution that takes advantage of the traceability of products sold directly to consumers. It not only provides traceability but is also enriched with media content such as live videos. Shidong also provides DNA detection technology to support necessary inspection.	Shidong focuses on e-commerce rather than building a system that serves the public and authority. It is a business model; therefore, it likely requires a business plan before deployment. In addition, there is currently no known local presence/support in Vietnam.	Shidong's model is instructive. If any traceability project is initiated by the private sector (perhaps without government support), this could be a good model to follow.

6.2.5. High-end market: Quaderno di Campagna (QdC - Italy)

QdC is an Italian online software application developed in 2002 to assist users in managing their farms more efficiently and in compliance with current legislation. The software enables the products' origins to be traced. QdC was founded by Image Line, an Italian SME specializing in the invention and implementation of digital agriculture solutions since 1988. Image Line developed a variety of digital solutions to assist producers in ensuring food safety, including an agriculture web magazine (AgroNews), a search engine for crop protection products (Fitogest), and a database of fertilizers (Fertilgest). Figure 36 depicts the products created by Image Line.

Figure 36: Products of Image Line

Source: Image Line 2021.

In terms of the target market, the system serves over 12,000 customers who purchase a variety of products across 20 Italian regions, all 88 provinces and 14 metropolitan areas. Many customers are high-end producers. For example, Zuegg is renowned for growing the finest fruits in the purest and most natural manner possible, paying close attention to quality in both raw materials and every phase of harvesting, processing, and distribution.

Technology deployment

QdC provides traceability solutions for all stakeholders in the agri-food supply chain, from producers to consumers.

Figure 37: Users of QdC

Source: QdC 2021.

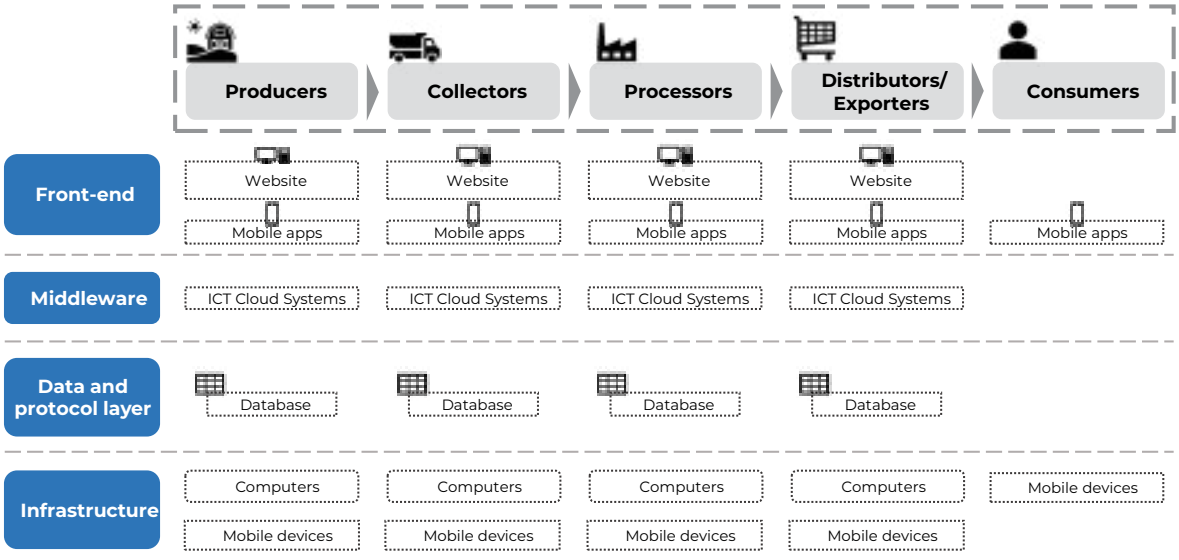
The system includes four layers: front-end, middleware, data and protocol, and infrastructure.

- **Front-end layer**: Users can access QdC through a website from a PC, smartphone, or tablet device. They can scan the QR code with a QR code scanner app on their mobiles to obtain traceability information on the products. Users can manually insert necessary information in Excel files aligned with the form provided by Image Line. For users with multiple companies, QdC will help them import their data to the software. QdC will provide a 'source' Excel file to the users, and they must accept the following compilation methods fully.
    - In the 'source' Excel file, the users undertake to adhere to the cell formats and the arrangement of columns; therefore, only lines with adequate information content can be inserted.

- IMAGE LINE® will not accept files with empty mandatory data or with formats that do not correspond to the original 'source' file provided.
- The parties agree that the final validation of the data will be the responsibility of the users who assume full responsibility for it.
- Once the validation has been completed, the users will manage the data independently through the QdC ® - Quaderno di Campagna ® procedures.

- **Middleware layer**: ICT cloud systems are used in the middleware layer.
- **Data and protocol layer**: Data are stored in a hosting cloud. The cloud shares data among stakeholders.
- **Infrastructure layer**: QdC will generate a unique QR code for each traceable object, party, and location in case users want to make their production batches traceable. The QR codes of QdC can be read by a simple QR code reader on any smartphone. In addition, QdC uses IoT sensors to record the location and environmental factors such as rain, humidity, and temperature. After users enter all the details of the farm, the technology will locate the fields with a simple mapping system and provide the users with the overall picture of their production units, a seven-day weather forecast for each plot on quadrants of 1 km × 1 km, updated daily, and historical weather data of the last 30 days on single plots always with a 1 km × 1 km mesh.

Figure 38: QdC component elements



Source: QdC 2021.

The technologies that QdC implements include QR codes for traceable products, ICT cloud systems, and IoT sensors.

Figure 39: QdC's IoT sensors

Source: QdC, 2018.

Table 26: Assessment of the system

No.	Criteria	Description of the system
1	**Functionality**	QdC provides traceability solutions for all stakeholders in the agri-food supply chain, from producers to consumers. So far, there have been about 12,406 companies in Italy adopting QdC to optimize their activities. For identification, QdC provides the QR code. For automatic capture, the QR code can be read by any smartphone. Data recording can be obtained through IoT sensors and input of data by the producers via an Excel file. The data can be stored on a cloud-based platform.
2	**Operational ease**	• Installation: QdC does not require users to install any applications for entry. • Daily operation: Requires basic technical knowledge • Data storage and backup: The solution provider oversees the operating of the database.
3	**Interoperability**	The system deploys a unique QR code containing information about each traceable object, party, and location and can link with the ERP system of the users and Fertilgest and Fitogest databases.
4	**Access and protection of stakeholder information**	The information is visible and accessible only to users. They have the right to decide which information to be shared with others. Regarding protection, the automatic backup takes place every day; data are saved on five different media located throughout the Italian territory for greater security, and QdC complies with regulatory requirements on data protection in Italy and the EU.
5	**Reliability**	• Unique QR codes ensure the correct link • The system requires entering internal traceable information (for example, fields and crops, warehouse management, and phytosanitary treatments) • Automatic data collection (IoT sensors) reduces human errors
6	**Scalability**	QdC has been adopted by about 12,406 companies.

No.	Criteria	Description of the system
7	**Affordability**	The cost to adopt QdC is not high. QdC is available in three versions, ranging from EUR 100 to EUR 250 per year (22% VAT excluded) (equivalent to VND 2,500,000 to VND 7,000,000 and US$120 to US$300, respectively). For the management of a multi-company entity, the price depends on the number of companies that the buyers have, so the buyers must contact QdC for more information.
8	**Vietnam infrastructure Compatibility**	QdC uses technologies that are usable in Vietnam.
9	**Localization and local support**	There is no information about whether the system can be localized to Vietnam.
10	**Compatibility with existing policies and regulations in Vietnam**	There are some technical standards governing the use of barcodes (including QR code), including: TCVN 7322:2009 on Information technology - Automatic identification and data capture techniques - QR code 2005 bar code symbology specification. If QdC is to be adopted in Vietnam, the system shall follow the technical standards in generating the barcode. The use of data shall comply with cybersecurity regulations (Law on Cyber Security and detailing decrees).

Table 27: Key conclusions on the pros and cons of the QdC system

Pros	Cons	Conclusion
QdC provides a platform through which farmers can perform many tasks relating to farming management. QdC has strong features for integration to other systems such as ERP, WMS, and even simply Excel sheets. Its user-friendly interface helps QdC to be easily set up and used. QdC is also compatible with EU regulations on food safety and data protection.	Although QdC is widely used and complies with many rules and regulations in Italy, to deploy and use this system in Vietnam, t certain customization will be needed, which is costly. Deployed technologies are quite advanced for informal market players in Vietnam.	QdC is a comprehensive system and can be a good example for Vietnam. If it can be applied in Vietnam, it will also create an opportunity for Vietnamese farmers to access the European market.

6.2.6. High-end market: SecureTrack (Italy)

Alfacod developed SecureTrack software for production management and traceability in the agri-food, industrial, and chemical sectors. It is a Manufacturing Execution System (MES) that enables the safe management of the entire production chain by providing the necessary documentation in accordance with applicable regulations: from the receipt of raw materials to the shipment of the finished product. It provides complete control over each production phase, processing, handling, warehouse, and shipping. The software is divided into nine modules: a stock management module, a handling management module, a materials management module, a production planning module, a personnel planning module, a production management module, a production management module,

a traceability management module, and a shipping management module. SecureTrack enables computerized management of production, from order planning to warehouse deposit, via centralized programming of machines, phase progress, real-time monitoring of processes, and the collection of production data for process control and optimization, as well as traceability management.

Alfacod Group has been active in the field of automatic identification and data capture since 1986 and is one of the industry's largest system integrators. Each solution is tailored to the customer's requirements and assigned to a team of specialists who assist the customer throughout the implementation process.

Regarding the target market, SecureTrack serves mostly customers of the high-end market.

Technology deployment

- **Front-end layer**: The user interface of SecureTrack software is displayed on terminal devices and PCs.
- **Middleware layer**: SecureTrack software.
- **Data and protocol layer**: SecureTrack stores data to a central database on the Microsoft SQL Server platform (standard or express version depending on the size of the factories and the number of workstations).
- **Infrastructure layer**:
    - A unique barcode/RFID tag is used as an identifier, marking and attributing each traceable object. Starting from a batch, it is possible to trace the processes undergone, the environments in which it was processed (or seasoned), and the time spent in each environment (and the weight loss suffered). Starting from a traceability code affixed during shipment, the history of the product in the factory, the processes, and the environments crossed are recovered, tracing the lot to which it belongs and its path.
    - RFID readers/portable radio-frequency terminals equipped with a barcode reader are used to automatically capture (through scanning or reading) the movements or events involving the traceable object.
    - A standard Windows PC is used for system supervision, with industrial touch screen PCs located directly in the production environment.
    - Video panels for viewing the main indicators directly at the lines of production are available.

Table 28: Assessment of the system

No.	Criteria	Description of the system
1	**Functionality**	The system manages the entire production chain safely, providing the necessary documentation according to the regulations in force: from the receipt of raw materials to the shipment of the finished product, complete control of every production phase, processing, handling, and warehousing or shipping. SecureTrack ensures that products are trackable and traceable for all stakeholders in the agri-food supply chain, from producers to consumers.
2	**Operational ease**	• Installation: Technical support for the installation process. • Daily operation: Users can define and customize the features of the package, choosing the modules that best suit their needs.
3	**Interoperability**	This system can integrate with plant management systems (ERP) and physical production devices (Supervisory Control and Data Acquisition, programmable logic controller, labeling systems, machines, scales, and so on)
4	**Access and protection of stakeholder information**	Alfacod (the company that developed Secure Track) processes the users' data in compliance with the European Regulation (EU) 2016/679 (GDRP) concerning the protection of individuals regarding the processing of personal data. The data are stored both in digital and paper form at the registered office of Alfacod and are accessible exclusively to authorized personnel. Alfacod observes specific security measures to prevent data loss, illicit, or incorrect use and unauthorized access.
5	**Reliability**	• The software collects all the data from receipt to shipment. • Automatic data capture (barcode and RFID) reduces human errors. • Data are in real time and are integrated into the production process.
6	**Scalability**	SecureTrack's modular and scalable design adapts it to the needs and availability of both small and large businesses. Users can define and customize the functionality of the package, choosing the modules that best suit their needs.
7	**Affordability**	n.a.
8	**Vietnam infrastructure compatibility**	The system uses technologies that are usable in Vietnam. SecureTrack's data management system is based on Microsoft SQL Server or Microsoft SQL Express, as needed by the user. A supervision PC with a Windows operating system is provided, while the network connection to the company information system is optional, as are any consultation PCs that are connected to the supervision PC via the ethernet network. The system interfaces with peripheral data capture devices, such as wi-fi terminals, barcode readers, or RFID tags.
9	**Localization and local support**	There is no information about whether the system can be localized to Vietnam.
10	**Compatibility with existing policies and regulations in Vietnam**	SecureTrack uses barcode and RFID technology. MOST of Vietnam has issued technical standards for barcode and RFID technology. If SecureTrack is applied in Vietnam, the use of barcodes and RFID shall follow the technical standards and cybersecurity regulations.

Table 29: Key conclusions on the pros and cons of the Secure Track system

Pros	Cons	Conclusion
Secure Track is a true MES developed by Alfacod, a large software and solution company. It shows robust performance at the processing stage. Therefore, it can be used not just for traceability but can extend to operation of the enterprises (for example, manufacturing).	This system can be used for far more than traceability. Traceability is more of a feature, a byproduct of implementing the MES. There is a lack of information on integrating with other MES/WMS/ERP systems to create an ecosystem that facilitates traceability on a large scale. There is no information about the implementation cost. This system does not have the feature of using the Vietnamese language and currency.	Secure Track is strong if there is a need to implement MES for a large manufacturer. It can be part of the supply chain traceability system. However, the cost of implementation might be high.

6.2.7. High-end market: Trackyfood (Italy)

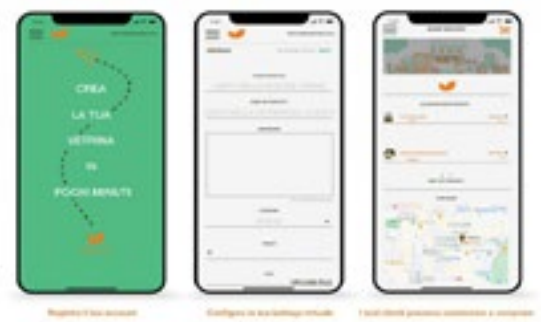
Trackyfood is a platform developed in 2018 by Trackysat SRL for providing complete traceability and enhancing the e-certification of agri-food supply chains via experiential and storytelling platforms. Trackysat SRL is a technology company that initially offered a fleet management solution. It has been providing satellite tracking services to over 2,500 customers since 2007, monitoring over 20,000 vehicles used in heavy road transport, and managing integrated services to optimize operations and reduce operating costs. Since 2017, Trackysat has expanded its services by establishing a business unit dedicated to developing solutions for agri-food chain traceability. The high-end segment is Trackyfood's target market.

Technology deployment

Trackyfood has developed and integrated a private blockchain based on Amazon Web Services Managed Blockchain with its services. Any traceability and origin data or documents can be certified on immutable blockchain nodes. The system includes four layers: front-end, middleware, data and protocol, and infrastructure.

- **Front-end layer**: The user interface of Trackyfood's mobile app allows users to connect and upload information onto the database.

Figure 40: User interface of Trackyfood's mobile app



- **Middleware layer**: ICT cloud systems are used in the middleware layer.
- **Data and protocol layer**: Data are stored in a cloud-based platform that shares data among stakeholders. In addition, users have their option of whether or not to use blockchain. Trackyfood uses blockchain technology to certify all processes and offers the possibility of facing the market using the most advanced technological standards.
- **Infrastructure layer**: Through an interactive label (QR code), the system can associate all the information related to a supply chain product. The label is designed to be easily recognizable and unique.

Any smartphone can be used to download applications. With the smartphone QR code scanner, consumers can access the website containing information about that product.

Table 30: Assessment of the system

No.	Criteria	Description of the system
1	**Functionality**	Through an interactive label, the system can associate all the information related to a supply chain product. The key makes it recognizable and unique. The system provides support for the producers (to certify and monitor field parameters), distributors (traceability management and batch input and output, generating the batch ID), carriers (to monitor data and transport), retailers (traceability verification and certification), and customers (traceability and certification control).
2	**Operational ease**	Trackyfood is easy to operate for users and the final consumer; all product information is just a click away.
3	**Interoperability**	Trackyfood integrates with the companies' management systems already in use and with the cloud. Trackyfood is integrated with blockchain technology that can be activated for each supply chain or product. The system focuses on marketing and sales of the products (e-commerce); it does not seem to show integration capability with other systems on the supply chain (ERP, MES, WMS, and so on)
4	**Access and protection of stakeholder information**	Trackyfood has developed a privacy policy according to Article 13 of Regulation 679/2016 (EU) (GDPR) for those who access and browse the website www.trackyfood.com (the 'Website') and use the 'Trackyfood' platform ('Platform'). Trackyfood is committed to ensuring that the information collected and used is appropriate with respect to the purposes described and that this does not lead to an invasion of data. Suppliers have access only to personal data necessary to perform their duties. They agree not to use the data for other purposes and are required to process personal data according to current regulations.
5	**Reliability**	The system enables users to access product information, agri-food supply chain, quality and safety certifications, ingredients, energy, and nutritional values. In addition, it uses the interactive label.
6	**Scalability**	There is not enough information about the architecture and case studies.
7	**Affordability**	SMEs are the main target customer for Trackyfood, and it offers different plans (starter, active, and custom)
8	**Vietnam infrastructure compatibility**	Trackyfood supports QR codes, blockchain, RFID, and mobile apps, which are usable in Vietnam.

No.	Criteria	Description of the system
9	**Localization and local support**	Trackyfood offers a customized plan; it is likely to be able to build a customized version for a dedicated market.
10	**Compatibility with existing policies and regulations in Vietnam**	Trackyfood uses barcodes. MOST of Vietnam has issued technical standards for barcode technology. If Trackyfood is applied in Vietnam, the application of barcodes and RFID shall adhere to technical standards and cybersecurity regulations.

Table 31: Key conclusions on the pros and cons of the Trackyfood system

Pros	Cons	Conclusion
Trackyfood is not only a traceability system but also a platform for marketing and sales. There are three plans from which businesses can choose the most suitable to their needs and budget.	Trackyfood is a commercial platform that is more complex than a standard traceability system where features such as scalability, integration ready, and so on, might be more critical. There needs to be a certain level of knowledge training for the local market stakeholders regarding the use of blockchain. It is currently unknown whether this system supports the Vietnamese language and currency.	Trackyfood is suitable for enterprises that want to utilize traceability data to promote their products through storytelling.

6.2.8. High-end market: Food safety management certification (smart HACCP) service platform (Korea)

Korea's MFDS submitted a proposal in 2018 for the establishment of a Food Safety Management Certification (HACCP) Service Platform. The platform integrates the HACCP information collection process with the IoT to enable real-time data collection and the development of a blockchain-based platform for registering critical control point (CCP) data and HACCP certificates. It guards against data forgery and alteration by continuously recording, managing, checking, and storing CCP monitoring data. Additionally, it develops a component for sharing authentication information to verify the web and app authentication processes. The pilot project uses blockchain technology to track the distribution path of food. It was created with a consortium comprising Nongshim Data System (NDS), Phillink, and Geomatics and was selected to implement the pilot project for the Food Safety Management Certification (HACCP) service platform construction. In a nutshell, the government proposes this system, and the private sector implements it.

Technology deployment

- **Front end**: Interface of website and mobile application deployed by the system.
- **Middleware**: IoT software and cyber 2016 system (CPS).
- **Data and protocol**: The system deploys blockchain technology as a platform for registering CCPs.
- **Infrastructure**: The system requires IoT sensors, mobile devices, and blockchain nodes.

Table 32: Assessments of the system

No.	Criteria	Description of the system
1	**Functionality**	The system uses IoT to collect data in real time at CCPs, which are activities happening across the supply chain. Then the captured data are stored and shared with supply chain stakeholders using a blockchain platform.
2	**Operational ease**	IoT is used to collect data in real time at CCPs, which occur regularly across the supply chain. Once applied, IoT will automatically capture those data, and there is a blockchain platform for storing data at CCP. By collecting data in real time through the construction of the HACCP service platform and monitoring it always will be able to respond immediately in the event of a food safety incident.
3	**Interoperability**	This system can work well with IoT sensors, blockchain, and mobile devices to enable tracking and tracing within the system.
4	**Access and protection of stakeholder information**	There is a system for sharing authentication information so that the authentication process can be verified and available on the web and in the app.
5	**Reliability**	The use of automatic data collection tools such as IoT sensors to collect data in real time enhances the reliability of the system.
6	**Scalability**	The system is widely used for collecting data and providing certification.
7	**Affordability**	No available information on the cost of the system for enterprises.
8	**Vietnam infrastructure compatibility**	There is no information available.
9	**Localization and local support**	The system is well designed for the Korean market under a public-private partnership model. There is no evidence that it can be customized for Vietnam.
10	**Compatibility with existing policies and regulations in Vietnam**	The system makes use of IoT devices and blockchain databases. There is no specific law or policy in Vietnam regarding the requirements for blockchain technology in applying traceability. But based on the Vietnam Law on Food Safety, there are two government decrees related to the Law of Food and Safety, which provide specific provisions and measures to ensure the traceability of food products, such as record keeping and required information. The blockchain system can help companies with record keeping and will be able to capture the required information depending on the implementation of the system. In addition, the Law on Crop Production stipulates traceability in the production process, for which blockchain can also be used. If blockchain is to be implemented, it should follow the national standards for traceability systems such as TCVN 12850:2019 on Traceability - General requirements for traceability systems. Data use shall comply with cybersecurity regulations.

Table 33: Key conclusions on the pros and cons of the HACCP system

Pros	Cons	Conclusion
HACCP supports traceability and contributes to the improvement of quality, productivity, and marketing sales activities for farmers and enterprises at a significant rate.	While this system may prove easy to use, it should be noted that some training should be provided for local market stakeholders on using blockchain.	The system is suitable for recording and controlling the internal traceable data of medium to large companies as it deploys complex and costly technologies, including blockchain and IoT sensors.

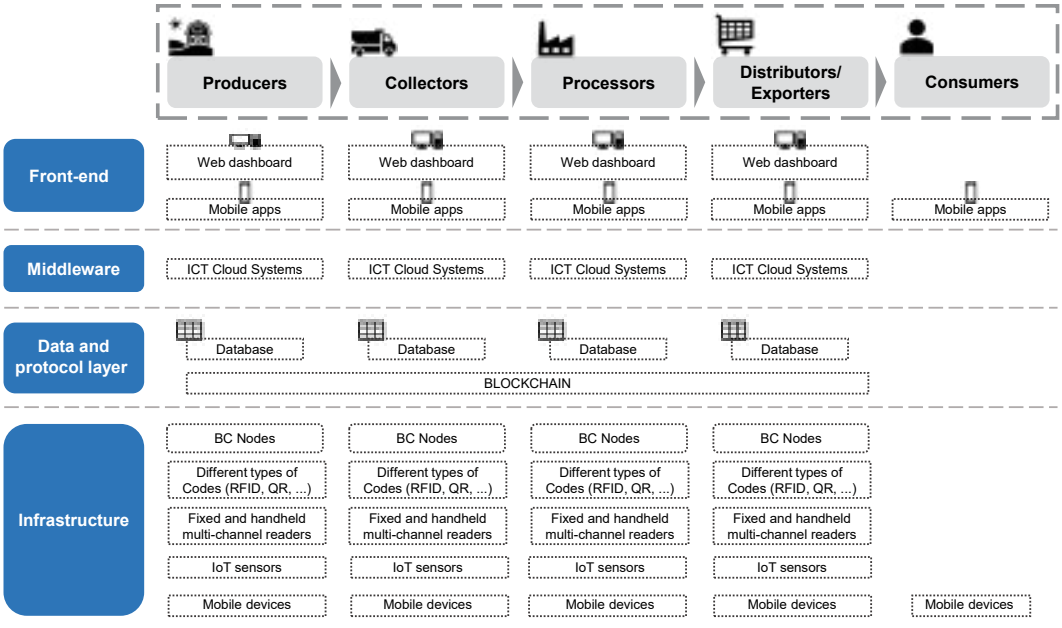
6.2.9. High-end market: Hezhi fresh agricultural products anti-counterfeiting traceability system (HezhiIoT - China)

Shenzhen Jinjia Hezhi Technology Co., Ltd. is an IoT subsidiary invested and established by Jinjia Group focused on new retail solutions and improving e-commerce. The company leverages blockchain traceability and a smart packaging marketing system to empower the packaging industry, reshape the added value, and create a safe and secure SaaS platform for food and medicine across sectors and local governments.

Hezhi Technology has developed and implemented innovative printed electronics, sensor chips, QR codes, augmented reality/virtual reality, cloud computing, the IoT, artificial intelligence, Beidou positioning (a satellite GPS), blockchain, big data, and other technologies to ensure the traceability of a wide range of products. These safeguard consumer rights and interests as well as the corporate brand image while lowering government supervision costs.

Shenzhen Jinjia Group, a private company in the printing industry, developed the system. The company creates and prints packaging for a variety of consumer products, including cigarettes, electronics, cosmetics, and others. The system is aimed primarily at the high-end market. Over 1 million users have adopted Hezhi Technology's blockchain logo products, including golden pear producers in Hubei province, Ole Star Red Wine, Moutai Constellation Wine, Lotus Wine, and Junyu Glory Wine, among others, for anti-counterfeiting protection (iShare - iFeng 2019).

Figure 41: IT architecture of the Hezhi system



The Hezhi traceability platform supports a variety of technologies, including QR codes, quantum cloud codes, NFC anti-counterfeiting labels, and ultrahigh frequency RFID, as well as a variety of anti-counterfeiting technologies that are applicable in several scenarios (Seo 2019). Hezhi's blockchain was created by Ant Financial Blockchain, which previously enabled

the tracking of food imported from Australia and New Zealand. It also provided technical solutions for Moutai's traceability (Jin Jia Box 2018a,b).

Figure 42: Usage of RFID in the Hezhi system

The authenticity verification and traceability platform built into the Hezhi system's blockchain provides consumers with a variety of authentication and query methods that can be implemented quickly and conveniently via mobile phones. Their application is optimized for both iOS and Android or users can query the data using any other code reader application on their mobile devices. By scanning the QR code on the product or downloading the Hezhi app, the mobile phone or handheld/fixed multi-channel readers, as illustrated in figure 43, can instantly verify the product's authenticity and obtain information about the product's production site, batch, and basic information. Businesses that join the Hezhi blockchain authenticity traceability platform can access only the anti-counterfeiting back-end and the IoT database.

Figure 43: Handheld and fixed multi-channel reader

Through the collection of various data, Hezhi designs data analysis models and status displays to describe the attributes of consumers and retailers and provides information such as location, purchase preference, consumption structure, and purchase frequency to facilitate product maintenance and consumer selection (Jin Jia box 2018a,b).

Table 34: Assessment of the system

No.	Criteria	Description of the system
1	**Functionality**	The Hezhi traceability platform supports a variety of perception entrances, such as QR code, quantum cloud code, NFC anti-counterfeiting label, and UHF RFID, and diversified anti-counterfeiting technologies suitable for different application scenarios and realizing the full life cycle monitoring of product production, circulation, and consumption.
2	**Operational ease**	Automatic data collection and capture requires less time in daily operation. It supports free one-object one-code QR code sending and data activation, with one-time sending of up to 1 million codes. Users only need to download the Hezhi customized app, and the mobile phone can inquire about product traceability information and immediately verify authenticity. Supported by the Hezhi platform, personalized and customized products can be realized with a minimum order of one bottle, one-minute design, one-day delivery, and one-second authenticity verification. The system supports the SaaS model, which can help SMEs quickly implement and deploy the traceability system to enter the application.
3	**Interoperability**	The system can integrate the information from the database of clients for seamless interaction—all information link from systems such as ERP, WMS, and transportation management system or order management system (OMS).
4	**Access and protection of stakeholder information**	The system uses an information center to collect the information from each stakeholder, making the principle of collecting information here 'centralized'. Blockchain technology helps safeguard the data, ensuring tamper-proof information.
5	**Reliability**	QR codes and RFID tags are deployed to ensure the link of the product. Automatic data collection and capture (via IoT sensors, scanners, and so on) mitigates human errors.
6	**Scalability**	Hezhi Technology's blockchain logo products have reached more than 1 million, including Ole Star Red Wine, Moutai Constellation Wine, Lotus Wine, Junyu Glory Wine, Wangbing Dry Wine, Jiangxiang Leader Jiangjiang Wine, Yilite 717 Wine, and other brands, providing a blockchain system for authentic anti-counterfeiting traceability.
7	**Affordability**	Not applicable. It should be noted that the system is widely used in China.
8	**Vietnam infrastructure compatibility**	The system uses technologies that are usable in Vietnam. The Hezhi traceability platform supports a variety of perception entrances, such as QR code, quantum cloud code, NFC anti-counterfeiting label, and UHF RFID, and diversified anti-counterfeiting technologies suitable for different application scenarios and realizing full life cycle monitoring of product production, circulation, and consumption.
9	**Localization and local support**	There is no information available about the likelihood of the system being localized in Vietnam.
10	**Compatibility with existing policies and regulations in Vietnam**	This system uses QR codes, RFID, and NFC for the identification of traceable products and blockchain for data storage and data sharing. MOST of Vietnam has issued technical regulations governing QR codes, RFID, and NFC technologies; however, there are no current technical standards for blockchain. If the Hezhi system is applied in Vietnam, it shall follow the national standards for traceability systems, such as TCVN 12850:2019 on Traceability - General requirements for traceability systems and cybersecurity regulations.

Table 35: Key conclusions on the pros and cons of the Hezhi system

Pros	Cons	Conclusion
Hezhi makes use of several relevant technologies that enhance the robustness of the system in terms of functionality, technology, and compatibility (QR code, RFID, mobile apps, handheld scanners, blockchain, big data, and cloud computing). It has proven successful in many cases, including importing fruits from New Zealand and Australia and has a strong track record in the wine industry. It also shows integration capability with ERP, WMS, and transportation management systems.	It is not clear that the system can be deployed in another country, such as Vietnam.	Hezhi could be a good reference case for Vietnam.

6.2.10. High-end market: 'Reassure on Code' fresh food traceability system (AliHealth - China)

The 'Reassure on Code' (Ma Shang Fang Xin) traceability platform is designed for enterprises. It provides traceability services throughout the product's life cycle, reaches consumers via traceability codes, establishes a membership system, facilitates consumer education on products and shopping guides, develops interactive marketing, and enables brand promotion. It aims to assist businesses in strengthening their product brands, expanding channels, and promoting sales. It also assists industry and governments at all levels by providing professional consultation on traceability systems planning, traceability standards, product specifications, innovation in regulatory services and improving the efficiency of oversight of product quality, safety, and public safety management. Interfacing with platforms in Guangdong, Guizhou, and Fujian has been completed, and work is under way with platforms in other provinces. The system is capable of handling hundreds of billions of lines of code and 100,000 enterprise users concurrently; is highly compatible, open, and secure; and offers high-quality professional services at an affordable price.

The 'Reassure on Code' traceability platform embodies Alibaba Health's mission to "make health accessible to everyone" and its vision to "serve one billion people be healthy throughout China." Alibaba Health has been focusing on product traceability and digital services for more than a decade and has extensive experience operating platforms. It will continue to invest in platform technology and collaborate with enterprises, industry associations, governments, and third-party technology service providers to jointly build a health ecosystem, assist the industry in its development, take on social responsibility, and protect public health. A joint public-private platform initiates the system, launched by Alibaba Health in collaboration with government entities (AliHealth 2020). The high-end market is the intended distribution channel. This platform is intended to serve as a solution for businesses looking to establish a membership system and increase brand recognition.

Technology deployment

The platform accepts inquiries via a variety of channels, including mobile applications, web pages, direct phone calls, and short message service. Additionally, it has opened standard interfaces for public inquiries to third-party social applications to facilitate consumer production verification and traceability. The platform is highly integrated and connected to third-party

management systems, such as dealers' ERP and WMS, via open standard interfaces. It can assist organizations in increasing work efficiency, reducing IT costs; flexibly expanding applications; and building a low-cost, safe, and reliable product traceability management platform with the help of cloud computing and IoT technology. Based on a unified coding mechanism, the platform assigns a unique ID card, either a barcode or a QR code, to each brand's smallest packaged product, including the product's name, manufacturer, specifications, and other registration information, and facilitates multiple activations. However, blockchain is currently only used to track medicines, not fresh foods, such as vegetables or fruits.

Table 36: Assessment of the system

No.	Criteria	Description of the system
1	**Functionality**	The 'Reassure on Code' (Ma Shang Fang Xin) traceability platform is designed for enterprises to provide traceability service throughout the life cycle of the product, reaching consumers through traceability codes.
2	**Operational ease**	• Installation: This system is easy to access because users simply need to apply online and wait for approval from the company. Customers can also scan the code using third-party applications such as Taobao, Alipay, or Tianmao app and a result will appear. • Daily operation: The platform is highly integrated and interconnected with third-party management systems, such as dealers' ERP and WMS.
3	**Interoperability**	Through open standard interfaces, the platform is highly integrated and interconnected with third-party management systems, such as dealers' ERP and WMS. The 'Reassure on Code' traceability platform is fully compatible with the traceability standards of the China Product Quality Electronic Supervision Network and China Drug Electronic Supervision Network. It supports the seamless migration of historical data between enterprise networks and relies on the powerful computing and data processing capabilities of Alibaba Cloud.
4	**Access and protection of stakeholder information**	Mobile inspection app tools help government regulatory agencies effectively carry out inspection and strengthen business supervision, including single-code flow direction query, batch flow direction query, and abnormal event early warning functions.
5	**Reliability**	• A unique QR code/barcode ensures the correct link. • Automatic data collection tools (IoT sensors) avoid human errors.
6	**Scalability**	It can handle hundreds of billions of code volume large data concurrently, supporting 100,000 enterprise users.
7	**Affordability**	The system costs CNY 50,000 per year, which may be considered expensive in Vietnam.
8	**Vietnam infrastructure compatibility**	The deployed technologies are usable in Vietnam.
9	**Localization and local support**	The system was built by Alibaba in a public-private project and aimed to support 1 billion people in China; there is no information on whether the system can be localized to Vietnam.
10	**Compatibility with existing policies and regulations in Vietnam**	The system uses barcodes to identify traceable products. MOST of Vietnam has issued technical regulations governing QR code technology. If the 'Reassure on Code' system is applied in Vietnam, it shall follow the national standards for traceability systems, such as TCVN 12850:2019 on Traceability - General requirements for traceability systems as well as cybersecurity regulations.

Table 37: Key conclusions on the pros and cons of the 'Reassure on Code' system

Pros	Cons	Conclusion
This system provides a platform with traceability features and offers a range of functions for marketing and sales activities.	To support Vietnam, a much smaller market, it will be necessary to negotiate and discuss the implementation of the 'Reassure on Code' system, which may take a long time. Although the system is widely used in China, the cost for deployment is about CNY 50,000 per year (equivalent to around VND 177,000,000 or US$7,000). This is considered high compared to local systems in Vietnam. To date, this system cannot use the Vietnamese language and currency. There is also no known support for this system in Vietnam.	This system could be useful for large-scale implementation. Its connection to Alibaba could help open access to the China market and the Alibaba business-to-business marketplace. It should be noted that 'Reassure on Code' is a public-private initiative, a joint project with a mission to serve the Chinese people.

6.2.11. Institutional procurement: Sunshine Lunch—school food safety traceability management platform (China)

The Sunshine Lunch Smart Food Safety Management Platform was created in 2016 and implemented on the Shanghai campus in January 2017. It now encompasses over 4,300 kindergartens and primary and secondary schools throughout Shanghai. By 2018, it covered all hospitals, pension institutions, and corporate canteens in Shanghai. In 2019, it was promoted in Shenzhen, Hunan, Zhejiang, and other places.

The food safety traceability system was developed and designed by Tianfang Information Technology Co., Ltd., a private company. The system adopts a three-party, three-dimensional supervision model. It was approved and authorized by the Shanghai Municipal Education Commission and the Shanghai Food and Drug Administration.

Technology deployment

The system is used solely as a platform to connect the users to the food information. The system deploys a website, mobile application, cloud system, big data, analytics, and QR code technologies.

Figure 44: Sunshine system's deployed traceability technologies

Table 38: Assessment of the system

No.	Criteria	Description of the system
1	**Functionality**	It seamlessly connects with the database of government regulatory agencies to realize the flow and sharing of data between systems. It can synchronize dangerous goods and unsafe food information, supplier business scope, qualification certificates, and other content, and send food safety alert in time.
2	**Operational ease**	In daily operation, once participants are connected to the platform, information is automatically used and shared to the platform from their database. Parents can access the information via mobile apps on their smartphones.
3	**Interoperability**	The system seamlessly incorporates data between the database with the systems of all stakeholders in the value chain. The information from their OMS, WMS, and transportation management system is uploaded to the food safety traceability platform.
4	**Access and protection of stakeholder information**	Parents can access information (for example, recipes, raw materials, suppliers, nutritional knowledge, and food education activities). In addition, the database seamlessly connects with the database of government regulatory agencies to realize the flow and sharing of data between systems.
5	**Reliability**	The operators claim that their system has an accuracy rate of 98%.
6	**Scalability**	The system is used by more than 6,000 schools, hospitals, civil administration and elderly care institutions, and enterprises and institutions in Shanghai.
7	**Affordability**	Not applicable. However, it should be noted that the system is widely used by 6,000+ schools, hospitals, and other institutions.
8	**Vietnam infrastructure compatibility**	The components of the system, including websites, cloud systems, mobile apps, and QR codes, are widely used and can be supported by the IT infrastructure of Vietnam.
9	**Localization and local support**	It has been promoted in Shenzhen, Hunan, Zhejiang, and other places. There is no information available on whether it can be localized to the Vietnam market.
10	**Compatibility with existing policies and regulations in Vietnam**	The platform uses a web dashboard, QR codes, and mobile applications. MOST of Vietnam has issued technical regulations governing QR code technology. If the Sunshine system is applied in Vietnam, it shall follow the national standards for barcode technology and traceability systems, including TCVN 12850:2019 on Traceability - General requirements for traceability systems, as well as cybersecurity regulations.

Table 39: Key conclusions on the pros and cons of the Sunshine system

Pros	Cons	Conclusion
Sunshine is a powerful tool that can be procured by institutions such as schools and hospitals, among others. Its simplicity is sufficient to handle schools' and hospitals' operations, and it meets fundamental requirements from parents/patients and regulations and supports monitoring food safety in this market segment.	The system does not seem to show details of production materials used prior to arrival at the school, but it provides information on the sources, suppliers, and processing at schools and hospitals. To date, this system cannot accommodate the Vietnamese language and currency. There is also no known support for this system in Vietnam.	This model is well suited to Vietnam as this is also an important area (enhancement of food safety in school lunch) that has attracted considerable attention across society.

6.2.12. Lessons learned

This section presents the lessons learned on the key conditions for implementing national or private traceability systems based on desk research.

No.	International experiences with implementing traceability systems	Lessons learned on the key conditions for implementing similar systems
1.	**Implementation of national traceability systems**	
a.	RTO and RTV (Italy): • Initiated by the government of Italy and managed by ICQRF • Covers the entire nation to trace all olive oil and wine produced and store data in the database • Utilizes basic technologies (QR codes, mobile apps, and web-based applications) • The ICQRF (the department of the central inspectorate for fraud repression and quality protection of the agri-food products and foodstuffs) not only manages agri-food databases but also implements the relevant controls.	**To develop and deploy a similar system in Vietnam, the following conditions should be met:** • For olive growers, broadband connectivity must be ensured to avoid creating a 'digital divide', which increases the difficulty of accessing and managing digital services. Other potential contributing factors are the absence of broadband connectivity in several agricultural and rural areas in addition to the practical challenges of a start-up project phase. • The effectiveness of the register is dependent on farmers entering information correctly, which affects the reliability of the automated system. • The accuracy of data entry is inevitably linked to the simplicity of the compilation process (reporting); therefore, the system operator (for example, RTO and RTV) has created several documents providing guidance on the process. **Other factors enabling the success of RTO and RTV in Italy:** • The government has provided extensive guidance and has strict controls for farmers and processes. Government resources are sent on site to the field to assist the farmers in using the tools. • The ICQRF department has been established and serves as the management body for the system to verify the completeness of the data entered. Field resources/officers must be physically present on site to ensure that data reliability is managed throughout the process.

No.	International experiences with implementing traceability systems	Lessons learned on the key conditions for implementing similar systems
b.	UPSS (Korea): • Initiated and managed by KCCI and MFDS • Connects 173,708 stores across the country (as of 2019), ranging from large-scale retailers, including hypermarkets and department stores, to small and medium businesses, such as supermarkets and convenience stores, and many other retail channels • Is reliable, with a database that is interoperable with other government systems (using a unique GTIN code) to utilize results from inspections, and is easy for retailers to operate since it relies on tools they use daily.	**To develop and deploy a similar system in Vietnam, both the government and users need to meet certain conditions:** • For users, retailers in Vietnam need to meet the following conditions to deploy a similar system: - Use POS system. - Integrate GTIN and barcodes attached to the products into the POS systems and employ internal systems to manage inventories. • For the government, in addition to developing a system like the UPSS: - Develop a non-compliant food emergency reporting system to integrate the GTIN or unique barcode of the reported product. - Issue relevant standards and guidance regarding the systems and related inspection mechanisms. - Improve the quality and quantity of the current human resources performing inspections on food safety and food traceability. - Assign an agency to specialize in managing, operating, and maintaining such systems. - Develop agreements with the government and stakeholders on the KDEs and protocol to ensure the implementation of the system and provide support and training to small-scale retailers. **Other factors enabling the success of the UPSS in Korea:** • **Demand from consumers**: The melamine scandal in 2008 has significantly and negatively affected Korean (and Chinese) consumers' trust in the food system. The establishment of the UPSS initiated by the government and private sector received support from both consumers and retailers. As a result, consumers feel safer and better protected since the risk of purchasing an unsafe product has been significantly decreased. • **Legal framework**: The Act on Food Sanitation stipulates traceability as a mandatory requirement for food sellers based on sales volume and store size (for example, department stores, supermarkets, and chain stores, with an area of more than 300 m^2 of business).[33] These stores must also participate in the UPSS.

33 Article 39, Enforcement rule of Act on Food Hygiene Act on Food Sanitation.

No.	International experiences with implementing traceability systems	Lessons learned on the key conditions for implementing similar systems
c.	National Agricultural Products Quality and Safety Traceability Management Information Platform (China): • Is initiated and managed by the government of China • Covers the entire nation to unite all traceability system databases into one platform for monitoring and inspection • Utilizes common technologies (mobile applications and barcodes) that can be deployed by both formal and informal markets • Offers a regular inspection mechanism to monitor compliance by participating businesses • Can connect to provincial traceability platforms	**To develop and deploy a similar system in Vietnam, the government needs to meet certain conditions:** • For national traceability platforms, there needs to be an agreement between the government and the stakeholders on the KDEs to be captured, recorded, and shared, and a framework for the overall data governance and data privacy rules. • The implementation of a national traceability system is dependent on the current resource and technology capacity of Vietnam. For example, the system implemented in China offers users mobile applications and web dashboards to input data into the system, which most supply chain stakeholders can easily obtain. In Vietnam, cooperatives, large-scale companies, formal distribution channels, etc., can adopt such technologies, but small-scale farmers may require training and technical support. • The national system may require that the Vietnamese government builds competent, trained teams with clear institutional arrangements to manage and perform regular inspections on traceability data provided by stakeholders. • Interoperability among systems is essential to implement a national system.
2.	**Implementation of private traceability systems**	
	• Private traceability systems are implemented to serve different markets (both formal and informal ones). • Common technologies include barcodes (including QR codes) and mobile applications. • More advanced technologies include sensors (including RFID, NFC, and IoT sensors) and software (including blockchain). • Private traceability systems deployed by private ABs are normally developed by solution providers and the deployed package of technologies can be customized based on the needs and the capacity of each individual AB.	**Lessons learned based on private system implementations for high-end/formal markets and informal markets:** • Communication with the final consumer is one of the main drivers for private companies in this market. It helps create a better perception of a higher product quality. • Companies in the high-end market are more willing to adopt emerging technologies and innovate. • Informal markets have more difficulty launching digital traceability systems due to the many steps in their supply chain and production processes, in addition to the challenges encountered in automating them. **Key factors/conditions for successful implementation:** • Legal framework - Like Vietnam, traceability is compulsory in Italy and China. - To increase the adoption rate of both formal and informal markets, Italy has conducted thousands of checks on the compliance of food operators with traceability every year. • The system should not disrupt existing processes, but build upon existing ones, ideally without additional steps in the supply chain and production processes. If additional steps are introduced, these would be beneficial only if they result in a reduction of existing manual steps or processes that may be prone to errors. • The lower the amount of data to be manually added to the system, the higher the reliability of the system.

SECTION 7. RECOMMENDATIONS AND PROPOSED INTERVENTION AREAS

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7.1. Recommendations on the approaches

Food industry operators in Vietnam who serve different market segments face different levels of financial and technological constraints affecting scalability. Firms cannot expand domestically or export if supply chains are not robust and resilient and guarantee safe and traceable food. As a result, they may consider a few technologies and system architectures to understand which ones best suit their business goals and capabilities. While traceability is adopted and well implemented in the formal retail and export markets, it almost does not currently exist in the informal market. This section presents recommendations for both informal and formal food supply chain stakeholders based on strong worldwide experience and the use of currently available technologies for traceability purposes.

7.1.1. Supporting small FBOs in the informal market and the role of the government

As no digital or manual traceability systems are currently in place in the informal market, there is a need to create greater demand for F&V traceability among domestic consumers, merchants, traders, and producers. To make it happen, both public and private sectors should make more efforts to raise public awareness about the need for food safety and the risks of consuming unsafe and untraceable food. There is a big role for the government to provide technical and material assistance to small producers and traders in the informal market to reduce their investment and operating costs of adopting food traceability. In terms of implementation arrangements, the government should assist individual small-scale farmers and vendors at community wet markets or street vendors in joining cooperatives or producer/trader organizations, where appropriate. The management boards of these entities will represent the groups and are responsible for registering and managing traceability data and tools, as well as training and supervision.

- **Phase 1 (the transition phase)**: Since the informal market's stakeholders have limited technical and financial capabilities and operate on a smaller scale, it is recommended that they perform manual data collection and recording for internal traceability. Under the guidance of cooperatives, traders who collect vegetables from farms and farmers who operate as traders can keep track of their batches or lots using existing farm books or Excel files.
    - Once farmers have been determined to be compliant using manual methods (farm diaries), capacity building is recommended to enable the transition to e-farm diaries using smartphones as data input devices. Several e-farm diary solutions are presently being piloted and deployed in the Vietnamese market.
    - Capacity building might extend to market traders who collect vegetables from farmers, allowing them to connect to an e-farm diary in a one-step-up/one-step-down traceability functionality. To ensure that vegetables from different farms are not commingled, this external traceability mechanism would necessitate cooperative management controls and training at the trader's stall.

  - External traceability is critical, and it can be handled and monitored by the cooperative's management board, which oversees registering of all traders with the municipal or provincial traceability system. Several towns and provinces have already built traceability systems that allow enterprises and cooperatives to register for QR codes that link product and provenance information. In the absence of a municipal or provincial traceability system, farmers should be assisted in forming production partnerships with ABs to market their farm output, with the ABs handling traceability for all farm produce. Similarly, the wholesale market's management board is advised to assist traders and distributors in securing signage and QR codes for their food stalls. This methodology is similar to the HCMC-based pork traceability pilot plan, in which the management board registers pork sellers and provides them with QR codes to display at their food stalls.

- **Phase 2 (the mature stage)**: At a later stage, these stakeholders can deploy labeling with a barcode and QR code on consumer packaging and a simple mobile application based on a global standard such as GS1 and Vietnamese technical standards or TCVN. These technologies are significantly less expensive and easy to use.

7.1.2. The formal retail and export markets and the leading role of the private sector

Stakeholders in the formal retail market and export-oriented markets must leverage GS1 Vietnam's industry standards, which were adapted and published as TCVN. Additionally, firms with strong technical and financial capabilities and larger-scale operations are urged to consider deploying more advanced technologies, such as IoT-based sensors, blockchain, and customized mobile applications, to improve traceability and recall of unsafe foods. Automatic data collection and recording will assist in minimizing human error and time. These stakeholders may continue to use manual systems if they meet their current needs, but digital technologies are recommended for larger-scale processes involving much more complex processes. Apart from the minimum data required to comply with the 'one-step-back and one-step-forward' traceability principle, internal traceability should be applied to ensure a stronger connection between food products received and processed internally to identify potential vulnerabilities in internal stages. The decision to invest in common technologies and simpler systems versus advanced technologies and complex systems is entirely dependent on the needs and budget of the individual stakeholder. To encourage the adoption of digital traceability in the formal market, the government could draw on Korea's experience, beginning with larger companies and then rolling out to medium and small businesses (details are presented in Section 6 of the report).

Note: In research conducted in Italy on voluntary traceability in vertically integrated supply chains, researchers contended that while supplier monitoring costs may increase to ensure compliance, implementing traceability was shown to reduce uncertainty among economic actors, enhance chain transparency and accountability, improve chain coordination, and reduce transaction costs and risk (Banterle and Stranieri 2008).

7.1.3. The government's role in facilitating and managing food traceability

The government has a crucial role in facilitating and managing food traceability, especially in helping small FBOs participate in food traceability and ensuring traceability systems developed by provinces and private sector companies are interoperable. At the provincial level, it is recommended MOST issues guidance and standards on establishing provincial traceability systems to ensure data can be shared and traced for food safety management purposes. For the existing provincial portals, it is necessary to conduct a comprehensive review and assessments to recommend solutions to improve them to meet the national required standards, especially in data sharing and privacy protection, and applied to high-risk, high-value, and signature products. The government should have incentive policies to encourage small FBOs to join their provincial traceability portals, preferably through their groups or organizations. The government should also build competent and trained local teams with clear institutional arrangements to manage and perform regular inspections on traceability data provided by stakeholders.

At the national level, it is recommended that the government accelerates the implementation of the national traceability portal. The main function of the national traceability system is to connect public and private traceability systems, aggregate data and information, and manage food safety risks and traceability at the country level. It also serves as the platform for FBOs in provinces whose provincial traceability portals have not yet been developed.

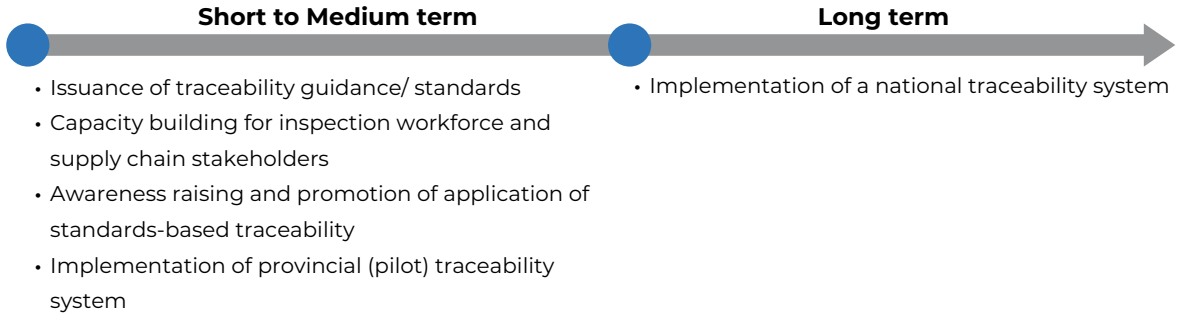
7.1.4. The private sector's role in investment and implementing traceability

The private sector plays the primary role in investment and implementation of traceability in both export and domestic markets. Its investments are usually motivated by consumer demands, risk mitigation, standards compliance, efficiency gains, or some combination of these incentives. In fragmented informal value chains such as in Vietnam, the private sector's cost-benefit analysis does not always add up to a strong enough business case for investment. To provide incentives for the private sector to invest more in food traceability, besides creating an enabling environment, the government should also assist in training and organizing small producers and small traders into groups to link them with private sector firms that have the capacity to implement and supervise food traceability across entire food value chains. It is important for private producers and traders to recognize traceability as an excellent tool to showcase their adherence to food safety standards, differentiate themselves in the market, safeguard from trade disputes, and better engage their consumers. These benefits would help enhance their competitiveness in the market, especially when there is increased demand for information and transparency about the sources of products.

7.2. Recommendations on intervention areas

Based on the review of good international practices, the following intervention areas are recommended: (a) issuance of traceability guidance/standards, (b) capacity building for inspection workforce and supply chain stakeholders, (c) awareness raising and promotion of the application of standard-based traceability, and (d) implementation of the provincial (pilot) traceability system.

Figure 45: Proposed short-term to medium-term intervention areas



7.2.1. Issuance of traceability guidance/standards

It is recommended that MOST and its subordinate unit (for example, STAMEQ) collaborate with MARD and its subordinate units at the national level and with DARD and its subordinate units at the provincial level to develop specific traceability guidance for high-value and high-risk products and those with geographic indicators.

Note: Voluntary technical standards exist as TCVN and are encouraged to be developed further for specific high-value, high-risk, and signature products, including provincial specialties and those awarded geographic indications. Specific guidance for activities that are heavily featured in F&V supply chains and have the potential to apply digital technologies is also encouraged..

7.2.2. Capacity building for inspection workforce and supply chain stakeholders

Central ministries and their provincial units should mainstream and conduct training on traceability requirements and enforcement of food safety regulations for the inspection workforce. Capacity-building activities may include holding national, regional, and provincial events and training courses for F&V supply chain stakeholders to enhance general technical knowledge, promote digital traceability technologies, and adopt national standards/guidance.

7.2.3. Awareness raising and promotion of the application of standard-based digital traceability

It is essential to raise awareness of all concerned government agencies and supply chain stakeholders, especially those involved in the informal sector with limited financial capacity.

7.2.4. Gender

From farming to selling in informal marketplaces to preparing and cooking meals in street cafes and restaurants, women play a critical part in Vietnam's agri-food ecosystems. Women are also the leading buyers of fruits and vegetables in households. It is recommended that the public awareness program should also include specific training for women on food safety and food safety handling awareness at home, in food service, and at markets, plus worker safety and food traceability.

7.2.5. Implementation of provincial traceability systems

Provinces should develop their traceability portals targeting high-risk, high-value, and signature products and those with geographic indicators.

7.2.6. Implementation of the national traceability portal

MOST is currently cooperating with all concerned central agencies and 63 provinces to accelerate the implementation of the national traceability portal with consideration for common and easily adopted technologies (such as barcodes, QR codes, and mobile applications). The following should be considered by the Vietnamese government:

- Implementing a national traceability portal depends heavily on Vietnam's current technical resources, cross-ministerial collaboration, and capacity building with both the public and private sectors. For example, the public sector traceability system(s) implemented in China offers users both mobile applications and web dashboards to enter data into the system, which most supply chain stakeholders can easily obtain. In Vietnam, cooperatives, large-scale food companies, formal distribution channels, and so on, can adopt such technologies, but small-scale farmers will require training and technical support.
- Implementing a national traceability system would require the government to build competent and trained teams with clear institutional arrangements to manage and regularly inspect traceability data provided by stakeholders.

  Note: Digital transformation is often incorrectly discussed as the diffusion of new and disruptive technologies. However, preparing *people* and *organizations* for the transformation to digital business model is essential as successful digital transformation lies at the intersection of technology, organizations, and people (Queiroz and Fosso-Wamba 2022).
- Raising awareness of related government agencies and supply chain stakeholders regarding the national traceability portal is essential to increase the adoption rate. As GS1 Vietnam is tasked with implementing the VNTP, this significantly benefits capacity building with industry players, including food cooperatives, organized retail trade, food processors, and solution providers, as many firms are already members of GS1.
- Consumer education on F&V safety and traceability is highly recommended, as they will be primary users of the VNTP, once it is operational. Recent research (Tran et al. 2022) in Vietnam has positively indicated that consumers are willing to pay a premium for products

with labels (including VietGAP) and traceability data accessible via QR codes. However, further studies are needed to better understand the historical, cultural, and socioeconomic relevance of wet market purchasing traditions and willingness to pay for traceability.

- It would take time to fully implement a traceability system at the national level. In the short term, pilot traceability systems should be implemented at the provincial level targeting signature products, including those that are provincial specialties (including products under the OCOP program), those awarded geographic indications by the government of Vietnam or other countries, or those that are of high risk and high value.
- It is highly recommended that the national and provincial traceability systems be based on interoperable industry standards that facilitate compliance with regulations and data exchange between different systems. Ultimately, the national system must connect to multiple regional traceability systems, and the EPCIS standard adopted by the national traceability portal facilitates this data exchange. For example, a shopper in Hanoi can use a single-user interface (such as a mobile phone application or web interface) linked to the national system to scan and query a product grown in the Mekong and seamlessly access traceability data from local or regional systems.

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APPENDIXES

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APPENDIX A: DETAILED DESCRIPTIONS OF KEY PLAYERS OF THE F&V SUPPLY CHAIN IN VIETNAM

Table 40: Key players of the F&V supply chain in Vietnam

Role	Players	Detailed description
Producers	**Individual small-scale farmers and farmers under old-type cooperatives**	Agricultural production in Vietnam is decentralized and depends on small-scale households. Small-scale households account for most of the total vegetables produced. For example, in Hanoi, individual small-scale farmers and farmers under old-type cooperatives account for 95 percent of total vegetables produced and supply 61.9 percent of Hanoi's total vegetable demand for consumption.[34] Although large-scale production areas are gradually established, they still rely on small-scale and scattered households who face difficulties in applying modern technologies (Toan 2020). Production areas of F&V have kept increasing; however, they lack chain links (PSAV 2017). In addition, old-type cooperatives still exist that do not operate well under market mechanisms and are considered ineffective. Individual small-scale farmers may produce and then sell fruits and vegetables • Directly to informal distribution channels such as traditional community markets; or • Indirectly to final distribution channels via traders.
	New-type cooperatives	New-type agricultural cooperatives include individuals and households (for example, workers, officers, business households, farms) willing to voluntarily contribute and take responsibility for the business under the new Cooperative Law provisions issued in 2012. New-type agricultural cooperatives play a vital role in supporting implementation of the National Target Program to build new rural areas for sustainable development. In agricultural production, several cooperatives effectively gather farmers together to form large-scale and efficient production areas and resources. New-type cooperatives account for approximately 4.32 percent of total vegetables produced in Hanoi and supply 2.8 percent of Hanoi's total vegetable demand for consumption.[35] In addition, some new-type agricultural cooperatives also provide farm inputs to ensure the quality of F&V production of cooperative members (for example seeds, production materials, fertilizers, and technical assistance). Some cooperatives also support their members to sell products to distribution channels. Cooperatives may produce and then sell fruits and vegetables • Directly to informal distribution channels, such as traditional community markets; • Directly to formal distribution channels, such as supermarkets and restaurants; • Directly to exporters; • Directly to processing companies; and • Indirectly to final distribution channels via traders or trading companies.

34 Calculation based on figures provided by Loc (2016) and by Hanoi DARD (2019).

35 Ibid.

Role	Players	Detailed description
	Large-scale farming companies	In addition to the involvement of individual farmers and cooperatives, there is also participation from large-scale farming companies. However, their total production is minor compared to the production volume from small-scale farmers or new-type cooperatives. Large-scale farming companies supply about 0.3 percent of Hanoi's total vegetable demand for consumption.[36] • Companies may produce and sell fruits and vegetables • Directly to formal distribution channels; • Directly to processing companies; and • Directly to exporters.
Traders	**Traditional traders**	Traders or collectors involved in on-field procurement and transportation often buy produce directly from farms. Traditional traders play a key role in connecting producers and distribution channels. Traditional traders procure and distribute about 22% of Hanoi's total volume of vegetables for consumption.[37] • Traders sell post-harvest F&V products • Directly to informal distribution channels, such as traditional community markets; • Directly to formal distribution channels, such as supermarkets and restaurants; • Directly to processing companies; and • Indirectly to final distribution channels via trading companies.
	F&V trading companies	F&V trading companies purchase from other producers for resale. Some large-scale farming companies currently act as F&V trading companies, for example, Vineco owns 14 farms that produce F&V, but it also signs F&V procurement agreements with several small-scale farmers.
Processors	**F&V processing companies**	F&V processing companies perform washing operations, post-harvest treatment, and packaging, among other functions. Some large-scale farming companies also function as F&V processing companies, which procure post-harvest products from producers. Pre/processed products are sold • Directly to formal distribution channels in the domestic market; and • Directly to exporters.

36 Calculation based on figures provided by Loc (2016) and by Hanoi DARD (2019).

37 Ibid.

Role	Players	Detailed description
Distributors	**Informal distribution channels in the domestic market**	In the domestic market, agricultural products are mainly sold through informal distribution channels, including individual retailers, traditional community markets, small food services, and so on. For example, regarding vegetables produced in Hanoi, informal distribution channels serve 55% of Hanoi's total volume of vegetable consumption.[38] In 2018, Vietnam had 8,539 traditional community markets operating, of which 83 are wholesale markets (MOIT 2018). Aside from official markets, unofficial markets with individual street traders exist throughout the country. Regarding consumer behavior toward informal channels, a study conducted in 2017 in Hanoi, HCMC, Lao Cai, and Son La reported that more than 90% of total F&V expenditure was in traditional (informal) community markets (Umberger et al., 2019).
	Formal distribution channels in the domestic market	Formal domestic markets for F&V include supermarkets, foodservice suppliers, and establishments such as restaurants, cafés, hotels, hospitals, and corporate canteens. Vietnam is estimated to have 957 supermarkets (Vietnam Domestic Market Department - MOIT, 2019). Although the number of supermarkets has been rising, the total quantity of F&V purchased through these distribution channels is still minor compared to the traditional distribution channel. For example, only just over 2% of Hanoi's total vegetable demand is distributed through formal distribution channels.[39] Regarding consumer behavior toward formal channels, 6% to 10% of total F&V expenditure was through formal distribution channels (such as supermarkets, shopping malls, convenience stores, and special stores) (Umberger et al., 2019).
	Exporters	Exported products are distributed mainly through export enterprises, with some traded via cross-border channels. For example, 85.5% of dragon fruit produced in Binh Thuan province is exported to foreign markets, mainly through export-oriented traditional collectors.[40] The main export markets for Vietnam F&V include China, the Association of Southeast Asian Nations (ASEAN), the US, Korea, and the EU. In the first seven months of 2020, the total value of F&V exported from Vietnam to China, Korea, and the EU was over US$1.1 billion, US$94 million, and US$82 million, respectively.

Vegetables supply chain in Hanoi

As of 2017, Hanoi had 12,040 ha for growing vegetables, with average annual output of 650,000 metric tons per year serving approximately 65 percent of the city's total demand. The remaining 35 percent is supplied by other provinces and imported from other countries (mainly China). In particular, the production areas that are eligible to produce safe vegetables comprise 5,044 ha with total output reaching nearly 400,000 metric tons per year and serving 40 percent of the city's total demand for consumption (Hanoi DARD 2017). Hanoi still has about 7,000 ha of vegetables that have not been qualified to produce safe vegetables.[41]

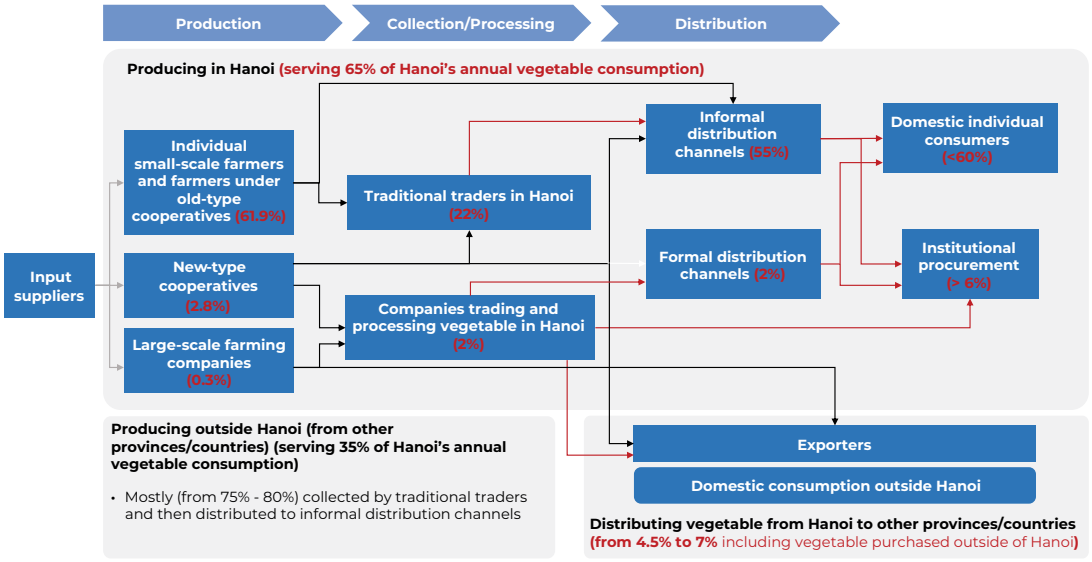
38 Calculation based on figures provided by Loc (2016) and by Hanoi DARD (2019).

39 Ibid.

40 Calculation based on figures provided by IPSARD 2020.

41 Calculation based on figures from Hanoi DARD (2017).

Figure 46: Hanoi vegetable supply chains



Production stage

In Hanoi, there are three main groups of vegetable producers: (a) individual small-scale farmers and farmers under old-type cooperatives, (b) farmers under new-type cooperatives, and (c) large-scale farming companies (Loc 2016). As of 2018, there were 48 safe vegetable vertical supply chains in Hanoi: 9 produce vegetables independently, without collecting from other producers; 23 perform both producing and collecting; and 16 only collect vegetables produced by other producers (Hanoi DARD 2019).

- Individual small-scale farmers and farmers under old-style cooperatives

  Most of Hanoi vegetable production areas are cultivated by small-scale farmers and are fragmented with low output levels (Thanh 2019). There are over 200,000 small-scale farmers in operation (Thanh 2018) scattered across 17 suburban districts, 1 town, and 3 urban districts in Hanoi. They account for 61.9 percent of the city's total demand for vegetables.[42]

  Individual farmers and farmers under old-type cooperatives sell 53 percent of their total vegetable production to traditional traders (accounting for about 33 percent of Hanoi's total demand for consumption) and nearly 40 percent to less formal distribution channels (including traditional wholesale markets and small community markets). Together, these account for about 24 percent of Hanoi's total demand.[43]Individual small-scale farmers and farmers under old-type cooperatives are mainly responsible for all stages, from production to consumption, because of the lack of a connection linking production to consumption. Most old-type agricultural cooperatives do not provide support for distributing post-harvest vegetables due to inadequate links between farmers, cooperatives, and distribution channels (Thanh 2018).

42 Calculation based on figures provided by Loc (2016) and by Hanoi DARD (2019).

43 Ibid.

- New-type cooperatives

  Farmers under new-type cooperatives produce 4.32 percent of total annual vegetable production in Hanoi, which serves 2.8 percent of total vegetable demand for consumption.[44]

  New-type cooperatives operate under Cooperative Law no. 23/2012/QH13 issued in 2012, by which, the cooperatives' boards of directors are not only in charge of general management but also direct activities from production to consumption in alignment with initial agreements made with cooperative members. Boards of directors also need to sign procurement agreements or contracts committing to the vegetable consumption rate for which the cooperative is responsible. However, farmers under new-type cooperatives report that they must still identify distribution channels themselves. For example, the safe vegetable production area in Van Noi, Dong Anh district (with more than 200 households operating around 220 ha under 12 cooperatives) sells only a small amount of vegetables under the Van Noi brand. As with the Van Noi cooperative, despite having 18 participating households with 5 ha of vegetable cultivation, it can only be responsible for distributing two-thirds of the total output produced by participating farmers (Hanoi DARD 2017b).

  In contrast to old-type cooperatives, new-type cooperatives distribute their vegetables to supermarkets and restaurants.

- Large-scale farming companies

  In addition to the involvement of individual farmers and cooperatives, there are also participations from large-scale farming companies. Although there are few of them, these companies focus on large-scale growing and production, and their production area is much larger than that of small-scale households and cooperatives. Companies participating in this field face several challenges, and their total vegetable production only meets 0.3 percent of Hanoi's total demand for consumption.45 As they are shared with the owner of Bac Tom company, the production and sale of safe vegetables requires a large amount of capital; however, the distribution system for agricultural products is not sufficient, creating difficulties for companies to participate in this field (Tung 2017).

Collection and processing stage

- Traditional traders

  Traditional traders procure and distribute approximately 22 percent of Hanoi's total volume of vegetables for consumption, with individual farmers and farmers under old-type cooperatives selling 53 percent of their total production to traders.46

  Traditional traders play a much more significant role in vegetable distribution for consumption from other provinces to Hanoi. Traditional traders buy vegetables from the production area for transport to Hanoi. Traditional traders are responsible for the distribution of 75 to 85 percent of the total vegetables produced by other provinces (Loc 2016).

44 Ibid.

45 Ibid.

46 Calculation based on figures provided by Loc (2016) and by Hanoi DARD (2019).

- Companies trading and processing vegetables in Hanoi

  According to Hanoi DARD, as of 2019, there are 208 companies committing to procure 42 metric tons of safe vegetables per day from producers (under written contracts), which meets 2 percent of Hanoi's total vegetable demand.[47] These contracts ensure stable output with reasonable prices for farmers and is, therefore, promoted by the city government. For example, Thanh Tri district actively contacts and instructs cooperatives and households to sign contracts with companies at prices that are 10 to 15 percent higher than market price (Tung 2017).

Distribution stage

Vegetables are distributed via three main channels: (a) Informal distribution channels, (b) formal distribution channels, and (c) exporters. In addition, some green vegetables grown in Hanoi are provided to corporates' canteens and restaurants via institutional procurement.

- Informal distribution channels

  Informal distribution channels serve 55 percent of Hanoi's total volume of vegetable consumption.[48] In addition to the Minh Khai and Southern wholesale markets, there are also several secondary markets and smaller wholesale markets in operation, such as Long Bien, Van Quan, and North Thang Long, along with many other community markets within the city. Most vegetables produced in Hanoi are distributed to these wholesale and community markets, only a small portion is sold via supermarkets (Loc 2016). Vegetables distributed at these traditional markets include those (a) directly sold by the producers themselves, (b) procured by traditional traders from producers in other provinces, and (c) procured by traditional traders from producers in Hanoi.

  For informal distribution channels, transactions are made verbally without official written contracts.

- Institutional procurement

  Canteens (of corporates, schools, and so on) consumed more than 6 percent of Hanoi's total vegetable volume.[49] To ensure the output channels for safe vegetables produced in Hanoi as well as to improve the quality of food safety in the city, the city government promotes several actions to strengthen the connection between safe vegetable producers and canteens in the form of institutional procurement. For example, Chuong My district has suggested that school canteens procure safe vegetables with clear origins (Thanh 2019).

- Formal distribution channels

  Formal distribution channels handle more than 2 percent of Hanoi's total vegetable demand.[50] There are 29 chains supplying safe vegetables, linked to 41 supermarkets and stores, such as Soi Bien chains, AEON mall supermarkets, Unimart, and Vinmart, among

47 Ibid.

48 Ibid.

49 Ibid.

50 Calculation based on figures provided by Loc (2016) and by Hanoi DARD (2019).

others (Thanh 2019). Within these channels, vegetables are traded under official written contracts. In addition, a small portion of vegetables sold in supermarkets is procured from small-scale households, but this amount is not significant because supermarkets apply high standards that can only be adopted by large-scale production models (Do 2019).

- Exporters

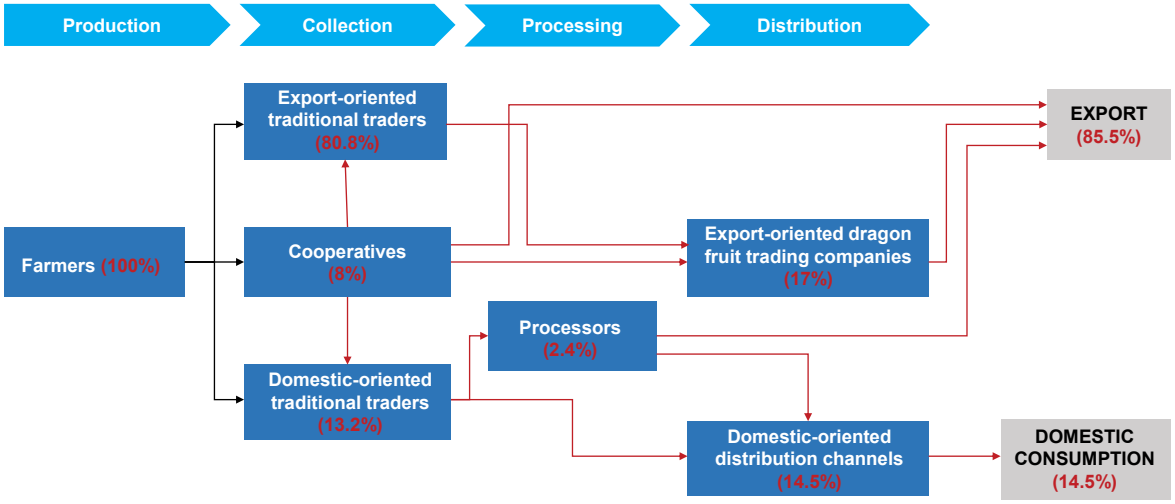
  Vegetables are distributed mainly through export-oriented enterprises. However, vegetables are primarily consumed domestically in Vietnam, with minor amounts for export.

Binh Thuan Dragon fruit supply chain

Binh Thuan province is the biggest dragon fruit production area in Vietnam. As of 2020, its total dragon fruit production area covered 32,644 ha. In the first six months of 2020, total reported production stood at 330,800 metric tons, an increase of 7.6 percent over the same period in 2019. As of 2019, the entire province accounted for 10,210 ha of dragon fruit production area that meets the VietGAP standard (Binh Thuan GSO 2019).

The Binh Thuan dragon fruit supply chain includes producers, traders, processors, and distributors. Detailed descriptions are presented in figure 47.

Figure 47: Binh Thuan dragon fruit supply chain



Source: EY calculation based on IPSARD report 2020.

Production stage

- In Binh Thuan province, dragon fruits are produced by small households. On average, they sell 80 percent of total dragon fruit production to export-oriented traditional traders, around 8 percent to cooperatives, and approximately 12 percent to domestic-oriented traditional traders. For dragon fruit procured by export-oriented and domestically oriented traditional traders, 80 percent of the households do not have a contract, and there is no advance communication. Therefore, households may not have an opportunity to actively negotiate the price and the quantity to be sold and must depend on the traders. For dragon fruit procured by cooperatives, the number of fruits procured is small, but stable (IPSARD 2020).

Collection stage

- Export-oriented traditional traders

  Traditional traders play a key role in collecting dragon fruit products for export. The trading or collection systems are diversified, which sufficiently serve the needs of the market. Annually, on average, 1,500–2,000 metric tons of dragon fruit is collected for export, of which 80 percent is exported directly to China (with support from export services provided by individuals or companies at border checkpoints). The rest is sold to other distribution channels for domestic consumption or to be exported to other markets. Traditional traders identify farms that meet the requirements set by Chinese traders and buy dragon fruit directly from the farms (IPSARD 2020).

- Cooperatives

  Cooperatives are well developed in Binh Thuan. Many cooperatives support the producers and connect them with trading companies, which promotes links between stakeholders in the supply chain. Although the cooperatives do not buy in large volume, they distribute dragon fruit to many different parties. Annually, on average, cooperatives distribute 8 percent of total dragon fruit produced in Binh Thuan, of which 10 percent is sold to export-oriented traditional traders, 15 percent is sold to domestic-oriented traditional traders for domestic consumption, 65 percent is directly exported (with support from export services provided by individuals or companies at border checkpoints), and 10 percent is distributed to export-oriented dragon fruit trading companies. Most cooperatives are small, with on average only 22 members per cooperative. They focus on production with low capital requirements and rarely have the potential or capacity to purchase and export dragon fruit. Therefore, dragon fruit is still mainly traded via traditional traders (IPSARD 2020).

- Domestic-oriented traditional traders

  Binh Thuan dragon fruits are produced for export, thus, distribution channels for domestic consumption only account for a minor percentage, which is collected and distributed by traditional traders. On average, domestically oriented traditional traders procured 12 percent of total dragon fruit produced in Binh Thuan from farmers. These traders also purchase around 15 percent of cooperatives' dragon fruit volume, which is equivalent to around 1.2 percent of total dragon fruit produced in Binh Thuan. This dragon fruit will then be distributed for domestic consumption within Binh Thuan province and in other regions of Vietnam (IPSARD 2020).

Processing stage

- Processors purchase dragon fruit from domestically oriented traditional traders and from export-oriented dragon fruit trading companies and then distribute 90 percent of the semi-processed and processed products for domestic consumption and 10 percent for export. The number of dragon fruit purchased, processed, and redistributed by processors accounts for 2.4 percent of total dragon fruit produced in Binh Thuan (IPSARD 2020).

Distribution stage

- Export-oriented dragon fruit trading companies

  These companies are in Binh Thuan or surrounding provinces, such as Lang Son and Lao Cai. They typically function as intermediaries between the traditional collectors operating within production areas and the Chinese importers and often own facilities with large cold chain storage warehouses. These companies, which distribute 17 percent of total dragon fruit produced in Binh Thuan, have started to pay attention to food safety and product traceability, an issue raised by the market in China (IPSARD 2020).

- Domestically oriented distribution channels

  Domestically oriented distribution channels handle 14.5 percent of the total dragon fruit produced in Binh Thuan province (IPSARD 2020), distributing to several regions within Vietnam, including northern provinces, HCMC, and surrounding provinces, as well as to provinces in the central coastal areas. Dragon fruit trading activities are carried out by companies, traditional traders, and wholesale markets: in Hanoi, dragon fruit is distributed in wholesale markets such as the Long Bien and South Hanoi wholesale markets, while in HCMC, this is done through wholesale markets that specialize in distributing fruits and vegetables. Binh Thuan dragon fruit can also be found in several supermarket systems (IPSARD 2020).

APPENDIX B: CURRENT TRACEABILITY SYSTEMS EMPLOYED BY STAKEHOLDERS OF DRAGON FRUIT AND LEAFY GREEN SUPPLY CHAINS

Table 41: Current traceability systems employed by stakeholders of dragon fruit and leafy greens supply chains

No	Vendor's information	Target market	Description	Difficulty
1	Company 1 **Sector:** Fruits **Roles:** • Producer • Collector • Exporter	Export: Europe: 30% China: 50% Thailand: 20%	**1. Traceable data:** **Internal traceable data:** The company records information in each step from production, collection, and export to enable internal traceability if needed **External traceable data** • Farm code • Lot identification • Packinghouse code **2. Current traceability system** Currently, the company has not applied a digital traceability system. Farmers use farm books to manually record information about production procedures. The data are updated to an Excel file to make it easier to monitor. The company's accountants also record product transaction information in the Excel file. The company will deploy a traceability system using a mobile app developed by Vietnam Posts and Telecommunications Group in the future.	• The company does not recognize any significant difficulty.
2	Company 2 **Sector:** Fruits and vegetables **Roles:** • Producer • Collector • Distributor • Exporter	• Domestic: Supermarket, e-commerce • Export	**1. Traceable data** **Internal traceable data:** The company records all information relating to production procedures, including: • Production date • Type of vegetable/fruit • Seed used • Fertilizers/protection chemicals and amount used • Area of cultivated land • Cultivating method • Water quality • Harvesting date • Harvesting personnel	• Farmers have difficulties with using mobile apps to record production information • Farmers' awareness of recording and managing production information is low • Lack of centralized database providing information related to land areas, geography, and weather

No	Vendor's information	Target market	Description	Difficulty
			• Information relating to transporting procedure: name of transporter, time, product volume and classification, which is synchronized with the factory's systems, applications, and products system **External traceable data** • PUCs • Lot identification • Packinghouse code **2. Current traceability system** **Front-end** • The company uses an E-farmer application to manage PUCs and record farm diaries • PUCs are automatically generated on the system and used throughout the life cycle from growing to collecting • E-farmer helps farmers manage PUC information from production, harvest, and collection according to the terms of the consumption contract **Middleware** • E-farmer is connected to the ERP system of factories and other devices to monitor product storage • The company uses its own cloud-based system **Data and protocol layer** • The company has its own database using blockchain technology **Infrastructure** • Laptops/computers • Mobile devices • IoT sensors and locators on the farm are used to monitor, send a warning to farmers if there are problems, and show suitable cultivating methods for farmers • Smart cold storage automatically adjusts temperature, humidity, pressure for each product	

No	Vendor's information	Target market	Description	Difficulty
3	Company 3 **Sector:** Fruits and vegetables **Roles:** • Producer • Distributor	• Domestic: Supermarket, modern retail channel	**1. Traceable data** Company records information in each step from production, collection, distribution, and export **2. Traceability system** **Front-end** • The company used to pilot the Kipus tool developed by a German company (KIAG) to collect and upload data from production, harvest, and processing from the farm daily, weekly, and monthly • This tool helps farmers monitor the production unit for production procedure, weather, and temperature; forecast the production volume of each production unit (PU); and automatically calculate the price of products **Middleware and data protocol layer** are provided by the solution provider **Infrastructure** • Laptops/computers • Mobile devices • IoT sensors and locators	The company does not recognize any significant difficulty
4	Company 4 **Sector:** Fruits **Roles:** • Collector • Exporter	• Export: China (official quota, cross-border)	**1. Traceable data** • The company records external traceable data, including PUCs, farm identification, lot identification, and packaging date **2. Traceability system** Currently, the company has not applied a digital traceability system • Information is recorded into Excel files and handbooks • This information is recorded in a barcode printed on product packaging • Traceable data are recorded to meet the traceability requirement for targeted markets **Infrastructure** • Laptops/computers • Barcode printer supported by a third party	• Small-scale business • Lack of resources • Low demand from buyers for traceable products

No	Vendor's information	Target market	Description	Difficulty
5	Cooperative 1 **Sector:** Fruits **Roles:** • Producer	• Export: EU, US, Australia • Domestic: Supermarket, modern retail channel	**1. Traceable data** **Internal traceability:** • Information from production, harvest, and collection according to the guidance of GlobalGAP **External traceable data:** • PUCs: one code divided into 11 coordinates • Packing plant code **2. Traceability system** **Front-end** • Currently, the cooperative uses farm books to record information from production, harvest, and collection. The cooperative is piloting a traceability system using the mobile application VietGAP 4.0 to replace manual recording. • There is a farm manager for each farm to manage production procedures and the recording of information. At the end of each week, an accountant uploads information in farm books to an Excel file. If there are problems or violations, the accountant will notify the farm manager to fix them. **Middleware and data and protocol layer** are provided by the solution provider **Infrastructure** • Laptops/computers • Mobile devices	• Older farmers (over 60) have difficulty using mobile apps to record farm diaries

No	Vendor's information	Target market	Description	Difficulty
6	Cooperative 2 **Sector:** Fruits **Roles:** • Producer	• Export: China (cross-border) • Domestic: Traditional market	**1. Traceable data** • The cooperative records internal traceable data according to guidance from VietGAP **2. Traceability system** **Front-end** • The cooperative is piloting a traceability system using a mobile app. However, farmers have not yet used this application and are still using handbooks to record farm diaries according to guidance from VietGAP. **Middleware and data and protocol layer** are provided by the solution provider **Infrastructure** • Computers/laptops • Mobile devices	• Farmers are not familiar with using technology applications • Difficulty in finding stable output for products • Lack of detailed guidance from authorities
7	Cooperative 3 **Sector:** Vegetable **Roles:** • Producer	• Domestic: Supermarket, traditional market	This is a large cooperative with 1,100 households cultivating an area of 230 ha. Although farmers operate under a cooperative model, they produce independently from each other. The products' quality and cultivating methods have not been managed consistently. Products are sold through two channels: - Products from some households are collected, processed, and packaged by the cooperative. The cooperative then distributes these products to supermarkets. - Farmers directly sell their products to wholesale traders or to individual consumers at traditional markets. **1. Traceable data** • Farmers receive guidance on recording information about production, harvest, and packaging procedures using farm books. However, the recording of information is not well deployed. Many households do not record or inaccurately record information.	• Consumers and distributors have not expressed much interest in traceable products • Human resources lack qualifications • Lack of infrastructure • Lack of detailed guidance from authorities

No	Vendor's information	Target market	Description	Difficulty
			2. Traceability system **Front-end** • Manually recorded in farm books • Some farms used a pilot mobile application to record information. However, they cannot maintain the system till the end of the pilot period because of the small scale of production. • There is a manager for each area to monitor and guide farmers on recording information into farm books. However, monitoring has not been done regularly due to a lack of supervisory personnel. **Middleware and data and protocol layer** are not applicable **Infrastructure** • Laptops/computers • Mobile devices • Barcode printers - supported by a third party	
8	Cooperatives 5, 6, 7 **Sector:** Fruits and vegetables **Roles:** • Producer	• Domestic: Retail store	**1. Traceable data** • The cooperatives record information about production, harvest, and packaging procedures using farm books **2. Traceability system** • Currently, the company has not applied a digital traceability system • Information is manually recorded using farm books • Product information is recorded in a barcode, which includes the PUC, production date, harvest date, and product price • Farm books are used to monitor production procedures to ensure that product quality meets requirements for maximum chemical residue levels **Infrastructure** • Barcode printers - supported by a third party	• Farmers are not familiar with using technology applications • Consumers and distributors have not expressed much interest in traceable products

No	Vendor's information	Target market	Description	Difficulty
9	Small-scale farmers: five households **Sector:** Fruits and vegetables **Roles:** • Producer	Domestic: Traditional market	**1. Traceable data** • These farms do not record traceable data. Products are sold to wholesale traders to distribute at traditional markets, which do not have traceability requirements. **2**. **Traceability system** - Not applicable	

APPENDIX C: TYPES OF TRACEABILITY IDENTIFICATION KEYS

Table 42: Identification keys

Key	Full name	Type of object identified
GTIN	Global Trade Item Number	Types of products at any packaging level, for example, consumer unit, inner pack, case, pallet.
SSCC	Serial Shipping Container Code	Logistic units, combination of trade items packaged together for storage and/or transport purposes: for example, a case, pallet, or parcel.
GSIN	Global Shipment Identification Number	Grouping of logistic units that need to be delivered together; typically used by shippers to instruct transport providers or freight forwarders.
GIAI	Global Individual Asset Identifier	Assets such as vehicles, transport equipment, warehouse equipment, spare parts.
GRAI	Global Returnable Asset Identifier	Returnable transport items such as pallets, crates, beer kegs, roll cages.

Table 43: Identification levels of trade products

Identification level	Identification key	Description	Example
Grower-specific trade item	GTIN	The GTIN is a globally unique number based on the GCP assigned by GS1 and the item reference. This level of identification provides the ability to identify different products and their source. This is typically the least expensive because marking can be incorporated into package artwork that is printed in bulk for a single producer/processor/distributor.	All products of a given type from a brand/producer are marked identically (for example 10 kg bag of dragon fruit). It is possible for an information system to tell one product from another (for example, a 10 kg bag of Queen Dragon Fruits from a 10 kg bag of Lavifood dragon fruits).
Batch or Lot	GTIN + batch or lot number	This level of identification provides the ability to distinguish products in one batch or lot from another. This is especially useful in business processes that deal with quality or food safety issues that occur on a batch-by-batch basis, such as a product recall of a contaminated batch or lot.	All products of a given type within a batch or lot are marked identically (for example, a case of red peppers). It is possible for an information system to tell one product from another (for example, a case of red peppers and green peppers) and to distinguish two products of the same type from different lots or batches (a case of red peppers from Lot #20100201 and a case of red peppers from Lot #20100204), but do not distinguish two products of the same type within the same batch or lot.

Identification level	Identification key	Description	Example
Instance (full serialization)	GTIN + serial number (a combination also known as SGTIN)	This level of identification provides the ability to distinguish each product individually. This is especially useful in business processes that require strict regulatory compliance, such as tobacco, alcohol, pharmaceuticals, and medical devices. There is no requirement for serialization of individual food items.	Each occurrence of a product is marked with a unique serial number. Thus, the combination of GTIN + serial number is a globally unique identifier for a single instance of a product, which is distinct from all other physical objects in the world.

Table 44: Identifications of traceable parties

Identification key	Full name	Description
GLN	Global Location Number	The GLN of a party (either sender or receiver of a shipment) is a serial number containing (a) the Company Prefix registered with the GS1 and (b) location reference number allocated by a company to a specific location. The GLN of a party can also identify the company's legal entity engaging in a particular transaction (such as selling or buying shipments of fruits or vegetables).
GSRN	Global Service Relation Number	The GSRN of a party is a serial number containing (a) the Company Prefix and (b) service reference number The GSRN can identify either a recipient or a provider of the organization's services, and both roles often need to be captured or recorded simultaneously.

Table 45: Identification of the traceable location

Key	Full name	Description
GLN	Global Location Number	The GLN is a serial number containing (a) the Company Prefix registered with the GS1 and (b) the location reference number allocated by a company to a specific location. The GLN can identify a company's physical location, for example, a store and a warehouse.
	Global Location Number + GLN extension component	Internal locations within a site

APPENDIX D: LEGAL SYSTEM HIERARCHY IN CHINA

Tier 1: Basic laws

Tier 1 includes the basic laws enacted by the National People's Congress, China's top legislative body (Jia and Jukes, 2013). The regulations on food traceability system in China are based on a combination of the (a) Food Safety Law (2015), (b) Agri-food Quality and Safety Law (2006), (c) Product Quality Law (1993, last amended 2009), (d) Agriculture Law (1993, last amended 2012), (e) Law of Standardization (1989), (f) Law on the Inspection of Import and Export Commodities (1989, last amended 2013), and (g) Consumer Rights Protection Law. Article 42 of China's 2015 amended Food Safety Law sets out the mandatory traceability requirements for producers and traders of all commodities.

Tier 2: Subordinates laws

Tier 2 of the legal framework consists of subordinate laws, including administrative regulations of the State Council, regulations issued by ministries and committees at the ministry level, and food standards. Until 2015, approximately 52 food traceability system regulations and laws have been established in China (Tang 2015). These regulations detail traceability technology, material support, pilot projects, and inspection requirements (Bai et al., 2013).

In April 2017, the China Food and Drug Administration published the Provisions for Establishment of Food Safety Traceability Systems by Food Production and Trading Companies (the Provisions) (PWC 2017). The provisions include requirements for traceable data to be recorded and traceability systems utilized by businesses involved in food production; trading of food and agricultural products and food service, as well as transportation, storage, and distribution of food (PWC 2017). However, this should be viewed as merely the minimum requirements for records, documentation, systems, and procedures related to traceability. Moreover, food businesses must also fulfill other separately issued requirements for specific products (for example, infant milk formula) and channels while working closely with provincial food and drug administration and local governments to fulfill additional local requirements (PWC 2017).

In addition to the overarching regulations for traceability for all kinds of products, the government of China adopts one of the strictest product-specific approaches for infant milk. In 2015, the China Food and Drug Administration issued the standards for infant milk formula powder production and the company's food safety traceability records. The latter details record keeping requirements, including product research and development and formulation; raw and supplementary material management, production, and processing; finished product management; sales management; risk information collection; and product recalls (PWC 2017).

Tier 3: Local laws and regulations

Tier 3 includes the local law and regulations. These laws and regulations are tailored to specific local needs. Currently, China has 118 local regulations for enhanced government inspections and financial investment in food traceability systems (Bai 2013).

APPENDIX E: DETAILED ANALYSIS OF FOOD SAFETY RISKS IN SELECTED F&V SUPPLY CHAINS IN VIETNAM

We chose leafy greens and dragon fruit supply chains as two focus commodities to be analyzed. The selection was made based on the criteria in table 46.

Table 46: Reasons for selecting the two commodities

Criteria	Dragon fruit	Leafy greens
Consumption	Dragon fruit is present in most domestic markets and is one of the top exported fruits. Dragon fruit is exported to about 40 countries and territories and is the most exported commodity in the F&V category. In the first seven months of 2020, the total export value of Vietnamese dragon fruit reached US$669,746,000. Regarding domestic consumption, dragon fruit accounts for 15–20% of the fruit consumed (GSO 2021).	Leafy greens are widely consumed in Vietnam: cabbage and morning glory respectively accounts for 14.4% and 13.5% of total vegetable consumption in Hanoi and 12.3% and 13% in HCMC. Morning glory ranks first and cabbage ranks second as the favorite vegetables in Hanoi HCMC (SCAP-IPSARD 2017).
Food safety risk	Dragon fruit is ranked as a commodity with high food safety risks and hazards by large export markets. • **Chemical hazards:** Vietnam's exported dragon fruit is frequently rejected because of contamination with excessive pesticide residue. For example, from 2015 to 2018, there were 17 warnings issued for excessive amounts of carbendazim, dithiocarbamates, carbofuran, permethrin, dimethoate, iprodione, and azoxystrobin.	Leafy greens are associated with recurring outbreaks with high numbers of illnesses in at least three world regions. • **Biological hazards:** These present the greatest concern in terms of microbiological hazards, including contamination with *Salmonella spp., Shigella spp., E. coli, Campylobacter, Enterobacter sakazakii, E. cloacae, Entamoeba coli, Cryptosporidium*, other parasites, for example, helminth eggs, *Ascaris lumbricoides*, and *Ancylostoma spp.*, norovirus. • **Chemical hazards:** The edible portions of leafy greens are in direct contact with soil, water, pesticides, fertilizers, and so on, which may contaminate the products.
Application of digital technology for traceability	In Vietnam, there are several use cases of digital technology applications in dragon fruit traceability.	In Vietnam, numerous traceability models for cabbage, lettuce, and so on, are implemented in different regions, creating the basis for the use of technologies in traceability systems.

1. Risks and hazards relating to production soil

a) Risk description

Soil can be both chemically contaminated (excessive residues of persistent active ingredients such as aldrin, chlordane, DDT, heavy metals) and biologically contaminated (excessive residues of harmful microorganisms and parasites such as *E. coli*, coliforms, *Salmonella*, worms, flukes, and pinworms). This risk is critical, especially for leafy greens, because of their direct contact with soil during production.

b) Causes and current situation

Soil may carry harmful contaminants from (a) polluted surrounding areas such as landfills, industrial activities, waste treatment plants, historic battlefields and (b) improper previous/ current farming practices such as inappropriate usage of approved pesticides and fertilizers, usage of banned pesticides, or disposal of manure packaging in contravention of standards.

At present, the soil contamination of leafy green production areas in Vietnam is a major concern. Several recent studies provide evidence that some production areas in Vietnam were chemically and biologically polluted.

- A 2018 study in Hoai Duc district of Hanoi indicates that the soil was contaminated with excessive amounts of arsenic and cadmium that were 1.11 to 1.49 and 1.07 to 1.13 times higher than the allowable limits, respectively (Ha Nguyen 2018).
- In Bac Ninh province, of 35 soil samples, two were polluted with lead (Pb), cadmium (Cd), copper (Cu); two samples contained excessive amounts of Cu (with 71.78 mg/kg and 71.12 mg/kg); and the remaining were close to the allowable limits (Pham 2020).
- A 2019 investigation by the DARD of Quang Nam discovered several production soil samples in Quang Nam province containing excessive amounts of coliforms (DARD 2019).
- A 2019 investigation by the HCMC Plant Protection Department found that 70 percent of morning glory samples collected from production areas in HCMC contained excessive amounts of *E. coli* bacteria (HCMC Plant Protection Department 2019a).

International attention to F&V agricultural soil quality has grown in recent years. GlobalGAP (previously named EuropeGAP) and VietGAP view soil as a significant source of contamination and make recommendations regarding soil assessment, use, and management activities. Additionally, the Vietnamese government expressed grave concerns about heavy metal residue in production soil, promulgating national regulations QCVN 03:2008/BTNMT, QCVN 01-132:2013/BNNPTNT, and QCVN 03-MT:2015/BTNMT to establish allowable limits for heavy metals in agricultural soil.

2. Risks and hazards relating to water for irrigation and processing

a) Risk description

Chemically contaminated water (excessive residues of persistent active ingredients, heavy metals, and other chemicals such as chlorine, trisodium phosphate, and organic acids) and biologically contaminated water (excessive residues of harmful microorganisms and parasites such as *E. coli*, coliforms, *Salmonella*, worms, flukes, and pinworms.) have been observed. During agricultural irrigation and product processing, products with large surface areas (for example, leafy greens) may be more susceptible to chemical or biological cross-contamination from the water. With regard to dragon fruit, the fruit peels exhibit antimicrobial activity against a variety of microorganisms, lowering the risk of contamination through contact with water (Mavani et al. 2020).

b) Causes and current situation

When primary producers use chemically or biologically contaminated water for irrigation and processing of fruits and vegetables, food safety risks increase. Irrigation water may become contaminated because of (a) polluted rivers, streams, and drilled wells or (b) improper prior/current treatment practices, such as excessive chemical use in water treatment.

Irrigation and processing are frequently carried out using groundwater, surface water, and, in some cases, human wastewater. Significant concern has been expressed regarding the contamination of the water used in F&V irrigation and processing:

- Due to water scarcity, the Vietnam Ministry of Natural Resources and Environment permits producers to reuse treated wastewater for irrigation if they adhere to national technical regulations on domestic wastewater (QCVN 14:2008/BTNMT) and irrigation water quality (QCVN 08-MT:2015/BTNMT). However, there are instances when producers have violated the requirements. Inspections conducted by the Hanoi Department of Natural Resources in 2018 revealed that certain production areas in Hanoi were using polluted wastewater to grow vegetables without adhering to the required dilution rate (Dung Nguyen 2018). Additionally, significant migration of microorganisms from wastewater to vegetables has been demonstrated. According to a 2012 study conducted in Dak Lak province, the following parasitic pathogen contamination rates were observed in 660 samples of vegetables irrigated with wastewater in urban and rural areas: 6.1 percent and 10.6 percent for general prevalence of helminths (including roundworm, whipworm, and hookworm pathogen) respectively and 27.9 percent and 44.2 percent for general prevalence of protozoans), respectively (including pathogens of the amoebic cysts *Entamoeba histolytica*, *Cryptosporidium, Cyclospora,* and *Giardia*) (Nguyen 2012).
- Improper control of processing water may result in elevated concentrations of antimicrobial chemicals (such as chlorine) and may pose a risk to consumers. In 2011, chlorine found in cabbage hospitalized over 250 employees from Vietnam Hong Fu Ltd. For several days, 33 of them suffered from severe illness (Lan Anh - Duy Tuyen 2011).

International and domestic attention is paid to the quality of water used for F&V irrigation and processing. Risk assessment of the quality of water used in pre-harvest, harvest, and post-harvest activities is highly recommended under international standards (for example, GlobalGAP) and domestic standards (for example, VietGAP). For instance, GlobalGAPs control points AF. 1.2, FV1, and FV4 require producers to conduct risk assessments to ensure compliance with food safety standards at the production site (GlobalGap 2019). Additionally, the Vietnamese national technical regulation (QCVN 08-MT:2015/BTNMT) governing surface water quality specifies the maximum contamination residue in terms of heavy metals including arsenic (As), cadmium (Cd), lead (Pb), chromium (Cr), copper (Cu), zinc (Zn), nickel (Ni), manganese (Mn), mercury (Hg), iron (Fe) as well as chemicals including chloride (Cl-), fluoride (F-), nitrite (NO_2-), nitrate (NO_{3-}), phosphate, cyanide, and so on and pathogens including coliform (*E. coli*).

3. Risks and hazards relating to pesticide use

a) Risk description

Excessive residual amounts of pesticides (for example, insecticides, fungicides, herbicides, and rodenticides) in a product would significantly harm human health. In addition, excessive or inappropriate implication can also contaminate underground water which might indirectly harm people in surrounding areas. Dragon fruit and leafy green production involves significant pesticide usage.

- Dragon fruit is vulnerable to pests (for example, ants, beetles, fruit flies, and snails) and diseases primarily caused by fungi bacteria (*Aspergillus avenaceus, A. awamori, F. lateritium, Penicillium charlesii)* (Le 2013), frequently causing farmers to apply large amounts of pesticides during cultivation.
- The risk of chemical contamination from pesticides is particularly high for leafy greens (as opposed to dragon fruit) because pesticides come in direct contact with the edible portion's surface area (Farha et al. 2018).

b) Causes and current situation

Food safety risks increase when primary producers misuse pesticides in cultivating fruits and vegetables:

- **Using unapproved pesticides increases the risk of acquiring adulterated, counterfeit, substandard, or expired products that might contain banned or unapproved ingredients:** Some primary producers have purchased counterfeit or low-quality pesticides with unknown origins and pesticide products containing banned agrochemicals, resulting in severe crop damage. According to the MARD inspection department, in 2020, several plant protection products are smuggled into Vietnam each year, including those of unknown origin or excluded from the permissible list, some of which contain extremely high levels of toxicity, such as pesticide 666, which is banned from circulation in Vietnam (Thao 2020).
- **Overusing pesticides (mixture of many types, higher doses compared to regulations/ instructions) and spraying near harvested product or packaging materials leave**

pesticide residues in the product containers: The improper usage of pesticides is also cited as one of the main causes of excessive chemical residue in leafy greens and dragon fruit. For example, in 2016, The Plant Production and Protection sub-department of Thai Nguyen province reported the inspection results conducted for 320 producers regarding their pesticide usage, which showed that there were 104 cases of violation, including incorrect use, such as improper dosage and timing of pesticide applications. Assessment results reported in 2019 by the Agricultural Food Safety Supervision Team of Loc Ha district, Ha Tinh province showed that 76 percent of samples (32 of 42), comprised mostly of cabbages, cauliflower, and dragon fruit collected from wet markets, contained excessive amounts of pesticide residue (Tan 2019).

- **Non-compliance with the PHI before harvesting:** Non-compliance with the standard PHI is also an issue. The standard PHI specifies that no pesticide and fertilizer applications are allowed for a certain number of days before the harvest date to minimize chemical residues. However, there were cases in which producers did not comply with the standard PHI (Tuoi tre e-news 2017).

In acknowledging the need to assess, manage, and control pesticide usage in agricultural activities, many countries, including Vietnam, have issued lists of permissible and banned agrochemicals. In Vietnam, the list is updated annually. The most recent version is Circular No. 19/2021/TT-BNNPTNT dated December 28, 2021, issued by MARD, providing a complete list of permissible and banned agrochemicals in Vietnam.

4. Risks and hazards relating to chemical use

a) Risk description

Excessive residual amounts of chemicals in a product (used for a variety of purposes such as crop growth enhancement; processing of post-harvest products; equipment cleaning; or chemicals used to operate machines such as lubricants, grease, oils, fuels) would have a significant adverse effect on human health.

b) Causes and current situation

Food safety risks increase when stakeholders misuse chemicals in F&V production:

- **Utilization of unapproved chemicals, counterfeit, substandard, or expired products that may contain prohibited ingredients:** Leafy greens have been found to contain several chemicals that may be harmful to human health and safety. For instance, morning glory is a hydroponic plant capable of absorbing nutrients, toxic metals, and emerging contaminants found in water. In 2015, HCMC DARD reported several instances of producers using automotive waste oil (an agriculturally prohibited chemical) to control brown plant hopper in morning glory production (VTV24 channel 2015). Additionally, according to a 2019 assessment conducted by the HCMC Division of Plant Production and Protection, 30 percent of producers use automotive waste oil in the production of morning glory.
- **Chemical overuse; improper use of chemical preservatives:** In several instances, leafy green vegetables were found to contain an excessive amount of chlorine, a chemical used for washing and processing, as with Vietnam Hong Fu Ltd., when cabbage was

contaminated with chlorine, forcing over 250 workers of the company to spend several days in the hospital, with 33 of them suffering from severe illnesses (Lan Anh - Duy Tuyen 2011). To meet importers requirements for dragon fruit size and appearance, several producers were found to use excessive amounts of growth-stimulating and beautifying chemicals, despite their potential health risks (Vietnam News Agency 2016).

5. Risks and hazards relating to biological fertilizer use

a) Risk description

Excessive amounts of biological residues from fertilizers found in products that would significantly harm human health.

b) Causes and current situation

Excessive fertilizer application in violation of regulations/instructions and non-compliance with PHI regulations prior to harvesting increases food safety risks: For instance, there have been reports of unprocessed manure being used. Fertilizing with undecomposed livestock and poultry manure in the dragon fruit production area in Tien Giang province has resulted in a significant risk of disease spread (Radio The Voice of Vietnam - VOV 2018). Another study conducted for Phuoc Hau, Vinh Long, and Can Tho to assess the risk of biological contamination (with coliforms, *Salmonella*, *Shigella*) associated with the use of organic fertilizers in leafy green cultivation revealed that fecal samples were contaminated with microorganisms at moderate to high levels. Coliforms and *E. coli* had densities ranging from 3.84 to 5.26 log (mpn/g), while *Salmonella* had a density of 3.08 log (cfu/g), indicating that improperly processed or unprocessed organic fertilizers are likely to contain intestinal bacteria (Nguyen 2013).

Due to the necessity of evaluating, managing, and controlling fertilizers during the production process, several markets (including Vietnam) have issued lists of permitted fertilizers that may be produced, traded, and used to ensure food safety. In Vietnam, MARD issued Decision No. 40/2004/QD-BNN, which regulates the list of fertilizers allowed to be produced, traded, and used. Four years later, MARD issued Decision No. 59/2008/QD-BNN to update the list to include 256 additional permitted fertilizers.

6. Risks and hazards relating to seeds quality

a) Risk description

Usage of chemical or biological contaminated seeds, seedlings, and rootstocks might cross-contaminate the products.

b) Causes and current situation

According to NAFIQAD (2013), there are two major risks associated with seed contamination: (a) buying and using seeds from uncertified sellers resulting in contaminated seed in cultivation and (b) performing unsafe chemical treatments, such as overdosing or using toxic chemicals not on the permitted list for plant seeds, seedlings, cutting, and rootstocks.

Many vegetable seeds used in Vietnam are of unknown origin, increasing the risk of contamination. Farmers can easily obtain seeds of unknown origin from seed retailers and traditional markets. According to a 2008 inspection report by MARD and provincial authorities, only 18 percent of vegetable seeds passed the seed test, which focused on labeling requirements, quality, and compliance with trading requirements (Phuc 2017).

7. Risks and hazards relating to worker/equipment/facility hygiene

a) Risk description

Cross-contamination of products can occur because of interactions with workers, farming equipment, and tools and equipment in processing facilities. The risk is increased when the product sustains unintentional damage during pre- and post-harvest, such as small cuts, holes, or other minor damage.

b) Causes and current situation

When unhygienic workers and unsanitary equipment or tools come in direct contact with fresh produce, food safety risks increase. Chemically contaminated equipment, tools, and machinery, as well as unsafe chemical residue (for example, from previous use, cleaning using detergent, oil, and grease leakage from equipment) on the surface of these items may have the potential to cross-contaminate the product through direct contact. Additionally, non-compliance with worker/equipment and facility pest control hygiene standards increases the risk of contamination significantly.

In terms of biological hazards, microorganisms, including human pathogens, more readily adhere to cut surfaces (on products) than uncut surfaces. Hence, it is recommended to respond appropriately to help reduce, control, or eliminate the risk of pathogen introduction via contact at the cut surface post-harvest (for example, frequent knife sanitation, avoiding placement of cut surfaces of harvested product on the soil, container sanitation, single-use container lining).

8. Risks and hazards relating to temperature control

The longer perishable food is exposed to extreme temperatures or is left in direct sunlight during transportation and storage, the faster bacteria grow, spoilage increases, and shelf life is reduced. As a result, it is critical to implement stringent time-temperature controls.

Previous studies have established that there are several common risks/hazards associated with the preservation temperature of dragon fruit and leafy greens, including the following:

- The main post-harvest risks for dragon fruits are mechanical injury, chilling injury, decay, and water loss, in which post-harvested dragon fruit is more susceptible to chilling injury (Jadhav 2018). Dragon fruit stored below 5°C can develop chilling injury (Razali 2017), and at 7°C, dragon fruit can become infected with fungi.
- For leafy greens, at 12°C, the proliferation of *E. coli* O157:H7 can be observed (Luo et al. 2010). In addition, *Listeria monocytogenes* could grow on contaminated iceberg lettuce in

favorable conditions and time. In particular, *L. monocytogenes* could grow on packaged shredded iceberg lettuce held at 13°C or 5°C (maximum growth rate of 0.019 and 0.013 log cfu/h, respectively), with increments of 4.85 and 2.66 log cfu/g, respectively, after 14 days (Koseki 2014). Thus, it is critical to maintain proper storage temperature to prevent bacteria spoilage and mitigate food safety risks if the post-harvest product has already been contaminated.

Farmers in informal markets demonstrate a lack of awareness of the critical nature of post-harvest preservation. Concerning leafy greens, the current study's interviewees in informal markets revealed that farmers did not properly preserve their post-harvest produce. Meanwhile, the most frequently encountered pathogens associated with post-harvest produce are *Alternaria spp., Bipolaris cactivora, Colletotrichum gloeosporioides, Curvularia lunata, Fusarium oxysporum, Fusarium sp., Phomopsis sp., and Rhizopus sp*. (Nguyen Khanh Ngoc 2017).

APPENDIX F: MAPPING IDENTIFIED CHALLENGES IN VIETNAM AND LESSONS LEARNED FROM INTERNATIONAL EXPERIENCES WITH PROPOSED INTERVENTION AREAS FOR THE GOVERNMENT OF VIETNAM

Based on the present study's results, potential intervention areas are presented in table 47.

Table 47: Major findings of international experiences and key intervention areas for Vietnam

No.	Challenges in implementing food traceability in F&V supply chains in Vietnam	International experiences	Proposed intervention areas
I.	**Challenges from Vietnam legal and institutional framework**		
1.	Lack of guidance/ standards for specific groups of F&V products	The EU, Italy, Korea, and China have requirements for high-risk, high-value, or signature F&V products. • **EU** has specific requirements on traceability of high-risk products: sprouts and seeds intended to produce sprouts. • **Italy** follows EU requirements regarding the traceability of sprouts and seeds intended to produce sprouts and focuses on the traceability of its signature and high-value products: olive oil and wine. • **Korea** has specific requirements on traceability for products relating to the government: agri-products purchased or imported or processed by/on behalf of the government. • **China** has specific national standards on traceability for its signature product: tea. The government of China also promotes traceability standards for cold chain activities and e-commerce transactions.	• Develop specific traceability guidance (voluntary technical standards) targeting signature products, including those that are provincial specialties (including products under the OCOP program) and those awarded geographic indications by the government of Vietnam or other countries. • Develop specific guidance for activities that are heavily featured in F&V supply chains and that have the potential to apply digital technologies.

No.	Challenges in implementing food traceability in F&V supply chains in Vietnam	International experiences	Proposed intervention areas
2.	Lack of resources for inspection/check on the compliance with traceability regulations	• **Italy** performs thousands of checks on the compliance of food operators with traceability every year. Inspectors are well trained on traceability requirements. • **China:** After the recent issuance of national technical standards on traceability, China has planned to conduct training for its inspection workforce.	• The government should strengthen, mainstream, and conduct training on traceability requirements and food safety regulations for the inspection workforce.
II.	**Challenges from availability of digital solutions/platforms**		
1.	Public traceability system: (a) national traceability system is planned but not implemented and (b) provincial systems with limited number of users, only record simple information about products and places of production, and do not follow the established TCVN on traceability.	National traceability systems help reduce product recall costs and enhance information transparency, focusing on high-risk, high-value, or signature F&V products. • **EU:** (a) the system for animal products and (b) the system for sharing food safety information among EU members. • **Italy:** systems for (a) olive oil and (b) wine • **China:** (a) a national system for agricultural products and (b) provincial systems for meat and vegetable products. • **Korea:** systems for (a) banning sales of non-compliant products and (b) agricultural products.	A national traceability system is needed. However, the following notes should be considered by the Vietnamese government: • The implementation of a national traceability system depends on the current resource and technical capacity of Vietnam. For example, the system implemented in China offers users mobile applications and web dashboards to enter data into the system, which most supply chain stakeholders can easily obtain. In Vietnam, cooperatives, large-scale companies, formal distribution channels, and so on, can adopt such technologies, but small-scale farmers may require training and technical support. • A national system requires that the Vietnamese government builds competent and trained teams with clear institutional arrangements to manage and regularly perform inspections on traceability data provided by stakeholders. • Raising awareness of related government agencies and supply chain stakeholders regarding the national traceability system is essential to increase the adoption rate.

No.	Challenges in implementing food traceability in F&V supply chains in Vietnam	International experiences	Proposed intervention areas
			• It would take time to fully implement a traceability system at the national level. In the short term, pilot traceability systems should be implemented at the provincial level targeting F&V supply chains that suit some of the following criteria: o high risk o high value o high level of development in existing supply chain. It is highly recommended that any regional or national traceability system be based on interoperable industry standards that facilitate compliance with regulations and data exchange between different systems. Ultimately, a national system must connect to multiple regional traceability systems. For example, a shopper in Hanoi can use a single-user interface (such as a mobile phone application or web interface) linked to the national system to scan and query a product grown in the Mekong and seamlessly access traceability data from local or regional systems.
2.	Private traceability systems are mainly applied by exporters and large-scale domestic companies. Their systems are not compatible for data sharing and exchange.	n.a.	• Raise awareness of supply chain stakeholders (especially those operating in the informal sector) regarding traceability by conducting national/regional capacity-building events or coordinating with existing food safety programs to include traceability awareness training. • The government should set guidelines and recommendations for technical interoperability that facilitate compliance with regulations and data exchange between public and private traceability systems.

No.	Challenges in implementing food traceability in F&V supply chains in Vietnam	International experiences	Proposed intervention areas
III.	**Challenges from organizational capacity of F&V supply chain stakeholders**		
1.	Lack of financial and technical capacities to implement digital traceability	**Regarding financial capacities:** Users lacking financial capacities may join the national traceability systems invested and implemented by the government that meet minimum requirements to perform traceability. In China, the fees are offered at low rates. **Regarding technical capacities** • These markets establish guidance on the application of traceability systems and digital traceability systems from which users can learn. • In China, QR codes are widely promoted and used by major retailers and in street markets due to low implementation costs and ease of application.	Vietnam's F&V sector still depends largely on small-scale production areas and informal distribution channels, which lack technical knowledge and need training to implement digital traceability systems. **Capacity building for informal stakeholders is essential.** • Capacity-building activities may include holding national or regional events and training courses for F&V supply chain stakeholders to enhance general technical knowledge, promote the application of digital technologies in traceability, and promote the application of national standards or guidance on applying some digital technologies. • In addition, competent authorities may coordinate with specialized associations, such as Vietnam Digital Agriculture Association, to hold and promote capacity-building events to improve the technical knowledge of food operators, especially those in informal markets and disseminate knowledge regarding international standards and export markets' requirements. For stakeholders with limited financial and technical capacities • Promote the use of a national traceability system that interoperates with local and regional systems in the public and private sectors. • Promote the adoption of basic traceability systems (involvement of common technologies with low implementation costs such as barcodes, QR codes, and mobile applications). • Assist small producers in joining cooperatives or producer groups or linking with ABs to register for QR codes and apply traceability for their farm produce or products.

No.	Challenges in implementing food traceability in F&V supply chains in Vietnam	International experiences	Proposed intervention areas
IV.	**Challenges regarding consumer awareness**		
1.	Low public awareness	In Korea, the annual Food Safety Day has been held by MFDS for the past 20 years to raise public awareness of food safety and promote food safety for food-related workers.	Disseminate knowledge and enhance consumers' awareness of food traceability via national or regional food safety events. Promote the benefits of food traceability to the public.