

# A Pragmatic Approach to Traceability in Food Supply Chains

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**Abstract**— Traceability systems have become vital within business organizations in enhancing the reliability of products while facilitating the management of the supply chains and production processes efficiently. Despite the potential of traceability systems to reap multifaceted benefits, most industries do not still feel traceability systems as a catalyst for financial gains, thus limit its use for facilitating compliance with mere legal requirements. Moreover, the practical deployment of traceability systems in complex supply chains and production processes remain a challenge due to several issues such as lack of cost effectiveness, incompatible production system, and inadequate technological knowledge of the staff. In this paper, we introduce a traceability system, by integrating internal and chain traceability features together with backward and forward traceability functionalities, which deliver higher cost effectiveness, accuracy, user friendliness and security. The system specially targets food supply chains in Japan with special focus to Small and Medium Size Enterprises.

**Keywords**— Traceability System, Traceable Unit, Food Supply Chain Management, Farm-to-Fork Traceability

## I. INTRODUCTION

In the light of intensified competition and due to adoption of sophisticated technologies, the business operations have become more complex than ever. This trend has lead business operations to be spanned across different companies, both locally and internationally, involving numerous stakeholders who are beyond the direct control of each other. This complexity, not only has increased tensions among consumers and public authorities regarding the reliability of the products and created a range of health and safety issues, but also has created a challenge for business managers in managing complex supply chains. In such a context, traceability is becoming popular as a tool for winning consumer trust and managing complex supply chains while complying with ever increasing legal standards notwithstanding the nature of the industry.

### A. Food Supply Chain Traceability

As a unique solution for diverse crisis associated with food safety, traceability has become a buzz word and remains vitally important in food industry supply chains compared to other supply chains. Food chain Traceability refers to ‘the ability to trace and follow a food component

intended to be, or expected to be incorporated into a food product through all stages of supply chain’ [1].

Food products are extremely time critical. Compared with other supply chains, the time taken from manufacture of raw materials to consumption of the final product remains relatively shorter in food supply chains. Thus, the time available for the manufacturer or seller for an effective product recall or necessary corrective actions remains critically low. Moreover, food is widely consumed commodity on which consumers are not supposed to spend a longer search time though they are highly concerned about the quality, health and safety issues. Thus, the maintenance of consumer trust is fundamental for the success of any food supply chain.

Particularly, the food industry in Japan is characterized with strict and well established legal requirements to which the consumers are highly sensitive and responsive; while at the same time, over 60 percent of the of the food consumed in Japan are imported from overseas [2]. Consumers are becoming more interested in the information about specific aspects of the product, production process and the raw materials used in the production in order to form a comprehensive understanding about the quality and reliability of the product [3]. Thus, the necessity of sound traceability system in food supply chains in Japan remains relatively higher.

The cost of a mismanaged food crisis, nowadays, remains extremely high in the light of tightened legal standards and increased consumer awareness, and can create catastrophic consequences on the business operations. Recent incidents such as Bovine Spongiform Encephalopathy (BSE) crisis since 1996, the Belgian chicken dioxin crisis in 1999 or the foot-and-mouth disease in early 2001 provide practical examples for the severity of consequences associated with food crises.

These critical concerns associated with food industry have attracted much attention of regulatory authorities and have forced them to make traceability in food chains mandatory [3-4]. For instance, food traceability has become mandatory in EU since 2005, whereas similar actions have been taken in Japan too [5]. The Law for Special Measures Concerning the Management and Relay of Information for Individual Identification of Cattle has been enacted by the Ministry of Agriculture Forestry and Fisheries of Japan in 2004; while the Study Group on the Improvement of Product Traceability of Ministry of Economy, Trade and Industry of Japan has published its interim report in 2003 with detailed information

about product traceability. Further, ISO 9001 quality standard requires the product to be able to trace back through all stages of production in an accurate and timely manner.

Advantages of traceability to stakeholders are multifaceted and expand well beyond mere fulfilment of legal requirements towards effective management of supply chains and building consumer trust and brand equity. GS1 Global Traceability Standard recognizes wide range of benefits of traceability [6]. These benefits include compliance with regulations, reduction of business risk, product recall and withdrawal, attainment of quality standards, management of logistics, provision of information for consumers and product authentication/ increased brand equity etc.

### **B. Problem Statement**

Despite multifaceted potential benefits, the operational conditions of current traceability systems are kept at bare minimum merely to fulfil legal requirements.

Business managers have been failed to identify traceability as a value adding, integrated element in businesses value chain.

Necessity of costly investment, reluctance to change, lack of skilled staff to handle advanced systems and limitations of existing traceability systems etc. act as major barriers for successful implementation of traceability systems.

Particularly Small and Medium Enterprises (SMEs) are either do not use a traceability system or use paper-based record systems due to limited scale of their operations, necessity of heavy investment and nature of their manufacturing processes.

In view of the above facts, it remains important to investigate 'How a traceability system can be effectively designed and deployed in a cost and user friendly manner facilitating integration of information across entire supply chain in a secured context ensuring consumer trust and compliance with legal and quality standards'.

### **C. Objectives of the Research**

The study aims to (a) explore the factors impeding the practical deployment of traceability systems in food supply chains, with special focus to Japan; (b) develop a traceability system prototype that can coexists with conventional paper based recording systems and evolve gradually towards a fully automated system in an industry friendly manner; (c) propose a framework and traceability best practices to assist deployment of traceability and facilitate Business Processes Reengineering (BPR).

The discussion of this paper is arranged into five sections. Section two provides an illustrative review of related work with special focus on food traceability. Section three discusses the characteristics and deployment conditions of the proposed system whereas section four extends the discussion of the proposed system with a discussion on recommendations. Finally, section five concludes.

## **II. RELATED WORK**

### **A. Current Context of Food Traceability**

Potential of traceability systems to deliver numerous advantages have been well documented in the literature [3-4]. Nevertheless, the operational conditions of current traceability systems are kept at bare minimum merely to fulfil legal requirements due mainly to misconceptions regarding how to use traceability systems as a value adding, integrated element in businesses [3, 7-8]. Necessity of costly investment, limitations of existing traceability systems, lack of skilled staff to handle advanced systems and reluctance to change etc. can be identified as other factors that hinder the deployment of traceability. Hence, most of companies, particularly Small and Medium Enterprises (SMEs), are using paper-based record systems [9] while many others do not use one [10].

Particularly in the case of SMEs, the need of traceability is pretty much an afterthought in the business strategy. This is mainly because SMEs do not find traceability systems as an attractive fit to its investment plan due to many reasons: (a) SME's operating scale is not large enough to realize the benefits of traceability; (b) traceability systems require costly initial investment; (c) traceability systems cannot easily be accommodated in traditional manufacturing processes.

Hence, majority of companies tend to deploy traceability systems merely to comply with legal requirements, facilitate product recall [4] and guaranteeing system certification [11]. However, traceability systems that are narrowly focused on such aspects do not facilitate the realization of full scale benefits. Design and deployment of an advanced traceability system capable of delivering full range of benefits is complex, costly and require additional efforts [12].

### **B. Technical Aspects of Traceability**

In principle, traceability encompasses both internal and chain traceability [10]. Chain traceability is the ability to trace a product through its entire supply chain from origin to the consumption. On the other hand, internal traceability refers to the ability to trace a product or component along various production processes within a particular business enterprise.

Further, the system should allow both backward and forward traceability which are sometimes recognized as 'trace-back' and 'track-forward' respectively. Forward traceability refers to the ability to follow the downstream path of a product along the supply chain while backward traceability refers to the ability to determine the origin and characteristics of a particular product through following the upstream path [11-12]. Importantly, realization of one aspect does not always guarantee the achievement of the other aspect and hence require focused attention on both aspects.

Combining internal and external traceability together with backward and forward traceability features, the traceability system should facilitate efficient recall of a food from the market where a risk to the consumer health is apparent and should enable the identification of the source of the problem so that it can be rectified promptly.

Alphanumeric codes, bar-codes and RFID tags are commonly used in present traceability systems to facilitate data

capture [13]. Each technique has its own advantages and disadvantages. Thus, the selection of a particular technology depends on the nature of the product and stage of production etc. More importantly, effective and secure communication methodologies must be adopted in order to ensure accurate and secure exchange of the information recorded on various types of codes or IDs along various stages in the production process and among various stakeholders in the supply chain.

Finally, traceability systems must be robust, secure and flexible in application. Moreover, user friendliness and access time can also be identified as additional traceability requirements in determining the usability of a traceability system [9]. Nevertheless, despite numerous merits of sophisticated traceability systems, generally traceability systems are associated with varying levels of limitations and deployment issues. Thus, the nature of the system to be deployed and its success depends on the nature of the business model [10] and the degree of commitment of its stakeholders.

### **C. Issues Associated with Deployment**

Despite the numerous efforts made to design and deploy effective traceability systems, current deployment results reveal some critical limitations of existing traceability systems [11]. One of the critical issues associated with deploying fully functional traceability systems is the lack of commitment from all supply chain members. In majority of cases, it is observable that only few of the supply chain members are deploying its proprietary traceability systems [11], which lack the compatibility with each other's system, and thus attaining chain wide traceability remains a challenge [13].

One of the key concerns in optimizing the benefits of a traceability system is the selection of a Traceable Resource Unit (TRU) which, to large extent, determines the precision and the amount of details processed in the system. TRU can be defined as the resource representation that must be traceable, thus a TRU is neither an abstracted nor aggregated entity [14]. Moreover, the desired degree of information and the size of TRU vary with the purpose of traceability [4] and the specific nature of the industry or supply chain. Item identification is the highest possible level of traceability in which the TRU is smallest [13]. However, it raises the design and management cost of traceability systems while hampering the access time as the amount of information to be processed becomes larger. Thus, in majority of cases batches or lots are taken as the TRU in which the size and scope is dependent upon the nature of the business operations and the degree of information required.

In principle, TRU size is negatively correlated with accuracy and associated management costs [13]. Thus, as the size of TRU decreases, the accuracy of the information and the management costs rise. More importantly, precise decisions have to be made how to deal with situations where several TRUs are combined to form a single unit or when a single TRU is split or disaggregated into several sub units during the production process [14]. Further, the identification

of TRU becomes even complicated in a continuous manufacturing process [4].

Moreover, majority of existing traceability systems are poorly aligned with current operational conditions of business operations. Thus, they lack adaptability and necessitate drastic changes in the business processes and/or require costly investment.

The above discussion reveals necessary technical characteristics of traceability systems, their inherent limitations and issues associated with the deployment. The following section describes how the proposed traceability system is capable of addressing these issues while maintaining required traceability features.

## **III. PROPOSED TRACEABILITY SYSTEM**

Drawing upon the experiences of current traceability practices, this study introduces Total Traceability System (TTS) which can be deployed in food supply chains with minor adjustments to their existing systems as it can accommodate existing paper based systems and evolve gradually towards a fully-automated system. This system is equipped with required features of traceability while facilitating the easy deployment and maintenance in an existing industrial setting.

Field trials with the system prototype resulted in favourable assessments on the security and robustness while guaranteeing the user friendliness and adaptability in production processes of SMEs. Necessity of costly investment and expertise human resources could be avoided as the system can accommodate, in the initial stage, with existing manufacturing and business processes even though their recording systems are paper based.

### **A. System Architecture of TTS**

The TTS interconnects supply chain members so that they can transmit and efficiently store relevant product information in a centralized database (see figure 1). Each stakeholder in the supply chain may have its own centralized traceability systems with suitable interfaces to its host in order to exchange relevant information. The system fosters a win-win situation for all stakeholders by creating positive gains through deployment. Following is an illustrative list of main design features of TTS.

- *Cost effective initial deployment:* At the initial phase of the deployment, TTS can fully accommodate the paper based or electronic document based record keeping systems in most of food supply chains. Hence, with slight modifications to an existing system, TTS can be introduced with a minimum capital expenditure at the same time keeping running costs low.
- *Easy integration to existing system:* The success of a traceability system is determined by its ability to be a part and parcel of the business value chain. The optimal design of TTS supports twofold integration: use of existing input modalities (hard prints, manual input tables) for traceability recording and more importantly, integrating traceability system modalities to the value chain (transformation from paper based to document based).
- *Interface for cascaded deployment:* While the TTS begins in its initial phase as an isolated sub process segment of a

large production change; as it evolves, the XML based metadata handling mechanism allows easy integration with different isolated segments to realize a total traceability.

- *User friendly and easy to learn:* By providing menu driven functionalities, interface support for most of scanning devices, and other features that are required for efficient data input, editing and viewing etc. the system is made more and more user friendly.
- *High security:* By using state of the art secure transmission and authentication technologies, TTS provides a highly secured traceability system with special tools to protect the company secrets. In TTS design, VPN connections, secure protocols and digital signatures are used for this purpose.

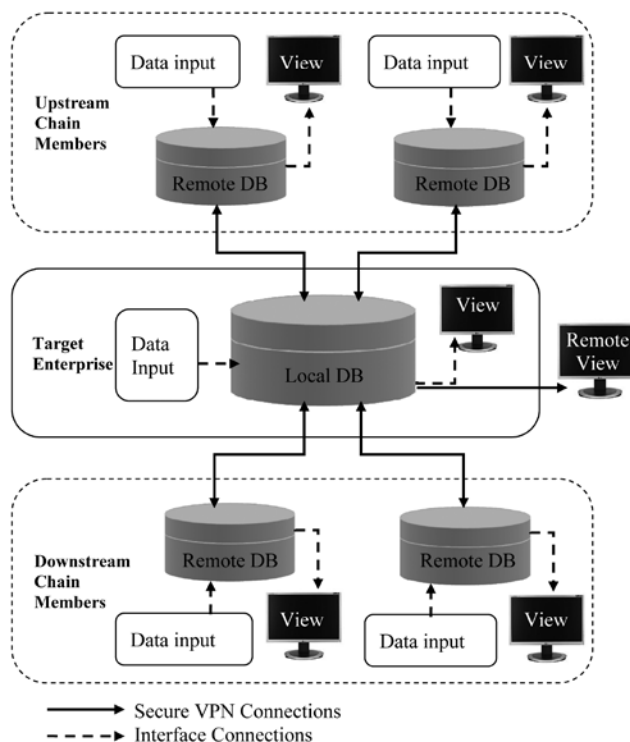


Figure 1: TTS architecture

## B. Target Business Model

In this research, the main focus was food supply chains in Japan with special focus on SMEs. The central management of these companies have to maintain a continuous look up the production process and the supply chain in order to maintain the quality, safety and reliability of the products. The schematic food supply chain, illustrated in figure 2, spans from variety of raw material suppliers to variety of distributors where the product is passed through an array of different processes causing intermediate products to stay in backlog from few days to several months. The complexity of the production/supply chain is further aggravated by involvement of many different companies in the process.

TTS has been designed in such a way that it adapts to the existing system and eventually guides SMEs to adopt and adapt their production systems to keep pace with sophisticated traceability systems which are equipped with advanced technologies for capturing, processing and exchanging of information.

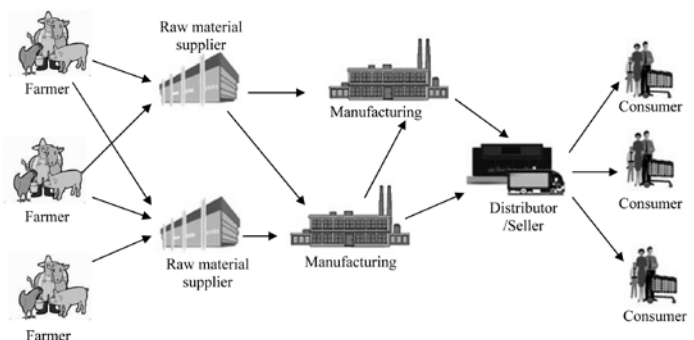


Figure 2: Simplified food supply chain

Farm-to-fork traceability is impractical at once due to lack of consistent standards in the traceability systems adopted by different members in the value chain and/or some members still have not deployed traceability in their production process. Hence, first stage deployment requires a segmentation of the complex supply chain into simpler segments so that deployment becomes feasible and so that all segments can be integrated eventually. The deployment process necessitates the establishment of a win-win situation for the stakeholders rather than creation of a diplomatic model where the enterprises forced to deploy traceability systems.

## C. Deployment

In order to reduce the risk exposure and to enhance the adaptability, the proposed TTS has been planned to be implemented in three phases. At phase 1, the TTS fully accommodates existing paper-based recording system with slight modifications to the operating procedures. At this stage, it introduces an efficient interface to store and retrieve the information (see figure 3). Here, scanned paper based records are stored in a central database allowing efficient and prompt retrieval according to a given query. The ability to accommodate existing paper based record systems help business partners, particularly SMEs, to avoid heavy investment at the initial stages and hence motivate them for adopting and deploying traceability in their production processes.

At phase 2, TTS introduces user friendly online interfaces to input the data directly instead of paper based recording system used in phase 1. At this stage, the business operations are gradually integrated with advanced techniques of traceability while allowing for more efficient operations. This phase facilitates the arrangement of business operations effectively through necessary BPR so that fully automatic traceability is feasible at phase 3. Thus, this stage serves as an intermediary stage in moving to stage 3.

At phase 3, TTS introduces advanced techniques such as bar-code systems, RFID systems etc. to capture data, while introducing standards and quality control methods with necessary BPR in order to enhance the compliance and integrity with other supply chain members. Successful completion of this stage guarantees the realization of a fully functional advanced traceability system that caters full range of benefits for all stakeholders in the supply chain.



Figure 2: System interface snapshots

#### IV. DISCUSSIONS AND RECOMMENDATIONS

The analysis of existing traceability systems and issues associated with their deployment reveal that majority of existing traceability systems lack the adaptability in food supply chains due to specific nature of the business operations, inflexibility and lack of ability to merge with existing record keeping systems. Thus, such systems necessitate drastic changes in the business operations which require greater effort, skilled human resources and costly investment. Further, inability of business managers to perceive traceability as an integrated value adding element in the business operations and lack of qualified human resources to handle sophisticated traceability systems also act

as barriers for traceability in food supply chains in which most of the stakeholders are SMEs.

In order to overcome inherent limitations of majority of existing traceability systems, proposed TTS is equipped with both internal and chain traceability together with backward and forward traceability functionalities. Integration with other stakeholders in the supply chain, with necessary interfaces and advanced communication technologies, ensures information exchange among each other in a secure and reliable context. Thus, it facilitates chain wide traceability through which effective product identification and recall can be made promptly. Further this network can be used as a medium for communicating and exchanging information relevant to market requirements and customer expectations so that higher level of consumer value can be delivered.

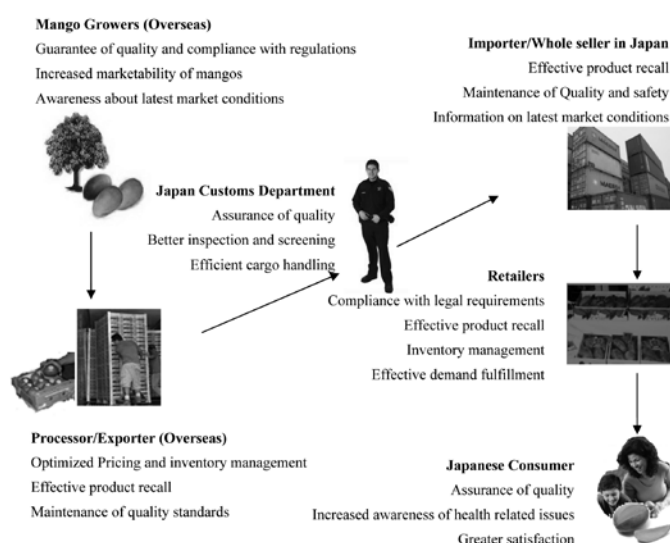


Figure 3: Simplified supply chain of imported mangos in Japan (information flow, stakeholders and, potential benefits)

Analysis of TTS features and initial deployment results indicate that TTS can deliver numerous benefits to stakeholders in the entire supply chain. Figure 4 provides an illustrative review of potential benefits assuming a fruit supply chain. First, it enables the fulfilment of market requirements through complying with regulations, building customer trust and brand image while enhancing the marketability of the products.

Second, it mitigates quality and safety issues associated with food crisis by providing a strategic response to the negative impact associated with increased consumer overall risk perceptions. Moreover, TTS helps minimize the potential delay, scope and volume of product recall. Further, prompt and accurate information provided by TTS enables the corrective actions to be taken promptly so that the risk exposure is minimized.

Third, successful implementation of TTS in a particular segment of the supply chain motivates other supply chain members to adopt and deploy traceability systems and adhere to certain quality standards through which a costly investment required for quality management can be avoided. Standardized

and reengineered business operations result in lower production costs and open up sources of direct financial gains.

Fourth, the system can be easily integrated with other existing information and management systems, such as inventory management systems, material requirement planning systems etc., through which higher level of cost efficiencies can be achieved. Further, as it can accommodate with the existing paper based recording systems, the necessity of skilled human resources to handle the traceability system can be avoided.

Finally, TTS enables the delivery of a quality guaranteed product at a reduced price together with prompt and additional information for consumers facilitating higher customer value and satisfaction which inevitably brings additional profits through enhanced customer loyalty.

Nevertheless, successful implementation of chain wide traceability systems requires commitment from all stakeholders involved. Thus, establishment of inter-company trust and faith is a prerequisite in developing a chain-wide traceability system, as external companies are not willing to share production methods and secrets with a third party. Hence, continuous discussions with other stakeholders, building up chain wide trust and reliability become an integral part in adopting and deploying chain wide traceability systems in which binding business partnerships play a great role than mere advanced technology.

## V. CONCLUSIONS

Despite the fact that traceability is becoming a popular tool in effectively managing complex supply chains, attaining compliance with regulatory standards and building consumer trust, current operating conditions of traceability systems, particularly in food supply chains, are unsatisfactory. In this study, first we investigate the current operating conditions, deployment issues, strengths and weaknesses of existing traceability systems. Then we introduce a novel traceability system as a pragmatic solution for existing issues associated with the design and deployment of traceability systems.

While the proposed system is equipped with necessary features of traceability such as internal and chain tractability features, it particularly focuses on SMEs in Japanese food supply chains. It specifically addresses issues of common concern to SMEs in food supply chains and minimizes the necessity of costly investment and drastic changes in production processes ensuring the user friendliness and adaptability of the system even in an existing small scale manufacturing setting. More importantly it can coexist with existing paper based recording systems allowing for subsequent gradual evolution towards a fully automated system.

After all, the commitment of the supply chain members and intercompany trust, in the whole process of design, deployment and implementation of traceability systems, plays an equally important role in realizing a fully

functional chain wide traceability system that is capable of delivering full scale benefits.

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