Executive Summary:

Project to Develop an Interoperable Seafood Traceability Technology Architecture: Issues Brief

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Global Food Traceability Center

www.globalfoodtraceability.org

Unprecedented challenges are impacting the seafood industry. The industry is becoming increasingly competitive, global, and complex. Consumers are placing greater expectations on suppliers' ability to verify product safety, authenticity, value, and sustainability. Aquaculture is replacing wild caught as the largest source of seafood and increasing the ecological concerns voiced by advocacy groups. Regulators are enacting increasingly stringent compliance standards at all points along the supply chain.

These changes also offer opportunities for businesses to create value, reduce costs, and mitigate risks when they take a whole-of-chain perspective. Securing these opportunities relies on the accurate exchange of information within and between businesses, which itself depends upon interoperable data systems that extend from production / harvest to consumer. Accordingly, this project, led by the Institute of Food Technologists' Global Food Traceability Center (GFTC), is developing a technology architecture for enabling effective interoperable seafood traceability systems.

As shown by industries such as automotive, fresh produce, and finance, the ability to implement interoperable data systems along the supply chain—whether for traceability or other purposes – relies on the existence of a shared common technology architecture; meaning a consistent and coherent series of specifications, models, guidelines, and concepts.

Technology architectures are developed through engaging industry stakeholders in understanding why an architecture is required; the benefits provided to the industry and individual businesses and supply chains, and how the architecture will translate into practical results. This encourages participation in the activities required to design and implement a sustainable technology architecture.

From Heterogeneous, Proprietary Systems to Effective Whole-Chain Collaboration

In the seafood sector, the current situation of many heterogeneous proprietary systems prevents global interoperable traceability from occurring. Described in its simplest form, addressing this situation can only be achieved by following a two-step process that establishes:

1) A series of standards, protocols, specifications, and guidelines that provide computerized information systems with the ability to communicate effectively by sharing standardized packages of data.

2) A common language (ontology)

Contributions of experts from industry, government agencies, and nongovernment organizations enabled the GFTC's Interoperable Seafood Traceability Technology Architecture project to understand and address the challenges faced in moving toward interoperable traceability in the global seafood industry. The experts formed four Technical Advisory Groups (TAG), each organized around a factor expected to impact the design and development of a technical architecture suited to facilitating effective global interoperable seafood traceability. The four factors are: (1) Practices and Processes, (2) Content Mapping, (3) Context Mapping, and (4) Engagement and Communication.

Glossary of terms

CTE – Critical Tracking Event – Point at which product is moved between premises or is transformed, or which is determined to be a point where data capture is necessary to maintain traceability.

KDE – Key Data Element – Data input required to successfully trace a product and/or its ingredients through all relevant CTEs.

Ontology – In information science, an ontology is formal naming and definition of the types, properties, and interrelationships between entities that enable a particular type of discourse to occur.

Semantic Interoperability – The ability of information systems to not only exchange unambiguous data that two or more systems understand, but also enable computerized systems to converse in ways that result in a shared sense of meaning and the creation of new knowledge.

Syntactic Interoperability – The ability of two or more information technology systems to communicate through a standardized process for packaging and sharing data—the prerequisite for functional interoperability.

Practices and Processes

Commercial firms' practices and processes[1] are the starting point for determining an effective architecture for enabling global interoperable traceability. Processes and practices determine the extent to which firms can collect, gather, and use data for commercial purposes. This TAG:

1) Defined the processes and practices used by the seafood industry in managing and using traceability-related information;

2) Compared identified systems with industries that have developed comprehensive traceability architectures;

3) Determined gaps and challenges facing the seafood industry in developing information systems within and across firms; and

4) Recommended key practices that are vital for developing a successful sustainable architecture.

For a technology architecture, a key to meeting traceability-related information needs is understanding information systems' core processes, as well as the strategic practices that bring those processes to life. The processes that determine the effectiveness of information technology for achieving commercial purposes are fundamental and relatively few in number. The practices that firms use to record, store, analyze, and distribute information will vary according to the stakeholders' role in the supply chain, scale of their operations, and technical capabilities. This is especially true given the seafood industry's diversity of:

- species and geography,
- resource management systems,
- production methods and scale/scope, and
- supporting economic, technological, and governance "infrastructures."

[1]Practices and processes determine how firms utilize traceability to acquire sustainable competitive advantage. Practices are the activities that individual firms and supply chains implement to create value through producing products and services. Processes are the activities that individual firms and supply chains implement to capture and transform data into information that is used to make informed management decisions.

From a supply chain perspective, a common finding is that inefficient and ineffective flow of material through a supply chain is caused by failings in the information flow. However, most of the benefits that are realized from implementing a traceability system are not within the control of a single company in the chain, because, for example, they depend upon the integrity of data and information exchanged. Achieving the expected outcomes is therefore dependent upon the behavior of other chain members, and not solely on the sophistication of the traceability-related information practices and technology capabilities of an individual firm. The effectiveness of traceability will therefore rely on the processes that firms use to align with external processes as well as internal ones.

The lower the uncertainty over the behavior of others, the greater a firm's confidence will be in investing in establishing systems and practices that align with those employed by the firms with which it conducts business—and that investments will deliver the anticipated returns. Indeed, the stronger those relationships are across the whole chain, the more ambitious and strategic the investments can be generating higher and longer-term returns.
It is for these reasons that inter-firm relationships affect firms' expectations as to what returns information and traceability systems should deliver, and therefore induce their willingness to invest in more costly and sophisticated "best" practices. A global traceability architecture must address this fundamental reality of supply chains and be able to accommodate the diverse practices of individual firms, as well as the information needs and contractual agreements across entire chains possessing different levels of trust and strategic alignments.

For a technology architecture to accommodate the wide diversity described above, it must enable both syntactic and semantic interoperability. Syntactic interoperability flows from computerized systems having the ability to share standardized packages of data. Syntactic interoperability enables transactional communications to occur across different computerized systems by standardizing how content-related data are shared. Semantic interoperability flows from the ability of computerized systems to communicate in ways that lead to the creation of new knowledge. Employing a standardized ontology (language) enables businesses to contextualize data, providing the ability to use traceability in potentially unprecedented ways.

The Food Track & Trace Ontology (FTTO) prototype is a model system for sharing knowledge in food traceability along a supply chain (Pizzuti and Mirabelli 2013; Pizzuti and others 2014). The FTTO consists of two main classes: food product and process. The food product class includes food in the form of primary food commodities or processed products, beverages, and food additives used during various phases of production. The process class includes business processes and agro-food processes operated by the different agents involved in the food supply chain.

Content Mapping

The existence of common standards, protocols, specifications, and guidelines is vital to establishing traceability systems that businesses can use to capture and create commercial value in implementing traceability systems.

Content mapping characterizes what data are collected and shared to enable businesses to use syntactic interoperable traceability. Syntactic interoperability is the ability of two or more systems to exchange the same content-related data. Syntactic interoperability addresses aspects of the "what" and "how" that must be considered in designing a technology architecture to enable effective global interoperable traceability.

Factors effecting syntactic traceability practices include agreement on the Critical Tracking Events (CTEs) that the system must encompass. The most important CTEs are Point of Harvest (farmed and wild), Trans-shipment, Transportation, Processing, and Distribution. As an example, CTEs that occur from the processing facility to the point of consumer sale include:

- Product creation/repackaging
- Product shipping
- Product receipt
- Product sale to retailer or foodservice, and
- Product depletion

Barriers to achieving full traceability for seafood include the lack of standardized systems for data collection and sharing, along with business concerns around confidentiality and data security. Achieving full traceability relies on the existence of secure complementary external and internal traceability functions and enablers.

The Content Mapping TAG reviewed best practices for CTEs. The group also reviewed data inputs and common gaps in data identified as negatively impacting the effectiveness of interoperable traceability. A Key Data Element (KDE) is data which is fundamental to firms' tracking critical events. KDE inputs that occur along the supply chain are typically those that are based on food safety, food quality, food sustainability, and food fraud considerations, and which reflect current practice in the seafood industry.

During the review of current best practices, two topics were identified as particularly important for enabling the operation of syntactic interoperable traceability. Each needs to be considered in the technology architecture's design. The topics are: (1) information requirements for enabling syntactic traceability; and (2) challenges to address when designing a technology architecture. Together they provide a brief synopsis of factors to consider in the design of a technology architecture for enabling syntactic full-chain traceability.

Context Mapping

Without a common language to which internal and external systems adhere, semantic traceability cannot occur. Achieving semantically interoperable traceability relies on establishing a common set of terminology and hierarchy, sometimes referred to as a common information model or ontology.

A seafood traceability ontology is needed to facilitate and simplify interoperability among technology providers, businesses, and other stakeholders. Sharing of foundational standards and terminology opens the market to workable interoperable solutions. Without adhering to a clear and concise ontology, issues arise that undermine the effectiveness and value of traceability, particularly in instances where traceability relies on the sharing of data across multiple networks, technologies, and jurisdictions.

An example of the extent to which the required ontology presently does not occur—and its impacts on effective traceability—are the differences in how countries define seafood species. This situation exists even though species is in principle a relatively straightforward terminology to standardize into a common ontology.

To aid the creation of an ontological hierarchy that formalizes terms and relationships, the Context Mapping TAG completed a literature review and environmental scan of existing ontologies, protocols, practices, and standards in the seafood industry. The group then conducted a gap analysis to identify factors impacting the effectiveness of traceability systems and practices. This involved mapping existing and desired ontologies, protocols, practices, and standards in the seafood industry that could be useful in designing a technology architecture for enabling semantically interoperable seafood traceability.

Engagement and Communication

It is critically important to engage industry stakeholders in processes designed to enable interoperable information and communication systems. In an industry as complex and diverse as seafood, it is especially critical to develop an effective process of engaging industry stakeholders in meaningful discussions of the development of a technology architecture designed for enabling effective traceability. As has occurred in other sectors, specific engagement methods may differ according to stakeholders' involvement in the operation of a supply chain, their technological capabilities or sophistication, and geographic location.

Given that the seafood sector generally misunderstands the concept of traceability, any engagement effort must begin with an extensive awareness-raising process. Industry subsectors must be able to see past their differences by acquiring a level of mutual understanding towards issues and challenges that extends beyond that which presently exists. Increased understanding will enable more stakeholders, including partners on both the supply and demand side of business, trade associations, government, and solution-providers, to agree on a common vision and goals based on industry drivers. As has occurred in other industries, the existence of clearly defined vision and associated benefits can motivate stakeholders to collaboratively focus their efforts toward defining and following a roadmap to implementing changes that enable industry to meet those goals.

Four main industry-wide benefits were identified through analyzing industries that have or are in the process of establishing interoperable information and traceability systems. They are:

- the ability to precisely locate potentially harmful products through supply chain visibility;
- ensuring trustworthy product information and data quality;
- reducing food and associated waste; and
- enhancing operational efficiencies.

Case Studies of Another Food Sector and Other Industries

To assist in developing a technology architecture suited to enable semantic interoperability across the global seafood industry, the researchers reviewed literature on initiatives undertaken in another sector of the food industry—produce—and non-food industries. The researchers also spoke to individuals involved in the development and implementation of interoperability solutions described below. Insights and lessons learned that can guide the design and development of a technology architecture suited to enabling interoperable traceability in the seafood are summarized below.

Fresh Produce. Most firms in the produce industry possess an internal traceability system for regulatory compliance and inventory control. The standardized format of products in this industry–package or batch size and variety, for example–means that the essential tools for identifying products are common to the entire supply chain. Verification of data and company practices is generally conducted by third party auditors, with the costs borne by industry.

Automotive. The automotive industry is focusing on tracing each component to its source, throughout the entire life cycle of the vehicle. Firms generally maintain sophisticated Enterprise Resource Planning (ERP) systems to link sub-components to components, sub-assemblies, assemblies, and finally to the completed automobile. Enterprise Quality Management Software (EQMS) packages are increasingly being used to facilitate the integration of a firm's ERP with its business processes. The existence of a common ontology enables analysis and comparisons between the operation and performance of different supply chains, firms, and vehicle components.

Pharmaceutical. Compared to automotive and fresh produce, the pharmaceutical industry is not as advanced in the development of global traceability solutions. Most approaches remain national, while global solutions are being explored mainly via the GS1 organization and the use of their unique product identification systems. Given that the most fundamental concern for effective global traceability in the healthcare industry is the use of a unique product identification, the use of a single organization to assign and record that identification reduces complexity. However, implementing global traceability in the pharmaceuticals industry is extremely challenging given supply chain complexities, the disparity in regulations among countries, and the variable speed at which government regulations are evolving.

Financial. The most standardized element of financial transactions that result in efficient and effective interoperable traceability is the Society for Worldwide Interbank Financial Telecommunication (SWIFT). Established in 1973 with the support of 239 banks operating in 15 countries, SWIFT acts as an international clearinghouse for wire transfer messaging. SWIFT does not transfer funds, but standardizes the messages that go from one bank to another. This minimizes errors and enhances the rigor of data exchanged. The system's standardization is maintained and enforced by this global entity determining what everyone else must do.

Comparative Analysis

Analysis of the fresh produce sector and non-food industries' interoperability efforts highlights the challenges that factors such as diversity in firm size—ranging from household-level producers to large multinational corporations—will have on the design of a technology architecture for enabling interoperability. That internal traceability systems range from simple paper-based record keeping and data storage to complex ERP (Enterprise Resource Planning) systems that are automated and integrated with a firm's business operations will also impact the architecture's design, as it creates major challenges in designing interoperable systems that can interface with such a wide range of technologies. Establishing a common language, processes, practices, and technology standards are critical to addressing barriers that would otherwise prevent interoperable traceability.

Of encouragement to the seafood industry is that similar challenges are being overcome in fresh produce, and other industries, such as the finance industry, albeit at differing paces. A key learning that flowed from the analysis is the importance of a strong impartial governance structure, led by industry leaders, which transcends international borders. Such structures typically stem from firms proactively coalescing around a pre-competitive issue that may not itself have been explicitly related to traceability. As the initiatives progressed and momentum increased, they encompassed a widening array of industry stakeholders and focused on more ambitious objectives. This produced a steadily evolving foundation that benefited the wider industry. Seafood can utilize capabilities developed to enable individual businesses, and the supply chains in which they operated, to adapt to market demands and manage risk in ways that would be unattainable without global interoperable information technologies.

Summary

Traceability is enabled through the collection, management, and sharing of data and information. The *Project to Develop an Interoperable Seafood Traceability Technology Architecture: Issues Brief* discussed determinants that are important to the collection, management, and sharing of traceability-related data and information in firms, along supply chains, and across industries.

Two levels of interoperability were discussed: syntactic and semantic. Syntactic interoperability enables the exchange of standardized data and reporting. This is the foundation that enables interoperability to occur. Semantic interoperability is the ability for internal and external systems to converse in a common language. This provides businesses with the capability to use data in a myriad of ways to create and capture value.

The ability to translate interoperability into commercial benefit is determined by the structure and nature of the supply chain(s) in which businesses operate. As has occurred in other industries (such as automotive and finance) increasingly stringent compliance standards mean that the functions of interoperable traceability must reflect the evolving needs of industry and regulators, otherwise they will not be sustainable or foster industry-wide support. Inter- and intra-company agreement on CTEs and sharing of KDEs is essential to achieving this interoperability, as well as controlling food safety, sustainability, fraud, and the efficient management of product and ingredients for added value.

The development of technology architecture should provide flexible options which:

- can be selected and later developed to reflect the variable and dynamic nature of inter-firm relationships, so that firms have choices appropriate to their current state, but which can easily extend that system as collaboration deepens;
- allow chains to agree and pursue a collective strategy over what outcomes are desired and realistic, from "legal compliance only," through different combinations of operational efficiencies, business risk mitigation, and market access; and
- include guidance on how to select options within the architecture which are most suitable for the current relationships within a particular chain, and its initial objectives.

The table on page 10 summarizes recommended practices in designing and managing a global seafood traceability architecture detailed in the *Project to Develop an Interoperable Seafood Traceability Technology Architecture: Issues Brief*.

References

Bhatt T, Cusack C, Dent B, Gooch M, Jones D, Newsome R, Stitzinger J, Sylvia G, and Zhang J. 2016. Project to Develop an Interoperable Seafood Traceability Technology Architecture: Issues Brief. Comp Rev in Food Sci F 15:392–429. doi: 10.1111/1541-4337.12187.

Olsen P, Borit M. 2013. How to define traceability. Trends Food Sci Technol 29(2):142–50.

Pizzuti T, Mirabelli G. 2013. FTTO: An example of food ontology for traceability purpose. The 7th IEEE International Conference on Intelligent Data Acquisition and Advanced Commuting Systems: Technology and Applications; Berlin, Germany, 2013 September 12-14.

Pizzuti T, Mirabelli G, Sanz-Bobi MA, Goméz-Gonzaléz F. 2014. Food track & trace ontology for helping the food traceability control. J Food Eng 120:17-30.

Recommended practices in designing and managing a global seafood traceability architecture

PROCESS	RECOMMENDED GLOBAL SEAFOOD ARCHITECTURAL PRACTICES
Product Identification	Human- and machine-readable codes on each product that represent at least a unique global identifier. The unique global identifier is comprised of a global identification number that identifies the product type and a lot number that identifies data at a finer scale (for example, dates, vessel, production facility). The original harvest lot number should be identified and linked to all other "lot" or "process/batch" numbers generated during supply chain activities.
Data Addition	All data generated by each node in the supply chain are linked to the unique global identifier. When a new lot number is assigned, previous lot numbers are linked to it. All Key Data Elements (KDEs) are linked to the unique identifier.
Data Partition	Firm level partitioning or "data-siloing" is minimized to provide access to product data via the architectural portals (conditional on proper "permissions" and high-level security). Clear definitions of data requirements are needed.
Data Storage	All or most data should be stored at the level of the individual firm. Some "core" traceability data could be stored at the "architectural cloud" level if efficient and secure.
Data Transmission	Data are transmitted electronically (via data portals) with required permissions. Unique identifiers are transmitted with both the data and the product. Data can be transmitted using predesigned modules and/or menus that best meet the strategic needs of individual firms and supply chains.
Data Security and Access	Architectural framework must be secure to protect the privacy and intellectual property of individual companies. Access is granted by each firm via "permissions" to users of data. Different classes of data may have different permission requirements.
Data Collection and Measurement	Industry must define KDE and standardize measurement. Data collection is by individual firms using a variety of techniques (such as paper, electronic sensors, scanners). Interfaces that convert manually recorded data to electronic form for transmission may be required.
Data Validation	The architecture may identify key missing data in transmission process. The architecture can also transmit third party authenticators for firm-level data or other firm-level validation information.