System tracks movement of food through global humanitarian supply chain

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Users of a new mobile app can scan barcodes to access the history of commodities and report damage to individual cans with photographs of the damage and geolocation and timestamp data. Credit: Lincoln Laboratory researchers.

Although more than enough food is produced to feed everyone in the world, as many as 828 million people face hunger today. Poverty, social inequity, climate change, natural disasters, and political conflicts all contribute to inhibiting access to food. For decades, the U.S. Agency for International Development (USAID) Bureau for Humanitarian Assistance (BHA) has been a leader in global food assistance, supplying millions of metric tons of food to recipients worldwide. Alleviating hunger—and the conflict and instability hunger causes—is critical to U.S. national security.

But BHA is only one player within a large, complex supply chain in which food gets handed off between more than 100 partner organizations before reaching its final destination. Traditionally, the movement of food through the supply chain has been a black-box operation, with stakeholders largely out of the loop about what happens to the food once it leaves their custody. This lack of direct visibility into operations is due to siloed data repositories, insufficient data sharing among stakeholders, and different data formats that operators must manually sort through and standardize. As a result, accurate, real-time information—such as where food shipments are at any given time, which shipments are affected by delays or food recalls, and when shipments have arrived at their final destination—is lacking. A centralized system capable of tracing food along its entire journey, from manufacture through delivery, would enable a more effective humanitarian response to food-aid needs.

In 2020, a team from MIT Lincoln Laboratory began engaging with BHA to create an intelligent dashboard for their supply-chain operations. This dashboard brings together the expansive food-aid datasets from BHA's existing systems into a single platform, with tools for visualizing and analyzing the data. When the team started developing the dashboard, they quickly realized the need for considerably more data than BHA had access to.

"That's where traceability comes in, with each handoff partner contributing key pieces of information as food moves through the supply chain," explains Megan Richardson, a researcher in the laboratory's Humanitarian Assistance and Disaster Relief Systems Group.

Richardson and the rest of the team have been working with BHA and their partners to scope, build, and implement such an end-to-end traceability system. This system consists of serialized, unique identifiers (IDs)—akin to fingerprints—that are assigned to individual food items at the time they are produced. These individual IDs remain linked to items as they are aggregated along the supply chain, first domestically and then internationally. For example, individually tagged cans of vegetable oil get packaged into cartons; cartons are placed onto pallets and transported via railway and truck to warehouses; pallets are loaded onto shipping containers at U.S. ports; and pallets are unloaded and cartons are unpackaged overseas.

With a trace

Today, visibility at the single-item level doesn't exist. Most suppliers mark pallets with a lot number (a lot is a batch of items produced in the same run), but this is for internal purposes (i.e., to track issues stemming back to their production supply, like over-enriched ingredients or machinery malfunction), not data sharing. So, organizations know which supplier lot a pallet and carton are associated with, but they can't track

the unique history of an individual carton or item within that pallet. As the lots move further downstream toward their final destination, they are often mixed with lots from other productions, and possibly other commodity types altogether, because of space constraints. On the international side, such mixing and the lack of granularity make it difficult to quickly pull commodities out of the supply chain if food safety concerns arise. Current response times can span several months.

"Commodities are grouped differently at different stages of the supply chain, so it is logical to track them in those groupings where needed," Richardson says. "Our item-level granularity serves as a form of Rosetta Stone to enable stakeholders to efficiently communicate throughout these stages. We're trying to enable a way to track not only the movement of commodities, including through their lot information, but also any problems arising independent of lot, like exposure to high humidity levels in a warehouse. Right now, we have no way to associate commodities with histories that may have resulted in an issue."

"You can now track your checked luggage across the world and the fish on your dinner plate," adds Brice MacLaren, also a researcher in the laboratory's Humanitarian Assistance and Disaster Relief Systems Group. "So, this technology isn't new, but it's new to BHA as they evolve their methodology for commodity tracing. The traceability system needs to be versatile, working across a wide variety of operators who take custody of the commodity along the supply chain and fitting into their existing best practices."

As food products make their way through the supply chain, operators at each receiving point would be able to scan these IDs via a Lincoln Laboratory-developed mobile application (app) to indicate a product's current location and transaction status—for example, that it is en route on a particular shipping container or stored in a certain warehouse. This information would get uploaded to a secure traceability server. By

scanning a product, operators would also see its history up until that point.

Hitting the mark

At the laboratory, the team tested the feasibility of their traceability technology, exploring different ways to mark and scan items. In their testing, they considered barcodes and radio-frequency identification (RFID) tags and handheld and fixed scanners. Their analysis revealed 2D barcodes (specifically data matrices) and smartphone-based scanners were the most feasible options in terms of how the technology works and how it fits into existing operations and infrastructure.

"We needed to come up with a solution that would be practical and sustainable in the field," MacLaren says. "While scanners can automatically read any RFID tags in close proximity as someone is walking by, they can't discriminate exactly where the tags are coming from. RFID is expensive, and it's hard to read commodities in bulk. On the other hand, a phone can scan a barcode on a particular box and tell you that code goes with that box. The challenge then becomes figuring out how to present the codes for people to easily scan without significantly interrupting their usual processes for handling and moving commodities."

As the team learned from partner representatives in Kenya and Djibouti, offloading at the ports is a chaotic, fast operation. At manual warehouses, porters fling bags over their shoulders or stack cartons atop their heads any which way they can and run them to a drop point; at bagging terminals, commodities come down a conveyor belt and land this way or that way. With this variability comes several questions: How many barcodes do you need on an item? Where should they be placed? What size should they be? What will they cost? The laboratory team is considering these questions, keeping in mind that the answers will vary

depending on the type of commodity; vegetable oil cartons will have different specifications than, say, 50-kilogram bags of wheat or peas.

Leaving a mark

Leveraging results from their testing and insights from international partners, the team has been running a traceability pilot evaluating how their proposed system meshes with real-world domestic and international operations. The current pilot features a domestic component in Houston, Texas, and an international component in Ethiopia, and focuses on tracking individual cartons of vegetable oil and identifying damaged cans. The Ethiopian team with Catholic Relief Services recently received a container filled with pallets of uniquely barcoded cartons of vegetable oil cans (in the next pilot, the cans will be barcoded, too). They are now scanning items and collecting data on product damage by using smartphones with the laboratory-developed mobile traceability app on which they were trained.

"The partners in Ethiopia are comparing a couple lid types to determine whether some are more resilient than others," Richardson says. "With the app—which is designed to scan commodities, collect transaction data, and keep history—the partners can take pictures of damaged cans and see if a trend with the lid type emerges."

Next, the team will run a series of pilots with the World Food Program (WFP), the world's largest humanitarian organization. The first pilot will focus on data connectivity and interoperability, and the team will engage with suppliers to directly print barcodes on individual commodities instead of applying barcode labels to packaging, as they did in the initial feasibility testing. The WFP will provide input on which of their operations are best suited for testing the traceability system, considering factors like the network bandwidth of WFP staff and local partners, the commodity types being distributed, and the country context for scanning.

The BHA will likely also prioritize locations for system testing.

"Our goal is to provide an infrastructure to enable as close to real-time data exchange as possible between all parties, given intermittent power and connectivity in these environments," MacLaren says.

In subsequent pilots, the team will try to integrate their approach with existing systems that partners rely on for tracking procurements, inventory, and movement of commodities under their custody so that this information is automatically pushed to the traceability server. The team also hopes to add a capability for real-time alerting of statuses, like the departure and arrival of commodities at a port or the exposure of unclaimed commodities to the elements. Real-time alerts would enable stakeholders to more efficiently respond to food-safety events. Currently, partners are forced to take a conservative approach, pulling out more commodities from the supply chain than are actually suspect, to reduce risk of harm. Both BHA and WHP are interested in testing out a food-safety event during one of the pilots to see how the traceability system works in enabling rapid communication response.

To implement this technology at scale will require some standardization for marking different commodity types as well as give and take among the partners on best practices for handling commodities. It will also require an understanding of country regulations and partner interactions with subcontractors, government entities, and other stakeholders.

"Within several years, I think it's possible for BHA to use our system to mark and trace all their food procured in the United States and sent internationally," MacLaren says.

Once collected, the trove of traceability data could be harnessed for other purposes, among them analyzing historical trends, predicting future demand, and assessing the carbon footprint of commodity transport. In

the future, a similar traceability system could scale for nonfood items, including medical supplies distributed to disaster victims, resources like generators and water trucks localized in emergency-response scenarios, and vaccines administered during pandemics. Several groups at the laboratory are also interested in such a system to track items such as tools deployed in space or equipment people carry through different operational environments.

"When we first started this program, colleagues were asking why the laboratory was involved in simple tasks like making a dashboard, marking items with barcodes, and using hand scanners," MacLaren says. "Our impact here isn't about the technology; it's about providing a strategy for coordinated food-aid response and successfully implementing that strategy. Most importantly, it's about people getting fed."

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