



(REVIEW ARTICLE)



Reducing food waste through predictive analytics and cold chain monitoring: A U.S. Retail Review

Sarah Usoro ^{1,*} Precious Orekha ² and David Azikutenyi Galadima ³

¹ College of Business, East Texas A&M University, Commerce, Texas, United States.

² College of Computing and Informatics, Drexel University, Philadelphia, United States.

³ Hankamer School of Business, Baylor University, Texas United States.

International Journal of Science and Research Archive, 2026, 18(03), 382-388

Publication history: Received on 19 January 2026; revised on 03 March 2026; accepted on 05 March 2026

Article DOI: <https://doi.org/10.30574/ijrsra.2026.18.3.0403>

Abstract

Food waste represents a systemic inefficiency in the United States food supply chain, with approximately 30–40% of produced food failing to reach consumers (Buzby et al., 2014). This study examines how machine learning-based demand forecasting and Internet of Things (IoT) cold-chain monitoring have been deployed by major U.S. food retailers and distributors to reduce waste and improve supply chain performance. Drawing on publicly available corporate sustainability reports, industry case studies, and peer-reviewed literature, the analysis evaluates implementations at Walmart, Kroger, Sysco, and FreshDirect. Company-reported outcomes suggest that algorithmic forecasting systems improve prediction accuracy by 20–42% relative to conventional statistical baselines, while continuous IoT-based temperature monitoring reduces cold-chain spoilage rates by 15–30%. These figures, it should be noted, are drawn almost entirely from self-reported disclosures; the absence of independent verification limits the strength of causal claims. Nevertheless, the consistency and scale of reported improvements Kroger's documented 26% reduction in food waste (245,289 tons) since 2017, Walmart's 78% waste diversion rate, and FreshDirect's sub-2% waste generation suggest that technology-enabled distribution represents a viable pathway toward USDA 2030 waste reduction targets. The study also identifies implementation barriers including capital constraints, data interoperability gaps, and workforce skill deficits that may limit uptake among smaller operators. Future research should prioritize independent performance audits and cost-benefit analyses for small- and medium-scale distributors.

Keywords: Food Waste Reduction; Demand Forecasting; Internet of Things; Cold-Chain Monitoring; Supply Chain Optimization; Predictive Analytics

1. Introduction

The United States food supply chain loses between 30 and 40 percent of produced food before it reaches consumers (Buzby et al., 2014). This waste is not confined to any single stage; it accumulates through post-harvest handling, transportation, distribution, and retail operations. The economic cost exceeds \$218 billion annually, while the environmental toll approximately 170 million metric tons of CO₂ equivalent, plus disproportionate demands on freshwater and agricultural land adds urgency to what might otherwise appear a logistics problem (ReFED, 2021; Gunders and Bloom, 2017).

In 2015, the U.S. Department of Agriculture and Environmental Protection Agency established a national target to reduce food waste by 50 percent by 2030 relative to 2010 levels (USDA and EPA, 2015). Progress toward that target has been uneven. Distribution operations where perishable goods face time-sensitive quality constraints and complex routing requirements remain among the most significant sources of avoidable waste.

* Corresponding author: Sarah Usoro

Traditional distribution relies heavily on historical sales averages and manual inventory management. Forecasting errors for perishable products average 30–50% under conventional approaches (Waller and Fawcett, 2013), producing chronic mismatches between supply and actual demand. When retailers overstock, spoilage follows; when they understock, sales are lost and consumer trust erodes. Cold-chain management has historically faced similar limitations: temperature excursions during transport often go undetected until product arrives at its destination, at which point remediation is no longer possible.

The proliferation of machine learning algorithms capable of processing heterogeneous real-time data streams point-of-sale transactions, weather forecasts, regional demographics, promotional schedules offers a potential corrective to these forecasting deficiencies (Kamble et al., 2020). Simultaneously, IoT sensor networks have made continuous environmental monitoring economically feasible for refrigerated logistics at scale (Zhu et al., 2018). When integrated within broader distribution management platforms, these technologies enable adaptive, data-driven decision-making that more precisely aligns inventory positioning with actual demand.

This paper examines the evidence for such claims. The primary objective is to assess the technical implementations and reported outcomes of automated forecasting and IoT monitoring systems at four major U.S. food distributors, evaluating whether the reported performance gains are sufficiently robust to support broader policy recommendations. A secondary objective is to characterize implementation barriers that may constrain adoption among smaller operators a population whose participation would be necessary for industry-wide progress toward USDA targets.

An important caveat governs the analysis throughout: the performance figures reviewed here derive almost exclusively from corporate sustainability reports and company press releases. These sources have obvious incentives toward favorable presentation. Where methodological details are disclosed, they are noted; where they are absent—which is frequent this limitation is acknowledged directly rather than glossed over.

2. Materials and Methods

2.1. Research Design

This study employs a mixed-methods approach, combining quantitative analysis of publicly reported performance metrics with qualitative evaluation of system architectures and implementation contexts. The design incorporates three components: (1) a structured review of algorithmic forecasting and IoT monitoring technologies as documented in peer-reviewed supply chain literature; (2) case study analysis of deployments at Walmart Inc., Kroger Co., Sysco Corporation, and FreshDirect; and (3) evaluation of sustainability and operational outcomes from published corporate disclosures.

2.2. Data Collection

2.2.1. Industry Case Studies

Case study organizations were selected to reflect diverse distribution models traditional retail (Walmart, Kroger), foodservice distribution (Sysco), and online grocery (FreshDirect) and to provide documented evidence of algorithmic or IoT-enabled interventions with associated waste or efficiency metrics. Primary source materials include annual sustainability reports, ESG disclosures, and corporate press releases published between 2020 and 2024. Secondary sources include trade publications (Retail Dive, Food Logistics, Food Dive) and consulting firm reports (McKinsey and Company). The trade and consulting sources introduce their own potential biases toward technology adoption and toward the vendors whose products they profile and results drawn from these sources are treated with commensurate skepticism.

2.2.2. Technical System Components

Three system categories are examined. Demand forecasting systems encompass machine learning models including random forest, gradient boosting, and neural network architectures that generate store- and SKU-level inventory predictions from multi-source data inputs. IoT monitoring infrastructure encompasses sensor networks deployed in refrigerated transport and storage, transmitting continuous temperature, humidity, and location data to centralized analytics platforms. Data integration platforms include cloud-based systems aggregating inputs from enterprise resource planning (ERP), warehouse management (WMS), and transportation management (TMS) systems.

2.3. Performance Metrics

Waste reduction was assessed through reported spoilage rate changes, absolute tonnage of food waste avoided, and waste diversion percentages. Operational efficiency was evaluated via forecast accuracy improvement (expressed as percentage reduction in mean absolute percentage error, or as improvement over a stated baseline), inventory accuracy, stockout frequency, and logistics cost changes. Environmental impact metrics include energy consumption reductions, greenhouse gas emission changes, and food recovery volumes.

2.4. Data Analysis

Literature synthesis followed a structured review of peer-reviewed publications indexed in Web of Science and Scopus between 2010 and 2024, using search terms combining 'food waste,' 'demand forecasting,' 'machine learning,' 'supply chain,' and 'IoT cold chain.' Corporate document analysis extracted reported performance figures and matched them to specific technology interventions where disclosures permitted. Comparative analysis set reported outcomes against industry-average baselines documented in the academic literature, though the absence of common measurement standards across organizations limits strict numerical comparison.

Limitations

This study's central methodological constraint is its reliance on company-reported data. Corporate sustainability reports are not subject to the same verification standards as financial disclosures, and there is no independent auditing body for food waste metrics. Organizations may selectively report favorable outcomes, define baseline periods advantageously, or attribute gains to technology investments that coincided with other operational changes. These concerns are not hypothetical; the reporting bias in corporate environmental disclosures is well-documented in the literature (see, e.g., GRI Standards compliance studies). The findings presented here should therefore be read as preliminary evidence of plausible effects rather than as rigorously established causal relationships. Controlled experimental comparison between conventional and technology-enabled distribution operations was not feasible within this study's scope. Long-term performance data beyond three to five years remain unavailable for most implementations reviewed.

3. Results and Discussion

3.1. Demand Forecasting: Reported Performance

The most consistently reported outcome across implementing organizations is improvement in demand forecast accuracy. Industry-facing publications estimate accuracy gains of 20–42% compared to traditional statistical methods when machine learning models are substituted for conventional approaches (Walmart, 2023; McKinsey, 2022). These figures require careful interpretation. Neither source specifies a common accuracy metric, and the baselines against which improvements are measured differ across organizations. A 20% improvement in MAPE starting from a 40% error rate is materially different from the same relative improvement starting from 15% a distinction that most corporate disclosures do not make.

Walmart's published materials describe an AI-assisted forecasting system processing point-of-sale data from over 4,700 U.S. stores alongside weather forecasts, promotional calendars, and regional demographic data. The company reports a 21% improvement in seasonal merchandise forecast accuracy and a 16.4% reduction in stockouts during promotional periods (Walmart, 2023). Additional reported outcomes include a 90% gain in inventory accuracy and a 10% reduction in logistics costs figures that, if accurate, represent substantial operational improvements. However, Walmart's disclosures do not specify the forecast horizon, the product categories where gains were most pronounced, or whether the reported improvements were sustained over multiple seasons. These omissions matter for generalizing the findings.

Ensemble modeling approaches combining random forest and gradient boosting algorithms with meta-learners that select optimal predictions by product category and forecast horizon appear to outperform single-algorithm implementations in the technical literature, with reported MAPE reductions of 40–60% versus conventional statistical forecasting (Waller and Fawcett, 2013). Smaller-scale evidence is consistent with this: House of Spices reported a 30% improvement in forecast accuracy and a 20% reduction in inventory waste following implementation of an algorithmic forecasting platform (Relewise, 2024). The smaller operator context is noteworthy here, as it suggests the approach may generalize beyond large retailers, though a single case study is not sufficient basis for confident generalization.

The translation from forecast accuracy to waste reduction is not automatic. A more accurate forecast reduces overstocking only if it is acted upon that is, if replenishment orders are actually adjusted downward and supply chain

partners respond accordingly. This behavioral and organizational dimension of implementation receives little attention in the technical literature but is likely an important determinant of whether forecast improvements translate to measurable waste reductions in practice.

3.2. IoT Cold-Chain Monitoring

Continuous monitoring of temperature and environmental conditions in refrigerated logistics represents a more technically straightforward intervention than demand forecasting: the counterfactual (periodic manual checks or post-delivery data review) is clearly inferior, and the mechanism of effect earlier detection of excursions enabling faster corrective response is well understood. Research literature places the spoilage reduction attributable to IoT monitoring at 15–30% in cold-chain operations (Martin et al., 2023; Patel et al., 2022), though effect sizes in individual studies vary with baseline spoilage rates and the severity of excursion events in the study period.

Sysco's investment is the most extensively documented among the cases reviewed: a \$215 million capital commitment to equip 2,350 refrigerated trucks with real-time temperature monitoring and GPS tracking. The company reports a 22.7% reduction in food spoilage attributable to this program (DCF modeling, 2023). The Sysco case is notable both for the scale of investment and for the fact that the performance claim originates from a financial modeling source rather than from Sysco's own sustainability report introducing a different, though not necessarily less biased, form of third-party characterization.

Beyond spoilage prevention, IoT sensor data enables energy optimization in refrigeration units by providing the empirical basis for predictive algorithms that reduce unnecessary cooling cycles. The energy efficiency gains are plausibly substantial given that refrigeration represents one of the larger variable costs in cold-chain logistics, though specific figures were not consistently reported across organizations reviewed.

Real-time alerting automatically notifying drivers and dispatch coordinators when temperature thresholds are breached represents a qualitative improvement over retrospective monitoring that is difficult to quantify but operationally significant. The practical limitation of this capability is connectivity: rural distribution corridors frequently experience intermittent cellular coverage, creating data gaps precisely in regions where monitoring may be most critical (FCC, 2020). Edge computing architectures that buffer data locally during connectivity lapses offer a technical workaround but add hardware cost and system complexity.

3.3. Integrated System Outcomes

FreshDirect provides the most striking summary statistic in this review: the company reports less than 2% food waste generation through a platform that tightly integrates predictive inventory management with real-time warehouse and delivery monitoring (FreshDirect, 2024). The online grocery model is structurally different from brick-and-mortar retail in ways that make direct comparison difficult. FreshDirect fulfills orders rather than holding open-shelf inventory, which reduces the overstocking dynamic characteristic of traditional retail. This context does not diminish the figure, but it does caution against treating it as a benchmark for conventional distributors.

The proposed mechanism of integration benefits is intuitive: demand forecasts reduce over-ordering, IoT monitoring preserves the quality of what is ordered, and automated replenishment systems continuously reconcile the two against current inventory status. Industry implementations report that safety stock can be reduced by 20–35% while maintaining service levels above 98% when automated systems respond to real-time demand signals (McKinsey, 2022). Dynamic route optimization adjusting delivery schedules in response to updated demand forecasts addresses both stockouts and spoilage by directing product to where it is actually needed rather than where it was expected to be needed.

Predictive shelf-life management represents a particularly high-value integration point. When systems can identify products within two to three days of expiration across entire warehouse inventories in real time, automated routing to same-day delivery orders, promotional bundles, or food bank donation networks becomes operationally feasible. This proactive redistribution substantially reduces write-offs and has the collateral benefit of increasing food recovery volumes, which has social value independent of its contribution to corporate waste metrics.

3.4. Sustainability Metrics Across Implementing Organizations

Four organizations provide the primary quantitative evidence for this review's central claims.

Kroger reports a 26% reduction in total food waste since 2017, equivalent to 245,289 tons, with 82% waste diversion from landfills company-wide and 106 million pounds of surplus food donated through its Zero Hunger | Zero Waste program (Kroger, 2023). The company also reports a 15.2% reduction in greenhouse gas emissions from its 2018 baseline. Using a standard conversion factor of approximately 1.2 tons CO₂ equivalent per ton of food waste, the waste reduction alone represents roughly 294,000 tons of avoided emissions. These figures are internally consistent and represent multi-year trends, which makes them somewhat more credible than single-year announcements, though independent verification remains unavailable.

Walmart reports 78% diversion of unsold products from landfills, 760 million pounds of food donated globally in FY2023, and a 12% reduction in food waste since 2016 (Walmart, 2022; Food Dive, 2024). The donation figure is large in absolute terms; the 12% reduction in waste generation is more modest relative to the company's stated target of 50% by 2030 and suggests that the remaining progress will require more than incremental improvement in existing systems.

Sysco's environmental disclosures are less specific regarding waste reduction directly attributable to technology interventions. Total GHG emissions of approximately 102,900 kg CO₂e in 2023 are reported, with ongoing investment in fleet modernization and cold-chain optimization (Sysco, 2023). The absence of a clear waste reduction trend line in Sysco's disclosures is notable, given the scale of its IoT investment.

FreshDirect converted 667 tons of food waste to eco-fuel and recycled an additional 829 tons in 2023, preventing 25 tons of methane emissions and maintaining a food donation partnership with City Harvest yielding approximately 2.6 million meals annually (FreshDirect, 2024). The company's sub-2% waste generation rate is the single most compelling outcome statistic in this review, though as noted above, the online grocery context limits direct extrapolation.

3.5. Implementation Barriers

The performance gains documented above are real, but they have been achieved by organizations with substantial technical and financial resources. The barriers to broader adoption deserve more systematic attention than they typically receive in technology-optimistic reviews of this literature.

Capital requirements are the most frequently cited obstacle. Comprehensive implementation covering IoT hardware, network infrastructure, cloud computing, software licensing, and systems integration requires investments in the hundreds of thousands to low millions of dollars for mid-scale operations serving 50–100 retail locations (McKinsey, 2021). For independent grocers operating on thin margins, this is not a marginal investment; it may represent an existential risk if performance falls short of projections. The extended payback periods typical of these implementations estimated at 24–36 months before positive return is achieved compound the financial challenge.

Data interoperability remains a structural problem across the sector. IoT sensors, warehouse management systems, transportation platforms, and point-of-sale systems commonly operate on incompatible protocols and data formats. GS1 product identification standards and EDI protocols provide partial coverage, but the absence of comprehensive data exchange standards for real-time inventory and environmental monitoring data necessitates costly custom integration development. This is not simply a technical inconvenience; it means that the value of analytics systems scales with the breadth and consistency of data inputs, and smaller operators—who are least able to afford integration work—are also least able to realize the potential value of the platforms they invest in.

Workforce capability gaps compound both of the above challenges. Predictive analytics platforms require users to interpret probabilistic recommendations and exercise judgment about when to override automated suggestions. Many distribution and warehouse managers lack this background, and the training investments required to develop it are not trivial. Large retailers have developed structured training programs to address this gap; smaller operators often have neither the budget nor the instructional infrastructure to replicate them.

Finally, connectivity limitations in rural distribution corridors create genuine technical constraints on real-time monitoring. Edge computing architectures mitigate but do not eliminate this problem and add cost and complexity that partly offset the value of continuous monitoring.

3.6. Scalability and Policy Implications

Despite the barriers outlined above, there are grounds for cautious optimism about broader adoption. Modular implementation strategies prioritizing high-impact, lower-cost components (temperature monitoring before full AI forecasting integration, for example) and expanding incrementally as returns materialize can reduce initial capital requirements by 50–65% while delivering 60–75% of total projected benefits within 18–24 months, according to

industry estimates (McKinsey, 2021). These figures are themselves drawn from consulting publications with commercial interests in the technology they analyze, but the underlying logic of phased implementation is sound.

Software-as-a-Service delivery models for demand forecasting platforms represent a structural shift that could substantially lower adoption barriers for smaller operators. Subscription-based access to analytical capabilities previously requiring significant capital expenditure democratizes the technology though questions of data sovereignty, vendor dependency, and SaaS pricing escalation deserve attention before smaller operators commit to these arrangements.

Industry consortia focused on data standardization offer a high-leverage policy intervention. If common protocols for IoT sensor data and real-time inventory exchange were established through bodies such as GS1 or government-convened working groups, the integration costs that currently fall disproportionately on each adopting organization could be substantially reduced. USDA grant programs and technical assistance targeted at small and medium distributors could further lower financial barriers, though the effectiveness of such programs would depend heavily on implementation design.

4. Conclusion

The evidence reviewed here supports a qualified conclusion: algorithmic demand forecasting and IoT-based cold-chain monitoring demonstrably reduce food waste in the organizations that have implemented them at scale, with reported outcomes that despite the limitations of self-reported corporate data are consistent in direction and plausible in magnitude. Kroger's 245,289-ton waste reduction, Walmart's 78% diversion rate, FreshDirect's sub-2% waste generation, and Sysco's 22.7% spoilage reduction collectively represent meaningful progress toward USDA 2030 objectives.

The mechanisms are well-understood and technically sound. More accurate forecasts reduce structural over-ordering; continuous monitoring preserves quality and enables rapid response to excursions; integration of the two enables proactive redistribution of at-risk inventory to donation networks before it becomes waste. These are not marginal improvements they represent a fundamentally different operating model for perishable distribution.

That said, the findings must be tempered by the absence of independent verification, the structural advantages of large retailers that make their results difficult to generalize to smaller operators, and the evidence that even leading implementers remain well short of their own stated targets. Walmart's 12% waste reduction against a 50% goal is a reminder that early deployments, however impressive, represent the easier part of a longer trajectory.

The more pressing question for the field is not whether this technology works at Walmart it appears to but whether it can be made accessible and economically viable for the independent grocers, regional distributors, and mid-scale food service operators whose collective waste contribution is substantial and whose participation is necessary for national targets to be achieved. Answering that question requires research designs capable of generating evidence that corporate sustainability reporting cannot: independent performance audits, controlled comparisons, and rigorous cost-benefit analyses in small and medium operator contexts. The present study identifies what the technology can do; establishing what it reliably will do across a broader range of organizational conditions remains the work ahead.

Future research priorities should include independent audits of corporate food waste claims, longitudinal studies tracking performance beyond the initial implementation period, and empirical investigation of adoption dynamics among smaller distributors particularly the conditions under which modular implementation strategies succeed or fail to deliver projected returns.

References

- [1] Buzby, J. C., Wells, H. F., and Hyman, J. (2014). The estimated amount, value, and calories of postharvest food losses at the retail and consumer levels in the United States. Economic Information Bulletin No. EIB-121. U.S. Department of Agriculture, Economic Research Service.
- [2] DCFmodeling. (2023). Sysco Corporation (SYY) DCF valuation model. Retrieved from <https://dcfmodeling.com>
- [3] Federal Communications Commission. (2020). 2020 Broadband deployment report. FCC 20-50. Washington, DC.
- [4] Food Dive. (2024). Walmart cuts food waste 12% since 2016, eyes 50% reduction by 2030. Retrieved from <https://www.fooddive.com>

- [5] Food Logistics. (2024). Retailers are using AI to improve demand forecasting. Retrieved from <https://www.foodlogistics.com>
- [6] FreshDirect. (2024). Sustainability and food waste initiatives. Retrieved from <https://www.freshdirect.com>
- [7] Gunders, D., and Bloom, J. (2017). Wasted: How America is losing up to 40 percent of its food from farm to fork to landfill (2nd ed.). Natural Resources Defense Council Issue Paper IP:17-05-A.
- [8] Gustavsson, J., Cederberg, C., Sonesson, U., van Otterdijk, R., and Meybeck, A. (2011). Global food losses and food waste: Extent, causes and prevention. Food and Agriculture Organization of the United Nations, Rome.
- [9] Kamble, S. S., Gunasekaran, A., and Gawankar, S. A. (2020). Achieving sustainable performance in a data-driven agriculture supply chain: A review for research and applications. *International Journal of Production Economics*, 219, 179–194.
- [10] Kroger Co. (2023). 2023 Environmental, social and governance report: Creating a more sustainable future. The Kroger Co., Cincinnati, OH.
- [11] Martin, S. L., Bhakta, R., and Singh, P. (2023). IoT-enabled cold chain management for reducing food spoilage in supply chains. *Journal of Food Engineering*, 338, 111–125.
- [12] McKinsey and Company. (2021). How technology is reshaping supply chain management. McKinsey Digital Supply Chain Practice.
- [13] McKinsey and Company. (2022). AI-powered decision making for the consumer goods supply chain. McKinsey Analytics.
- [14] Patel, K. J., Patel, H. R., and Shah, M. B. (2022). Temperature monitoring systems in cold chain logistics: A comprehensive review. *International Journal of Refrigeration*, 135, 45–58.
- [15] ReFED. (2021). A roadmap to reduce U.S. food waste by 20 percent. ReFED Solutions Database. Retrieved from <https://refed.org>
- [16] Relewise. (2024). House of Spices case study: AI-driven demand forecasting. Retrieved from <https://www.relewise.com>
- [17] Retail Dive. (2024). How Walmart is using AI to transform inventory management. Retrieved from <https://www.retaildive.com>
- [18] Sysco Corporation. (2023). Sysco's recipe for good: 2023 corporate social responsibility report. Sysco Corporation, Houston, TX.
- [19] U.S. Department of Agriculture and U.S. Environmental Protection Agency. (2015). U.S. food waste challenge. USDA Office of the Chief Economist and EPA Sustainable Management of Food Program.
- [20] Walmart Inc. (2022). Regeneration: Walmart environmental, social and governance report 2022. Walmart Inc., Bentonville, AR.
- [21] Walmart Inc. (2023). Walmart advances AI-powered supply chain innovation. Walmart Corporate Press Release. Retrieved from <https://corporate.walmart.com>
- [22] Waller, M. A., and Fawcett, S. E. (2013). Data science, predictive analytics, and big data: A revolution that will transform supply chain design and management. *Journal of Business Logistics*, 34(2), 77–84.
- [23] Zhu, Z., Chu, F., Dolgui, A., Chu, C., Zhou, W., and Piramuthu, S. (2018). Recent advances and opportunities in sustainable food supply chain: A model-oriented review. *International Journal of Production Research*, 56(17), 5700–5722.