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Review

Implementing a Circular Economy Approach to Prevent Food Waste: A Comprehensive Synthesis of Strategies, Metrics, and Systemic Deficiencies

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ABSTRACT

One of the most urgent issues in the governance of sustainable agri-food system is food waste, and about one-third of all the food produced is lost or wasted during supply chains all over the world. Nevertheless, despite increased policy focus, supported by Sustainable Development Goal (SDG) targeting to reduce per-capita food waste by half by 2030 and supplemented by a new European Union (EU) circular economy law, more applied research is focusing on downstream valorization at the expense of preventive interventions. This systematic review is based on 374 peer-reviewed articles identified through a systematic search in the Scopus, Web of Science, PubMed, and DOAJ databases using predefined keyword combinations. These articles were then screened and coded by supply chain stage, strategy type, intervention level, economic methodology, and evidence of implementation. The literature analysis indicates that eight structural gaps are present: a prevailing prevention-valorization asymmetry; the rhetorical use of Circular Economy (CE) as a framework instead of its operational use; lack of comparative supply chain-level assessment; weak connections between metrics and decision-making; lack of evidence of actual effectiveness; low-level economic methodological rigour—at least preventive interventions and Small and Medium-sized Enterprises (SMEs); poor examination of trade-offs and lock-in mechanisms; and weakening of retail and hospitality, restaurant and catering. To manage the diagnosis-implementation gap, the proposed study will incorporate an operational decision-support logic that will connect known structural gaps with actionable aspect of intervention pathways. In particular, the framework shows how the actors of the supply chain can switch in reality as to where the gaps are seen, and how to move to decisions by making hotspots mapping and intervention selection criteria and cost-based evaluations reflected in one process. This facilitates ordered construction of problem awareness to action, and

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increases practical applicability of the principles of the Circular Economy to the real-world agri-food systems.

KEYWORDS: circular economy; food waste prevention; agri-food supply chain; decision hotspots; cost analysis; accounting and ESG performance

INTRODUCTION

Food Loss and Waste (FLW) represents a systemic failure at the intersection of environmental, economic, and social sustainability. Globally, approximately 1.3 billion tonnes of food are lost or wasted annually, accounting for roughly 8%–10% of global greenhouse gas emissions and generating economic losses exceeding USD 1 trillion per year [1]. Within the European Union alone, an estimated 88 million tonnes of food is wasted annually, with associated costs of approximately €143 billion [2]. These figures underscore not only the scale of the problem but also the structural inefficiencies embedded within contemporary agri-food supply chains [3,4].

The policy response has been substantial. The 2011 EU Roadmap to a Resource Efficient Europe marked the beginning of coordinated action on food waste, while SDG 12.3 institutionalized a 50% reduction target for per-capita food waste by 2030 [5]. The EU Farm to Fork Strategy (2020) has cemented prevention as the preferred hierarchy of intervention [6]. Yet despite this regulatory scaffolding, empirical evidence on how to operationalize prevention remains fragmented, methodologically heterogeneous, and often decoupled from real-world decision-making contexts [7].

Circular Economy (CE) has become a key organizing principle of sustainability science, leading to growing hopes for its ability to systemically tackle food waste [8]. The CE principles, which include the maintenance of value in the material, the avoidance of waste through design, and the renewal of natural systems are a theoretically sound approach to the reconfiguration of food systems [9]. This review uses mainly the framework established by the Ellen MacArthur Foundation as the primary lens for the analysis, with the vocabulary, concepts and principles provided by ISO 59004:2024 (circularity performance—terminology, principles and guidance) as a secondary reference. The two-step adoption enables a structured and internationally recognized framework to classify interventions and to measure circularity beyond waste diversion. Systematic evaluations of the implementation of CE in food waste research, though, show a recurring disconnect between normative statements, values, and principles and their practical use [10].

The conceptual linkage between Circular Economy (CE) and food waste prevention is increasingly being examined through the lens of systems thinking and sustainable supply chain management [11]. Contemporary agri-food systems are highly complex networks involving multiple actors, including farmers, processors, distributors, retailers, and consumers, each influencing the generation or prevention of food waste [12]. Scholars argue that the persistence of FLW cannot be attributed solely to inefficiencies at individual stages but rather to coordination failures and structural misalignments across the entire supply chain [13,14]. Within this context, CE provides a framework that emphasizes closed-loop resource flows, industrial symbiosis, and regenerative production systems [15]. When applied to food systems, CE encourages practices such as improved forecasting and inventory management, by-product utilization, redistribution of surplus food, and the redesign of packaging and logistics to extend product shelf life [16]. Despite these conceptual advantages, empirical research indicates that the implementation of such practices remains uneven across regions and supply chain stages, with many initiatives concentrated at the post-consumer level rather than addressing upstream production and distribution inefficiencies [17].

Another dimension that has gained increasing scholarly attention is the role of technological innovation and digitalization in enabling food waste prevention within CE-oriented supply chains. Emerging technologies such as blockchain, Internet of Things (IoT) sensors, artificial intelligence—driven demand forecasting, and smart packaging systems offer new opportunities to enhance transparency, traceability, and efficiency throughout the food supply chain [18]. For instance, blockchain-based traceability systems can provide real-time visibility of product movement, thereby reducing uncertainty, improving inventory coordination, and minimizing spoilage during transportation and storage [19]. Similarly, predictive analytics can support retailers and distributors in aligning supply more closely with demand patterns, reducing the overproduction and overstocking that often lead to food waste. Smart packaging technologies capable of monitoring freshness indicators further enable stakeholders to make more accurate decisions regarding product handling and distribution [20]. However, while these technological solutions demonstrate significant potential, their adoption remains constrained by high implementation costs, limited interoperability between digital systems, and governance challenges related to data ownership and standardization.

A further critical aspect concerns the behavioral and institutional drivers that influence food waste generation and prevention across different governance levels. Food waste is not solely a technical or logistical problem but also a socio-institutional one shaped by consumer norms, regulatory frameworks, and market incentives [10]. Consumer behavior, particularly in high-income regions, plays a major role in food waste generation due to factors such as over-purchasing, misunderstanding of date labeling, and aesthetic standards for food products [21]. At the same time, institutional arrangements—including liability concerns for food donation, contractual practices between suppliers and retailers, and pricing strategies—can either facilitate or hinder prevention-oriented interventions. Policy instruments such as tax incentives for food donation, mandatory waste reporting, and standardized labeling reforms have shown promise in encouraging behavioral change and improving accountability within the food system [22]. Nevertheless, research examining the effectiveness of these policy measures remains limited and often context-specific, highlighting the need for more comparative and longitudinal studies that evaluate the real-world impact of governance mechanisms in reducing food waste under a circular economy framework.

This article addresses this gap through a systematic synthesis of the scientific literature on circular economy, food waste, and supply chain management. The review is grounded in a structured bibliometric and thematic analysis of 374 documents identified and screened through the Scopus database. The central objective is to map the structural gaps in existing knowledge and to develop a research agenda capable of supporting evidence-based, prevention-oriented decision-making across the agri-food supply chain. By doing so, this review makes four contributions: first, it documents the prevention-valorization asymmetry in the literature with systematic evidence; second, it critiques the operational deficit in CE applications to food waste; third, it identifies stage-level inequities in research coverage; and fourth, it proposes a gap-linked research agenda centered on decision relevance, comparative evaluation, economic grounding, and real-world effectiveness.

In addition to the recognition of structural flaws, this study specifically deals with the fact that how the structural flaws should be operationalized to form part of decision-making processes. In this direction, the paper presents a systematic decision-making framework which bridges (i) food waste hotspots identification, (ii) intervention based on the Circular Economy, (iii) effectiveness and feasibility assessment, and (iv) implementation within economic limitations.

The article is designed in the following manner. Section "Literature Review" outlines the methodological plan containing search strategy, inclusion, and exclusion criteria, analysis plan. In Section "Results", the thematic findings are provided and structured in accordance with the four research questions. Section "Methodology" brings together the eight structural gaps and evidences to support them. Section "Discussion" provides the implications of future research and practice. Section "Toward a Conceptual Framework for Food Waste Prevention under CE" ends by giving a prospective outline of food waste prevention within a CE paradigm.

LITERATURE REVIEW

Search Strategy and Database

The literature search was conducted in the Scopus database since it offers a huge number of peer-reviewed publications relevant to the worlds of environmental sciences, business and engineering. To reduce the selection bias and to also be comprehensive, we used three other major bibliographic databases identified as Web of Science Core Collection, PubMed and DOAJ (Directory of Open Access Journals) alongside the Scopus search. The search was done in the fields of title and abstract as well as keys words with the following Boolean query:

("circular economy" AND "food waste") AND ("supply chain" OR "cost" OR "eco-nomic analysis")

Each of the following queries was modified to meet the syntax of that database (either because of the use of the appropriate field tags and Boolean operators). Publications from 2011 till 2025 were only included if there had been important policy changes, such as the EU Resource Efficiency Roadmap, since their time of publication, in order to come to a better understanding of the current state of the discourse over the Circular Economy. It is only important that written articles written in English from peer-reviewed papers be only selected to ensure quality and uniformity [23]. The search query (NOT) operator was used in some cases as well to exclude the fields which are not related to the search term. The majority of the nature of these types of documents were confined to journal articles and reviews, other documents like book chapters and conference papers were perceived as secondary and kept to be used with the future trends in technology. All four databases generated a total of 21,876 records across all databases before Deduplication (Scopus: 14,444, Web of Science: 4210, Pub-Med: 2102, DOAJ: 1120). When duplicate data was removed there were 16,423 data records left. After applying the two filters, the number of records had reduced to 374. The screening and inclusion process is described in Section "Study Selection Process (PRISMA Flow)" and in a PRISMA flow diagram

Inclusion and Exclusion Criteria

The following categories were taken as the inclusion criteria:

(1) research into food waste in the framework of a Circular Economy;
(2) research (quantitative or qualitative) that is empirical or applied in nature;
(3) significance to any of the agri-food supply chains stages;
(4) access to full-text in English.

Exclusion criteria included:

(1) research that is not related to food waste or Circular Economy;
(2) non-peer-reviewed information (e.g., blogs, editorials);
(3) non-English publications;

(4) inadequate methodological transparency in studies;
(5) Studies published only as conference abstracts or book chapters were also excluded, as they typically lack the methodological detail required for systematic synthesis.

Selective inclusion of institutional reports (e.g., FAO, EU) was resorted to in order to support policy context.

Study Selection Process (PRISMA Flow)

The PRISMA framework was used to select the studies (Figure 1):

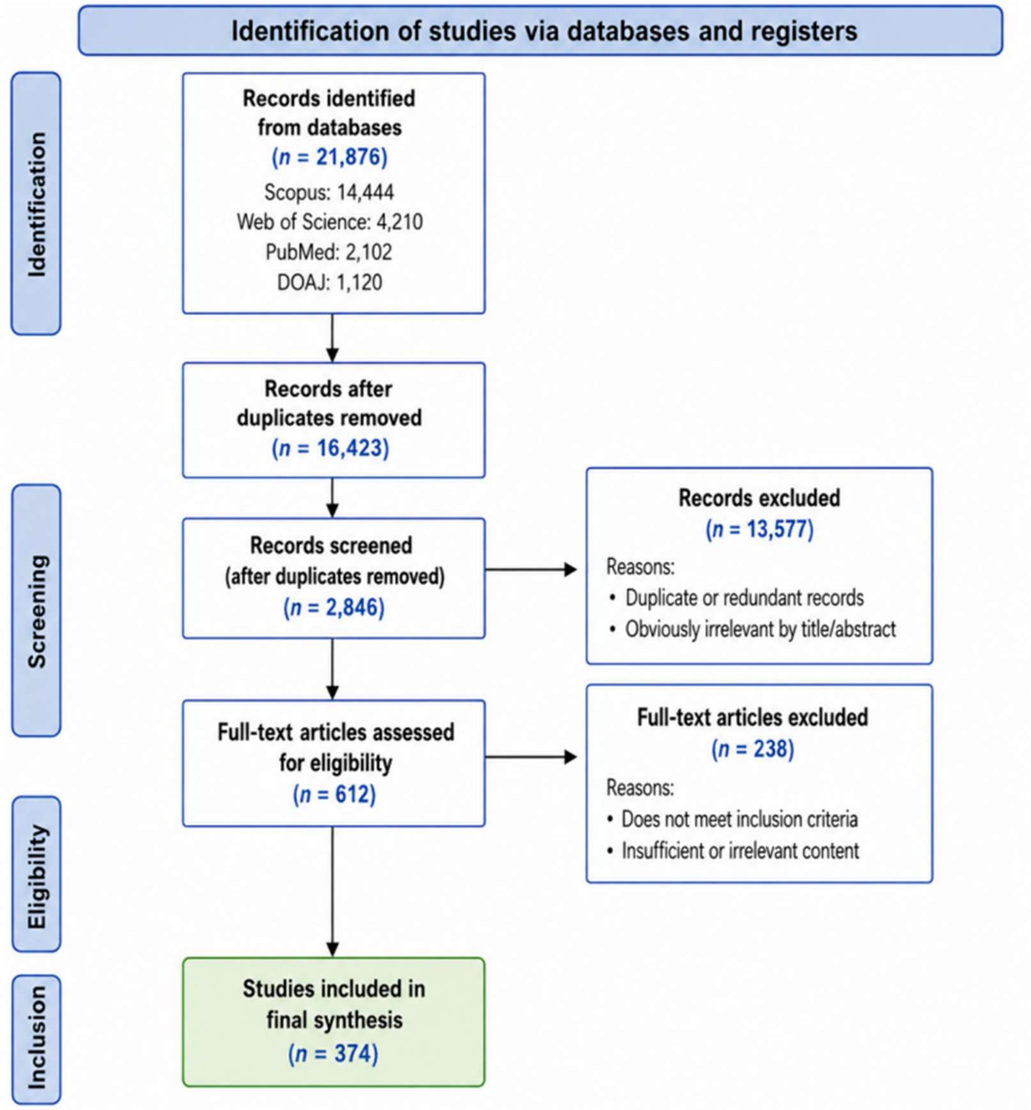

Figure 1. PRISMA 2020 study selection flow diagram [24].

- Identification: A total of 21,876 records were identified across four databases: Scopus (n = 14,444), Web of Science (n = 4210), PubMed (n = 2102), and DOAJ (n = 1120). After removing duplicates, 16,423 unique records remained.

- Screening: Following the elimination of the duplicates and obviously irrelevant records because of the titles and abstract screening, 2846 articles were left.
- Eligibility: These articles were assessed in terms of full-text, and 612 articles met the inclusion criteria.
- Inclusion: After careful screening and coding, 374 articles were included in the analysis.

Displayed is this multiple-stage filtering process to collect only the useful and good quality studies synthesized.

Screening and Coding

The screening was carried out in two stages. Phase 1 was title and abstract screening of the trials in relation to the inclusion criteria, which was carried out independently, and checked between them, to ensure their similarity. Phase 2 involved reading of records which passed the initial screening to completion. A subset of the articles was then coded based on: (a) stage of supply chain (production, processing, distribution, retail, Hospitality, Restaurant and Catering (HoReCa), consumer); (b) type of strategy (prevention, redistribution, valorization, optimization, systemic redesign); (c) level of evidence of implementation (yes, partial, theoretical only). A spreadsheet database was created to manage and structure the data and cross-deleting it with the Zotero reference manager system.

The coding results in the following allocation of the data in the analytical categories. At supply chain stage, production and processing influenced 47 per cent of articles (176/374), distribution and retail did so 22 percent (82/374) HoReCa influenced only 9 percent (34/374) and consumer-stage influenced 14 percent (52/374), with cross-stage studies representing the remaining 8 percent (30/374). With regard to type of strategy, the articles that are valorization-focused were 58 per cent (217/374) of the total. Prevention-based articles represented only 23 per cent (86/374) of the total. The redistribution and optimization strategies had 12 per cent (45/374) and 7 per cent (26/374) of the total, respectively. Homage to implementation showed only 19% (71/374) of papers were empirically validated under actual conditions of operation, 34% (127/374) were partially or pilot-scaled, and 47% (176/374) were purely theoretical or simulation-based. The degree of operationalization of the CE (scaled out of three (rhetorical, partial, operational) points) showed 62% (232/374) with the use of CE as a rhetorical framing, 26% (97/374) with the partial integration, and only 12% (45/374) with the full operationalization with explicit intervention mechanisms and criteria of decision making. The rigor of the economic methodology in use was similarly skewed: only 9% (34/374) used formal methods such as Cost-Benefit Analysis, Life Cycle Costing, or Techno-Economic Assessment, with the rest offering aims and objectives that were merely descriptive in nature of the costs involved.

The coding involved a systematic codebook that was established in several steps. In the stage of supply chain, articles were determined to the dominant stage of the analysis, cross-stage studies needed to specifically discuss at least two stages with systemic linkage. Docoding of strategy type Prevention was only do-coded in case the intervention targeted ex ante waste generation (e.g., forecasting, redesign) whereas valorisation required end-of-pipe treatment of already generated waste. Evidence based on partial implementation was allocated when the results were based on pilot studies, controlled experiments or simulations with specified limitations to real-world generalisability; theoretical only covered concept papers, without primary data. CE operationalisation was rated on a three-level scale (CE is mentioned only in the introduction or discussion without analytical application; CE principles inform the intervention logic but no decision criteria or trade-offs; CE embedded in research design and with measurable indicators and decision rules). A second reviewer independently coded a random 20% subset (75 articles). The inter-rater agreement in terms of Cohen, 0.84 stage, 0.79 strategy type, and 0.81 CE operationalisation. All discrepancies were solved in an agreement manner and the complete codebook is given as Supplementary Material.

The coding structure was also developed and intended to facilitate comparative analysis as well as multi-dimensional analysis. The studies were systematically coded on five dimensions: supply chain stage, type of intervention, the degree of Circular Economy operationalization, methodology of the economic approach, and implementation evidence. This hierarchical coding allowed comparing the cross-studies and determining systemic gaps.

Analytical Framework

The thematic synthesis was based on a pre-established gap-identification protocol, and it relied on the developed strategies in systematic literature reviewing applied to sustainability research. The synthesis was guided by four dimensions of analysis, which are (1) prevention orientation vs. valorization orientation; (2) depth of operationalization of CE; (3) coverage of and comparative capacity on the supply chain level; and (4) economic methodological rigor. These dimensions were then directly corrupted to the four research questions and eight structural gaps that were found in this review, which provided internal consistency on methodological design and the analytical outputs.

Notably, the analysis model aimed at contributing to the classification of available literature, as well as, decision-driven synthesis. The framework can be used to translate the insights of the literature into pragmatic implications of the supply chain actors and the policymakers by connecting each analytical dimension to the context of research gaps and decisions.

RESULTS

The Prevention-Valorization Asymmetry

The most structurally relevant discovery of this review relates to the great asymmetry between prevention efforts and valorization efforts research. Out of the 374 examined documents, the overwhelming majority focus on food waste by means of what can be done with food that already has turned into waste, i.e., on how it can be processed into energy, bio-based materials, or turned into compost [25]. This trend may be compared to previous analyses of literature CE that have reported a biased focus on end-of-life and recovery strategies and not redesign and reduction strategies.

The focus on valorization is not evil in itself; the strategies in bio-refinery, in particular, can play a useful role in enhancing the efficiency of the resources by creating value out of the waste that cannot be avoided [26,27]. Nonetheless, its systemic impact is that ex-ante measures intervention i.e., the one that can alleviate the waste generation in advance by modifying decision-making processes and supply chain flows and business model design, remain relatively underdeveloped, at least theoretically and empirically [28]. Research on the ways in which the decisions that have been made at the level of production, procurement, and distribution may be redesigned in order to reduce waste is much less prevalent, and is frequently not as rigorous a study as the valorization one [29]. This asymmetry strengthens what we can call a downstream lock-in: the warehousing of systems built around the valorization of waste implies that these systems actually rely on the continued production of waste in order to be viable [30].

The EU Waste Hierarchy has placed prevention at the top tier, reuse then comes after that is recycling, recovery, and disposal. The target of SDG 12.3 is the reduction of food waste, but not its better management as the measure of accomplishment [31]. But these normative priorities have not been reflected in the scientific literature. In a bibliometric review of food waste research, Cano et al. (2025) [32] and Gál et al. (2025) [33] affirm that the focus on the prevention is significantly lower than the focus on the end-of-life management, and the disparity in high-impact journals is even greater. It produces a mismatch between research and policy of practical direct implications practitioners of preventative interventions who demand literature that is relatively lean in operational specificity and empirical basis.

Crucially, the literature review reveals a tendency to frame prevention and valorisation as opposing strategies. We maintain that this is a concept mistake. In a CE scheme prevention is not necessarily an alternative to valorisation; the two are two distinct slices on a cascading value-retention chain. While prevention is the most valuable method for avoiding food waste, the CE method of valorisation (which could be composting, anaerobic digestion or bio-refining) is seen as a legitimate approach to avoidable by-products and residual streams when they are unavoidable, or cannot be avoided and re-distributed for human consumption. Rather than the lack of valorisation research, the issue is the overarching level of its prevalence in relation to the lack of prevention research, which leads to an imbalance creating a downstream 'lock-in' and thus an anti-incentive to redesign upstream. It is important to note that a balanced CE approach needs to include both approaches: the most maximizing of the prevention where both technically and economically possible and the most maximizing of the value recovery from the inevitable residual flows.

Circular Economy Integration: Between Rhetoric and Operationalization

One of the key aspects of the analysis relates to the nature of Integration of Circular Economy based on the literature reviewed. CE is found in an overwhelming majority of the 374 documents in the sense that its purpose is mainly rhetorical or abstract, as opposed to being operational. Articles continuously draw on CE as a validating context, i.e., citing definitions of its core or matching its findings according to the principles of CE in the discussion at its conclusion, without incorporating the concept of CE as an analytical instrument determining the framework of the research design, underpinning the logic of the intervention, or decision criteria [34].

The concept of operationalization in this context of the review is construed as the translation of the CE principles into specified intervention mechanisms, formulated intentions of success, quantifiable measures, trade-off analyses, and decision-relevant results [35]. The definition relies on the overall literature on the implementation of CE as it is widely acknowledged that the existing gap between the conceptual frameworks and operational tools is the most common obstacle to walking the short path to a more circular transition [36]. Compared to this criterion, only less than 20 of the studies reviewed can be considered as operationally integrating CE to food waste management; the others are considered as background normative framing of CE. Blackburn et al. (2025) [37] capture this tendency with the display of the ways in which technological innovations are contextualised within the framework of CE discourse without defining mechanistic connections between intervention design and CE outcomes.

In the absence of working CE structures, the possibility of judging the extent to which a particular intervention will move the circular transition or simply push wastes into a different level or jurisdiction is nonexistent. Strategies can also not be compared based on CE criteria, there cannot be trade-offs and there cannot be portfolio design of interventions that are jointly geared towards CE objectives. Balasbaneh et al. (2025) [38] apply fuzzy TOPSIS multicriteria analysis in order to illustrate the kind of structured decision-support that operationalized CE may offer- however their method is unparalleled as opposed to being standard in the academic realm. The fact that CE is seen more as a label than a framework is consistent with the criticism of CE as a practice expressed by [39], who chew a structural impediment of imprecision and abs definition-inconsistency in CE.

Supply Chain Coverage and Comparative Analysis

The third aspect of the thematic synthesis refers to how research interest spreads out among agri-food supply chain phases. The review demonstrates a strong focus on production and processing stages, and a significantly less impressive coverage on distribution, retail, HoReCa, and consumer stages. This disparity can be considered concerning the fact that empirical data about the food waste generation continuously shows that downstream food waste sources, especially those related to retail, HoReCa, and household consumer, contribute disproportionately significant proportions of aggregate food waste in rich nations [40].

Of special note is the underrepresentation of HoReCa. Hospitality, restaurant and catering industry deposits huge amounts of food waste via different mechanisms than those involved in production [41] or processing, such as through menu over-planning, standardization of portions, behavioral aspects, and the structural incentive to over-provide in service situations. However, the research on the CE-based interventions to use with HoReCa is slim and methodologically immature. Likewise, retail-scale waste, propelled by the cosmetic norms, over-stocking, markdowns, and supply-demand ratio, have received a comparatively few accesses to systemic solutions based on CE [42].

This is compounded by the fact that there is no comparative, supply chain-level assessments. Most of the research works have a one stage study or one case study design, and they will not be able to make comparative conclusions on which strategies are most effective in which circumstances and why. Hettiarachchi et al. (2025) [43] are unique in that they offer a comprehensive reversal, covering a multistage supply healthcare chain, of zero-waste processing [44] and carbon footprint estimation [45]. Likewise, a multi-dimensional nexus presented by [46] is a linkage of food, energy, water, health, and pollution on a supply chain level. Nevertheless, such cross-stage comparative analysis is still a minority in the reviewed corpus. Its practical impact is on a piecemeal evidence base that cannot serve to make portfolio-level decisions by the supply chain manager or policymaker, or even investors aiming to allocate prevention efforts effectively over the value chain.

Metrics, Measurement, and the Decision-Link Gap

The literature provides a significant amount of content devoted to the measuring, mapping, and estimating food loss and waste. Quantitative evaluations based on Life Cycle Assessment (LCA), material flow and input-output modeling have yielded more and more finer and detailed data on quantities of FLWs, hotspots and environmental impacts at supply chain phases [47].

In the analysis, a number of dimensions of this gap were determined. First, the metrics that are available are more of an output-oriented category than a decision-oriented one: they record the magnitude and location of waste without integrating measurement with causal processes or pathways of intervention [48]. Second, the lack of a framework of consensus upon what constitutes a real reduction in waste and what constitutes a shift in waste, manifested by improvements on a single stage that are counterbalanced by increments in a different part of the system, is to be found with [49,50] using an EOQ model to describe food waste circularity. Third, the literature seldom clarifies the types of key performance indicators (KPIs) that are best informative to which types of decisions they can apply-a vacuum that restricts the ability of the managers of supply chains to adopt measurement as a tool of management and not as a reporting tool. Fourth, digital and computational technologies, such as IoT-based monitoring, AI-based decisions forecasting, and blockchain traceability, have increased the technical potential of real-time measurement to a significant degree [51], but their connection to strategic decision-making models is not fully developed.

The metrics mapping, provided in Table 1, demonstrates the environment of the existing measuring instruments, their major applications in the literature and the particular gaps in decision-support that each tool has. It is identified that composite and prevention-specific measures, like Prevention Efficiency Index, are hardly found, whereas the environmentally and economically aggregated ones prevail [52]. This distribution promotes and enforces the bias in valorization recorded in the Section “The Prevention-Valorization Asymmetry”: a measurement system which is designed to record waste instead of avoiding it.

Table 1. Screening and coding results by analytical category.

Analytical Category	Sub-category	Number of articles (n = 374)	Percentage (%)
Supply chain stage	Production & processing	176	47%
	Distribution & retail	82	22%
	HoReCa	34	9%
	Consumer	52	14%
	Cross-stage	30	8%
Strategy type	Valorisation	217	58%
	Prevention	86	23%
	Redistribution	45	12%
	Optimisation	26	7%
Evidence of implementation	Empirical (real operational conditions)	71	19%
	Partial/pilot-scale	127	34%
	Theoretical/simulation only	176	47%
CE operationalisation depth	Rhetorical framing	232	62%
	Partial integration	97	26%
	Full operationalisation	45	12%
Economic methodology rigour	Formal methods (CBA, LCC, TEA, etc.)	34	9%
	Descriptive cost references only	340	91%

Economic Assessment: Breadth vs. Methodological Depth

Economic factors run through the food waste scholarship-around 2/3 of the 374 articles read in the review contain the economic vocabulary. Nevertheless, there should be a categorical difference between the reference to the economic dimensions and their strict methodological evaluation. The use of explicit economic techniques such as Life Cycle Costing (LCC), Cost-Benefit Analysis (CBA), Net Present Value (NPV) analysis, Techno-Economic Assessment (TEA), Monte Carlo simulation, and cost-based optimization could be found in about 34 out of 374 documents, which is about 9 percent of the corpus. This scientific flaw of the methodology is of two dimensions.

The former is the economic analysis of preventive measures, in particular. Most economic rigorous analyses investigate valorization or waste management opportunities [53], the production of hydrogen using municipal waste [54], the use of biochar in the environment [55,56], instead of the cost-effectiveness of preventive measures. However, as a decision-making scenario, the relative cost-efficiency of prevention against valorization is exactly the exposure that the practitioners need in the allocation of resource so as to efficiently allocate resource and warrant investment in upstream redesign. The apparent appeal of the validation avenues might not be a sign of cost-effectiveness but the impact of publication bias without stringent economic comparison [57].

The second dimension relates to the organizational particularism of economic evaluations. SME situation is under-serviced especially. In most European and developing-country settings, small and medium-sized enterprises dominate the agri-food environment, but there exist qualitatively different financial constraints than the large firm, such as an increased relative capital expenditure (CAPEX) burden, a greater loss thereof of access to green finance, shorter cash flows, and the inability to absorb operational risk [58]. Economic analysis aimed at large processors within industries or retailers working in multinational corporations cannot be implemented in the case of SMEs without significant modification [59]. Literature reviewed has limited the number of studies that directly discuss the SME financial contexts in the assessment of food waste prevention strategies as the critical gap since the policy goals, such as SDG 12.3 and the EU Green Deal, should be implemented at the whole range of the enterprise size [60].

SMEs face higher cost of capital as they are seen as being more credit risky and having less collateral. This is a structural barrier because many prevention investments that would have positive net present values over a 5- to 10-year period would not be of interest to SMEs under generally very short payback periods (usually 1–2 years) caused by the liquidity constraint. Furthermore, the cost of establishing formal economic assessment tools (Life Cycle Costing (LCC) or Techno-Economical Assessment (TEA) may render them impractical for micro-enterprises, and decision making on investment projects may be based on intuitive or “rule of thumb" approaches which systematically undervalues the possibilities of preventative investments. The economic analysis of large processors in industries or retailers in multi-national companies will not be possible in the SME case without adaptations or modifications [59]. Future studies should thus build adapted models of economic approach more adapted to the realities of SMEs: models based on LCC frameworks that are more simplified and have a shorter time horizon, models that have modular cost benefit analysis tools based on which less data is required and valuation models which are risk-adjusted and take into account the characteristics of SMEs which implies greater uncertainty and lower risk tolerance. This disconnect between measuring waste and acting to prevent it is illustrated in Figure 2.

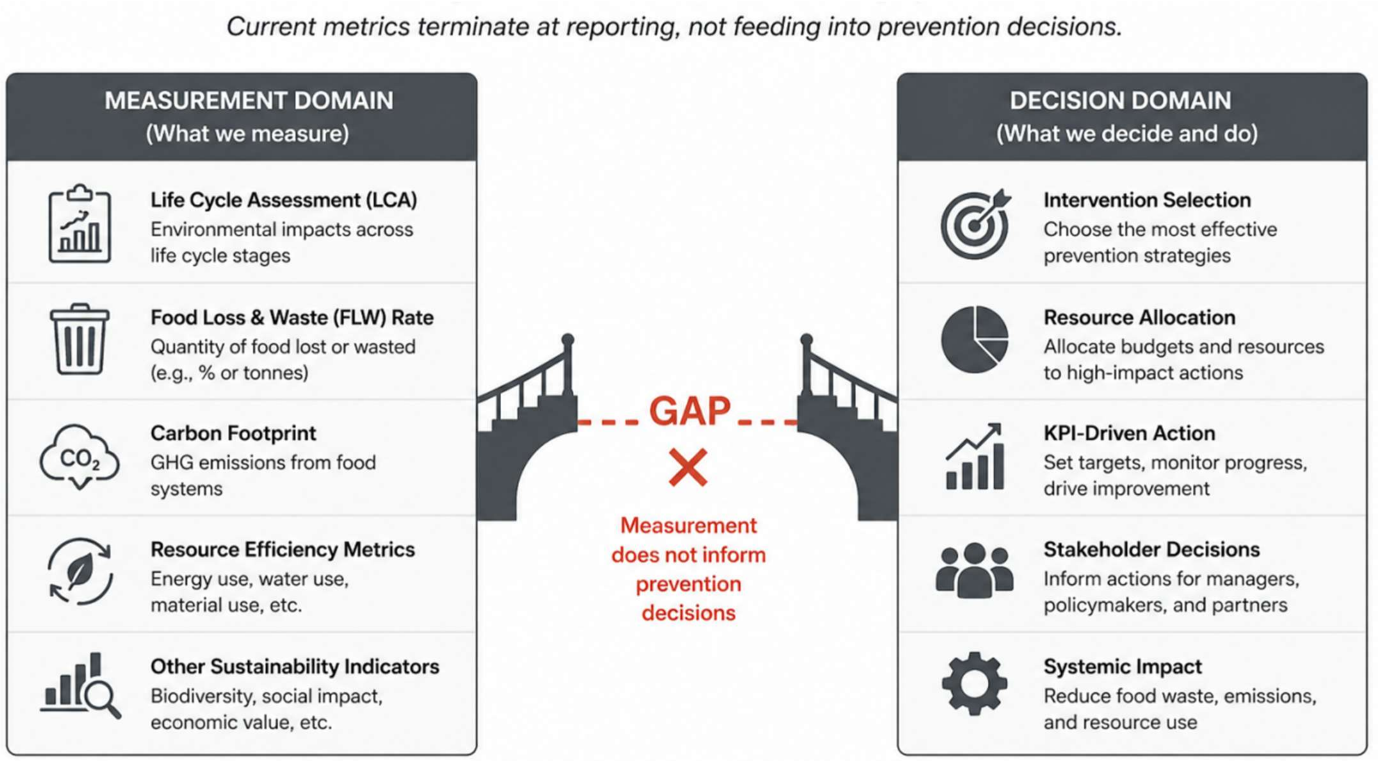

Figure 2. The decision-link gap: current metrics terminate at reporting rather than feeding into prevention decisions. Source: Authors, synthesised from [48,49,55,56,59,60].

Real-World Effectiveness and Transferability

Another structural gap implies the quality of the evidence related to effectiveness and its context-specificity. The literature is also full of investigations with positive results of food waste interventions- reduction of the volumes of waste, better use of resources, cost-effectiveness or environmental positive effect. But on closer scrutiny of study designs, it is apparent that a high percentage of these results are conditional, theoretical or obtained in controlled environments that may not be representative of the actual operational environments. Limited replicability Pilot studies, laboratory experimentation, simulation models, and case studies are a significant proportion of the positive evidence base.

Zhang et al. (2024) [61] report some of the more methodologically sound considerations of behavioral interventions targeting waste source separation with the results that stage-matched interventions can have a significant impact on participation rates yet that the effects vanish over time unless techniques are maintained through long-term reinforcement. This result identifies a tool of effectiveness that the literature has systematically not yet investigated: durability. Numerous studies indicate results at one point, which makes it impossible to identify long-term change in behavior, as well as operational change, and the effect of temporary compliance or a novelty effect [62].

There is an associated challenge with transferability. In the rare cases where its effectiveness has been demonstrated in the natural environment, the extent to which the results are generalized across the size of firms, institutional characteristics, national regulation frameworks, and supply chain designs are seldom studied in systemic terms [63]. In a review of the role of food industries in transition sustainability, Mylan et al. (2023) [64] point out the factors that allow the successful implementation in large-scale industrial settings are often inapplicable to smaller or less resource-intensive companies. The latter limitation applies especially to the HoReCa and retail industries, with their operational heterogeneity (restaurant types, categories of cuisine, customer segments, and supply chain relationships) preventing it from being possible to design and implement standardized interventions and evaluate them in large-scale settings [65].

Comparative Synthesis of Reviewed Studies

The comparative analysis indicates the presence of a number of structural patterns in the literature. To start with, downstream valorization studies are more likely to report good technical and economic performance but do not deal with the actual causes of waste production which further supports the prevention-valorization asymmetry revealed above. Second, prevention-based research, especially that which uses digital technologies, including IoT and AI, have a high potential to minimize waste at earlier supply chain levels, but implementation costs and scalability impede their adoption. Third, theoretical research based on principles of Circular Economy offers good theoretical frameworks but no operational mechanisms of how real-life decisions are made. Lastly, the economic studies are lopsidedly distributed, with extremely little emphasis laid on SME situations, even though they are predominant in the agri-food industry.

Collectively, these results confirm that the literature is still compartmentalized in per different types of interventions, methodological and supply chain phases, and as such, cannot be used to aid in integrated decision-making. This fragmentation is direct cause of the various structural gaps which have been identified in this review, specifically, the deficiency of comparative supply chain assessment (G3), the deficiency of connectivity between measures and determinations (G4) and the inadequate economic basis of deterrence strategies (G6).

Significantly, the comparative synthesis offers a basis to decision-support through cross-study analysis of intervention effectiveness, feasibility and applicability. This is because systematic comparisons of strategies in a variety of contexts can enable the decision-makers to have a more efficient measure of the kind of interventions that would be most suitable in particular stages of the supply chain and under certain conditions. This will bring the literature to a deeper level than the single case observations and more of an action-based evidence base.

METHODOLOGY

Summary of Eight Structural Gaps

The thematic analysis finds eight structural voids in the literature relating to the circular economy and food waste. The nature of these gaps is not independent, they make an interrelated system to shortcoming which, in its turn, limits the ability of the field to assist prevention-based decision-making. The most important description of these gaps and their interconnections with the four research questions formulated in Section "Research Questions" are given in Table 2 in an organized form.

Table 2. Metrics Mapping Framework: Food Waste Measurement Tools and Decision-Support Gaps (Source: Authors, derived from systematic analysis of 374 documents).

Metric	Measurement Unit	Category	Use in Literature	Decision-Support Gap
FLW Rate	kg wasted/kg produced	Quantity-based	Baseline measurement, benchmarking	Does not link to causal mechanism or decision
FLW Economic Value	€ lost year	Economic	Cost quantification, policy justification	Aggregated; masks stage-level drivers
Waste-to-Revenue Ratio	% revenue recovered from waste	Economic	Valorization performance	Incentivizes waste generation continuity
Prevention Efficiency Index	% waste avoided/intervention cost	Composite	Prioritization of preventive actions	Rarely used; methodologically underdeveloped
Carbon Footprint of FLW	kg CO_2-eq per tonne wasted	Environmental	LCA, sustainability reporting	Limited decision-support linkage
Supply Chain Loss Ratio	Stage-level waste/total input	Systems-level	Hotspot identification, targeting	Data availability challenges
Cost-Benefit Ratio (Prevention)	NPV/CAPEX ratio	Financial	Investment justification for prevention	Rarely applied, especially for SMEs

It is possible to group the gaps into three clusters. The first cluster—which involves the Gaps 1, 2, and 7—deals with the strategic and conceptual orientation of the literature: its emphasis on valorization over prevention, its use of rhetorical as opposed to operational CE, and its inability to analyse trade-offs and lock-in effects. All these gaps are restrictive to the normative value of the field in providing churnal transference. The second cluster—includes Gaps 3, 4, and 8—that relates to the analytical architecture and empirical architecture—the lack of comparative analysis, the low rate of connection to both metrics and decisions and the underrepresentation of downstream stages of the supply chain. Such gaps make the field less practically helpful in terms of making decision-making at the level of supply chain. The third grouping—with Gaps 5 through 6—has to do with the evidences of evidentiary quality of the literature: the paucity of available evidence of the effectiveness in the real world, and a methodological gap with regard to economic evaluation. These loopholes undermine credibility and applicability of knowledge claims that exist.

Although the eight structural gaps are a comprehensive diagnostic of the literature, they cannot be overly useful without regard to the way in which they are applied in decision-making. Every gap is representative of a particular point of managerial or policy decision. Considering these examples, the prevention, value biases (G1) have a direct impact on resource allocation choices and retribution performance management systems (G4). These gaps should thus be seen as triggers to decisions that facilitate the design and execution of interventions throughout the supply chain to go beyond the descriptive analysis.

Research Questions

With the identified gaps, four research questions are obtained in a systematic way and each question corresponds to one of the analytical dimensions and includes the full range of the deficits identified during the review.

RQ1: Mapping Losses Through a Decision Hotspots Logic

What would be the most effective way to map critical food loss and waste hotspots throughout the agri-food supply chain in a manner that would help bridge the gaps between where the losses occur and the mechanisms that create the losses and permits prioritization of preventive interventions? The requirement posed in this question is that FLW mapping requires a causal and decision-relevant methodology one that moves past quantification to determine how measurement and action are connected. It is associated with Gaps 3, 4 and 8 and puts the field to the challenge of coming up with mapping approaches that combine stage-based analysis, loss mechanism and prioritization of interventions into a logically consistent analytical structure.

RQ2: Operationalizing Circular Economy for Prevention

What is the extent of integration of Circular Economy as a working framework to food waste literature, and how the mainstream approaches are changing their own downstream valorization, to upstream prevention and redesigning the supply chain? This question aims to address Gaps 1, 2, and 7 of the rhetorical deficits to CE integration. It requires clear guidelines on how operational and conceptual CE use can be differentiated, and calls on the field to come up with supply management tools of supply chain management that formulated based on CE and spells out its intervention mechanisms, success criteria, and trade-off structures as applied to prevention-related supply chain management [66].

RQ3: Effectiveness in Real-World Conditions and Transferability

How effective is current preventive food waste reduction strategies in practice in implementation conditions, and which of the supply chain stage, firm size and type, institutional context is needed metrics of scalability and long-term sustainability of outcomes? This question answers Gaps 3, 5, 8, and the researcher looks to evidence beyond the conditional or the theoretical findings, to come up with strong conclusions based on what works, on what basis and on what lasts. It also prefigures the comparative aspect, which involves the study that cuts across several phases and organizational situations.

RQ4: Cost as a Selection Criterion

What role does cost—including capital expenditure CAPEX, operational expenditure OPEX, disposals costs, savings and risk exposure play in evaluation of food waste reduction strategies and what are the critical gaps in economic justification especially of preventive interventions and SMEs? It is a question that fulfills Gaps 5 and 6, requiring the creation of economically rigorous evaluation frameworks specially intended to prevent and adjusted to the financial limit and risk portfolios of SMEs. It further challenges the domain to come up with cost-based selection criteria that will hopefully allow the practitioners to select among competing strategies based on both economic evidence and environmental evidence [67].

DISCUSSION

Toward a Prevention-First Research Agenda

The overall results of this review provide evidence of the essence of a radical shift in the approaches towards food waste research in the context of CE. The recent trends in the literature, which include the prevalence of valorization, the rhetoric application of CE, incomplete coverage of the supply chain, and an ineffective economic foundation, are not just the result of the taste of the academia; they have a direct impact on practices. Supply chain management professionals are more likely to find an evidence-based literature providing advice on what to do with the waste once it has been produced than determining how to prevent the production of waste in the initial stages of development [68]. This imbalance should be resolved by a purposeful research agenda that emphasizes prevention, operationalizes CE as a decision support tool and constructs the evidence base on the effectiveness in the real world [69].

The prevention-first research agenda will possess various characteristics. It would place the research question in an upstream location whereby the issues, procedures and structural circumstances that create waste ex-ante are investigated and not the structural circumstances that control waste ex-post. It would utilize CE as a framework of analysis, and not a normative backdrop, indicating intervention mechanisms, trade-off structures, and success criteria that make an operationally meaningful sense [70]. It would put more emphasis on comparative and longitudinal designs that would determine which strategies have the best performance, at what circumstances, and how long lasting. It would entrench economic analysis across the board, not like an appendage, but as one of the dimensions to which strategy analysis is comprehensively molded, especially in the case of SMEs whose investment decisions are so cost-sensitive and risk-averse [71].

The possibilities of a focus on prevention are depicted by [72,73] when the authors investigate bio-based plastic substitutes based on cereal by-products and show that a redesign of packaging can not only minimize the amount of waste but also produce circular material streams. [74,75] describe an equivalent preventive or prevention logic in the design of food packaging and processing in one step with the use of systems level optimization in preventing downstream waste. Such studies are an indication of the kind of preemptive, proactive research that the discipline will require in order to magnify and multiply at more supply chain levels and organizational conditions [76].

CE Operationalization: From Concept to Decision Tool

The operationalization question that was revealed in this review is not strictly a scholarly matter. This practical ability of agri-food enterprises, retailers and HoReCa operators to interact with CE depends upon the presence of operational frameworks that can implement principles into tangible choices [77]. Conceptual tools applied by the Ellen MacArthur Foundation such as the butterfly diagram, the R-framework (Reduce, Reuse, Recycle, Recover, etc.), and so on have offered valuable heuristics, but heuristics is not a decision structure [78,79]. Figure 3 visualizes the priority hierarchy.

Decision systems are a specificity of logic of action or intervention, i.e., what to do, when, why, and at what cost, expressed in terms which can be turned into operationalized within the structures of the organization and its supply chain [80].

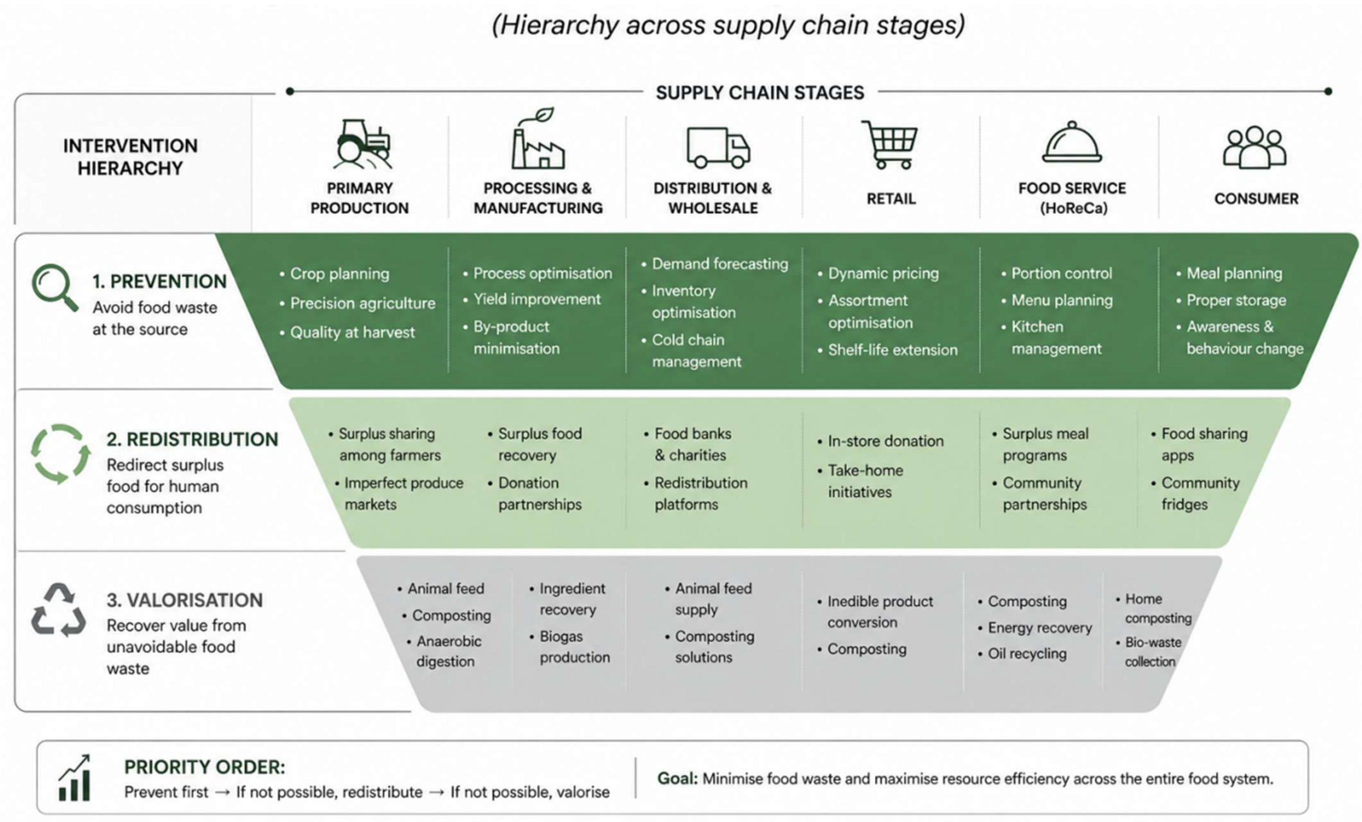

Figure 3. CE intervention hierarchy for food waste prevention across the agri-food supply chain. Source: Authors, synthesised from [8,9,78,79].

Such frameworks would aim to achieve the following (minimal): (a) a decision-specific taxonomy of preventive interventions; (b) a taxonomy of CE performance targets associated to decision criteria; (c) a trade-off evaluation and lock-in assessment methodology; and (d) an economic assessment module that would be calibrated to various organizational levels. The classification of the strategies given in Table 1 is an initial step towards that, synthesizing the available literature into a typology of intervention strategies by type, supply chain stage, whether orientated or not, indicated potential level of effectiveness, and cost implication. Table 3 metrics mapping also offers an ordered foundation in coming up with measurement systems related to decision. Collectively, all of these components make up the foundation of a working CE framework of food waste prevention capable of being optimized by means of empirical research and adjusting to a particular organizational environment [81]. The classification in Table 1 is complemented by Table 3, which compares selected empirical studies, while Tables 4–6 respectively map the structural gaps to research questions, classify prevention strategies by cost and impact, and analyze stage-level loss drivers and research coverage.

Table 3. Comparative Analysis of Selected Studies on Circular Economy and Food Waste.

Study	Focus Area	Supply Chain Stage	Key Findings	Methodology	Limitations
Study A (e.g., bio-refinery research)	Valorization	Processing	High efficiency in waste-to-energy conversion; improved demand	Techno-economic/LCA	Does not reduce upstream waste generation
Study B (IoT forecasting)	Prevention	Distribution/Retail	Forecasting reduces overstocking	AI/Predictive analytics	High implementation cost
Study C (food donation systems)	Redistribution	Retail	Reduces surplus waste through secondary markets	Case study	Dependent on policy frameworks
Study D (smart packaging)	Optimization	Cross-stage	Extends shelf life and reduces spoilage	Experimental	Limited scalability evidence
Study E (CE conceptual frameworks)	Conceptual	All stages	Strong theoretical alignment with CE principles	Conceptual	Lack of operational tools
Study F (SME-focused study)	Economic	Processing/SME	Cost constraints limit adoption of CE practices	Cost-benefit analysis	Limited generalizability

Table 4. Structural Research Gaps and Corresponding Research Questions (Source: Authors, based on systematic analysis).

#	Gap Label	Description	Linked RQ
G1	Prevention vs. Valorization Bias	Literature converges on downstream waste-to-X pathways; preventive ex-ante decision models are insufficiently documented	RQ2
G2	CE as Label vs. Framework	Circular Economy used rhetorically; lacks operational mechanisms, intervention logic, and success criteria for prevention	RQ2
G3	Lack of Comparative SC Evaluations	Studies focus on isolated SC stages; no comparative analysis across conditions or mechanisms explaining effectiveness	RQ1, RQ3
G4	Metrics Without Decision-Link	Extensive FLW measurement; weak translation into actionable prevention decisions or KPI-to-decision pathways	RQ1
G5	Real-World Effectiveness Gap	Shortage of evidence on sustained waste reduction under real operational conditions beyond pilots or theory	RQ3
G6	Cost Methodologically Underassessed	~9% of studies use rigorous economic methods; preventive interventions and SME contexts especially underserved	RQ4
G7	Trade-offs and Lock-in Mechanisms	Circular solutions rarely subjected to critical evaluation of dependency, burden-shifting, or long-term side effects	RQ2
G8	Underrepresentation of HoReCa & Retail	Production/processing stages dominate; downstream stages where significant real-world waste materializes are neglected	RQ1, RQ3

Table 5. Strategy Classification Matrix for Food Waste Prevention in Circular Economy Context (Source: Authors, derived from systematic literature analysis).

Strategy Type	Key Interventions	Primary SC Stage	Orientation	Effectiveness Potential	Cost Implication
Prevention	Pre-harvest planning, demand forecasting, product design	Production, Planning	Upstream	High (ex-ante)	Low to moderate
Redistribution	Surplus food reuse, food banks, secondary markets	Distribution, Retail	Mid-stream	Moderate (conditional)	Low
Valorization	Composting, biogas, bio-based products, energy recovery	Processing, Waste Mgmt	Downstream	Moderate (waste-dependent)	Moderate to high
Optimization	IoT, AI-driven inventory, smart packaging, cold chain	All stages	Cross-cutting	High (real-time)	Moderate to high
Systemic redesign	Supply chain restructuring, business model innovation	Systemic	Cross-cutting	High (structural)	High (CAPEX-intensive)

Table 6. Supply Chain Stage Analysis: Loss Drivers, Interventions, and Research Coverage (Source: Authors).

SC Stage	Key Loss Drivers	Dominant Interventions	Waste Share	Literature Coverage	CE Operationalization
Production	Climate variability, harvesting losses, over-production	Demand forecasting, crop planning, precision agriculture	High	Strong	Moderate
Processing	Quality rejection, by-product generation, over-processing	CE valorization, process optimization, bio-refinery	High	High	High
Distribution	Cold chain failures, transport damage, over-ordering	Smart logistics, route optimization, traceability	Moderate	Moderate	Moderate
Retail	Cosmetic standards, overstock, markdown policies	Dynamic pricing, AI demand management, supplier redesign	High	Weak	Moderate
HoReCa	Menu over-planning, portion size, consumer behavior	Plate waste reduction, menu engineering, behavioral nudges	High	Weak	Low-Moderate
Consumer	Purchasing behavior, storage practices, confusion dates	Education, packaging redesign, date labelling reform	High	Moderate	Low

CE principles need to be turned into plain evaluation criteria: expected waste reduction impact, feasibility, cost implications, and systemic trade-offs. Providing consistency in relation to the criteria applied to the various interventions enables supply chain actors to prioritise interventions both on the theoretical level and based on measured and comparable results. This allows the shift from CE as anormative ideal to an operational tool for strategic and operational decisions in agri-food systems [80,81].

Consistent assessment tools may also help to facilitate implementation in various supply chain settings. These kinds of approaches can help managers with the essential understanding of sovereignty's effect on programme outcomes, identifying interventions that are scalable and tracking long-term results in reduced waste, cost and the resilience of the system [80,81]. Incorporating CE principles into procurement, logistics and planning processes can help agri-food businesses in systematically progressing their sustainability target and continuously improve their organisation.

They have to be adapted to the particularities of the agri-food value chain, such as its perishability, seasonality, variability of the flows of supply and demand and the diversity of actors from farm to retail outlet from smallholder farmers to large retailers [25,58] when it comes to food waste prevention. This study proposed the decision-support logic using these frameworks to connect CE conceptual understandings to supply chain decisions ranging from hotspot diagnosis to intervention selection to economic feasibility assessment.

Cross-Sectoral Circularity and Industrial Symbiosis

A key attribute of the Circular Economy is the ability to circulate biomass, materials, nutrients and products—by cascading, industrial symbiosis and substitution—in a way that extends beyond an individual supply chain, but rather, between industries, sectors and provisioning networks. Although these wider systems thinking is integral to modern CE thinking, it is a stream that is relatively little explored in food waste literature.

The vast majority of circular solutions involve agri-food by-products beyond the core food system. An ever-expanding range of industries are benefiting from the use of agricultural by-products, fruit wastes, brewers' spent grain, whey, oilseed meal and other processing residues as raw materials such as biobased solvents in chemicals, bio-raw materials for pharmaceuticals including the extraction of active compounds, construction materials (e.g., biobased insulators), packaging (e.g., bio-based films), fabrics (e.g., citrus-fibre), biotechnology (e.g., feedstocks for fermentation) and energy (e.g., bio-raw materials for production of biogas and biofuels) [72,73]. The cross-sectoral pathways are mostly at the bottom of the food waste hierarchy when compared with prevention or redistribution activities but they are large scale and well-established CE activities which add to the value of resources.

The literature however is focused on the edge of the agri-food value chain and valorisation was mainly seen as a last mile solution within the agri-food value chain. Such a sectoral "silo approach" makes it hard to understand the full potential of CE for value generation through inter-industry collaboration, governance, logistical and economic pathways which facilitate cooperation between industries. Future studies would thus benefit from considering the facilitation and barriers of industrial sectors in creating industrial symbiosis networks, detailing how food waste can be used as a substitute for raw materials in other sectors and assessing the policy and infrastructure for supporting the upscaling and acceleration of such circular flows.

Supply Chain-Level Analysis and the HoReCa-Retail Deficit

The lack of HoReCa and retail stages as the underrepresented aspects in the analyzed works has its consequences, especially since the amount of food waste at such stages is vast. In the EU, households take a share of around 53 percent of the total food waste, with processing (19 percent), food service (11 percent), primary production (10 percent), and retail (5 percent) [82]. Although these numbers are country-specific and they depend on the approach to measure the waste, they all point to the fact that downstream waste is quite significant and systemic interventions at retail and HoReCa levels may achieve dramatic absolute reductions in the total volumes of food waste [83].

The available empirical evidence about these stages is however promising, but with caveats for context. longitudinal studies in the retail market suggest that adjusting prices using dynamic pricing and markdown optimisation can curtail the waste of fresh produce by 18%–25% in a consistent fashion across 12- to 18-month periods, but the benefits would be less marked if the pricing algorithms were not frequently revised to reflect changing demand patterns [80,83]. Likewise, multi-case studies of supermarket initiatives for tracking waste show that reductions ranging from 15% to 20% can be made if the stores can gain access to real time inventory visibility and their suppliers are coordinated [42,83]. Empirical evidence has become even more sparsely available in the HoReCa sector, but early findings of the ongoing research into introducing AI sensor devices to track plate waste in an HO have shown that, as in the FSR sector, by following the principles of the menu engineering approach and the standardisation of the portion size, plate waste can be reduced by between 20% and 30%, while the persistence of these effects has been strongly correlated with staff engagement and frequent monitoring [61,84]. These results highlight the critical importance of the quality of intervention implementation, the organisational culture, and regular monitoring for supporting real-world effectiveness, which are seldom discussed in brief pilot studies or simulated studies of interventions. More longitudinal, multi-site empirical studies to monitor the outcomes of interventions with multiple measures over multiple years and across a variety of operational contexts are needed in the field to build an evidence base for the effectiveness of interventions that might be scaled out.

Although Circular Economy is well known as a conceptual guideline on sustainable use of the resources, its implementation in literature on food waste is still mostly conceptual. In alleviating this shortcoming, this paper revitalises Circular Economy as a decision support framework made to facilitate systematic appraisal and choice of interventions through agri-food supply chains. CE, in this case, is not merely a normative ideal, but it occurs in the form of a device that helps to formulate concrete strategic and operational decisions.

The suggested framework will convert the principles of a Circular Economy into a decision process in steps. The first step involves diagnosing the critical waste hotspots in the supply chain stages through diagnostic metrics by decision-makers. Second, they categorize the possible interventions based on the priorities of the CE hierarchy, with prevention strategies being more important than redistribution and valorization. Third, alternative interventions are assessed in terms of anticipated effectiveness, feasibility and scalability. Fourth, financial viability is assessed by the consideration of the economic aspects such as capital expenditure (CAPEX), operational expenditure (OPEX), and the payback. Lastly, the implementation and monitoring of performed interventions is done with the help of performance indicators tied to the outcomes of waste reduction.

It is likely that the relatively low level of research coverage of the stages stems from a complex of factors: there is the operational heterogeneity of the HoReCa (especially fragmented small-business environment of restaurants and caterers); there is the commercial sensitivity of waste data on retail; there is the behavioral difficulty of consumer-facing waste interventions; and there is a perceived lower-visibility profile of retail and HoReCa in comparison with the more manageable engineering puzzle of production and processing [84,85] To overcome this shortage, intensive research on the following aspects is needed (a) systematized mapping of waste drivers at HoReCa through standardized audit procedures; (b) investigation of behavioral and operational interventions in reality conditions of the HoReCa business model; (c) economic analysis of prevention strategies based on the HoReCa business model; and (d) comparison of CE integration opportunities across the various hospitality categories. An appropriate example, which was given by [86], is the analysis of food waste harnessing to feed the sustainable hog farms, which demonstrates the potential of the circular solutions in the food service settings, but prevention is the priority. Figure 4 illustrates the structural components and operational flow of the proposed framework.

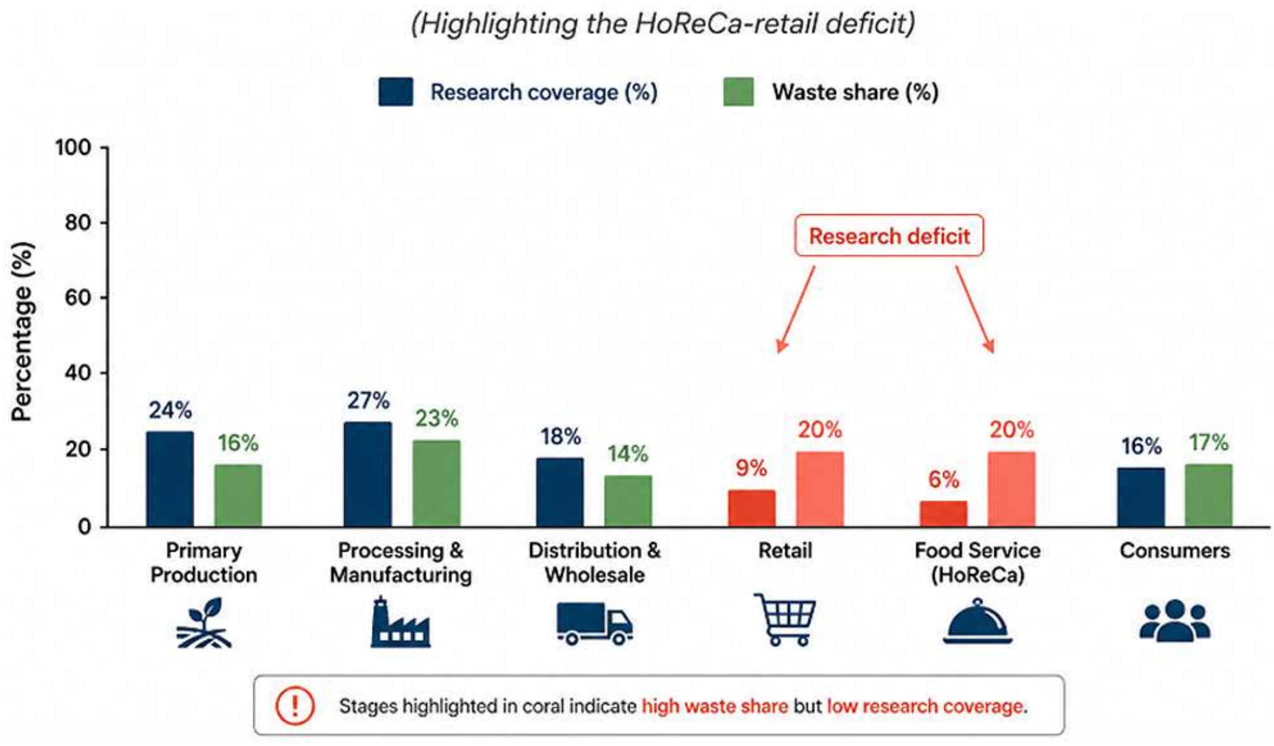

Figure 4. Research coverage vs. waste share by supply chain stage, highlighting the HoReCa retail deficit. Source: Authors, derived from [82–85].

This decision logic is operationalized in Strategy Effectiveness -Cost Matrix that arranges the interventions in a visual form based on their comparative cost and effect. It allows immediately recognizing priorities of high strategies, especially among SMEs of which it is profitable to concentrate on high-effect and low-cost actions. By doing so, the matrix acts as a viable intuition of the Circular Economy paradigm, providing the principles in an abstract form into real investment choices.

Notably, the approach to decision support fares well to close the structural gap that was noted in the literature. It helps address the prevention-valorization imbalance by providing an upstream emphasis on intervention, the metrics-decision divide by connecting the indicators with action and enhances economic foundation with cost assessment assessments. It also helps in breaking the fragmentation between supply chain stages and methodology, as it facilitates the cross-intervention comparison.

This study is an effort that will further inform both theory and practice with regard to food waste management by converting the idea of Circular Economy into a practical tool of decision-making. It offers an organized framework of converting theoretical knowledge into practical measures, thus increasing the applicability of Circular Economy in the context of practical supply chain decision-making.

Economic Grounding and SME Relevance

Even though the economic constraints are a very common aspect that has been well recognized in the literature, they are hardly put in a coherent decision-making framework. The given study fills this gap by presenting an economic decision logic that can be included with the Circular Economy framework and help evaluate interventions based on their environmental impact as well as financial viability. This is quite essential to small and medium-sized enterprises (SMEs), that work within resource limits of a considerable scale.

It is however important to note that the opportunities and limitations of SMEs and large companies are not comparable, but complementary. Therefore, the discussion on research and policy needs to be balanced and take both into consideration. Given that SMEs are more agile, embedded within local environments, and have flatter organisational hierarchies, niche innovations such as hyper-local-upcycling, community-based redistribution systems, customised packaging solutions are frequently developed there, can be piloted quickly and easily, and can be adjusted to local community needs [58].

On the other hand, large food manufacturers and retailers also have the scale, there are some certain by-product generation, well-established quality control systems (processes), and capital support infrastructure that enables them to put in place capital-intensive valorisation plants (such as bio-refineries), and to carry out extensive distribution logistic chains [64]. They have regular delivery patterns which helps them to enter into long-term deals with off-takers such as energy companies, chemical manufacturers and other bigger companies etc.—deals which can be difficult for individual SME's. This more well-rounded research agenda would also fail to concentrate exclusively on the deficit perspective of SMEs and go on to examine how large companies can incorporate innovations developed by SMEs through procurement policies, co-investment mechanisms and technical assistance programmes. Similarly, discrimination should be used in the policies giving support to SME experimentation (via grants and advisory services) or large firm industrial symbiosis (via regulatory incentives or infrastructure investment).

This limitation in the economic evaluation methodology found in this review (or about 9% of studies involving the use of rigorous economic methods) is one of the most significant gaps to make in practice. Supply chain management involves investment decisions that are inherently economic: depending on the evaluation of capital costs, operational costs, savings, payback periods, the exposures of risks, and opportunity costs [87]. In the absence of such an economic background, the evidence base of food waste prevention would be of insufficient decision-relevance to affect resources allocation among firms, investors, or policymakers [88]. Figure 5 maps the eight identified structural gaps to the four corresponding research directions.

Figure 5. Eight structural gaps mapped to four research directions. G = Gap; RD = Research direction. Source: Authors, derived from systematic analysis of 374 documents; [10,32,34,58,81].

This apprehension is magnified under the SME dimension. More than 90 percent of food businesses within the EU are SMEs, and the financial environment that applies to these businesses is qualitatively different than that that applies to large corporations, as SMEs have tighter cash flow constraints, have less access to capital, CAPEX that is relatively high, and limited vulnerability to the disruption of operational operations during periods of transition [89]. The type of economic evaluations that stems out of big time industrial cases cannot be straightforwardly applied to SMEs and the lack of economic analysis of the SMEs in the food waste prevention literature places the latter without sufficient proof to justify investment in circular strategies [90]. To develop an economic evidence base that is relevant to SMEs, it is necessary to have: applicable accounting costs accounting models of food waste; industry specific financial frameworks; cost-benefit approaches that are risk-adjusted; and available guidance-related feature tools that allow the SME manager who lacks specialized economic knowledge to estimate the value of prevention investments [91].

An important extension of this economic rationale is the difference between the expenditure (capital and operational expenditure) or the capital expenditure (capital expenditure or CAPEX) and operational expenditure (operational expenditure or OPEX) because these types of costs are important determinants of adoption. Interventions with high CAPEX can include, but are not limited to, advanced cold chain, AI-designed monitoring, or industrial symbiosis platforms and demand substantial investments yet could result in long-term benefits of efficiency and wasteness reduction. Conversely, low-CAPEX, low-OPEX plans, including inventory optimization, employee training, better demand, and redistribution partnerships, have the potential to be readily implemented and low financial risk. This difference allows decision-makers to match the choices of interventions to their potentials in terms of financial capability and strategic time-range.

Based on this difference, a feasible rule of decision can be developed to be used to conduct an implementation. These interventions are potentially the best because they provide the highest returns as far as resources are limited, and they should be implemented in organizations at the lowest cost of deployment and highest level of impact. More consideration and careful application should be considered in high-CAPEX strategies and only taken up in the case long-term returns, scalability, and aligning with the strategic goal is deemed to reimburse the investment. High-cost and low impact intervention on the other hand should not be adopted unless it is stipulated in the regulations or compliance issues. This rule would simplify complicated financial considerations to a systematic and practical selection procedure.

The Strategy Effectiveness-Cost Matrix (Figure 6) directly realizes this economic logic by ranking interventions based on total cost of ownership which is the cost of ownership (CAPEX + OPEX) and anticipated effect. Strategies in the high-impact, low-cost quadrant could be considered the most cost-effective interventions and could be implemented especially quickly. Conversely, high-impact, high-cost quadrant interventions are those that need meticulous financial planning, risk evaluation and extended investment paybacks. The matrix thus offers a visual decision-support tool that orientates they supplement the analytical framework and improves clarity of strategy.

Another methodological shortcoming is the focus on formal cost benefit modelling in the particular context of prevention interventions. A large number of tech-no-economic assessments of valorisation pathways are available in the literature (e.g., bio-gas, composting, bio-refining) [53,57] but comprehensive cost benefit analysis of preventive measures in the upstream on the inventory or packaging with redesign or cold-chain improvements are remarkably rare. This asymmetry is partly explained due to the more complex nature of the attribution: the prevention benefits are widely diffused and are present at lengthy time periods, and are usually brought on by external incentives or behaviors like shifts in consumer habits, regulatory modifications or price volatility in the marketplace [88]. There is almost no application of more sophisticated modelling methods such as real options analysis (which puts a value on flexibility in investment time) and probabilistic Monte-Carlo simulation (which accounts for un-certainty over cost and benefit estimates) in the literature on food waste prevention in SMEs; these methods are formidable tools for some food waste challenges. Modeling and testing these for prevention investments would give decision makers the economic information they need to make an up-front investment, secure funding, and take part in the competition for scarce internal capital priorities when determining investment orders.

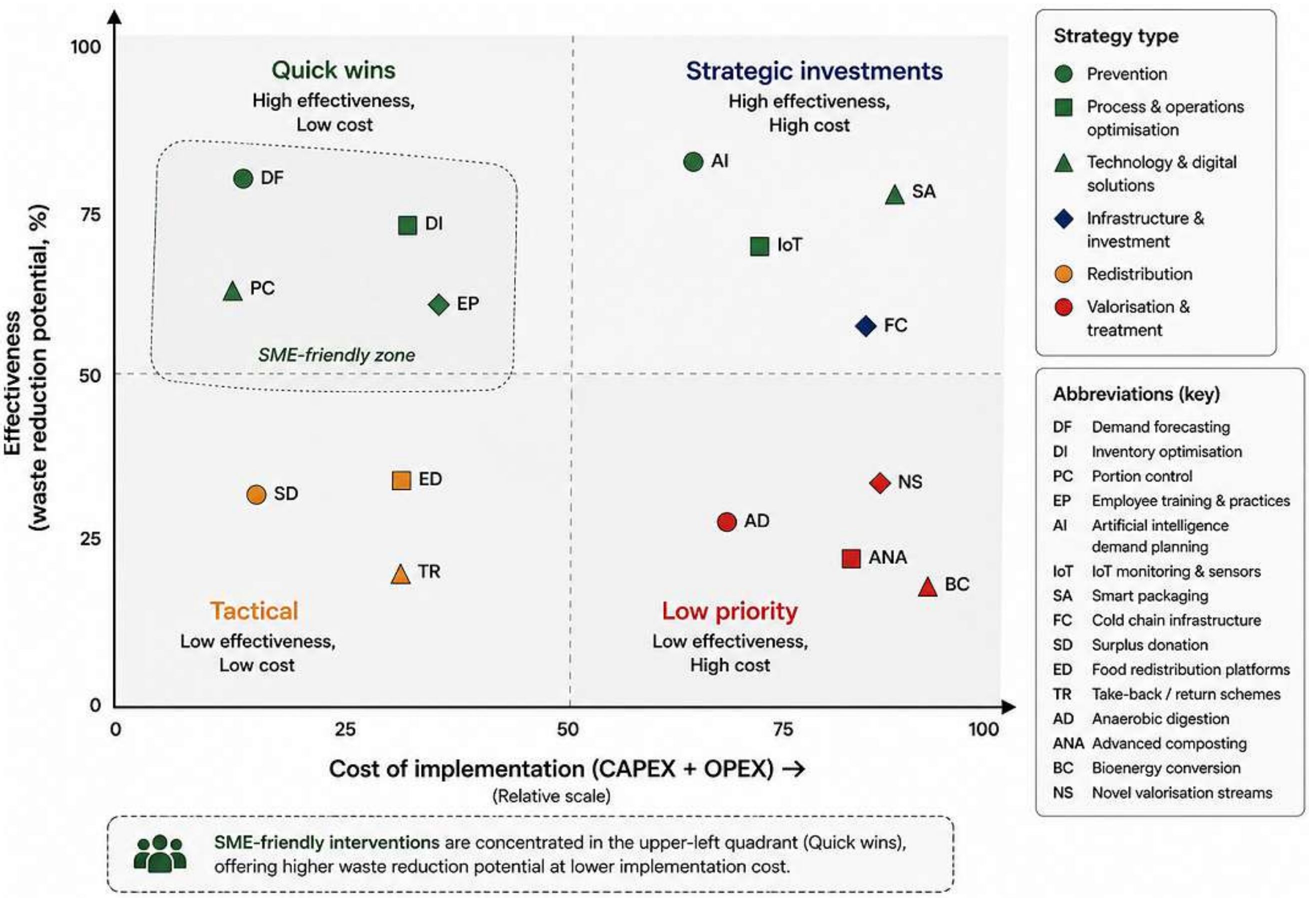

Figure 6. Strategy effectiveness vs. cost matrix.

This economic framing is critical especially to the views of SME. SMEs have, in most times, limited financial flexibility, to embrace capital-intensive technologies though the short-term gains may be effective in the long run. Consequently, a lack of structural fit between numerous of the solutions put forward in the literature and reality of SME adoption capacity exists. The focus on low-cost high-impact interventions makes this study a much more feasible and accessible route to the involvement of SMEs in Circular Economy practices, thus raising the chances of permeating the entire agri-food sector.

This economic viewpoint directly tackles the specified economic gap (G6) as it incorporates cost considerations into the decision-making process instead of considering them as additional constraints. It also helps towards, closing the implementation gap in that, implementation recommendations are adjusted to financial feasibility so that the proposed interventions are not only theoretically, but practicable within the organization constraints.

This research helps enact the economy beyond descriptive findings in its literature by applying cost structures, investment logic and organizational restriction into the greater analytical paradigm to better provide actionable financial decision support. This enhances the scholarly value and practical implication of the Circular Economy strategies, making the framework an instrument that could be useful in providing guidance to actual practice in managing food waste.

TOWARD A CONCEPTUAL FRAMEWORK FOR FOOD WASTE PREVENTION UNDER CE

Introduction to the Conceptual Framework

The conclusions of this systematic review can be synthesized to ensure the elaboration of an initial conceptual framework aimed to direct food waste prevention in a Circular Economy (CE) approach. Food waste has become one of the major sustainability issues of the agri-food systems all over the world, which need to be addressed by different strategies that are no longer focused on waste management as the ultimate measure but on the prevention of food waste practices [92]. The most adequate approach is the circular economy, which focuses on the minimization of waste, maintenance of material value, and reformation of natural systems [93]. Unlike the traditional linear economic framework, more often referred to as a take-make-use-dispose framework, the circular model aims at designing waste off the systems and retaining resources in use as long as possible [94].

Based upon the structural gaps they suggest in the literature review, this conceptual framework will combine four analysis axes that reflect four research questions that have been formulated earlier in the research. The axes include; decision hotspots mapping, CE operationalization, effectiveness and transferability, and cost integration. All the axes depict critical dimensions that are needed in the design and provision of prevention-oriented strategies in agri-food supply chains. Notably, those axes are not supposed to be regarded as the stages of the decision that follow one another; they are parts of wider decision-support architecture that are linked to each other. Proper food waste prevention will only become possible when these dimensions are considered and introduced in an integrated decision-making process [75]. The framework thus has the purpose of offering theoretical consistency and practical recommendations to the researchers, policymakers and supply chain managers interested in minimizing food waste using circular initiatives.

The contribution of our proposed framework is significant, but not in isolation. It explicitly draws upon and integrates existing operational frame work from the literature. To derive these, we refer to the Circular Capability Framework proposed by Kusumowardani et al. (2021) [95] that identified CE antecedents, principles and outcomes in agri-food SSCs, and to the integration model of CE proposed by Cahyadi et al. (2024) [96] which categorized principles of CE into SSCM practices and drew a causal map of the principles. These contributions were useful in offering theory-based foundations and high-level capabilities structures; however, they did not provide a structured way of making decisions about how to link the hotspot diagnosis to the selection of interventions and the cost-based feasibility assessment. Our framework builds upon and expands these previous models, and provides a step-by-step action-oriented logical pathway for decision-making that identifies the eight structural gaps documented in this review. It is therefore offered as a normative, synthetic framework which will need to be tested and verified with empirical research and tested with a case study approach over different time periods in different contexts of supply chain management.

Decision Hotspot Mapping: Diagnosing Where Waste Occurs

The axis of the framework that revolves around decision hotspot mapping is the first axis which is the diagnostic background of prevention strategies. There is food waste generated at various agri-food supply chain stages (production, processing, distribution, retail, food service, and consumption) and each operational stage has varying operational choices that determine the level of waste produced [97]. The aim of decision hotspots mapping is to determine the hotspots in such processes where waste is generated, how it is produced and who is the actors in decision making.

There are usually a number of complementary tools on which this diagnostic analysis is based. Data at stage-level loses may help demonstrate the quantitative distribution of waste by supply chain stages whereas process mapping may demonstrate operational flows and be inefficient [98]. Stakeholder analysis also assists in establishing the organizational and institutional players, who have critical decisions to make on food loss and waste [99]. Through integration of such approaches to analysis, a researcher and practitioner can determine which regions to be considered as hotspots-where specific intervention initiatives can achieve the best results in cutting waste production.

These hotspots are critical to comprehend in order to give priority to preventive measures. As an illustration, having high production quantities on the farm scale, waste at processing area due to quality, ineffective storage at retail outlets, and size of the portions at food service establishments potentially generate substantial amounts of waste [100]. Decision hotspot mapping allows interventions to be targeted at the most influential systemic points by diagnostics of the causal qualification of such wasteful creation.

Operationalizing Circular Economy Principles for Prevention

The second axis of the framework touches upon the operationalization of the Circular Economy principles to food waste prevention. Although CE has become a popular term in the sustainability research and policy literature, it is often applied to describe the idea rhetorically but not operationally [101]. The implementation of the CE principles should be converted into specific intervention mechanisms, measurable consequences [102] to be used as an operational decision-making model.

The operationalization of the concepts of CE, as it is presented in the framework of this concept, involves what are the relevant circular strategies that can be implemented in every one of the decision hotspots and how these strategies could be operationalized in practice [103]. These plans can involve upstream preventative actions like the enhanced demand prediction, supply chain management, pack design, inventory management, and product design adjustments increasing shelf life [104]. Additional options can look at redistributing the excess food to the secondary markets or enhancing logistical synchrony among supply chain participants [105].

Table 7 systematically maps specific operational prevention interventions in relation to the known stages of the Food Waste Hierarchy (prevention, redistribution, valorisation, recovery, disposal), transforming them from broad to specific categories. This mapping not only looks at them in terms of what they are doing technically, but also in terms of where they fit in the value-retention hierarchy, so that decision makers can prioritize in terms of what can provide the greatest value to be retained.

Potential trade-offs and systemic interactions among interventions need evaluations as well, to be able to operationalize CE [106]. Indicatively, an initiative aimed at minimizing waste in the supply chain of a specific stage can even end up creating more waste on a different stage as the system becomes the subject of neglect [107]. In turn, the CE operationalization in this context is based on a systemic approach, so any interventions in the context should assist in real waste reduction and not result in either solving the waste or transferring waste between organizational levels [108].

Table 7. Mapping Operational Food Waste Prevention Interventions to the Food Waste Hierarchy.

Food Waste Hierarchy Level	Operational Prevention Intervention	Supply Chain Stage(s)	Mechanism of Action	Example Evidence /Source
Prevention (Highest Priority)	Date-labelling reform (clarifying "best before" vs "use by")	Retail, Consumer	Reduces consumer confusion and premature disposal	[21,22]
	Shelf-life extension (modified atmosphere packaging, novel preservatives)	Processing, Distribution, Retail	Delays spoilage, increases usable product window	[16,72]
	Packaging redesign (portion optimisation, reusable/returnable systems)	Processing, Retail, Consumer	Reduces over-purchasing and packaging waste	[72,73]
	Cold-chain reliability (IoT monitoring, real-time temperature logging)	Distribution, Retail	Minimises temperature-related spoilage during transport/storage	[13,14]
	Demand forecasting & inventory optimisation (AI/ML-driven)	Production, Distribution, Retail	Aligns supply with demand, reduces overproduction and overstocking	[18,19]
	Quality specification reform (accepting "ugly" produce, relaxing cosmetic standards)	Production, Retail	Prevents waste at farm gate and retail shelves	[42,98]
	Procurement practice reform (flexible ordering, supplier collaboration)	Production, Distribution, Retail	Reduces order quantity mismatches and surplus	[14,80]
	Product redesign (longer-lasting formulations, modular portions)	Production, Processing	Extends product life and reduces batch rejects	[74,75]
Redistribution	Surplus food donation/ food banks	Retail, HoReCa	Captures edible surplus for human consumption	[22,103]
	Secondary/discount markets	Retail	Sells near-expiry or imperfect products at discount	[42,83]
Valorisation	Animal feed (e.g., brewers' grains, whey)	Processing	Uses by-products as livestock feed inputs	[16,25]
	Industrial symbiosis (by-product exchange)	Processing	Redirects by-products to other industries (e.g., chemicals, packaging)	[15,72]
	Composting/anaerobic digestion	Processing, Retail, HoReCa	Recovers energy and nutrients from unavoidable residual streams	[26,27]
Recovery/Disposal (Lowest Priority)	Incineration with energy recovery/Landfill	All stages	End-of-life disposal (should be minimised)	[2,31]

Effectiveness and Transferability of Prevention Strategies

The third axis of the framework is centered on effectiveness and transferability which gives the empirical underpinning of measuring prevention strategies. Although many food waste interventions have been suggested in academic literature, as well as policy reports, the literature is inconsistent when it comes to their actual results of the proposed intervention [109]. Most studies are based on pilot research, simulations or theoretical analysis as opposed to the long-term implementation data.

This axis consequently highlights the necessity of solid empirical evidence to establish whether the suggested measures can help to minimize food waste in the field of operative conditions [110]. There are important evaluation criteria such as the level of waste that is reduced, the results of the evaluation in the long-term, and the situational factors that impact success [111]. As an illustration, those interventions that work well in a large-scale industrial food processing system may not necessarily work in small and medium-sized businesses (SMEs) or decentralized food service systems [112].

It is also essential that transferability is considered. The agri-food supply chains vary extensively in geographical boundaries, legal frameworks and organizational structures. This leads to the fact that what works in one situation might have to be adjusted before being applied in a different situation [113]. It is thus essential to understand the circumstances in which interventions work or fail in scaling the preventive work in various sectors and regions.

Cost Integration and Economic Feasibility

The fourth axis of the framework deals with the cost integration as it acknowledges that economic factor is a forefront consideration in the decision-making process in agri-food systems [114]. Although prevention strategies prove to have environmental and social advantages, it does not mean that organizations do not need to consider whether these strategies are economically sustainable. Inclusion of cost analysis in the conceptual framework, consequently, makes it possible to determine that prevention interventions can be evaluated with regard to sustainable outcomes as well as sustainability to be economically viable [115].

Cost integration deals with the assessment of various economic aspects of preventative actions. They are capital expenditures, which are the costs required to introduce new technologies or infrastructure [116], operational expenditures, which are the costs used to continue implementing them, possible savings resulting in waste reduction, and avoided disposal costs [117]. Moreover, such risks as the ambiguity related to the demand on the market, the impact on the functioning of organizations, and regulatory alterations should also be taken into account by the organizations [118].

Notably, supply chain actors can have a significant difference in cost-benefit profile. Big companies might have more funds to invest in futuristic technologies, but SMEs might have a limited set of resources [119]. Therefore, economic evaluation systems need to be developed to consider those dissimilarities so that prevention measures are not too expensive or ineffective to organizations of different sizes [120].

Integrating the Four Axes into a Decision-Support Framework

The integration of the four axes can be translated into a practical decision-support sequence that guides implementation. Specifically, the framework operates as a stepwise process: first, decision-makers identify high-impact waste hotspots using stage-level diagnostics; second, they match these hotspots with appropriate Circular Economy interventions based on prevention priority; third, they evaluate the expected effectiveness and transferability of these interventions under real-world conditions; and finally, they assess economic feasibility through cost structures including CAPEX, OPEX, and risk exposure. This structured progression transforms the framework from a conceptual model into an actionable tool that supports operational decision-making in agri-food systems.

This can be given as a decision pathway:

Gap Identification → Hotspot Mapping → Intervention Selection → Effectiveness Evaluation → Cost Assessment → Implementation

The framework, by expressly organizing such a succession, allows the practitioners to proceed in a systematic manner between problem recognition and execution, which is one of the key constraints pinpointed in literature. Our conceptual model is normative in that it refers to a logical sequence of decision making, unlike non-normative descriptive conceptual models that expound on literature without prescribing that sequence. There are important caveats to this, however, because the effectiveness/cost balance of the various parts of the framework is highly context specific, depending on commodity, type of chain, firm size and regulations. The framework is thus provided as a fictional, temporary assistance decision support system, and not as a validated predictive model. Future research should empirically explore its usefulness and implications in applications across several case studies, sensitivity analysis and participative design with the practitioners of the supply chain.

This type of framework would help supply chain actors to identify the root cause of the waste creation with even greater accuracy, focus on prevention methods that reflect the idea of a circular economy, and assess the economic feasibility of the interventions prior to their implementation [121]. It would also enable the tracking of results in terms of decision-linked performance indicators, and thus the organization should measure the effectiveness of interventions over a period and correct the strategies as needed [122].

The conceptualization and testing of this paradigm is a principal way of where more research will take place in the future. Case studies, experimental and cross sector comparative studies will be required in order to test, refine and provide empirical evidence to prove the usefulness of the framework. This strategy will enable the enhancement of prevention-based agri-food supply-chain food waste governance and can lead to the overall shift towards a circular economy [123].

Strategy Effectiveness–Cost Matrix

Figure 6 depicts a decision-support matrix that relates food waste interventions to potential effectiveness and expense of implementation relative to the expected effectiveness. Considerable priority logic is brought to the fore through the visualization, high-impact, low-cost strategies, including those which are demand forecasting, redistribution systems, and inventory optimization, are immediate quick wins, especially in SMEs that are limited in their resources. Conversely, costly interventions, such as new cold chain technologies and AI-based monitoring systems, have long-term enormous benefits but demand high investment capacity. The matrix provides a way of operationalizing the principles of the Circular Economy by converting them into practical and cost-sensitive strategic decisions within the supply chain contexts.

CONCLUSIONS

Synthesis of Key Findings

This review study based on systematic analysis involves 374 peer-reviewed articles on the intersection of circular economy (CE), food waste and agri-food supply chain management. In the analysis, it is possible to note that the current state of knowledge is split and structurally disproportionate even though increasing academic and policy efforts focus on food waste reduction [124]. Eight sets of interrelated research gaps were found to limit the ability of the field to assist in making effective and preventive decisions at the agri-food systemwide level.

The key discovery is the consistent lack of balance between the studies that pay attention to valorization, and those that address the subject of prevention. The literature also focuses significantly on downstream solutions solving the problem of food waste through the secondary use of the food waste in the form of energy, a bio-material, or compost [125,126]. Although these strategies aid in recovery of resources in a circular system, they do not focus on decision-making processes that contribute to the creation of waste in the first place [127]. The presence of the current research accordingly reinforces implicitly many studies of a system where food waste is handled instead of avoided, which limits the transformative prospect of the approaches to the circular economy [128].

This imbalance is facilitated by a number of other structural constraints. To begin with, the principles of CE are often presented as a conceptual story, and not as an operational model that can be used to support specific interventions [129]. Second, the studies actualization on supply chain stages is inadequate, and production and processing stages get a disproportionately large fraction compared to downstream branches like retail and hospitality (HoReCa), where food waste is produced in large amounts [130]. Thirdly, the literature contains a lot of measurement and quantification of the food loss and waste but they are hardly connected with the decision-making process or strategic intervention [131]. Fourth, there is scanty empirical evidence related to the practicality and sustainability of prevention measures in the real-world [132]. Lastly, there is a lack of rigorous economic assessment especially concerning preventive interventions and finances of small and medium-sized businesses (SMEs) [133]. Collectively, these conceptual cracks in the research landscape indicate a remarkably fertile study area that is endowed with theoretical discourse and technological advancement but which is relatively feeble in decision-driven models that can be applied to form systemic prevention methods [134].

Implications for Future Research

These limitations have to be addressed by a coordinated research agenda based on 4 key analytical priorities. These priorities are explained by the four research questions which were created within the frames of the present review and each question addresses a certain aspect of the identified gaps.

To start with, it is necessary to move the literature towards decision hotspot mapping, a methodological tool that can be used to connect the food waste generation to the particular operational decision in the supply chain [135]. When referring to hotspots analysis, instead of simply recording where waste is generated, learning to identify the causal processes of waste production and focusing on intervening locations that prevention techniques can produce the most significant systemic effect is essential [136].

Second, the research should go beyond rhetorical appeals to the circular economy and create effective frameworks that would turn the principles of CE into action plans [137]. These frameworks must have defined intervention mechanisms, quantifiable performance metrics, and clear trade-off evaluations to make sure that circular solutions actually reduce the amount of waste instead of moving it through the levels of the supply chain [138].

Third, the profession needs a more solid empirical test of the actual efficacy and transfer of the food waste prevention methods into practice [139]. Longitudinal designs, cross-sector comparative analysis, and multi-case empirical studies should be used in the future to assess the performance of interventions in varying conditions of operation [140]. Of specific interest is the knowledge of how the contextual conditions, such as the size of firms in operating in various environments, regulatory settings, and supply chain structure, impact the success or failure of prevention initiatives [141].

Fourth, there is a need to incorporate economic assessment into the food waste studies more systematically [142]. Prevention strategies ought to be appraised with strong financial facts by decision-makers. Therefore, life-cycle costing, cost-benefit analysis, techno-economic assessment, and risk-adjusted investment modeling methodologies are to be used more frequently. These economic models are especially problematic in the cases of SMEs, as they usually have more restrictive lending and may experience greater risks during the application of circular innovations [95]. A combination of these research priorities will establish a prevention-first research program, including at the systems level, that may inform a stronger scientific basis of circular food waste governance [143].

Policy and Practical Relevance

The implications of this research agenda are far reaching beyond the scholarly researches or studies and straight to the world in trying to reduce food loss and waste. According to the global sustainability agenda of the United Nations Sustainable Development Goal (SDG) 12, Target 12.3, countries have invested to halve the per-capita food waste in retail and consumer level and decrease food losses along the supply chains by 2030 [144].

This is a global agenda that must be attained. According to the last estimates, over 1.05 billion tonnes of food are wasted each year, which is almost a fifth of the food offered to consumers everywhere in the world and creates both a substantial environmental and economic burden [145]. Also, food loss and waste contribute between 8%–10% of the global greenhouse gas emissions, which points to their topicality in terms of both the efficiency of the food system and climate mitigation and sustainable use of resources [146].

Nevertheless, achieving SDG 12.3 will not come as a result of gradual enhancement of the waste management practices. It will require radical reorganizations in the ways food systems are produced, regulated and controlled [147]. The players in the supply chain will have to change their reactive mode of responding to the impact of waste by adopting proactive measures that will redesign production, distribution, and consumption processes to produce less waste at the source [148]. The principles of the circular economy provide a potent outline of directing this change, yet the opportunities can be achieved only once they are transformed into practical decision-making methods that can bring together the aims of the environment and economic motivation [149].

Final Reflection

To summaries, the review has a role in the developing discussion of the topic of circular food systems, synthesizing the current body of knowledge, exposing the structural knowledge gaps, and aiding the development of a progressive research agenda. The results indicate that to result in substantial food waste reduction, a shift of waste management towards waste prevention with help of unified analytical frameworks comprising of causal diagnostics, circular strategy development, empirical effectiveness testing, and economic analysis is necessary.

Scientific community can play a very important role in facilitating such a transition. Researchers can assist in transforming the principles of the circular economy into practical strategies in order to transform agri-food systems by generating the strong evidence, and creating operational decision-making frameworks, as well as facilitating inter-disciplinary collaboration among supply chain actors [96,150]. At the very end, closing this divide between vision and practical application will be needed to realize food waste reduction and contribute to a wider shift to sustainable and resilient circular economies.

DATA AVAILABILITY

The data are contained within the article.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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The authors recognize the systematic literature review as doctoral research done in Circular Economy and Agri-Food Systems. The efforts of putting together and coding the literature corpus were done with scopus and Zotero reference management system. The study will be placed within the wider context of the doctoral dissertation that explores the potential of Circular Economy as a functioning and economically-based framework used to develop a series of preventive strategies to reduce food waste-based agri-food supply chain.

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