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Research Paper

A Conceptual Review of Six Sigma Applications in Supermarket Operations: Comparative Insights and a Framework for Sales and Inventory Optimization

[1]Ying Sun, [2]Amarnath Krishnamoorthy
[1]*Scotland Academy, Wuxi Taihu University, Jiangsu Province, Wuxi City, China*
[2]*School of CEPS, University of the West of Scotland, Paisley, United Kingdom*
[2]*Corresponding Author*

Abstract
Supermarkets operate in highly competitive, demand-volatile environments where inefficiencies in inventory management, replenishment, and shelf availability directly impact sales and operating costs. To address these challenges, Six Sigma and Lean Six Sigma (LSS) methodologies are increasingly applied in retail operations to improve process stability, reduce variability, and enhance customer performance. This paper presents a comprehensive conceptual review of peer-reviewed studies on Six Sigma and LSS applications in supermarkets, focusing on inventory control, replenishment, stockout reduction, and sales improvement. Using a structured review approach, the literature is systematically classified by process focus, methodological tools, and performance outcomes. Comparative analysis highlights dominant application areas, commonly used tools, operational benefits, and research gaps. Existing studies largely examine inventory or process efficiency separately, with limited integration of customer-facing sales metrics and inventory decision variables. To bridge this gap, the paper proposes a Sales and Inventory Optimisation Framework based on the DMAIC methodology, linking customer quality attributes, operational variables, and economic indicators. The framework offers a structured approach for managers and researchers to jointly optimise sales and inventory efficiency, contributing to theory and practice by consolidating fragmented knowledge and providing a practical roadmap for continuous improvement in supermarket operations.

Keywords
Six Sigma; Lean Six Sigma; Supermarket operations; Inventory management; Replenishment processes; Stockout reduction; Sales performance; Retail process improvement; DMAIC; On-shelf availability

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I. Introduction

1.1 Supermarket operations and performance challenges

Supermarkets operate within highly competitive environments characterised by thin profit margins, high product variety, frequent promotions, and pronounced demand variability. Operational proficiency in such settings depends heavily on maintaining product availability while controlling inventory-related costs. Prior research has regularly shown that even short-lived stockouts or shelf unavailability can result in immediate sales losses, substitution behaviour, or store switching, thereby directly affecting revenue and customer loyalty(Azeem et al., 2019; Larson & Ferrin, 2023; Mckinnon et al., 2007a). Empirical investigations further demonstrate that inventory decisions and shelf availability are not passive outcomes of demand but proactively shape purchasing behaviour, strengthening the crucial importance of operational implementation at the store level(Koren et al., 2024).

In addition to sales losses, supermarkets face ongoing challenges with excess inventory, waste, markdowns, and shrinkage, particularly in perishable categories with limited shelf life(Wang, 2025a). These issues are frequently worsened by execution-related failures such as inaccurate inventory records, delayed replenishment, inefficient shelf-filling routines, and weak exception management. As a result, improving supermarket performance requires methods that address not only planning and forecasting accuracy but also the stability, visibility, and control of underlying operational processes(Wang, 2025b).

1.2 Process improvement and continuous improvement in retail contexts

While retail performance problems are frequently framed as forecasting or system-level challenges, a substantial body of literature points to the role of process design and execution quality in driving operational outcomes(Marques et al., 2022a). Replenishment effectiveness, order accuracy, and shelf-filling discipline have been shown to strongly influence on-shelf availability and stockout incidence, indicating that demand satisfaction is closely tied to day-to-day operational practices(Vieira et al., 2025). Process-based improvement approaches are therefore particularly relevant in supermarket contexts, where variability comes from both demand-side uncertainty and execution-side inconsistencies(Reiner et al., 2013a).

Lean-based interventions in retail and grocery environments have demonstrated the potential to improve process efficiency, reduce handling effort, and boost responsiveness at the store level(Marques et al., 2022a). However, these studies also indicate that continuous performance improvement requires systematic identification of root causes, data-driven prioritisation of improvement actions, and ongoing control mechanisms that go beyond isolated lean tools or ad hoc process redesign(Gutierrez-Gutierrez et al., 2016a).

1.3 Six Sigma and Lean Six Sigma in service and retail environments

Six Sigma and Lean Six Sigma (LSS) provide structured, data-driven methodologies for reducing process variation, eliminating defects, and improving capability through disciplined improvement cycles such as DMAIC(Abreu-Ledón et al., 2021). Although originally developed for manufacturing, an expanding body of peer-reviewed literature has documented the application of Six Sigma and LSS in service and transactional environments, including logistics, healthcare, banking, and retail operations. These studies show the flexibility of Six Sigma principles to complex, people-intensive systems where process variability and execution errors significantly affect customer outcomes(Adeodu et al., 2023a).

In retail-related contexts, Six Sigma and LSS have been applied to inventory management, replenishment accuracy, labour productivity, and waste minimisation, with reported improvements in cost efficiency and process reliability(Madhani, 2020). Research in adjacent domains such as food operations and supply chain management further supports the suitability of these procedures for settings characterised by high variability, time sensitivity, and quality degradation risks. Nevertheless, the literature also notes challenges in contextual adaptation, metric selection, and integrating customer-facing performance measures into Six Sigma projects(Gutierrez-Gutierrez et al., 2016b).

1.4 Need for a consolidated review and integrated perspective

Although research on Six Sigma and Lean Six Sigma in retail contexts is expanding, the literature remains fragmented across operational domains and analytical perspectives. Most studies address inventory control, replenishment, or efficiency improvements in isolation, rarely linking these process-level interventions to customer-facing outcomes such as sales performance or on-shelf availability(Gomaa, 2024). Consequently, the connections between operational variability, inventory decisions, and realised sales outcomes are often implicit rather than systematically articulated.

Furthermore, supermarket-specific contexts, which involve high SKU counts, store-level execution constraints, and perishability risks, are underrepresented in integrative reviews of Six Sigma applications. Most existing reviews focus broadly on service or supply chain settings, providing limited insight into the coherent deployment of Six Sigma tools and logic across interconnected supermarket processes. This fragmentation restricts both theoretical synthesis and practical guidance for managers aiming to align continuous improvement initiatives with sales and inventory performance objectives(Abreu-Ledón et al., 2021; Gutierrez-Gutierrez et al., 2016b; Madhani, 2020).

1.5 Scope and contribution of this review

In response to these gaps, this paper offers a conceptual review of peer reviewed Six Sigma and Lean Six Sigma applications relevant to supermarket operations, with a focus on inventory control, replenishment execution, stockout reduction, and their implications for sales performance(Amasuomo & Baird, 2016a; Eren et al., 2022a; Marques et al., 2022b). By examining studies from operations management, retail, and supply chain journals, the review synthesises the application of Six Sigma methodologies, the prioritisation of specific tools, and the performance outcomes reported in supermarket-relevant contexts(Torres et al., 2022a).

By developing comparative insights across process focus areas and performance metrics, the paper highlights patterns, limitations, and underexplored connections within the existing literature. Building on these insights, the review proposes an integrated Sales and Inventory Optimisation Framework grounded in the DMAIC logic, linking customer-critical quality attributes, operational process variables, and financial

performance indicators(Tampubolon & Purba, 2021). In doing so, the paper aims to consolidate fragmented knowledge and provide a structured foundation for both future empirical research and practical continuous improvement efforts in supermarket operations.

II. Review methodology

A structured conceptual review approach was adopted to synthesise peer-reviewed research on Six Sigma and Lean Six Sigma applications relevant to supermarket operations. The review focuses on studies published in established operations management, retail, and supply chain journals that examine improvement initiatives related to inventory management, replenishment processes, on-shelf availability, waste reduction, and sales-linked operational performance(Amasuomo & Baird, 2016b; Marques et al., 2022c; Panayiotou & Stergiou, 2023).

Relevant literature was identified through targeted searches of major academic databases and publisher platforms using combinations of keywords related to Six Sigma and Lean Six Sigma, supermarket and grocery retail contexts, and operational performance outcomes. Only peer-reviewed studies with a clear application or discussion of Six Sigma–based methodologies in retail or supermarket-relevant settings were included. Practitioner articles that were not peer-reviewed and studies limited to manufacturing contexts without clear transferability to store-level operations were excluded(Marques et al., 2022a; Tampubolon & Purba, 2021; Torres et al., 2022b).

Instead of seeking exhaustive coverage, the review prioritises conceptual relevance and analytical depth. The selected studies were examined comparatively to identify common application areas, dominant tools and methodologies, reported performance outcomes, and recurring limitations. These insights were synthesised to develop an integrated perspective on the contributions of Six Sigma and Lean Six Sigma to sales and inventory performance in supermarket environments, which forms the basis for the conceptual framework proposed later in the paper.

III. Overview of Six Sigma and Lean Six Sigma

3.1 Evolution and positioning of Six Sigma

Six Sigma originated as a structured methodology aimed at enhancing organisational performance by reducing defects and process variation, emphasising measurement discipline and evidence-based decision making(Marques et al., 2022c). The literature has evolved to present Six Sigma not merely as a set of statistical tools, but as an integrated management system encompassing improvement projects, defined roles, governance structures, and customer-oriented performance objectives(Panayiotou & Stergiou, 2023). Consequently, Six Sigma is frequently characterised as a “quality management renewal” that formalises the identification of improvement priorities, project execution, and the institutionalisation of learning and control(Torres et al., 2022b).

Although Six Sigma was initially associated with manufacturing, peer-reviewed studies demonstrate that its principles of variation reduction, defect prevention, and process capability improvement are applicable to service and transactional environments. In service organisations, researchers have identified both the advantages and the contextual challenges of implementing Six Sigma, emphasising that success relies on effective project selection, leadership commitment, robust measurement systems, and the appropriate adaptation of tools to less tangible process outputs(Bhat et al., 2023).

3.2 DMAIC as the dominant improvement cycle

The DMAIC cycle (Define, Measure, Analyse, Improve, and Control) is the predominant framework for executing Six Sigma improvement projects, offering a disciplined structure for problem solving from initial scoping and measurement to solution design and process control(Rahmatillah & Rusindiyanto, 2025). While academic literature often presents DMAIC as a generic problem-solving method, more rigorous analyses contend that DMAIC operates as an evidence-driven cycle supporting both diagnosis and intervention design. Its practical effectiveness depends on the extent to which teams align measurement choices, causal analysis, and improvement actions(Ferreira et al., 2013).

In practical applications, DMAIC is valuable because it integrates two essential elements: a clear definition of “good performance” in both customer and business terms, and a measurable approach to identifying the sources of variation and defects and strategies for their reduction(Marques et al., 2022a). This is particularly relevant for supermarket operations, where operational losses such as lost sales from stockouts, waste from overstock, or inefficiencies in replenishment typically result from multiple interacting factors rather than a single technical failure. Therefore, structured scoping and causal analysis are critical(Ferreira et al., 2013).

3.3 Lean Six Sigma: integrating waste elimination and variation reduction

Lean Six Sigma (LSS) combines Lean's emphasis on flow efficiency and waste elimination with Six Sigma's focus on variation reduction and defect prevention. The literature generally regards Lean and Six Sigma as complementary approaches: Lean enhances process flow and identifies non-value-adding activities, while Six Sigma reinforces measurement discipline and analytical rigor to stabilise and sustain performance improvements. This integrated approach has been widely adopted across industries, with systematic reviews indicating that LSS is frequently chosen when organisations seek both efficiency gains and statistically validated performance stabilization (Daniyan et al., 2022; Pandiyan et al., 2023).

This integration is especially pertinent to supermarket operations, where performance relies on both "flow" (such as replenishment speed, work sequencing, and exception handling) and "stability" (including inventory record accuracy, consistency in shelf-filling routines, and minimisation of process-driven stockouts). Retail-focused research suggests that LSS aligns well with the dynamic and high-variability nature of retail environments, enabling systematic transformation of store operations through targeted projects and ongoing performance monitoring(Amasuomo & Baird, 2016c).

3.4 Common tools and techniques in Six Sigma and LSS projects

3.4.1 Process definition and stakeholder clarity (SIPOC, process mapping, CTQ identification)

In DMAIC-based projects, early-stage tools are employed to clarify process boundaries and explicitly identify stakeholders, inputs, and outputs. SIPOC (Suppliers–Inputs–Process–Outputs–Customers) is commonly utilised to provide a structured overview of the entire process and to minimise ambiguity in project scope(Ruwanpura et al., 2023). CTQ (Critical-to-Quality) analysis connects operational performance with customer expectations and business requirements. The frequent use of SIPOC in peer-reviewed DMAIC applications underscores its practical value as a tool for scoping and alignment, particularly in cross-functional processes(Chyon, BSc et al., 2020).

3.4.2 Root cause analysis and prioritisation (cause–effect logic, Pareto-based focus)

After measurement determines the magnitude and location of a performance issue, DMAIC projects generally employ structured diagnostic tools to identify and prioritise probable causal factors. Cause–effect analysis (often using fishbone diagrams), Pareto-based prioritisation, and process-step analysis help focus attention on the most significant sources of variation or defects(Jou et al., 2022). In service and transactional settings, where processes are often less visible than in manufacturing, research indicates that these tools are most effective when combined with measurable operational definitions and when teams avoid relying solely on subjective explanations(Churi et al., 2025).

3.4.3 Statistical and analytical tools for measurement and control (SPC and capability logic)

A defining characteristic of Six Sigma is its focus on measurement validity and statistical reasoning to support causal inference and long-term control. Statistical Process Control (SPC), capability analysis, and data-driven monitoring are employed to differentiate between common-cause and special-cause variation and to assess the stability of improvements over time. Even outside manufacturing, peer-reviewed studies emphasise that disciplined application of measurement and control principles is essential to prevent "improvement decay," where initial gains are lost due to unmanaged variation and insufficient standardization (Sabtu et al., 2023; Tufail et al., 2021).

3.5 Applicability to service and retail operations

The service-quality literature indicates that effective Six Sigma and LSS implementation requires adaptation to environments where outputs are often intangible, data quality may be inconsistent, and frontline work is highly dependent on personnel. In these contexts, the most successful projects are those that translate customer expectations into operational CTQs, establish robust measurement systems, and prioritise process reliability over isolated, short-term solutions(Sabtu et al., 2023).

In retail and supermarket contexts, Six Sigma and LSS methodologies are particularly relevant to processes where variability leads to customer-facing failures, such as empty shelves, delayed replenishment, inaccurate inventory, or poor product availability during promotions. Retail-focused LSS research further underscores the importance of careful project selection and establishing clear connections between operational initiatives and financial outcomes, as improvements in store operations are typically evaluated based on both service metrics (availability, speed, customer experience) and financial results (sales growth, waste reduction, working capital efficiency)(Madhani, 2020; Torres et al., 2022a).

IV. Supermarket operations: processes and performance metrics

4.1 Core operational processes in supermarkets

Supermarket performance is determined by a series of interdependent processes that transform upstream supply into products available to customers at the shelf(Hübner et al., 2023). Although planning systems may achieve high service levels upstream, research demonstrates that the final stages of store execution, particularly shelf replenishment, can undermine product availability at the point of purchase, which is essential for sales and customer behavior. Therefore, supermarket operations offer a valuable context for process-based analysis, as many operational losses arise from execution variability rather than a single technical constraint(Mckinnon et al., 2007b).

A process-oriented perspective typically begins with demand sensing and ordering, which includes forecasting, promotional planning, and translating expected demand into store orders and delivery schedules. In grocery retail, tactical planning is frequently described as a coordination challenge that integrates demand, supply, and store capacity constraints. Misalignment among these factors can result in both overstock and product unavailability. The inbound process comprises receiving, put-away, and backroom organization, each of which affects replenishment responsiveness and the accuracy of available-to-promise stock at the store level(Bixler et al., 2021; Nunes et al., 2022).

The next block is the subsequent process, which involves store replenishment and shelf execution: transferring products from the backroom or direct delivery to the shelf, maintaining planogram and shelf standards, and managing exceptions such as late deliveries, missing items, substitutions, and damaged goods. Empirical studies on on-shelf availability consistently identify in-store replenishment processes as a primary cause of out-of-stock events, even when upstream logistics are effective(Dharmawardane et al., 2021). Management is another foundational process that cuts across the above blocks. Retail operations depend heavily on “perpetual inventory” records, yet research demonstrates that inventory record inaccuracy is common and materially affects store performance by distorting ordering decisions, hiding stockouts (phantom availability), and weakening replenishment timing. This is particularly important in supermarkets because high SKU counts and high transaction volumes increase the likelihood that small record errors accumulate, affecting perishable handling and freshness management, which constitute a distinct operational regime. Fresh product categories require time-sensitive replenishment, systematic stock rotation, and timely markdown decisions to balance waste reduction with product availability and sales. Research on fresh departments explicitly frames performance as a joint objective encompassing waste reduction, freshness, and sales, rather than focusing solely on cost minimisation(Marques et al., 2022a).

4.2 Key performance metrics and how they connect to processes

A well-defined performance dashboard is essential in supermarket improvement initiatives, as identical symptoms such as lost sales may result from different underlying mechanisms, including shelf replenishment delays or inventory record errors. In the on-shelf availability literature, On-Shelf Availability (OSA) is widely recognized as a primary retail KPI, indicating whether customers can locate the product at the intended shelf location at the time of purchase. Studies emphasize that OSA and related out-of-stock measures are central to customer satisfaction and commercial performance(Chuang et al., 2016; Nunes et al., 2022).

The out-of-stock (OOS) or stockout rate is typically measured as the frequency or proportion of time or SKU-store instances when a product is unavailable to customers. Notably, the literature highlights that measurement is complex: stockouts may be identified through manual audits, point-of-sale (POS) inference, or aggregation rules applied to perpetual inventory data, each method introducing distinct error profiles and biases(Chuang, 2018; Chuang et al., 2016). These measurement challenges have direct implications for research synthesis and Six Sigma projects, as the validity of the measurement system affects the credibility of improvement claims.

Inventory Record Inaccuracy (IRI) denotes the discrepancy between system records and physical stock. Peer-reviewed studies demonstrate that IRI can degrade store-level performance by causing both overstock and phantom stockouts, undermining replenishment logic, and reducing the effectiveness of automated ordering. Within supermarket optimisation, IRI should be considered a process-quality variable that mediates the relationship between replenishment decisions and shelf availability, rather than being viewed solely as an accounting issue(Bassamboo et al., 2020; Linuwih & Handayati, 2025).

To evaluate inventory efficiency and capital use, supermarkets frequently track inventory turnover (turns), days of supply, and holding cost proxies. While these metrics are useful for efficiency, the OSA

literature cautions that efficiency targets can conflict with availability if they encourage under-stocking or reduce buffer capacity in highly variable categories(Saghiri et al., 2023).

In fresh categories, waste, markdown losses, and freshness or service-level metrics are critical. Research on supermarket fresh departments explicitly quantifies improvement potential by evaluating trade-offs among waste reduction, freshness improvements, and sales increases. This underscores the need to interpret inventory optimisation differently for perishables compared to ambient goods(Saghiri et al., 2023).

Sales performance measures, such as category sales, gross margin, and proxies for lost sales, are frequently employed to quantify the commercial impact of operational improvements. Evidence connecting inventory accuracy and store performance supports the view that operational quality variables, including IRI, influence sales by affecting product availability. This highlights the importance of integrating customer-facing and back-end metrics within a unified framework(Saghiri et al., 2023; Shabani et al., 2021).

V. Review of Six Sigma applications in supermarket operations.

5.1 Inventory management and inventory accuracy as "hidden drivers" of performance

In supermarket operations, inventory performance depends not only on the quantity of stock ordered but also on the reliability of inventory knowledge regarding stock levels and locations(Shabani et al., 2021). Retail and supply-chain research consistently identify inventory record inaccuracy, defined as a mismatch between system and physical stock, as a cause of phantom availability, delayed replenishment triggers, and persistent shelf gaps. This results in situations where the system indicates stock availability while customers encounter empty shelves(Mckinnon et al., 2007c). Studies modeling inventory record inaccuracy demonstrate that it can significantly distort operational decisions and degrade downstream performance, reinforcing the argument that inventory accuracy should be regarded as a process-quality variable rather than solely an accounting issue(Hofstra et al., 2024).

In supermarket contexts, this evidence indicates that Six Sigma or Lean Six Sigma (LSS) projects targeting inventory optimisation must explicitly address the measurement system, including stock records, audit logic, and shrink or adjustment routines. Improved ordering policies alone will not resolve availability issues if the underlying data are unreliable(Patra et al., 2021). Research examining store backrooms and execution processes further demonstrates that store configuration and handling routines can affect record accuracy and waste, supporting the need for end-to-end, process-based improvement rather than isolated parameter adjustments(Hübner et al., 2023).

5.2 Stockout reduction and on-shelf availability improvement

The operational and customer impacts of stockouts are well documented in the retail availability literature, which consistently emphasizes that on-shelf availability is a critical KPI associated with shopper behavior and financial outcomes(Marques et al., 2022a). Although many studies focus on measurement and consumer response, a recurring operational insight is that the effectiveness of in-store replenishment, defined by the speed and reliability of moving products from delivery or backroom to the shelf, often accounts for stockouts even when upstream supply performance is adequate(Marques et al., 2022a; Vieira et al., 2025).

Recent peer-reviewed case studies in retail operations demonstrate that lean-style redesign of store replenishment flows and task standardization can reduce out-of-stock events and enhance service performance, especially when improvements address bottlenecks and execution variability, such as backroom-to-shelf flow, prioritization rules, and exception handling(Adeodu et al., 2023b; Andersen & Skjoett□Larsen, 2020; Marques et al., 2022a).

From a Six Sigma or Lean Six Sigma perspective, these findings support projects that conceptualize stockouts as a defect outcome resulting from multiple interacting factors, such as inventory accuracy, replenishment cadence, shelf discipline, and promotion variability. The DMAIC framework provides a structured approach to define critical-to-quality (CTQ) metrics, validate measurement systems, identify root causes, and implement controls to prevent regression(Monday & Monday, 2022).

5.3 Replenishment and order-fulfilment processes: DMAIC-driven improvements

A significant portion of peer reviewed Six Sigma applications relevant to supermarkets are found in replenishment, logistics center operations, and order fulfillment settings that are operationally similar to supermarket replenishment, characterized by high volume, time sensitivity, and a focus on service levels. A well-cited example involves the use of a Six Sigma project to improve a replenishment process in a distribution or logistics context, demonstrating how DMAIC can stabilize performance and enhance service outcomes through structured diagnosis and control planning(Adeodu et al., 2023b; Wei, 2010).

In supermarket operations, comparable improvement strategies typically focus on enhancing the reliability of the replenishment pipeline, including ordering accuracy, receiving and put-away discipline, picking and handling errors, shelf refill cycle time, and governance mechanisms such as visual controls, standard work, and control plans that sustain process improvements(See & Tay, 2021). Peer-reviewed studies on in-store replenishment flow similarly emphasise that availability outcomes depend on effective pull or flow design and disciplined execution, reinforcing the value of integrated Lean–Six Sigma approaches in retail environments(Vieira et al., 2025).

5.4 Sales performance improvement through operational variability reduction

Direct sales uplift is not always the primary reported outcome in Six Sigma or Lean Six Sigma retail studies; however, the causal pathway is often driven by availability. Improvements that reduce stockouts, stabilize replenishment, and enhance record accuracy lead to higher realized sales by minimizing lost-sales events and improving customer experience. This relationship aligns with broader retail operations literature on on-shelf availability, which demonstrates that availability constraints can suppress sales and influence shopper behavior(Disney et al., 2021). Consequently, operational improvements should be evaluated using both process metrics, such as replenishment cycle time and audit accuracy, and commercial metrics, such as lost sales proxies and category sales.

Recent analytical research on phantom stockouts further supports the integration of operational and sales metrics. When shrinkage or hidden losses result in unobserved stockouts, the negative sales impact may persist until measurement and correction mechanisms are enhanced.

For a supermarket-focused review, the key implication is that "sales optimisation" via Six Sigma is most defensible when framed as sales protection (preventing lost sales caused by operational defects) and margin protection (reducing waste/markdowns), rather than promising sales gains from process change alone(Li et al., 2022; Theodorou et al., 2025).

5.5 Perishables, fresh departments, and waste/markdown reduction

Fresh food departments differ from ambient grocery sections because products are perishable, shelf life is short, and service level and freshness objectives are closely linked to waste and markdown decisions. Peer-reviewed hypermarket case studies employing lean or lean–green approaches in fresh sections, such as cold meat, demonstrate measurable operational and sustainability improvements through process analysis, standardization, and flow redesign. This evidence base aligns well with Lean Six Sigma logic when combined with robust measurement and control mechanisms. with stronger measurement and control layers.

Although not all perishables' studies are explicitly identified as Six Sigma, the improvement mechanisms closely align with Lean Six Sigma principles: defining freshness and availability CTQs, measuring waste and process drivers, analyzing root causes such as handling, batching, scheduling, and rotation discipline, implementing improved routines, and controlling with visual management and standard work. In review terms, perishables represent a high-value subdomain because they inherently require integrated optimization of availability and sales while simultaneously controlling waste and margin leakage.

5.6 Comparative synthesis: what the literature collectively suggests

Collectively, the supermarket-relevant Six Sigma and Lean Six Sigma literature supports three comparative insights. First, improvement efforts are most effective when they address the store execution layer, including backroom-to-shelf flow, standard work, and exception handling, in addition to planning decisions. This is because many availability failures originate in in-store processes rather than exclusively in upstream supply(Broekmeulen & van Donselaar, 2019).

Studies that explicitly address inventory accuracy and phantom stockouts highlight a critical measurement issue: without reliable stock visibility, interventions may be misdirected and improvements may be difficult to attribute(Ortiz-Porras et al., 2023).

Although many applications report operational benefits, the literature continues to under-integrate customer-facing sales outcomes with back-end processes and inventory levers. This gap provides a clear rationale for a unified Sales and Inventory Optimisation Framework based on the DMAIC methodology(Reiner et al., 2013b).

VI. Comparative Analysis of Reviewed Literature

6.1 Comparative focus by operational domain

The reviewed literature demonstrates that Six Sigma and Lean Six Sigma (LSS) applications in supermarkets predominantly address four operational domains: (i) on-shelf availability and stockout reduction,

(ii) redesign of replenishment flows at both store and distribution levels, (iii) inventory information quality, including record accuracy and phantom availability, and (iv) perishables management, encompassing waste and markdown control(Macedo et al., 2025; Moussaoui et al., 2016). Research on on-shelf availability (OSA) and out-of-stocks (OOS) consistently identifies availability as a critical retailer performance metric with direct commercial implications. These studies further indicate that the root causes are generally multifactorial and execution-related, rather than solely due to supply constraints(Hamim et al., 2023).

A notable comparative insight is that store-focused studies and action research interventions frequently attribute reductions in OOS to improve in-store replenishment discipline, optimized task sequencing, and more rigorous shelf monitoring. Conversely, studies with an upstream perspective emphasize the significance of planning accuracy and logistics center reliability. This distinction underscores a recurring theme in OSA research: high upstream service levels do not necessarily guarantee strong customer-facing availability if store-level execution is inconsistent(Mckinnon et al., 2007c).To synthesise the reviewed literature across operational domains,Table 1summarizes representative Six Sigma and Lean Six Sigma applications relevant to supermarket operations, highlighting their focus areas, tools, and performance outcomes.

Table 1. Comparative Summary of Six Sigma Applications in Supermarket Operations.

Study / Source	Operational Context	Primary Focus Area	Six Sigma / LSS Tools Used	Key Performance Outcomes	Relevance to Proposed Framework	References
Retail store replenishment case studies	Supermarket / grocery retail	On-shelf availability and stockout reduction	DMAIC, process mapping, root cause analysis, standard work	Reduced OOS events, improved shelf availability	Supports Layer A (CTQs) and Layer B (execution reliability)	(Broekmeulen & van Donselaar, 2019)
Logistics and distribution improvement projects	Retail logistics / distribution centres	Replenishment flow stability	DMAIC, SPC, flow redesign	Faster replenishment cycles, improved service levels	Supports Layer B (process Ys) and Layer C (flow design levers)	(Chuang et al., 2016; Jou et al., 2022)
Inventory accuracy and phantom stock research	Store inventory systems	Inventory record inaccuracy (IRI)	Measurement validation, audit routines, discrepancy analysis	Improved stock visibility, reduced phantom stockouts	Supports Layer D (information quality)	(Hübner et al., 2023)
Lean retail transformation studies	Supermarket store operations	Waste reduction and process efficiency	Value stream mapping, Lean–Six Sigma integration	Reduced handling waste, improved workflow efficiency	Supports Layer C (controllable process levers)	(Broekmeulen & van Donselaar, 2019)
Fresh/perishables operational studies	Supermarket fresh departments	Waste–availability trade-off	Process standardization, visual control, Lean methods	Reduced waste, improved freshness and availability	Supports category-specific framework application	(Broekmeulen & van Donselaar, 2019)
Service-sector Six Sigma case studies	Service and transactional systems	Process variation reduction	DMAIC, CTQ identification, statistical control	Improved process stability and quality	Provides theoretical grounding for framework design	(Broekmeulen & van Donselaar, 2019)

6.2 Methodological patterns and evidence types

The literature exhibits significant methodological diversity, which affects the strength of causal inferences. Improvement studies in retail and supermarket contexts primarily utilize case studies, action research, and before-and-after performance comparisons(Hamim et al., 2023; Marques et al., 2022a). Although these methods are appropriate for operational settings, they vary in measurement transparency. For example, action research on logistics rationalization and OSA often demonstrates improvement through structured participation and process redesign, providing substantial contextual detail but occasionally limiting generalizability(Broekmeulen & van Donselaar, 2019).

DMAIC-structured Six Sigma case studies are frequently used to demonstrate the identification, analysis, and control of process variation, particularly in replenishment and internal logistics operations. While these studies are not always conducted within supermarkets, their process characteristics, including high-volume replenishment and sensitivity to service times, make them operationally analogous and valuable for comparative analysis(Eren et al., 2022b).

6.3 Tool-chain comparison: what is used most, and where

Comparative analysis identifies a consistent division in tool usage: (a) diagnostic and visual tools clarify process flow and prioritize issues, while (b) analytical and control tools stabilize performance. In retail Lean and Lean Six Sigma applications, value-stream mapping and flow-oriented tools are widely used, as availability failures often originate in the backroom-to-shelf workflow and exception-handling routines. For instance, a retail case involving redesigned replenishment processes, including fresh product categories, demonstrates that process mapping and flow redesign can substantially reduce out-of-stock events, emphasizing the Lean component of LSS as an effective initial step in operational improvement.

In literature that is more distinctly focused on Six Sigma, there is greater emphasis on measurement discipline, such as defining defects and validating metrics, as well as on sustaining improvements through control mechanisms. A recurring limitation, however, is that statistical control and measurement-system validation are less consistently reported in supermarket-like environments, often due to the complexity and audit-dependence of availability and stockout measurement. This challenge is frequently noted in OSA-oriented research, where the definition and detection of OOS differ across studies and contexts.

6.4 Outcome comparison: operational improvements versus sales linkage

A principal comparative finding is that reported outcomes are most robust and frequent for operational KPIs, such as reduced OOS events, improved replenishment flow, and higher fulfilment or service rates, while sales and margin outcomes are less consistently quantified(Hollingshed, 2022). Retail case evidence indicates that improvements in replenishment flow can reduce OOS and improve fulfilment metrics, yet the link to sales uplift is often indirect or inferred rather than explicitly modelled(Qin & Liu, 2022).

This gap is particularly evident in studies focusing on inventory information quality. Research on inaccurate inventory information demonstrates that record inaccuracies can distort ordering and availability performance, suggesting a plausible pathway to lost sales through phantom inventory. However, many operational improvement papers treat inventory accuracy as a secondary detail rather than as a central causal mechanism requiring measurement, improvement, and control. Consequently, sales and inventory optimization are often discussed as parallel objectives rather than as components of an integrated system(Andersen & Skjoett□Larsen, 2020).

6.5 Supermarket-specificity and transferability

Another comparative insight is that supermarket-specific constraints, such as high SKU variety, category heterogeneity (ambient versus fresh), promotion-driven volatility, and frontline labor variability, are not consistently represented in the evidence base. Several sources address OSA and OOS as general retail issues and, while they provide valuable mechanisms such as replenishment frequency, shelf monitoring, and inventory inaccuracies, they often overlook supermarket-specific operational nuances, including perishability-driven trade-offs and daily workflow realities(Nunes et al., 2022; Saghiri et al., 2023).

Simultaneously, the supermarket context aligns closely with the LSS approach of improving flow through Lean principles and stabilizing outputs via Six Sigma. Systematic reviews of lean methodologies in retail identify value-stream mapping and LSS as prevalent strategies, supporting the broader assertion that retail environments are increasingly adopting structured improvement toolkits instead of isolated tactics(Gomaa, 2025; Lu et al., 2022).

6.6 Integrated insight: why the literature supports a combined sale–inventory framework

Collectively, the comparative evidence indicates that the most significant operational improvements arise when studies conceptualize availability losses as the downstream result of interacting process and information variables, such as replenishment flow reliability, shelf execution, and inventory accuracy, rather than as a single planning failure. The literature further reveals an underdeveloped integration between customer-facing measures (OSA/OOS, service level) and business outcomes (sales and margin), highlighting an area where a supermarket-focused Six Sigma review can provide conceptual value(Marques et al., 2022a; Nunes et al., 2022; Saghiri et al., 2023).

This comparative pattern provides a clear foundation for the following section, which will outline a structured set of research gaps and introduce a DMAIC-based Sales and Inventory Optimization Framework. This framework will explicitly link (i) customer-critical outcomes, such as availability and freshness, (ii) controllable process levers, including replenishment cadence, exception handling, and shelf discipline, and (iii) information quality variables, such as inventory record accuracy, to (iv) sales and margin performance(Ping et al., 2024).

VII. Research gaps and critical insights

The literature review identifies several persistent gaps that constrain both theoretical integration and practical guidance for supermarket operations. Although on-shelf availability and stockout reduction are widely acknowledged as commercially significant, most studies analyze customer-facing outcomes and back-end operational levers as distinct domains. Reported improvements in replenishment flow, inventory control, or process efficiency often lack explicit, quantified connections to sales protection or margin performance. This fragmented approach obscures the systemic nature of supermarket operations, where inventory decisions, execution quality, and realized sales are closely interrelated.

Measurement limitations remain a central weakness across studies. Out-of-stock detection and availability measurement are often audit-based or inferred from transactional data, while inventory record inaccuracy and shrinkage can create "phantom" availability that masks true operational failures. As a result, improvement claims are sometimes difficult to compare across contexts, and causal attribution between interventions and performance outcomes is weakened. For Six Sigma and Lean Six Sigma research, this highlights the need for stronger emphasis on measurement validity and information quality as core process variables rather than peripheral issues.

Supermarket-specific execution realities, such as high SKU counts, promotion-driven demand volatility, labor variability, and perishability, are not consistently incorporated into improvement frameworks(Ferreira et al., 2013). Although Lean and Lean Six Sigma tools have demonstrated effectiveness in retail environments, many studies insufficiently specify how in-store logistics and daily execution constraints influence performance outcomes. This limitation reduces the transferability of findings across product categories and store formats.

Furthermore, the sustainability of operational improvements receives limited attention in the literature. Control mechanisms, governance structures, and long-term monitoring are frequently addressed only briefly or implicitly, despite the high-variation, people-intensive nature of supermarket environments where performance gains can quickly deteriorate.

Collectively, these gaps indicate the necessity for an integrated, supermarket-specific framework that explicitly connects customer-critical outcomes (such as availability and freshness), controllable operational levers (including replenishment execution and shelf discipline), information quality (inventory accuracy), and financial performance. Addressing this need establishes the foundation for the Sales and Inventory Optimisation Framework presented in the subsequent section.

VIII. Proposed Sales and Inventory Optimisation Framework

8.1 Rationale and design principles

The comparative synthesis in Sections 5–7 demonstrates that supermarket improvement initiatives often achieve localized operational gains, such as faster replenishment, fewer handling steps, and reduced out-of-stocks(Marques et al., 2022a). However, these gains are rarely integrated into a unified logic that simultaneously addresses sales protection, inventory efficiency, and process stability. The retail operations literature further indicates that availability failures may persist even when replenishment policies are correctly implemented, due to inaccuracies in inventory records, shrinkage, or misplacement. These issues can result in phantom stockouts that necessitate inspection and information correction rather than additional stock orders(Broekmeulen & van Donselaar, 2019).

Accordingly, the proposed framework is based on three design principles: (i) availability and sales outcomes should be regarded as downstream results of controllable operational and information-quality variables; (ii) measurement validity and inventory visibility must be considered core process variables; and (iii) improvements require stabilization through explicit control mechanisms, given the high-variation and people-intensive nature of supermarket operations(Broekmeulen & van Donselaar, 2019; Marques et al., 2022a).

8.2 Framework structure

The proposed framework connects four layers in a cause-and-effect chain and is intended to be presented as a single conceptual figure within the paper, serving as a logic model that can be implemented using the DMAIC methodology.

Layer A — Customer-critical Outcomes (CTQs)

This layer defines success from both customer and commercial perspectives. The core CTQs are: (i) on-shelf

availability for planned purchases, (ii) freshness and quality for perishable categories, and (iii) shopping reliability, defined as the ability to find the correct product at the required time. These CTQs correspond to measurable business outcomes, including lost-sales avoidance, sales conversion protection, and margin protection through reduced waste and markdowns. Notably, sales are conceptualized primarily as *sales protection* resulting from reduced availability failures, rather than as an abstract sales uplift.

Layer B — Operational performance variables (process Ys)

This layer encompasses the measurable store-and-process outcomes that directly affect CTQs. Typical process Ys include replenishment cycle time from backroom to shelf, shelf refill responsiveness during peak periods or promotions, receiving and put-away delays, and shelf compliance, defined as correct and timely product placement. Empirical retail case studies demonstrate that redesigning replenishment flows and implementing pull or standardised routines can reduce labour requirements and enhance availability-related outcomes, underscoring the importance of execution reliability for supermarket performance.

Layer C — Controllable process levers (critical Xs)

This layer comprises the primary controllable drivers targeted during the DMAIC Improve phase. These levers are organized into five blocks relevant to supermarket operations:

1. **Replenishment flow design** (work sequencing, pull triggers, prioritisation rules, backroom layout, workload balancing). Lean interventions in retail replenishment demonstrate that flow redesign can materially reduce wasted handling and improve replenishment time and availability outcomes.
2. **Shelf execution discipline** encompasses standard work for shelf filling, shelf audits, exception escalation, and clear ownership. This lever is essential for ensuring that improvements are maintained despite daily operational variation.
3. **Ordering and parameter governance** includes order review cadence, safety-stock logic by category, and promotion handling rules. This approach prevents overly tailored solutions that generate waste in subsequent periods.
4. **Perishables-specific controls** involve freshness-first replenishment cadence, rotation rules, and markdown triggers. These controls explicitly manage the trade-off between sales and waste, rather than treating waste as a secondary concern.
5. **Exception management** addresses issues such as late delivery, substitution, damage, and misplacement. Effective exception management is critical, as supermarket performance frequently depends on the speed with which exceptions are identified and resolved.

Layer D — Information quality and visibility (enablers and constraints)

This layer is a deliberate addition because the literature shows inventory visibility problems can dominate store performance. Inventory record inaccuracy and unobserved shrinkage can generate phantom stockouts that persist until the organization inspects shelves and corrects records or identifies hidden loss mechanisms.

Therefore, the framework treats the following as first-order variables: inventory record accuracy, inspection/audit frequency (and the targeted areas), discrepancy resolution time, and the quality of the data used to trigger replenishment. The practical implication is availability is not only a replenishment problem; it is also an information-control problem.

8.3 How the framework runs through DMAIC

The framework is implemented using the DMAIC methodology, incorporating supermarket-specific requirements at each stage(Adeodu et al., 2023c).TheFigure 1describes the Proposed Sales and Inventory Optimisation Framework.

Define: Identify a clearly bounded operational problem where sales protection is both plausible and measurable, such as high-value SKUs with frequent out-of-stock (OOS) incidents, promotion periods, or fresh categories experiencing waste or markdown leakage. Explicitly define critical-to-quality (CTQ) parameters, such as availability and freshness, and translate these into a quantifiable business case.

Measure: Ensure measurement validity for out-of-stock/on-shelf availability (OOS/OSA), replenishment timeliness, and inventory accuracy. This step is essential, as phantom stockouts and record errors can undermine key performance indicator (KPI) reporting. The measurement approach must detect discrepancies and

distinguish between true stockouts and phantom stockouts.

Analyse: Apply a combined flow and variability perspective to identify sources of delays and defects, such as backroom constraints, task batching, misplacement, and inadequate trigger logic. Quantify which input variables account for the majority of output variation. Research on inventory auditing and phantom stockouts highlights that shrinkage, handling losses, and limited visibility necessitate explicit diagnostic methods rather than assumptions.

Improve: Implement the minimum necessary operational changes to address the primary causes. In supermarket settings, this typically involves two main interventions: (i) redesigning replenishment flow through pull triggers, standardized work, and workload smoothing, and (ii) enhancing visibility via targeted inspection and audit routines, as well as prompt discrepancy correction. Empirical evidence in retail replenishment supports the effectiveness of flow redesign, while inventory visibility studies underscore the importance of inspection policies for resolving phantom stockouts.

Control: Institutionalize the new processes within a control system that includes standardized work, regular monitoring, exception thresholds, and accountability mechanisms. Given the people-intensive nature of supermarket operations, control systems must incorporate behavioral and managerial routines, such as audit schedules and escalation protocols, in addition to dashboards. Evidence from retail interventions indicates that while process redesign yields benefits, sustaining these improvements requires consistent routines and ongoing monitoring.

8.4 Category-sensitive application

A key practical advantage of the framework is its adaptability to category-specific requirements. In ambient grocery, optimization can focus on stockout prevention and handling efficiency. In perishable categories, optimization must address the trade-off between freshness, waste, and availability, where replenishment frequency and markdown decisions are interdependent. Case evidence from fresh categories demonstrates that redesigning replenishment processes can reduce out-of-stock incidents and enhance fulfillment performance, reinforcing the necessity for category-specific approaches rather than a universal set of controls(Nunes et al., 2022).

8.5 Expected contributions and managerial implications

Conceptually, the framework integrates four elements that are often addressed in isolation: customer critical-to-quality (CTQ) requirements, execution reliability, controllable process levers, and inventory visibility or record integrity(Eren et al., 2022b). In practice, it provides supermarket managers with a structured approach for selecting improvement projects that directly support sales protection, while mitigating common pitfalls such as enhancing ordering rules without addressing inventory accuracy or improving process flow without establishing control routines. The framework also establishes a foundation for empirical validation in future research by specifying measurable variables at each level and clarifying the assumed causal relationships, particularly the roles of phantom stockouts and inspection or auditing policies in maintaining availability performance.

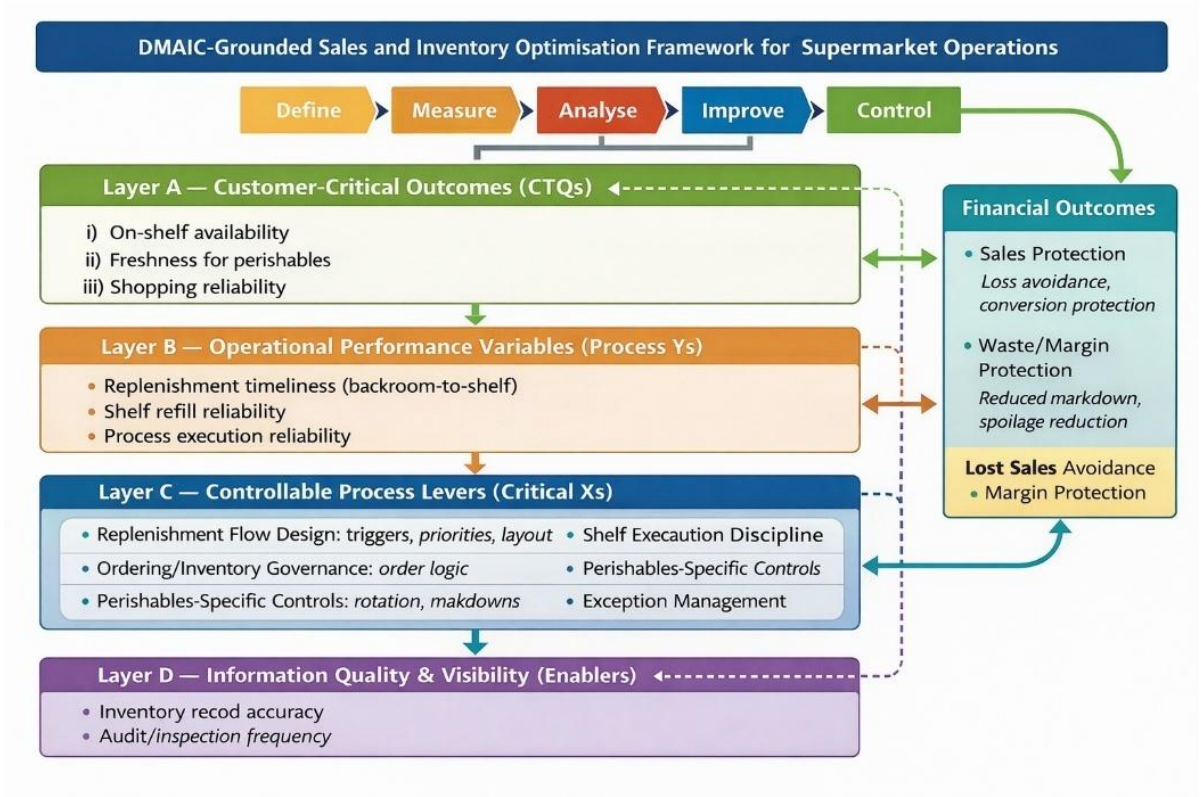

Figure 1: Proposed Sales and Inventory Optimisation Framework

9. Discussion

This review synthesizes evidence on Six Sigma and Lean Six Sigma (LSS) within supermarket contexts and clarifies the collective implications of the literature for researchers and practitioners. Three primary discussion themes emerge: the characterization of supermarket performance as a coupled system, the importance of measurement and inventory visibility, and the organizational conditions necessary to sustain improvements.

An initial implication is that supermarket performance should be understood as a coupled sale–inventoryexecution system, rather than as a set of isolated planning or efficiency challenges. The on-shelf availability (OSA) literature consistently frames stockouts as commercially significant events that can prompt substitution, delay, or store switching, thereby converting operational failures into revenue loss and diminished customer loyalty. The improvement-oriented literature indicates that the most influential levers are typically found in the final stages of execution, such as backroom-to-shelf flow, task sequencing, and exception handling. In these areas, Lean tools enhance process flow, while Six Sigma strengthens problem definition, prioritization, and control. The framework presented in Section 8 aligns with this logic: sales performance is often improved indirectly through sales protection, achieved by reducing availability defects and process variability rather than relying solely on demand-side increases.

A second, more distinctive insight is that information quality constitutes a primary operational variable in supermarket optimization. The phantom stockout literature demonstrates that certain stockouts persist despite replenishment, as unobserved shrinkage or record errors lead the system to assume inventory is available when it is not. Addressing these failures requires human inspection and data correction, rather than improved ordering alone. This has two significant consequences. For research, it clarifies why study results are often difficult to compare: OOS/OSA metrics differ by detection method, and reported improvements may reflect measurement changes rather than actual availability gains. For practice, it underscores that inventory-focused initiatives frequently underperform unless they directly address record accuracy, shelf verification routines, and discrepancy resolution cycles. In Six Sigma terms, this elevates measurement-system credibility and visibility loops from supporting activities to essential components of DMAIC execution.

Third, the literature indicates that the primary barrier to sustained impact is not the selection of tools, but rather deployment capability and governance. Reviews and empirical studies of LSS implementation in service and transactional settings consistently emphasize that long-term performance depends on leadership behaviors,

disciplined project selection, comprehensive training, and management routines that maintain controls beyond the initial improvement phase. This is particularly pertinent in supermarkets, where daily variability, labor turnover, and peak-period pressures can rapidly undermine progress. The practical implication is that the Control phase must be implemented as a set of routines, including audit schedules, exception thresholds, and clear accountability, rather than relying solely on dashboards.

Collectively, these discussion points reinforce the paper's central contribution: supermarket operations benefit from a DMAIC-based framework that explicitly connects customer-critical outcomes (such as availability and freshness), controllable execution levers (including replenishment flow and shelf discipline), information quality (inventory accuracy and inspection), and financial performance (sales and margin protection). The framework also suggests a research agenda in which future empirical studies should test category-specific configurations (ambient versus fresh), standardize measurement approaches for OSA/OOS and phantom stockouts, and investigate which governance mechanisms most effectively sustain improvements across various store formats and demand conditions.

10. Future research directions

This review identifies several targeted directions for future research. First, empirical validation of integrated sales–inventory frameworks in actual supermarket environments is necessary. Future studies should examine how modifications in replenishment execution, inventory visibility, and control routines collectively influence on-shelf availability, lost sales, and margin outcomes across diverse store formats and demand conditions. Category-specific analyses, especially those contrasting ambient and perishable products, would clarify how trade-offs among availability, waste, and inventory efficiency should be managed in practice.

Second, greater methodological consistency is required in measuring on-shelf availability, stockouts, and inventory accuracy. Research that explicitly compares audit-based, system-based, and hybrid measurement approaches would strengthen causal attribution and improve comparability across studies. In particular, further examination of phantom stockouts and inspection policies could clarify how information quality interacts with operational improvement initiatives.

Finally, future research should investigate the organizational and behavioral factors that influence the sustainability of improvements in supermarket environments. Longitudinal studies focused on governance mechanisms, control routines, and leadership practices would offer valuable insights into why some Six Sigma and Lean Six Sigma initiatives result in lasting performance gains while others deteriorate over time.

11. Conclusion

This paper presents a conceptual review of Six Sigma and Lean Six Sigma applications in supermarket operations, with particular emphasis on inventory management, replenishment execution, and their effects on sales performance. The review shows that, although existing studies report significant operational improvements, the literature remains fragmented, frequently separating customer-facing outcomes from the underlying process and information-quality variables.

By synthesizing evidence from retail operations and improvement research, this paper underscores the central importance of in-store execution reliability and inventory visibility in determining on-shelf availability and sales protection. In response, a Sales and Inventory Optimization Framework based on DMAIC is proposed, explicitly connecting customer-critical outcomes, controllable. The primary contribution of this review is the consolidation of dispersed insights and the provision of an integrated perspective that is both theoretically robust and practically relevant. For researchers, it establishes a structured foundation for empirical testing and theory development in supermarket operations. For practitioners, it offers a coherent roadmap for aligning continuous improvement initiatives with sales and inventory performance objectives in complex, high-variability retail settings. Performance objectives in complex, high-variability retail environments.

Author contributions

Ying Sun: conceptualization, methodology, investigation, data curation, writing – original draft. Amarnath Krishnamoorthy: methodology, writing – original draft, validation, resources, review and editing.

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References

[1]. Abreu-Ledón, R., Luján-García, D. E., Garrido-Vega, P., & Escobar-Pérez, B. (2021). Lean six sigma in the food industry: Construct development and measurement validation. *International Journal of Production Economics*, *231*, 107843. https://doi.org/10.1016/j.ijpe.2018.03.015

[2]. Adeodu, A., Maladzhi, R., Kana-Kana Katumba, M. G., & Daniyan, I. (2023a). Development of an improvement framework for warehouse processes using lean six sigma (DMAIC) approach. A case of third party logistics (3PL) services. *Heliyon*, *9*(4), e14915. https://doi.org/10.1016/j.heliyon.2023.e14915

[3]. Adeodu, A., Maladzhi, R., Kana-Kana Katumba, M. G., & Daniyan, I. (2023b). Development of an improvement framework for warehouse processes using lean six sigma (DMAIC) approach. A case of third party logistics (3PL) services. *Heliyon*, *9*(4), e14915. https://doi.org/10.1016/j.heliyon.2023.e14915

[4]. Adeodu, A., Maladzhi, R., Kana-Kana Katumba, M. G., & Daniyan, I. (2023c). Development of an improvement framework for warehouse processes using lean six sigma (DMAIC) approach. A case of third party logistics (3PL) services. *Heliyon*, *9*(4), e14915. https://doi.org/10.1016/j.heliyon.2023.e14915

[5]. Amasuomo, E., & Baird, J. (2016a). The Characteristics of Retail Wastes in the City of Yenagoa, Nigeria. *Journal of Management and Sustainability*, *6*(4), 59. https://doi.org/10.5539/jms.v6n4p59

[6]. Amasuomo, E., & Baird, J. (2016b). The Characteristics of Retail Wastes in the City of Yenagoa, Nigeria. *Journal of Management and Sustainability*, *6*(4), 59. https://doi.org/10.5539/jms.v6n4p59

[7]. Amasuomo, E., & Baird, J. (2016c). The Characteristics of Retail Wastes in the City of Yenagoa, Nigeria. *Journal of Management and Sustainability*, *6*(4), 59. https://doi.org/10.5539/jms.v6n4p59

[8]. Andersen, M., & Skjoett□Larsen, T. (2020). On-shelf availability and logistics rationalization. A participative methodology for supply chain improvement. *Journal of Retailing and Consumer Services*, *52*(2), 101889. https://doi.org/10.1108/13598540910941948

[9]. Azeem, M. M., Baker, D., Villano, R. A., Mounter, S., & Griffith, G. (2019). Response to stockout in grocery stores: A small city case in a changing competitive environment. *Journal of Retailing and Consumer Services*, *49*(9), 242–252. https://doi.org/10.1016/j.jretconser.2019.04.001

[10]. Bassamboo, A., Moreno, A., & Stamatopoulos, I. (2020). Inventory Auditing and Replenishment Using Point-of-Sales Data. *Production and Operations Management*, *29*(5), 1219–1231. https://doi.org/10.1111/poms.13153

[11]. Bhat, S., Antony, J., Maalouf, M., E.V, G., & Salah, S. (2023). Applications of six sigma for service quality enhancement in the UAE: a multiple case study analysis and lessons learned. *International Journal of Lean Six Sigma*, *14*(7), 1492–1517. https://doi.org/10.1108/IJLSS-06-2022-0144

[12]. Bixler, M. J., Honhon, D., Rada, E. C., & Jindal, N. (2021). Exploring the Connections between Backrooms, Inventory Record Inaccuracies, and Waste. *Sustainability 2021, Vol. 13, Page 9490*, *13*(17), 9490. https://doi.org/10.3390/su13179490

[13]. Broekmeulen, R. A. C. M., & van Donselaar, K. H. (2019). Quantifying the potential to improve on food waste, freshness and sales for perishables in supermarkets. *International Journal of Production Economics*, *209*(PART 1), 265–273. https://doi.org/10.1016/j.ijpe.2017.10.003

[14]. Chuang, H. H. C. (2018). Fixing shelf out-of-stock with signals in point-of-sale data. *European Journal of Operational Research*, *270*(3), 862–872. https://doi.org/10.1016/j.ejor.2017.10.059

[15]. Chuang, H. H. C., Oliva, R., & Liu, S. (2016). On-shelf availability, retail performance, and external audits: A field experiment. *Production and Operations Management*, *25*(5), 935–951. https://doi.org/10.1111/poms.12519

[16]. Churi, N., Adams, L., & Witt, P. W. (2025). Integrated -Lean Six Sigma (LSS), Statistical Process Control (SPC), and Data Analytics (DA) Approach to Improve Process Efficiency in Micro-Finishing Process. *The Journal of Business Leadership*, *32*(Spring 2025). https://doi.org/10.69847/sk2jpu

[17]. Chyon, BSc, F. A., Ahmmed, BSc, M. S., Shuvo, BSc, M. K. A., Suman, BSc, M. N. H., & Hossain, PhD, M. M. (2020). Measuring Process Capability in a Hospital by Using Lean Six Sigma Tools—A Case Study in Bangladesh. *Global Advances In Health and Medicine*, *9*. https://doi.org/10.1177/2164956120962441

[18]. Daniyan, I., Adeodu, A., Mpofu, K., Maladzhi, R., & Kana-Kana Katumba, M. G. (2022). Application of lean Six Sigma methodology using DMAIC approach for the improvement of bogie assembly process in the railcar industry. *Heliyon*, *8*(3), e09043. https://doi.org/10.1016/j.heliyon.2022.e09043

[19]. Dharmawardane, C., Sillanpää, V., & Holmström, J. (2021). High-frequency forecasting for grocery point-of-sales: intervention in practice and theoretical implications for operational design. *Operations Management Research 2021 14:1*, *14*(1), 38–60. https://doi.org/10.1007/s12063-020-00176-7

[20]. Disney, S. M., Ponte, B., & Wang, X. (2021). Exploring the nonlinear dynamics of the lost-sales order-up-to policy. *International Journal of Production Research*, *59*(19), 5809–5830. https://doi.org/10.1080/00207543.2020.1790687

[21]. Eren, B., Fen, Ü., Dergisi, B., Aişeoğlu, S., & Karaçizmeli, İ. H. (2022a). REDUCING INVENTORY LEVELS IN A SUPERMARKET BY THE SIX SIGMA METHOD. *Bitlis Eren Üniversitesi Fen Bilimleri Dergisi*, *11*(3), 828–835. https://doi.org/10.17798/bitlisfen.1122251

[22]. Eren, B., Fen, Ü., Dergisi, B., Aişeoğlu, S., & Karaçizmeli, İ. H. (2022b). REDUCING INVENTORY LEVELS IN A SUPERMARKET BY THE SIX SIGMA METHOD. *Bitlis Eren Üniversitesi Fen Bilimleri Dergisi*, *11*(3), 828–835. https://doi.org/10.17798/bitlisfen.1122251

[23]. Ferreira, L. M. D. F., Silva, C., & Mesquita, C. (2013). Using the six sigma DMAIC methodology to improve an internal logistic process. *Lecture Notes in Mechanical Engineering*, *7*, 1461–1473. https://doi.org/10.1007/978-3-319-00557-7_118

[24]. Gomaa, A. H. (2024). Boosting Supply Chain Effectiveness with Lean Six Sigma. *American Journal of Management Science and Engineering 2024, Volume 9, Page 156*, *9*(6), 156–171. https://doi.org/10.11648/j.ajmse.20240906.14

[25]. Gomaa, A. H. (2025). Achieving operational excellence in manufacturing supply chains using lean six sigma: a case study approach. *International Journal of Lean Six Sigma*. https://doi.org/10.1108/IJLSS-03-2024-0045

[26]. Gutierrez-Gutierrez, L., de Leeuw, S., & Dubbers, R. (2016a). Logistics services and Lean Six Sigma implementation: a case study. *International Journal of Lean Six Sigma*, *7*(3), 324–342. https://doi.org/10.1108/IJLSS-05-2015-0019

[27]. Gutierrez-Gutierrez, L., de Leeuw, S., & Dubbers, R. (2016b). Logistics services and Lean Six Sigma implementation: a case study. *International Journal of Lean Six Sigma*, *7*(3), 324–342. https://doi.org/10.1108/IJLSS-05-2015-0019

[28]. Hamim, H., Hasnan, N., &Asha'ari, M. J. (2023). On-Shelf Availability (OSA) and Firm Performance: The Moderating Effects

of Lean Practices in Retail Industry. *JurnalPengurusan*, *68*. https://doi.org/10.17576/pengurusan-2023-68-12

[29]. Hofstra, N., Spiliotopoulou, E., & de Leeuw, S. (2024). Ordering decisions under supply uncertainty and inventory record inaccuracy: An experimental investigation. *Decision Sciences*, *55*(3), 303–318. https://doi.org/10.1111/deci.12564

[30]. Hollingshed, M. (2022). Standardizing Six Sigma Green Belt training: identification of the most frequently used measure phase DMAIC tools. *International Journal of Lean Six Sigma*, *13*(2), 276–294. https://doi.org/10.1108/IJLSS-12-2020-0220

[31]. Hübner, Alexander, Kuhn, · Heinrich, Kuhn, Heinrich, Hübner, A, & Kuhn, H. (2023). Decision support for managing assortments, shelf space, and replenishment in retail. *Flexible Services and Manufacturing Journal 2023 36:1*, *36*(1), 1–35. https://doi.org/10.1007/s10696-023-09492-z

[32]. Jou, Y. T., Silitonga, R. M., Lin, M. C., Sukwadi, R., & Rivaldo, J. (2022). Application of Six Sigma Methodology in an Automotive Manufacturing Company: A Case Study. *Sustainability 2022, Vol. 14, Page 14497*, *14*(21), 14497. https://doi.org/10.3390/su142114497

[33]. Koren, M., Perlman, Y., &Shnaiderman, M. (2024). Inventory management for stockout-based substitutable products under centralised and competitive settings. *International Journal of Production Research*, *62*(9), 3176–3192. https://doi.org/10.1080/00207543.2023.2222186

[34]. Larson, R. B., & Ferrin, B. (2023). Exploring Shopper Reactions to Grocery Stockouts. *Journal of Food Products Marketing*, *29*(1), 1–18. https://doi.org/10.1080/10454446.2022.2160223

[35]. Li, R., Song, J. S. J., Sun, S., & Zheng, X. (2022). Fight inventory shrinkage: Simultaneous learning of inventory level and shrinkage rate. *Production and Operations Management*, *31*(6), 2477–2491. https://doi.org/10.1111/poms.13692

[36]. Linuwih, H. W., & Handayati, Y. (2025). Quantitative Analysis of Inventory Record Inaccuracy (IRI): A Case Study on Warehouse Stock Discrepancies. *International Journal of Current Science Research and Review*, *08*(01). https://doi.org/10.47191/ijcsrr/v8-i1-26

[37]. Lu, G., Lee, H. S., & Son, J. (2022). Product variety in local grocery stores: Differential effects on stock-keeping unit level sales. *Journal of Operations Management*, *68*(1), 33–54. https://doi.org/10.1002/joom.1158

[38]. Macedo, H., Tomaz, L., Guimarães, L., Cerqueira-Pinto, L., Sá, J. C., & Dinis-Carvalho, J. (2025). Development of a Classification Model for Value-Added and Non-Value-Added Operations in Retail Logistics: Insights from a Supermarket Case Study. *Sustainability 2025, Vol. 17, Page 3177*, *17*(7), 3177. https://doi.org/10.3390/su17073177

[39]. Madhani, P. M. (2020). Lean Six Sigma Deployment in Retail Industry: Enhancing Competitive Advantages. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.4002472

[40]. Marques, P. A., Jorge, D., & Reis, J. (2022a). Using Lean to Improve Operational Performance in a Retail Store and E-Commerce Service: A Portuguese Case Study. *Sustainability 2022, Vol. 14, Page 5913*, *14*(10), 5913. https://doi.org/10.3390/su14105913

[41]. Marques, P. A., Jorge, D., & Reis, J. (2022b). Using Lean to Improve Operational Performance in a Retail Store and E-Commerce Service: A Portuguese Case Study. *Sustainability 2022, Vol. 14, Page 5913*, *14*(10), 5913. https://doi.org/10.3390/su14105913

[42]. Marques, P. A., Jorge, D., & Reis, J. (2022c). Using Lean to Improve Operational Performance in a Retail Store and E-Commerce Service: A Portuguese Case Study. *Sustainability 2022, Vol. 14, Page 5913*, *14*(10), 5913. https://doi.org/10.3390/su14105913

[43]. Mckinnon, A. C., Mendes, D., & Nababteh, M. (2007a). In-store logistics: an analysis of on-shelf availability and stockout responses for three product groups. *International Journal of Logistics Research and Applications*, *10*(3), 251–268. https://doi.org/10.1080/13675560701478075

[44]. Mckinnon, A. C., Mendes, D., & Nababteh, M. (2007b). In-store logistics: an analysis of on-shelf availability and stockout responses for three product groups. *International Journal of Logistics Research and Applications*, *10*(3), 251–268. https://doi.org/10.1080/13675560701478075

[45]. Mckinnon, A. C., Mendes, D., & Nababteh, M. (2007c). In-store logistics: an analysis of on-shelf availability and stockout responses for three product groups. *International Journal of Logistics Research and Applications*, *10*(3), 251–268. https://doi.org/10.1080/13675560701478075;SUBPAGE:STRING:ABSTRACT;JOURNAL:JOURNAL:CJOL20;REQUESTEDJOURNAL:JOURNAL:CJOL20;WGROUP:STRING:PUBLICATION

[46]. Monday, L. M., & Monday, L. M. (2022). Define, Measure, Analyze, Improve, Control (DMAIC) Methodology as a Roadmap in Quality Improvement. *Global Journal on Quality and Safety in Healthcare*, *5*(2), 44–46. https://doi.org/10.36401/jqsh-22-x2

[47]. Moussaoui, I., Williams, B. D., Hofer, C., Aloysius, J. A., & Waller, M. A. (2016). Drivers of retail on-shelf availabilitySystematic review, critical assessment, and reflections on the road ahead. *International Journal of Physical Distribution & Logistics Management*, *46*(5), 516–535. https://doi.org/10.1108/IJPDLM-11-2014-0284

[48]. Nunes, C., Rocha, D., Riesenegger, L., & Hübner, A. (2022). Reducing Food Waste at Retail Stores—An Explorative Study. *Sustainability 2022, Vol. 14, Page 2494*, *14*(5), 2494. https://doi.org/10.3390/su14052494

[49]. Ortiz-Porras, J. E., Bancovich-Erquínigo, A. M., Candia-Chávez, T. C., Huayanay-Palma, L. M., Moore-Torres, R. K., & Gomez, O. R. T. (2023). Green Lean Six Sigma model for waste reduction of raw material in a nectar manufacturing company of Lima, Peru. *Journal of Industrial Engineering and Management*, *16*(2), 169–185. https://doi.org/10.3926/jiem.4916

[50]. Panayiotou, N. A., & Stergiou, K. E. (2023). Development of a retail supply chain process reference model incorporating Lean Six Sigma initiatives. *International Journal of Lean Six Sigma*, *14*(1), 209–251. https://doi.org/10.1108/IJLSS-04-2021-0079

[51]. Pandiyan, V., Sundram, K., Ghapar, F., Lian, C. L., & Muhammad, A. (2023). Engaging Lean Six Sigma Approach Using DMAIC Methodology for Supply Chain Logistics Recruitment Improvement. *Information Management and Business Review*, *15*(1(I)SI), 46–53. https://doi.org/10.22610/imbr.v15i1(i)si.3401

[52]. Patra, S. S., Saboo, P., Arakeri, S. U., Mogali, S. D., Ahmed, Z., & Lanham, M. A. (2021). *Leveraging Insights from "Buy-Online Pickup-in-Store" Data to Improve On-Shelf Availability*. 417–433. https://doi.org/10.1007/978-3-030-71704-9_28

[53]. Ping, H., Li, Z., Shen, X., & Sun, H. (2024). Optimization of Vegetable Restocking and Pricing Strategies for Innovating Supermarket Operations Utilizing a Combination of ARIMA, LSTM, and FP-Growth Algorithms. *Mathematics 2024, Vol. 12, Page 1054*, *12*(7), 1054. https://doi.org/10.3390/math12071054

[54]. Qin, Y., & Liu, H. (2022). Application of Value Stream Mapping in E-Commerce: A Case Study on an Amazon Retailer. *Sustainability 2022, Vol. 14, Page 713*, *14*(2), 713. https://doi.org/10.3390/su14020713

[55]. Rahmatillah, H., & Rusindiyanto, R. (2025). Analysis Of Defect Waste Reduction In Metal Forming Process Using Lean Six Sigma. *ITEJ (Information Technology Engineering Journals)*, *10*(1), 141–152. https://doi.org/10.24235/itej.v10i1.203

[56]. Reiner, G., Teller, C., & Kotzab, H. (2013a). Analyzing the efficient execution of in-store logistics processes in grocery retailing - The case of dairy products. *Production and Operations Management*, *22*(4), 924–939. https://doi.org/10.1111/poms.12003

[57]. Reiner, G., Teller, C., & Kotzab, H. (2013b). Analyzing the efficient execution of in-store logistics processes in grocery retailing - The case of dairy products. *Production and Operations Management*, *22*(4), 924–939. https://doi.org/10.1111/poms.12003

[58]. Ruwanpura, U. D. R. E., Perera, B. A. K. S., &Ranadewa, K. A. T. O. (2023). Lean six sigma tools for improving administrative processes in different sectors: a systematic review. *World Construction Symposium*, *1*, 686–699. https://doi.org/10.31705/WCS.2023.56

[59]. Sabtu, S. H., Effendi, M., Matore, E. M., & Maat, S. M. (2023). Why Do You Need to Invest in Quality Control Tools? Smart Analytical Six Sigma DMAIC Model Continuous Improvement on Measuring Teacher's Performance. *International Journal of Academic Research in Business and Social Sciences*, *13*(6), 873–883. https://doi.org/10.6007/ijarbss/v13-i6/17210

[60]. Saghiri, S., Aktas, E., & Mohammadipour, M. (2023). Grocery omnichannel perishable inventories: performance measures and influencing factors. *International Journal of Operations & Production Management*, *43*(12), 1891–1919. https://doi.org/10.1108/IJOPM-06-2022-0397

[61]. See, J., & Tay, H. L. (2021). Application of Lean Six Sigma to Improve The Food Bank Singapore's Vending Machine Replenishment Process – A Case Study. *Proceedings of the International Conference on Industrial Engineering and Operations Management*, 3441–3453. https://doi.org/10.46254/an11.20210619

[62]. Shabani, A., Maroti, G., de Leeuw, S., &Dullaert, W. (2021). Inventory record inaccuracy and store-level performance. *International Journal of Production Economics*, *235*, 108111. https://doi.org/10.1016/j.ijpe.2021.108111

[63]. Tampubolon, S., & Purba, H. H. (2021). Lean six sigma implementation, a systematic literature review. *International Journal of Production Management and Engineering*, *9*(2), 125–139. https://doi.org/10.4995/IJPME.2021.14561

[64]. Theodorou, E., Spiliotis, E., &Assimakopoulos, V. (2025). Forecast accuracy and inventory performance: Insights on their relationship from the M5 competition data. *European Journal of Operational Research*, *322*(2), 414–426. https://doi.org/10.1016/j.ejor.2024.12.033

[65]. Torres, R. M., Machuca, J. P., Mauricio, R., & Flores, V. (2022a). *A Systematic Review of the Implementation of Lean Six Sigma Tools to Improve the Logistics of Retail Businesses*. 2349–2361. https://doi.org/10.46254/au01.20220506

[66]. Torres, R. M., Machuca, J. P., Mauricio, R., & Flores, V. (2022b). *A Systematic Review of the Implementation of Lean Six Sigma Tools to Improve the Logistics of Retail Businesses*. 2349–2361. https://doi.org/10.46254/au01.20220506

[67]. Tufail, M. M. B., Shakeel, M., Sheikh, F., Anjum, N., Tufail, M. M. B., Shakeel, M., Sheikh, F., & Anjum, N. (2021). Implementation of lean Six-Sigma project in enhancing health care service quality during COVID-19 pandemic. *AIMS Public Health 2021 4:704*, *8*(4), 704–719. https://doi.org/10.3934/publichealth.2021056

[68]. Vieira, E., Tomaz, L., Leitão, J., Fernandes, J., & Dinis-Carvalho, J. (2025). Enhancement of In-Store Product Replenishment Flow and Introduction of Pull Approach in a Food Retail Chain. *Logistics 2025, Vol. 9, Page 61*, *9*(2), 61. https://doi.org/10.3390/logistics9020061

[69]. Wang, K. (2025a). Research on Optimization Ideas of Inventory Management Problems in Cold Chain Logistics. *Advances in Economics, Management and Political Sciences*, *144*(1), 52–56. https://doi.org/10.54254/2754-1169/2024.ga19086

[70]. Wang, K. (2025b). Research on Optimization Ideas of Inventory Management Problems in Cold Chain Logistics. *Advances in Economics, Management and Political Sciences*, *144*(1), 52–56. https://doi.org/10.54254/2754-1169/2024.ga19086

[71]. Wei, C. C. (2010). Using Six Sigma to improve replenishment process in a direct selling company. *Strategic Direction*, *26*(8), 49–65. https://doi.org/10.1108/sd.2010.05626had.010