

From Counters to Self-Checkouts: A

Systematic Review of Factors Affecting Operational Efficiency in Retail Automation

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Abstract— The Self-Checkout System (SCS) is a key element of retail automation, designed to improve operational efficiency and enhance customer convenience. This systematic literature review synthesizes insights from 16 peer-reviewed Q1/Q2 studies published between 2020 and 2025, leading to the identification of four critical factors influencing efficiency: technological design, user behavior, organizational preparedness, and workforce impact. The findings suggest that a combination of advanced perception technologies (e.g., AI vision, depth cameras), user-centered interface design, process reengineering, and comprehensive staff training, including cross-training for hybrid support roles, plays a pivotal role in shaping outcomes. Recent research also highlights emerging adoption drivers such as reduced stigma around sensitive purchases, increased privacy awareness, and shifting dynamics of customer empowerment. Efficiency is not an inherent attribute of the system alone, but rather the result of interactions among technology, users, and institutional contexts. Retailers and policymakers are encouraged to pursue integrated design approaches that holistically align technological innovation, store operations, and human labor.

Keywords— Self-Checkout Systems (SCS), Retail Automation, Operational Efficiency, Systematic Literature Review

I. Introduction

Consumer experiences are being reinvented into automation, and people can scan and bag their own groceries through self-checkout. These systems assure low labor costs and quicker service [1], [2]. Nonetheless, technical flaws, usability, and accessibility issues still exist [3].

Problem Statement

Whereas some individual studies showcase technological condition, user behavior, or organizational preparedness, few have synthesized the studies in a systematic manner. In the absence of integration, strategies become vulnerable to a lack of alignment with the needs of customers [4]. The existed literature identifies the potential of technological interventions (e.g., YOLOv10, depth cameras), user-centered design aspects, and organizational processes (employee support) [5], [6], [7], [8]. However, there is no single research that links these views together.

Research Objective

The main focus of this review is to identify how various factors shape the operational efficiency of self-checkout systems in retail environments.

II. Literature Review

The effectiveness of self-checkout can be evaluated in four interdependent dimensions: technological innovations, behavior of users, organizational readiness, and the influence on workforces. Our results suggest that the overall success of these systems does not lie in a specific factor but instead in how these factors interact.

Technological Innovation

In a research Milella et al. demonstrate the enhanced on-shelf detection precision and reduced recognition errors of depth-camera vision, providing a vivid example of why accurate perception becomes a first-order determinant of reliability in the checkout process. [7]. Tan et al. then shows that better object detection with YOLOv10 leads to faster and more accurate scanning, which also reduces rescans and associate interventions [8]. Considering a broader scope, Worniak et al. [9] covering the in-store digital stack – scanners, AR, AI – point out that stores benefit most when hardware, software, and data pipelines are integrated, rather than adopted one piece at a time. Collectively these reports suggest that recent advancements are not just a collection of improvements: both computer vision and multimodal sensing are moving SCS into more autonomous modes of operation, and it still relies on store infrastructure (in the form of lighting, network, and placement of devices) to deliver on the efficiency promise.

User behavior and Demographics

Meta-level evidence supports that the perceptions are as important as the technology. Since technology readiness (optimism,

innovativeness enthusiasm vs. discomfort, insecurity) has expected trimetric proportionate impacts on the usage in different contexts [10], and performance expectancy and effort expectancy are still the greatest UTAUT determinants [1], the results are logically made. Context also moderates effects: Lee and Leonas [2] show that how millennials intend to use SCS differs based on the form of retail and perceived benefits and risks associated with using them; Hsiao and Tang [3] indicate continuance with SCS through mobile-app is determined by previous use of mobile payments, ease of navigation, and level of trust. Two recent studies further use behavioral language: Cardinali et al. [11] find SCS can reduce stigma when purchasing something sensitive, and Schultz and Paetz [12] find that satisfaction varies by cashier less method (app, face recognition, traditional SCS), suggesting that alternative designs matter because they can impact perceived effort and reward. The general adoption is also based on the aspect of perceived convenience, privacy/comfort and appropriateness of the interface and capabilities of the users.

Organizational Readiness

Success in operations relies on its surroundings. Bascur and Rusu [5] summarize that fallback procedures and just-in-time support are necessary to prevent breakdowns of queues. In a study by Duarte et al. [13], which relied upon necessary condition analysis, organizational enablers of performance were identified as managerial commitment, training, and process redesign, without which objectives are impossible to achieve even in the case of a highly equipped technology.

According to Darmody and Zwick [4], SCS may shift the workload to the customer (co-creation by design), obscuring the costs in case retailers do not invest in guidance and exception management sufficient to accommodate customers and address situations that cannot be predicted. The import is obvious: efficiency is in the system, as it occurs when SCS is integrated into staffing patterns, escalation patterns, and even store layout--not when kiosks are sprinkled into an existing pattern without modification.

Workforce Impact

Self-checkout does not reduce the number of jobs, it changes it. This has been captured by Nicholls [14] as consumption is being viewed as work with the service labor roles as well as later-life roles now being re-conceptualized into work that is done by the customers. Even frontline service positions that are among the most at risk of AI substitution [15] should be reskilled to help them take up tech-support and exception management roles. The first is emerging evidence (e.g., case findings summarized in your paper) indicating the strategy of hybrid staffing where employees circulate as coaches/triage, allowing SCS to perform the routine scanning without sacrificing service quality. In brief, the workforce aspect is a design factor: training, on-job redesign, prompting guidance pick high or low human labor accompaniment or contradiction with SCS.

Collectively, these studies show that efficiency is multidimensional. The aspects of technological reliability, user trust top-management strategies, and adaptability among workforces complement each other. Efficiency will be at its peak when there is the presence of sophisticated technologies in systems, customer confidence will be high, organizations will have provisioned the infrastructure and backup, and the employees will be modifying to engage in the new hybrid practices.

III. Methodology

This research employed a systematic literature review (SLR), limiting the scope of analysis to those peer-reviewed articles indexed in Q1/Q2 journals published between 2020 and 2025. The search methods were conducted in Scopus, Web of Science, ScienceDirect and MDPI, and with the implementation of Boolean combinations of the actual words “self-checkout”, “retail automation”, “YOLOv10”, “usability” and “workforce displacement”.

The literature review was organized and systematically reviewed in two stages and both inclusion and exclusion criteria were followed. Empirical, systematic or meta-analytic studies with a direct implication on the efficiency of SCS were retained.

In Scopus, Web of Science, ScienceDirect, and MDPI databases, Boolean operators (AND/OR) were employed in various combinations to narrow down database search criteria and the two-phase screening procedure was adopted on the following basis:

1) Inclusion Criteria

- Published between 2020–2025
- Peer-reviewed Q1/Q2 journal articles
- Focused on retail automation or self-checkout
- Employed systematic, empirical, or meta-analysis

2) Exclusion Criteria

- Articles published before 2020
- Conference proceedings, blogs, preprints
- Articles unrelated to retail or automation
- Theoretical or opinion-based papers

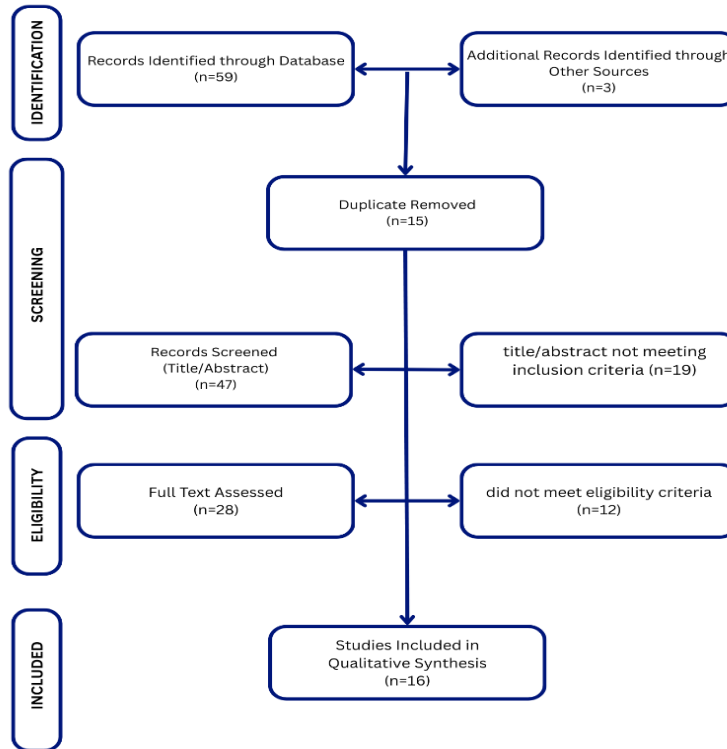


Figure 1: PRISMA Flow diagram of Study Selection Process

As shown in Figure 1, the discussed literature falls into four broad categories of self-checkout efficiencies that are technological advancements, consumer habits, store operation activities, and labor force situation. The visualization draws attention to the interdependencies of these areas, and newer Q1/Q2 research (2020-2025) has built on underlying adoption models to apply them in the contexts of AI-based recognition and customer loyalty. Studies related to Technological Innovations are represented in blue, User Behavior in orange, Retail Operations in red, and Workforce Impact in green.

The PRISMA 2020 guidelines were followed to ensure a transparent and systematic study selection process. Searching the database and other sources was used to identify the records, and the duplicates were eliminated. The list of studies was screened by title and abstract. It did not mean that full-text articles were not reviewed to determine their eligibility and studies that failed to meet the inclusion criteria were eliminated. The final set of studies that were included in the qualitative synthesis was sixteen (Figure 2).

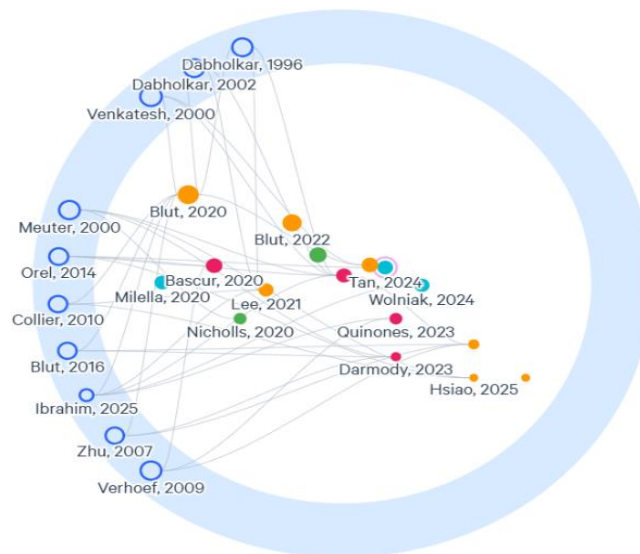


Figure 2: Litmap visualization of reviewed studies (2020–2025) across four dimensions of self-checkout efficiency

As it shows in figure 2, after applying the inclusion and exclusion criteria, 16 articles were selected for full-text analysis. Each article was coded based on variables such as: Technology discussed (e.g., YOLOv10, depth cameras); Research method used (e.g., SLR, case study, survey); Key themes (e.g., usability, organizational readiness).

Information was divided into four domains, namely, technology, the behavior of users, organizational readiness, and workforce, and the theme analysis in NVivo was performed.

The technological, behavioral, and organizational factors affecting the efficiency of self-checkout systems were represented by the following keywords that were subsequently combined:

Technological terms: Self-checkout technology, retail automation, artificial intelligence, YOLOv10, and automated retail systems.

Behavioral terms: Customer experience, user behavior, technology acceptance, digital confidence, usability

Organizational terms: Readiness of organizations, hybrid systems, fallback mechanisms, employee training, the effect on labor.

Workforce-efficiency terms: Displacement of jobs, job redefinition, technical skills.

To determine recurrent variables and concepts, a thematic analysis was carried out. Technological efficiency, customer interaction, organizational infrastructures and workforce impact were used to cluster the themes. In NVivo, a review of each article contribution was performed to provide structured synthesis of insights.

This research makes use of pure secondary data. Peer-review is utilized in all the cited sources to make them transparent. No human participants were used and therefore there was no formal review by an Institutional Review Board needed. This was countered by systematic screening and adherence to PRISMA guidelines to minimize bias.

IV. Key Findings and Discussion

The review summarizes the literature to develop a rigorous conceptual model of analysis of SCS efficiency. Academically, it progresses the current debates about retail digitalization with insights into consumer behavior, information systems, and operations management. To the practitioners, the review lays out effective strategies of implementing SCS systems. Policy makers on the other hand derive empirical data that can back regulatory measures that would allow creation of fairness and accessibility in the provision of SCS. This review explores how the operational efficiency of self-checkout technology in retail is influenced, revealing common themes and key contributing factors, as shown in Table I.

It was found in the review that self-checkout efficiency depends on both human and technological factors. Technological preparedness and architecture define the speed of transactions and error rates, and user characteristics influence the ease of adoption and comfort level with self-service. The implementation of these systems in retail environments is more successful when the environments provided intuitive designs, and fast support.

Table I Factors Increasing Operational Effectiveness of Self-Checkout Technology in Retail Setting

FACTOR CATEGORY	DESCRIPTION	REFERENCES
TECHNOLOGY DESIGN	Ease-of-Use, interface intuitiveness and system speed	[7], [8], [13]
USER BEHAVIOR & DEMOGRAPHICS	The level of acceptance dependent upon the age group, the level of tech-savviness, level of trust, and digital anxiety	[2], [3], [6]
OPERATIONAL READINESS	Technology and preparedness of infrastructure	[7], [8], [9]
OPERATIONAL READINESS	Technology and preparedness of infrastructure	[7], [8], [9]

In addition, customer experience is greatly influenced by the perception of benefit versus effort. As an example, convenient consumers are less sensitive to slight inefficiencies, but those who have to overcome obstacles leave the system [13].

These trends in customer experience also speak directly to the experiences of employees because the extent of customer autonomy often redeploys roles performed by front-facing staff and controls the extent of labor re-allocation to technical support, or supervision work.

There are also labor relations in play. As automation evolves, there will be a concern about job displacement, yet several studies have indicated the importance of a hybridized system that can add human support to a system on-demand, improving the usability and acceptance of systems, as well as work flow overall [4], [15].

Ultimately, the evidence indicates that efficiency in self-checkout is not due to a specific element but rather joint effects of technology advancements, customer patterns, shop activity, and labor flexibility.

An alignment of these four dimensions can lead to speed and customer satisfaction; a misalignment can induce efficiency gains paid by frustration, hidden costs, or workforce tensions.

V. Conclusions

This review shows that intuitive user-friendly design which uses powerful technological infrastructure, flexible technical support, and strategic combination of automation and human support depending on the customer needs will provide optimal efficiency of operations in self-checkout systems.

The summary of the key points is as follows:

- Self-checkout technologies achieve the highest operational efficiency when they feature intuitive, user-friendly interfaces, are supported by responsive and well-trained technical staff, and are deployed in retail environments with adequate infrastructure and customer demand.
- Efficiency is not only predetermined by technology, trust and perceived ease of use and support mechanisms play dominant roles.
- Efficient deployment will consider the variability in demographics and combine automation with human support.

This review determines that effectiveness of self-checkout systems lies in the appropriate interplay of technological advancements, customer adoption trends, company preparedness, and workforce fitment.

VI. Recommendations for Future Research

Future research could benefit from incorporating a wider range of sources such as conference proceedings and industry white papers to capture emerging developments in retail automation that may not yet be widely represented in peer-reviewed journals. There is also a need for studies that explore the long-term impacts of self-checkout systems on customer satisfaction, employee roles, and operational efficiency across different retail formats. In addition, examining the environmental and ethical implications of these systems, together with deeper qualitative investigations into customer experiences, accessibility for elderly or disabled shoppers, and levels of trust in automated technologies, would help to address gaps in the existing literature.

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