

AUTOMATION-ENABLED SPECIALIZATION AND RETAIL SERVICE PRODUCTIVITY: EVIDENCE FOR MANAGERIAL DESIGN AND OPERATIONAL PLANNING IN SUPERMARKET CHECKOUT SYSTEMS

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This article develops a theory-driven secondary analysis of how automation-enabled job redesign affects frontline productivity in retail service operations and why the result matters for managerial planning. The analysis interprets a transaction-level field experiment conducted in four outlets of a major Singapore supermarket group, where cashiers were rotated between conventional checkout counters and scan-only/self-pay counters over 38 days. The published dataset comprises 152,246 transactions completed by 38 cashiers in a within-cashier design. In the scan-only format, the cashier specialized in scanning and packing while customer payment was shifted to self-pay kiosks. The preferred fixed-effects estimate shows that scan-only checkout increased scanning speed by 10.9%, and the broader customer service rate rose by about 21%. Mechanism tests indicate that the productivity gain is consistent with a reduction in the marginal cost of effort in the remaining human task: at conventional counters, a 1% increase in scanning speed was associated with roughly a 0.66% increase in payment time. Robustness checks further indicate that the observed gains are not plausibly explained by customer sorting, fatigue, learning, or differential assistance. Framed for management and planning research, the article supports a bounded but important conclusion: automation can improve operational performance not only by substituting for labor in one task, but also by redesigning work in a way that sharpens specialization, improves cashier-side throughput, and strengthens managerial control over service capacity.

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INTRODUCTION

Automation is often evaluated as a straightforward substitution of machines for human labor. That view is too narrow for many service settings. In integrated frontline jobs, the automation of one task may alter how human effort is allocated across the remaining tasks and thereby change productivity in ways that are organizationally significant. This issue is especially important in management and planning contexts, where operational design choices shape staffing, customer throughput, service quality, and capital allocation.

Retail checkout is a particularly useful context for studying these effects. In a conventional supermarket checkout, the cashier scans and packs purchases and then collects payment. These tasks are operationally linked but cognitively distinct. The cashier must switch attention between item handling, transaction monitoring, cash or card processing, and customer interaction. A scan-only/self-pay format reorganizes this workflow. The cashier remains responsible for scanning and packing, while the customer completes payment at a designated kiosk. The change is not merely technological. It is a change in job design, workflow sequencing, and the division of labor between employee and customer.

The managerial relevance of this arrangement is immediate. If moving payment to a kiosk only replaces one discrete task, its value is limited to direct labor substitution. If, however, the redesign also makes the cashier materially more productive in the nonautomated task, then the investment case changes. The technology affects the design of work itself. It can alter staffing requirements, service capacity, queue management, and the timing of capital payback.

This manuscript develops a theory-driven secondary analysis of the supermarket field evidence reported by (author?) [6], reorganized for a journal audience concerned with organizational performance, planning, and decision support. It does not claim a new field experiment. Its contribution is instead interpretive and managerial. First, it clarifies the underlying organizational mechanism: automation can enable specialization without the coordination costs that would arise if the same tasks were split across multiple workers. Second, it translates the published estimates into a more disciplined planning logic that distinguishes cashier-side capacity gains from fully realized system-wide throughput. Third, it consolidates the empirical evidence on robustness, mechanism, and economic significance to show what the field evidence supports, what it does not by itself establish, and where managerial judgment remains essential.

THEORETICAL BACKGROUND AND MANAGERIAL FRAMING

Automation as job redesign rather than simple substitution

The classical argument of (author?) [3] is that specialization can increase productivity, but its gains are bounded by coordination costs. Splitting a job across multiple workers may create idle time, communication burdens, and incentive frictions. The central insight in the supermarket checkout setting is that automation changes this tradeoff. When a machine assumes one task, the worker can specialize in the remaining task without adding another employee and without incurring equivalent human-to-human coordination costs.

This perspective is important for management research because it reclassifies some automation projects. A technology investment may not simply remove labor from a workflow. It may also reconfigure the human task bundle, reduce switching costs, and increase effective effort in the tasks that remain with the worker. In organizational terms, the technology becomes part of the operating model, and its value must be assessed through workflow design rather than through headcount reduction alone.

Why checkout design is a planning problem

Checkout design sits at the intersection of operations management and planning. Managers must decide how many counters to open, how to allocate staff across formats, how to absorb peak demand, and whether a capital investment in kiosks is justified by labor savings and throughput gains. These are not purely technical decisions. They concern capacity planning, service process design, and the division of work between employees and customers.

The scan-only/self-pay format is therefore relevant to the core domains that JMPR emphasizes: operations management, services management, digital transformation, organizational performance, and resilience in day-to-day execution. The setting also speaks to practical planning questions: when should a firm invest in service automation, which tasks should be automated first, how should capacity be rebalanced across formats, and how should managers evaluate automation when the principal gains may arise in adjacent human tasks rather than in the automated task itself?

EMPIRICAL SETTING AND RESEARCH DESIGN

Context

The empirical setting is a major supermarket group in Singapore. As of December 2017, the group operated 44 stores with 404,000 square feet of retail space and annual sales revenue of \$830 million (US\$621 million). In response to tightening labor constraints and the need to raise productivity, the group introduced a scan-only/self-pay checkout design in 2015. In this format, the cashier scans and packs the customer's purchases and then directs the customer to a separate kiosk for payment in cash or by card.

This arrangement differs from full self-checkout systems common in many Western retail environments. The human cashier remains central to the process. What changes is the allocation of tasks within the transaction.

Field experiment

The evidence comes from a field experiment conducted in four supermarket outlets that were temporarily configured with both conventional and scan-only checkout formats. Over 38 days in December 2017 and May 2018, store managers rotated cashiers across checkout counters on a daily basis. This created a within-cashier design: each cashier served as his or her own control.

The design materially strengthens internal validity. Because cashiers rotated across both formats, the analysis is not driven by stable worker differences. The experiment also reduces concerns that more productive cashiers were selectively assigned to the new format. Cashiers were not informed that an experiment was underway, which helps reduce behavioral distortions associated with observation, even though the evidence should still be interpreted as coming from one organizational setting rather than from a fully general retail population.

Data

Management provided point-of-sale records and counter time logs recorded to the millisecond. For each transaction, the sales records identify the cashier, transaction details, product categories and subcategories,

prices, and payment method. Counter time logs record the transaction identifier, the start and end times of scanning, and the time at which payment was completed.

The published analysis focuses on scanning speed as the productivity measure for the nonautomated task. Scanning speed is calculated as the number of items purchased divided by the elapsed time between the start and end of scanning. Because the logs do not separately track packing time, the outcome should be understood as a bounded measure of cashier-side scanning productivity during the scanning interval rather than as a complete measure of end-to-end service performance.

The analytic sample is restricted to cashiers observed in both checkout formats. It includes 38 cashiers and 152,246 transactions, with 98,007 transactions at scan-only counters and 54,239 at conventional counters.

MEASURES AND ANALYTICAL APPROACH

The core published estimating equation is:

$$\ln(Y_{icst}) = \beta_0 + \beta_1 \text{ScanOnly}_{cst} + \gamma X_i + \gamma_c + \gamma_t + \varepsilon_{icst}, \quad (1)$$

where Y_{icst} is cashier productivity for cashier c in store s handling transaction i at time t , ScanOnly_{cst} equals 1 when the cashier works at a scan-only counter, X_i contains transaction characteristics, and γ_c and γ_t capture cashier and time fixed effects. Standard errors are clustered by cashier, and the published study further reports Wild cluster bootstrap p -values.

The coefficient of substantive interest is β_1 , which measures the within-cashier difference in productivity between the scan-only and conventional job designs.

Because the present article interprets published estimates rather than introducing new estimation, the evidentiary question is whether the original identification strategy and the reported triangulation across tests jointly support a credible managerial inference.

For management interpretation, four elements of the design are especially important.

First, the within-cashier rotation isolates the effect of workflow design from stable worker ability. Second, increasingly stringent fixed-effects specifications test whether the productivity gain survives controls for store context and time-of-day conditions. Third, robustness checks examine alternative explanations such as customer sorting, fatigue, and packing assistance. Fourth, mechanism tests evaluate whether faster scanning in the conventional format is associated with slower payment processing, which would be consistent with the integrated job imposing a multitasking cost.

RESULTS

Descriptive evidence

Table 1 reports the published summary statistics. Several patterns matter for management.

Raw scan time was lower at scan-only counters (0.508 minutes versus 0.532 minutes), and log-transformed scanning speed was higher (2.440 versus 2.379). Although the raw items-per-minute average appears lower at scan-only counters, that unlogged mean is sensitive to very short scan intervals and a small number of

extreme observations. The logarithmic specification used in the regression analysis reduces that leverage and is better aligned with proportional performance differences across a skewed distribution, which is why the preferred estimates indicate faster scanning under scan-only checkout. Cashiers also spent less counter work time per shift at scan-only counters, yet they handled a similar cumulative number of customers. This pattern is consistent with the operational logic of the format: the cashier is relieved of payment collection and can process demand more efficiently.

Customers at scan-only counters were less likely to pay in cash, and baskets were slightly larger but lower in value and average item price. These differences underscore the need for fixed effects and robustness checks. They complicate simple mean comparisons, but they do not by themselves overturn the central productivity result.

Table 1: Summary Statistics by Checkout Format

Variable	Unit	Scan-only	Conventional	Difference	Std. error	<i>p</i> value
Scan time	Minute	0.508	0.532	-0.024	0.003	< 0.001
Scanning speed	Per minute	14.021	14.701	-0.679	0.073	< 0.001
Scanning speed (ln)	–	2.440	2.379	0.060	0.003	< 0.001
Counter work time	Minutes per shift	103.488	127.994	-24.507	5.948	< 0.001
Time on shift	Minutes	404.451	377.520	26.931	15.129	0.075
Cumulative customers over shift	Count	203.757	194.405	9.352	12.228	0.445
Counters closed	Proportion	0.379	0.334	0.045	0.001	< 0.001
Cash payment	Indicator	0.677	0.765	-0.088	0.002	< 0.001
Basket size	Items	4.723	4.605	0.118	0.024	< 0.001
Basket value	US\$	16.466	16.913	-0.447	0.097	< 0.001
Item price	US\$	3.706	3.944	-0.239	0.016	< 0.001
Wednesday	Indicator	0.154	0.137	0.017	0.002	< 0.001
Payment time	Minute	NA	0.126	NA	NA	NA
Observations		98,007	54,239			
Cashiers				38		
Stores				4		

Notes: Reported values reproduce the published transaction-level descriptive statistics for the cashier field experiment.

Main productivity estimates

Table 2 presents the reproduced core regression results. The preferred specification is column (e), which includes cashier fixed effects and day-by-hour fixed effects. In that model, the coefficient on scan-only checkout is 0.109 ($p = 0.003$), implying that cashiers scanned items 10.9% faster at scan-only than at conventional counters.

The pattern across specifications is instructive for managerial inference. The estimate is small and statistically weak when only counter work time is controlled, but it increases substantially once store and cashier fixed effects are added and remains stable after richer time controls are introduced. This stability supports the view that the result is not an artifact of broad store-level differences or routine timing effects.

For managers, the key inference is not that a single coefficient mechanically settles the issue, but that the effect remains positive across increasingly demanding specifications designed to isolate workflow design from routine operational variation.

Table 2: Published Estimates of Cashier Productivity

	(a) Scan-only	(b) Store FE	(c) Cashier FE	(d) Cashier, date, hour FE	(e) Cashier and day×hour FE
Scan-only counter	0.060 (0.455)	0.141*** (0.004)	0.108*** (0.004)	0.100*** (0.005)	0.109*** (0.003)
Counter work time (ln)	-0.002 (0.873)	0.004 (0.803)	0.012 (0.183)	0.015 (0.123)	0.021** (0.034)
Store A		0.121* (0.074)			
Store B		0.265** (0.014)			
Store C		0.173 (0.139)			
Store fixed effects	No	Yes	No	No	No
Cashier fixed effects	No	No	Yes	Yes	Yes
Date and hour fixed effects	No	No	No	Yes	No
Day × hour fixed effects	No	No	No	No	Yes
Cashiers	38	38	38	38	38
Observations	152,246	152,246	152,246	152,246	152,246
R ²	0.002	0.027	0.074	0.080	0.081
Scan-only confidence interval	[-0.109, 0.239]	[0.059, 0.221]	[0.046, 0.165]	[0.043, 0.151]	[0.047, 0.166]

Notes: Dependent variable is items scanned per minute in logarithms. Parentheses report published Wild cluster bootstrap *p*-values. The preferred estimate is column (e). *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

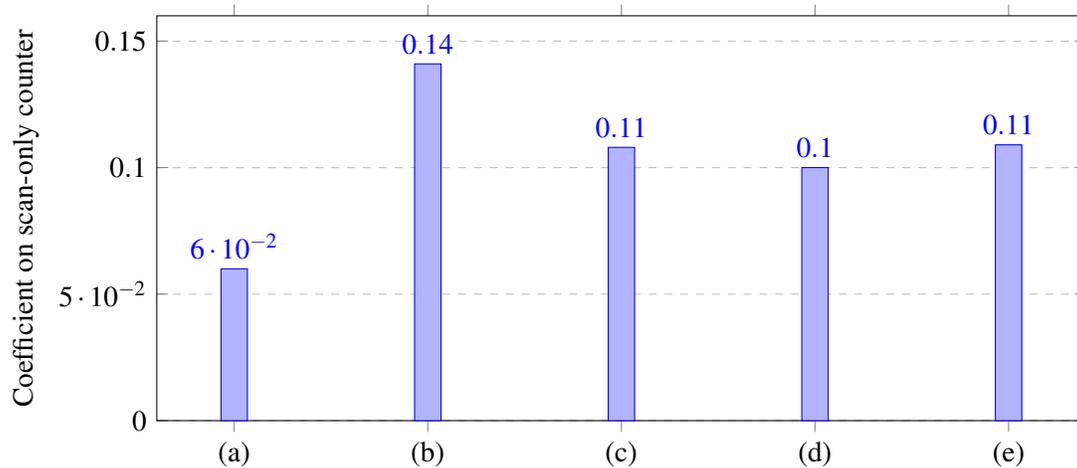


Figure 1: Scan-only coefficient across increasingly stringent specifications

Economic significance and throughput implications

The statistical effect is economically meaningful, but the most defensible interpretation is cashier-side rather than system-wide. At conventional counters, the average cashier spent 0.532 minutes scanning and packing and 0.126 minutes collecting payment, for a total of 0.658 minutes per customer. Applying the preferred estimate of 10.9% faster scanning implies that, at a scan-only counter and holding kiosk availability nonbinding, average scan-and-pack time falls to 0.474 minutes, while payment is removed from the cashier’s task set.

This changes cashier-side processing capacity from:

$$1/(0.532 + 0.126) = 1.52 \text{ customers per minute}$$

to:

$$1/0.474 = 2.11 \text{ customers per minute.}$$

The increase is substantial as a partial-capacity benchmark. Of the total cashier-side gain, 0.36 customers per minute comes directly from removing payment from the cashier's responsibilities, while 0.23 customers per minute comes from faster scanning itself. The latter component amounts to more than 60% of the direct gain from automating the payment task. The key managerial insight is therefore that a material share of the productivity benefit comes from redesigning the human task bundle, not solely from direct task substitution. Realized end-to-end throughput, however, will also depend on kiosk congestion, customer completion time, exception handling, and queue interactions.

The published study also reports that the broader customer service rate, measured as customers served per counter-hour, increased by about 21%, which provides a more conservative indicator of realized operating improvement.

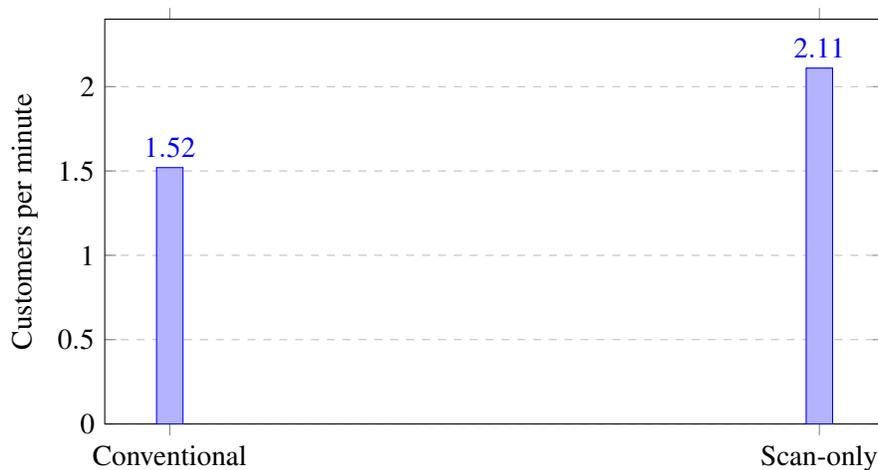


Figure 2: Implied customer throughput under the two checkout designs

Robustness and alternative explanations

A credible managerial inference must survive plausible alternatives, and the published analysis explicitly addresses this issue.

Table 3 summarizes the evidence. Controlling for purchase characteristics, product subcategories, payment mode, Wednesday shopping, time on shift, and the proportion of counters closed does not eliminate the core scan-only effect. Across these robustness checks, the scan-only coefficient remains positive, statistically significant, and generally close to the preferred estimate.

This matters because the most obvious managerial objections are exactly these: perhaps different customers selected into the new format, perhaps scan-only cashiers were less tired, or perhaps they were more likely to receive help packing. No single robustness test is dispositive on its own, but the combined pattern does not

support those interpretations as the primary explanation of the result.

Table 3: Alternative Explanations and Mechanisms

Mechanism	Evidence	Findings / reasoning
Customer sorting	No	Transaction characteristics were broadly similar across formats. Controlling for purchase characteristics, product subcategories, payment mode, and Wednesday shopping did not materially change the estimated scan-only effect.
Cashier fatigue or assistance with packing	No	Controlling for time on shift did not alter the main estimate. Controlling for the proportion of counters closed, a proxy for the likelihood of assistance with packing, also left the estimate largely intact.
Increase in effective wage	Not likely	Cashiers were rotated daily between formats, but their compensation did not vary with individual productivity, making a perceived wage explanation implausible as the primary driver.
Reduced marginal cost in scanning task	Yes	At conventional counters, cashiers took longer to collect payment when they scanned faster. This is consistent with a multitasking cost in the integrated job design.
Less task switching	Mixed	Adding basket-size measures reduced the scan-only coefficient modestly, but the basket-size proxy did not provide strong direct support for a pure task-switching interpretation.
Cashier learning	No	The published online appendix reports no meaningful evidence that repeated exposure to scan-only counters made cashiers progressively faster across days or within shifts.
Target time per customer	No	At conventional counters, scanning and payment time were positively rather than negatively related, which is inconsistent with a simple target-time explanation.
Different supervision / harder to shirk	No	The published discussion concludes that tighter supervision at scan-only counters is not a persuasive explanation of the observed productivity difference.

Notes: This table consolidates the published robustness and mechanism assessments into a management-oriented summary.

Mechanism: evidence on effort cost

The mechanism tests are central because they distinguish a superficial throughput improvement from a deeper organizational effect. Table 4 reproduces the main mechanism evidence.

In the conventional format, the OLS estimate in column (a) shows that faster scanning is associated with

longer payment time. To address endogeneity, the published study instruments scanning speed using the quantity of prepacked vegetables in the basket, on the logic that these items are easier to scan but should not directly affect payment time. The second-stage estimate in column (c) indicates that a 1% increase in scanning speed is associated with approximately a 0.66% increase in payment time. The instrumental-variable evidence is informative, although its interpretation depends on the maintained assumption that prepacked vegetables affect payment time only through scanning ease.

This pattern is the key empirical signature of a multitasking cost. In the conventional job design, scanning and payment are integrated. Exerting more effort in one task appears to raise the marginal cost of the other. Once payment is removed from the cashier's task bundle, that friction is plausibly reduced. From a management standpoint, the scan-only format does not merely automate a step; it changes the production function of the human job.

The same table also examines task switching using basket-size proxies. The evidence is suggestive but weaker. The scan-only coefficient declines somewhat when average basket size is introduced, yet the basket-size terms do not supply clean standalone support for a strong task-switching story. The most defensible interpretation is therefore that reduced marginal effort cost is the primary mechanism, with task switching at most a partial and secondary channel.

Table 4: Mechanism Evidence: Effort Cost and Task Switching

Variables	Payment time			Task switching	
	OLS (a)	First stage (b)	Second stage (c)	(d)	(e)
Scanning speed (ln)	0.256*** (0.000)		0.658** (0.026)		
Counter work time (ln)	0.011 (0.355)	0.045* (0.064)	-0.008** (0.032)	0.024** (0.024)	0.020** (0.036)
Payment in cash	-1.317*** (0.000)	-0.082 (0.100)	-1.284*** (0.000)		
Basket value (ln)	0.251*** (0.000)		-0.177*** (0.000)	0.316*** (0.000)	
Vegetables (ln quantity)		0.049*** (0.000)			
Scan-only counter				0.111*** (0.002)	0.097** (0.012)
Basket size (ln)				-0.114*** (0.000)	-0.114*** (0.000)
Average basket size (ln)				0.045** (0.043)	-0.022 (0.692)
Scan-only × average basket size (ln)					0.118 (0.187)
Cashier fixed effects	Yes	Yes	Yes	Yes	Yes
Day × hour fixed effects	Yes	Yes	Yes	Yes	Yes
Cashiers	38	38	38	38	38
Transactions	54,239	54,239	54,239	152,246	152,246
R ²	0.439	0.182	0.377	0.103	0.103
Kleibergen-Paap F statistic			29.29		

Notes: Parentheses report published Wild cluster bootstrap *p*-values. Columns (a) and (c) use payment time in logarithms as the dependent variable for conventional checkout transactions only. Columns (d) and (e) use scanning speed in logarithms as the dependent variable. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

MANAGERIAL AND PLANNING IMPLICATIONS

The findings carry direct implications for management and planning research.

First, managers should evaluate automation projects at the level of workflow design, not only at the level of the automated task. In the present setting, payment automation improved scanning performance itself. This means that return on investment calculations should incorporate productivity changes in both automated and nonautomated tasks and should distinguish cashier-side gains from fully realized system-wide service improvements.

Second, the results show that capital investment in kiosks can be justified by operational reconfiguration, not merely by labor replacement. The published back-of-the-envelope payback calculation is best read as an illustrative scenario rather than as a point forecast. Before full conversion, the supermarket group employed 471 full-time cashiers to staff 193 counters, with total annual cashier wages of \$11.79 million. If the 21%

increase in customer service rate enabled a 21% reduction in cashier headcount, the implied annual wage savings would be approximately \$2.48 million. Equipping each scan-only counter with two self-pay kiosks would require 386 kiosks at an average cost of \$20,000 each, or \$7.72 million. The added floor-space cost was estimated at \$683,220 per year. Under those assumptions, the kiosks would pay for themselves in roughly 4.3 years, although realized payback would also depend on utilization, maintenance, exception handling, and customer adoption.

Third, the results have implications for service planning under labor scarcity. Where staffing constraints are binding, managers can use automation not only to reduce headcount pressure but also to increase the output of the remaining workforce. This is particularly relevant in labor-intensive sectors facing wage pressure, hiring frictions, or demographic constraints.

Fourth, the findings illuminate the downstream boundary of the firm. In the scan-only format, part of the transaction is shifted from employee to customer. That can create efficiency gains, but it also raises a planning question: which tasks should be shifted to customers, and at what cognitive cost? The evidence suggests that the answer should not depend only on how cheaply the customer can perform the automated task. Managers must also consider whether the shift improves the productivity of employees in adjacent tasks and whether customer-side frictions offset part of the operational gain.

LIMITATIONS AND FUTURE RESEARCH

Several limitations and boundary conditions should shape interpretation.

The first is scope and contribution type. The evidence comes from four stores in one supermarket group in Singapore, and the present article is a secondary analysis of that published field experiment rather than a report of new data collection. The institutional setting is strong for internal validity but narrower for generalization. Retailers with different customer demographics, store layouts, labor rules, or payment habits may experience different magnitudes of gain.

The second is measurement. The outcome is scanning speed during the recorded scanning interval. Because packing time was not separately recorded, the estimate should be understood as a carefully defined but partial measure of cashier productivity in the nonautomated task.

The third concerns customer-side outcomes. The redesign clearly improved cashier-side and counter-side efficiency, but the data do not directly measure whether some of the burden shifted to customers in ways that affected satisfaction, delay, or error rates at kiosks. A fuller planning evaluation would integrate cashier logs, kiosk completion times, queue data, and customer experience measures.

These limitations point to a productive research agenda. Future work should examine similar workflow redesigns in pharmacy pickup, outpatient registration, hospitality service, call-center escalation systems, and assisted self-service retail formats. Research should also distinguish settings in which automation relieves a high-cognitive task from those in which it removes a lower-cognitive or highly routinized task. Finally, planning scholars can extend the analysis by linking workflow automation to facility layout, queue design, kiosk-side delays, and digital service adoption at the system level.

CONCLUSION

The supermarket checkout evidence shows, interpreted conservatively, that automation can improve performance in a more strategically important way than simple labor substitution implies. By moving payment collection to self-pay kiosks, the organization did not merely remove one step from the cashier's job. It redesigned the job. Cashiers became more specialized in scanning and packing, and their productivity in that remaining human task increased materially.

The managerial significance of the result is substantial but bounded. The preferred estimate indicates a 10.9% increase in scanning speed, while the broader service rate rises by about 21%. Mechanism tests show that the gain is consistent with a reduction in the marginal cost of effort in multitask work: when scanning and payment are integrated, more effort in one activity makes the other costlier. Once that burden is removed, the human task becomes more efficient, although realized system-wide gains remain contingent on customer-side execution.

For management and planning research, the broader lesson is that automation investments should be assessed as organizational design decisions. Their value lies not only in what machines do directly, but also in how they change the structure, efficiency, and planning logic of human work. The present article's contribution is to make that managerial design logic explicit and to state its evidentiary boundaries with precision.

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