OPERATIONS MANAGEMENT AND SERVICE MARKETING

Evaluating the Impact of Digital Technologies on Customer Experience and Operational Excellence in Saudi Arabia's Petroleum Retail Sector

Muhammad Usman Khan

Published November 2026

Abstract

Saudi petroleum retailing is increasingly shaped by connected dispensers, digital payment infrastructures, customer applications and data-driven service management. Yet the effects of these technologies on customer experience cannot be inferred from installation figures or transaction automation alone. This critical integrative review evaluates how digital capabilities may alter the fuel station journey while supporting operational excellence in a safety-sensitive, high-throughput service setting. It synthesizes fuel retail field studies with research on customer journeys, service encounters, retail technology, payment adoption and organisational transformation. The analysis distinguishes technical detection performance from behavioural outcomes, and identifies four interdependent mechanisms: reducing service friction, improving operational visibility, enabling relevant engagement and protecting customer trust. A dual-outcome framework connects these mechanisms to observable service measures and management decisions, accounting for contextual variation between urban, highway and neighbourhood stations. Illustrative numerical examples demonstrate how queueing, transaction reliability and operational capacity can be evaluated without representing hypothetical values as field results. The review argues that measurable benefits depend on reliable process integration, meaningful employee support, consent-aware information governance and site-level evaluation. It provides a staged research and implementation agenda for testing whether technology delivers both better journeys and more dependable operations across Saudi petroleum retail networks.

Keywords: Petroleum retail; customer experience; operational excellence; digital payment; connected fuel stations; Saudi Arabia; service quality

1 Introduction

Petroleum retail is one of the most routine yet consequential physical service encounters. A driver may spend only a few minutes at a filling station, but the visit requires decisions about site selection, lane choice, fuel grade, payment method and sometimes a convenience purchase. Each decision is influenced by the reliability of operational processes as well as the design of customer-facing technology. In Saudi Arabia, large geographical distances, urban traffic peaks, varied station formats and growing digital payment expectations make this interface particularly important. Digital transformation is therefore not adequately described as the replacement of cash with a mobile wallet or the installation of cameras; it involves the redesign of a connected service system in which customers, employees, equipment and information interact (Lemon and Verhoef, 2016; Verhoef et al., 2021).

The immediate appeal of connected stations is operational: inventory can be reconciled more rapidly, dispenser faults can be escalated, transaction records can be integrated and congestion can become visible. Customer-facing functions promise shorter queues, clearer receipts, targeted communication

and convenient payment. These goals overlap but are not identical. A station can reduce administrative work while worsening the journey if an unfamiliar application becomes a compulsory step. Conversely, human assistance may preserve satisfaction during a digital outage even when automation targets are missed. Work on the changing service encounter shows that value depends on how technology redistributes tasks among employees and customers, rather than on automation in isolation (Larivière et al., 2017; Grewal et al., 2023).

Fuel-specific studies provide an important but geographically constrained starting point. Purohit and Jain (2021) examined a camera-based system at one Indian station; later discussion of the initiative reports promising detection metrics and customer service possibilities (Purohit et al., 2024b). Work on technology migration in Indian fuel retail further describes the operational move from analogue practices towards connected assets and service insight (Purohit and Jain, 2020b). These sources do not constitute representative Saudi evidence, nor do technical classification results establish lasting loyalty, reduced operating cost or improved service equity. Their value lies in identifying testable mechanisms and revealing questions that a locally grounded evaluation must answer.

Research on Saudi retail identifies a different, complementary evidence base. Interviews with professionals show that analytics and artificial intelligence can support targeted communication and customer understanding, while also raising concerns about data governance and skills (Alhumaid and Alotaibi, 2025). Mobile payment acceptance studies similarly indicate that perceived usefulness, trust and risk shape adoption (Albarq, 2024; Ali et al., 2024). Such evidence speaks to the feasibility of digitally-enabled journeys, but it is not direct proof that a particular petrol station's customer satisfaction or throughput improves after a system is installed. Bridging that inferential gap motivates the present synthesis.

The principal contribution is a customer–operations perspective that treats digital technologies as interventions in an interdependent service environment. Instead of collapsing outcomes into a generic transformation score, the review defines distinct customer and operational endpoints, traces plausible pathways between them and specifies boundary conditions. This approach has practical significance for operators that need to decide whether to invest-first in pump reliability, electronic payments, queue insight, personalised communication or network-wide analytics. It also permits a narrower and more falsifiable research agenda than assertions that every new system simultaneously improves every aspect of the business.

2 Aim, objectives and research questions

The aim is to assess how digital technology can reshape the customer journey and operational excellence of petroleum retail stations in Saudi Arabia, and to develop an evaluable framework linking technological capabilities with service outcomes. The study has four objectives: to distinguish the customer-facing and back-office functions of common technologies; to analyse the mechanisms through which station processes affect convenience, trust and perceived service quality; to specify indicators for evaluating efficiency, reliability and customer experience jointly; and to identify contextual and governance conditions that could strengthen or weaken these relationships. The emphasis is on operational mechanisms and measurable effects, rather than on forecasting industry-wide adoption rates.

Three questions guide the synthesis. First, which station-level technologies have plausible, evidence supported routes to better customer experience, and where is the evidence indirect? Second, when do digital investments improve the operational efficiency of fuel and non-fuel services without

transferring effort or risk to customers? Third, how should Saudi operators compare outcomes across station archetypes while accounting for payment practices, site constraints, employee roles and data protection? These questions require a critical integrative review because the relevant literature spans marketing, service operations, information systems, fuel retailing and applied engineering (Ostrom et al., 2015; Grewal et al., 2017).

3 Review design and analytical method

The article uses a critical integrative review supported by conceptual framework development. This design is appropriate when empirical studies are methodologically heterogeneous and the principal task is to connect operational processes with customer-level outcomes. The evidence base covers peer-reviewed articles and academic chapters dated from 2015 to 2025. Topic searches combined terms for petroleum retail, fuel stations, customer experience, service quality, smart stations, IoT, payment acceptance, queue management, retail analytics, digital transformation and service automation. References were then checked against identifiable journal or publisher records and DOI information. This is a purposive, transparent synthesis rather than a claim of exhaustive database retrieval or a pooled effect size meta analysis.

Screening was guided by relevance to at least one of four analytical categories: petroleum station deployment or measurement, customer-facing technology and behavioral response, frontline service design and productivity, or Saudi digital retail context. Each source was examined for its setting, research design, intervention, reported endpoint and limits of transferability. The review kept technical proof of concept studies distinct from field experiments, perception surveys and conceptual frameworks. A device that accurately counts vehicles, for example, does not by itself demonstrate an increase in satisfaction; a mobile payment intention model is also not a direct measurement of pump-side payment time. These distinctions inform the weighting of conclusions rather than the arbitrary exclusion of useful but indirect evidence.

The synthesis proceeded through mechanism coding. Reported effects and theoretical propositions were grouped under service friction, operational visibility, personalisation and trust. For each proposed link, the analysis identified the operational activity that would change, the behavioural response that might follow, and the data required to evaluate it. Contradictory or ambiguous reporting was retained as a limitation. Specifically, a summary table in the 2024 fuel retail chapter presents customer feedback categories whose displayed percentages do not form a coherent exhaustive distribution; those figures are not used to estimate satisfaction effects here. The same publication family also overlaps with earlier work from the same researchers, so related reports are not treated as independent replications (Purohit and Jain, 2021; Purohit et al., 2024b).

Three numerical tables serve different evidential purposes. The first reproduces selected technical measurements from a fuel retail field report with setting and denominator cautions. The second defines illustrative performance indicators for a hypothetical Saudi station. The third demonstrates a transparent capacity sensitivity calculation; its values are calculations from assumptions, not observations. This structure guards against the common but serious mistake of placing generated figures beside published estimates without indicating their provenance. It also makes the proposed framework usable for future empirical audits.

4 Customer experience at the petroleum retail interface

Customer experience develops across an entire journey rather than at a single payment interaction. Search and approach precede the forecourt encounter; lane selection, fuelling, ancillary service and payment comprise the transaction; and receipts, loyalty communication or complaint resolution may continue after departure. Lemon and Verhoef (2016) describe experience as the cumulative effect of touchpoints, some controlled by the company and others influenced by external information. In fuel retail, a station's visual accessibility, cleanliness, dispenser availability and perceived safety can be decisive even before a digital tool becomes visible. Any evaluation that begins only at app activation will therefore omit important sources of customer satisfaction and abandonment.

The pre-arrival stage illustrates the promise and limits of an integrated channel strategy. A location service might offer dependable information about operating hours, available fuels, facilities and payment acceptance. Consistency between the digital listing and the physical site is essential: sophisticated interfaces generate little value if advertised amenities are absent or the advertised payment method fails at checkout. Omnichannel scholarship stresses cross-channel continuity, and research on technology-enabled stores shows that disjointed touchpoints can create new frustration despite additional features (Verhoef et al., 2015; Alexander and Kent, 2020). A fuel retailer must consequently treat data maintenance as a service obligation, not merely as an IT responsibility.

Figure 1 maps the customer touchpoints across the station journey and the outcome measures associated with each.

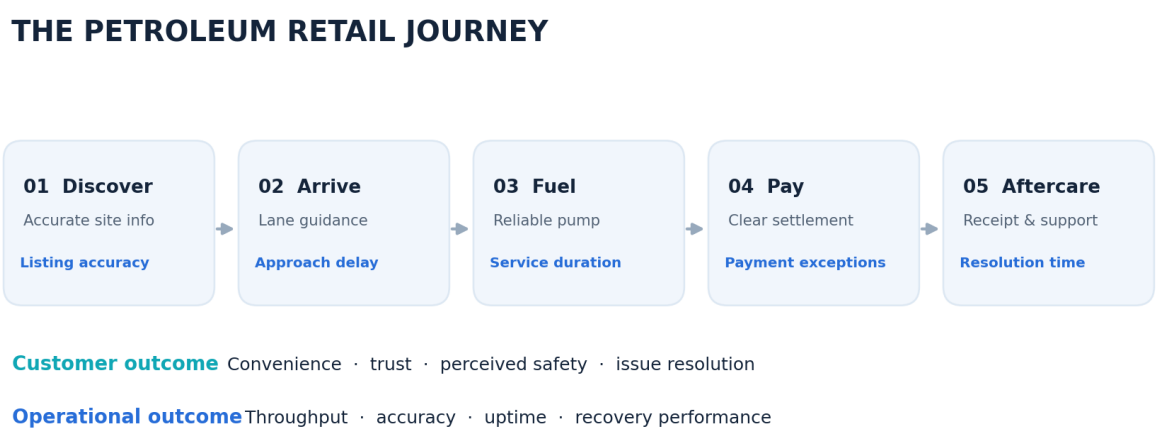


Figure 1. Customer touchpoints and corresponding outcome measures, developed by the author.

Within the forecourt, customers prioritise speed and predictability but also need reassurance about transaction accuracy and safety. A well-designed queue display can help drivers select a lane; real-time-dispenser status can reduce avoidable circulation; and a short, reliable checkout flow can minimise awkward handovers. The logic resembles other time-sensitive service encounters, where waiting time, expectations and clarity affect satisfaction. Research on customer waiting indicates that the emotional consequence of delays depends on what customers expected, while operational studies link retail competence to convenience through process efficiency (Kumar and Agrawal, 2024). A programme should therefore measure arrival to departure time and the fraction of customers who receive accurate service expectations, not simply screen views or app downloads.

The post-transaction stage has a different value proposition. Digital receipts, dispute handling and opt-in loyalty services can help customers verify purchases and resolve errors without returning to the site. However, the case for personalization should not be overstated. Fuel buying is highly routinised; customers may value receipt clarity and easy assistance more than elaborate promotions. The service quality construct developed specifically for petroleum retail is useful here because it recognises attributes beyond generic digital engagement, including the interplay of operator practices and customer perception (Purohit and Jain, 2024). Digital features should be assessed against the problems they solve for each service segment.

5 Connected operations: Sensors, systems and intervention

Internet-connected devices can convert intermittent manual checks into event-based records. Tank-level monitoring may flag unexpected inventory movements; dispensers and payment terminals may generate fault logs; and pump-to-point-of-sale reconciliation can reveal transaction exceptions. Early fuel station designs demonstrate technical possibilities for automation and alerts, although prototype feasibility must not be confused with outcomes at full commercial-scale (Kumar et al., 2017; Jemat et al., 2024). The central operational benefit is not the existence of sensors themselves. It is whether a reliable event causes a timely and correct response by the staff member, maintenance provider or station manager empowered to act.

Operational visibility has several layers. At the device-level, the system must distinguish sensor noise from actionable events. At the station-level, a manager needs context: a temporary dispenser stoppage may matter more at a congested urban site than during a quiet period. At network-level, asset patterns can inform spare parts allocation and maintenance planning. AI can help classify events, but the output needs clear thresholds, audit trails and mechanisms for staff to correct false alerts. The broader service technology literature points towards augmenting front-line judgement rather than removing it from exceptional decisions (Huang and Rust, 2018; Davenport et al., 2020).

Figure 2 summarises the layered information architecture that links station events to accountable action.

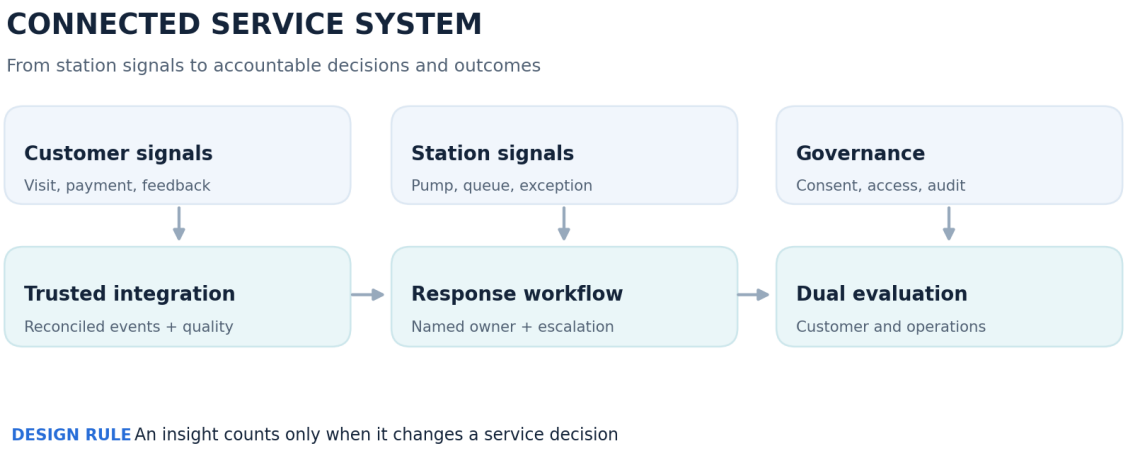


Figure 2. A layered service information architecture linking station events to accountable action.

Video and edge analytics offer another route to process visibility by identifying queue length, occupied islands and breaches of established safety protocols. In an Indian field context, the study

reported high-performance on selected detection objectives, including queue management and number plate recognition (Purohit et al., 2024b). These are technical performance outcomes tied to that deployment, not estimates of how long Saudi customers would wait. A deployment evaluation would need to test performance in the actual context, including heat, nighttime lighting, mixed vehicle types and periods of intensive traffic. For personally identifying video functions, the anticipated benefit must also justify collection and retention practices.

System integration is particularly important because an accurate device event can still be operationally useless. If a payment authorisation succeeds but the dispenser transaction does not reconcile, a customer may face a charge dispute even though both systems separately appear functional. Similarly, an inventory alert that cannot be linked to delivery and pump records may trigger unnecessary intervention. An operational architecture should therefore establish stable identifiers, timestamps, exception categories and reconciliation ownership across assets, payments and customer service. This is a form of service engineering: information only creates value when it changes the quality or speed of a specific decision.

The distinction between efficiency and resilience is also significant. A highly automated station may handle normal demand with fewer manual steps but become fragile when connectivity fails. Graceful degradation requires offline procedures, staff authority, safe pump shutdown and a clear route for completing or reversing payments. Strategic service research recognises technology and people as co-producers of value, while studies of self-service retail suggest that frontline support continues to influence evaluations even when consumers can transact autonomously (Ostrom et al., 2015; Sharma et al., 2021). Operational excellence should therefore include recovery time and the proportion of customers helped during disruptions.

6 Payment, loyalty and intelligent engagement

Digital payment is often the most visible sign of station modernisation, but consumers evaluate the entire payment experience rather than the technology category. They need certainty over the amount charged, assurance that the transaction was authorised once, and a quick route to resolve an unsuccessful payment. Saudi studies of mobile payment acceptance highlight perceived usefulness, perceived ease of use and trust; reimbursement conditions can also affect consumer responses (Ali et al., 2024; Albarq, 2024). These findings support the importance of a trusted payment design but cannot identify the average seconds saved at a specific fuelling island. Stations need time-and-motion evidence to establish that operational outcome.

A reliable payment journey begins before authorisation. Clear displayed prices and pump identifiers reduce ambiguity. A short confirmation sequence avoids repeated input, while instantaneous electronic receipts improve verifiability. Payment orchestration must handle authorised transactions whose associated pump flow was interrupted, and employees need a customer-friendly explanation of pending reversals. The operational metrics should include authorisation success, duplicate charge incidents, exception resolution time and settlement reconciliation. Such metrics are preferable to using the proportion of digital payments as a proxy for satisfaction, because widespread adoption can coexist with persistent errors.

Loyalty systems offer a different mechanism: they may reduce search effort for known customers, connect transactions to service history or provide relevant rewards. However, a customer should not have to surrender personal information merely to obtain safe, standard fuelling. Studies of AI marketing show that automation, analytical prediction and customer understanding are distinct

activities, each requiring a different level of information and managerial oversight (Huang and Rust, 2021). A station may gain more from remembering a customer's preferred digital receipt format than from invasive identity inference. Personalisation should be proportionate, revocable and supported by a demonstrable benefit to the visitor.

Studies outside Saudi Arabia point to potential functionality while underscoring the limits of generalisation. An Indian RFID-based retail fuel intervention reported favourable consumer responses to automatic identification and associated service messaging, but the observed setting cannot resolve Saudi privacy expectations or behaviour (Purohit et al., 2024a). Research on digital automation in retail also suggests that enjoyment and perceived interactivity can influence acceptance, yet fuel purchases are generally utilitarian; interfaces must remain accessible to customers who do not seek an immersive experience (Pillai et al., 2020). These differences imply that a focused test of accuracy, convenience and perceived control is more informative than indiscriminate feature expansion.

AI-supported customer contact can assist after a difficult transaction by routing an enquiry, retrieving a receipt or reporting a station problem. In less routine disputes, the customer may prefer a human who can take responsibility. Chatbot acceptance research identifies variation in customer readiness for automated dialogue; the wider service literature also emphasises the persistent importance of human interaction (Rese et al., 2020; Wirtz et al., 2018). An appropriate design has a clearly available handoff, with the details already provided by the customer preserved safely to avoid repetition. Reducing customer effort, rather than replacing every employee conversation, is the relevant success criterion.

7 Evidence appraisal and numerical interpretation

The evidence base is uneven in its relationship to Saudi petroleum retail. Fuel-specific deployments generally provide richer detail about equipment, service routines and feasibility than general retail studies. However, they are often single site or proof of concept investigations. Broader research provides stronger conceptual treatment of customer experience and sometimes larger datasets, but it may take place in supermarkets, hotels or automated stores rather than a forecourt. The main methodological risk is transferring an effect estimate across countries and service formats without considering whether customer motivations, staffing, technical infrastructure and site layout are comparable.

Table 1 preserves four objective-level performance figures reported in the Indian fuel retail study. It is intentionally presented as a bounded account of that technical trial: the percentages concern the system's assessment against locally defined expectations. They should not be interpreted as audited detection accuracy across Saudi sites, nor as the percentage improvement in customer satisfaction. The study's survey and the subsequent chapter publication should also be interpreted with care because overlapping presentations are not independent samples (Purohit and Jain, 2021; Purohit et al., 2024b).

Table 1. Reported objective-level performance in an Indian station-level camera/AI trial.

Technical objective	Reported result	Interpretation / scope
Traffic counting	100%	Study specific technical assessment
Queue management	95%	Study specific technical assessment

Technical objective	Reported result	Interpretation / scope
Automatic number plate recognition	92%	Study specific technical assessment
Monitoring defined safety parameters	100%	Study specific technical assessment

Source: Purohit et al. (2024b), reporting the Mumbai deployment. Figures represent reported trial objectives, not Saudi field results or changes in satisfaction. The published table does not provide a portable confidence interval or common validation denominator.

The complementary Saudi retail study interviewed 20 professionals about AI and big data applications and reported perceived benefits for marketing effectiveness and customer interactions (Alhumaid and Alotaibi, 2025). This is relevant contextual evidence but does not supply pump-side time measurements, station-level causal comparisons or consumer experience outcomes in the petroleum sector. Similarly, work on retail operations competence explains why productivity gains may be a pathway to better convenience, but this relationship must be tested locally before being quantified for fuel retailing (Kumar and Agrawal, 2024). Therefore, the ensuing numerical examples demonstrate operational measurement rather than claiming Saudi empirical effect sizes.

8 A dual-outcome framework for Saudi stations

The proposed framework has five layers: an encounter map, trusted data collection, process-specific decisions, customer and operational outcome measurement, and feedback for refinement. At the encounter layer, each intervention is assigned to a definable point in the journey—for example, approach, lane entry, fueling, payment or post-sale support. A station should not invest in advanced recognition technology if its primary constraint is an unreliable payment terminal. The framework therefore begins with the service failure rather than with an available technical product. This ordering is consistent with work suggesting that retail transformation involves business model, process and customer-facing change, not simple digitisation (Verhoef et al., 2021).

The trusted data layer captures only the event fields necessary to diagnose the identified problem. Anonymous queue counts may be sufficient to improve lane allocation; named customer profiles are not inherently needed. Stable identifiers should link a transaction to a pump, terminal and time window without broadening access to unrelated personal data. Where customer information is used, the purpose, retention period, deletion process and appeal route should be specified. Consumer studies of facial recognition in retail show that perceived control and benefits are central to reactions to privacy-intensive technologies (Pantano et al., 2023). The burden of justification is consequently greatest where processing identifies individuals rather than equipment states.

The decision layer converts information into a practical intervention. A queue threshold may trigger the opening of another island where staffing and safety rules permit; a dispenser fault may initiate maintenance; repeated payment reversals may trigger software inspection. Each decision requires an owner and an escalation time. Without these elements, a dashboard produces situational awareness but not operational excellence. Table 2 offers a hypothetical paired scorecard illustrating how both categories of outcome can be tracked over a comparable observation window. The target values are assumptions designed for evaluation planning, not measurements from Saudi businesses.

Figure 3 sets out the proposed causal links and the contextual conditions that qualify them.

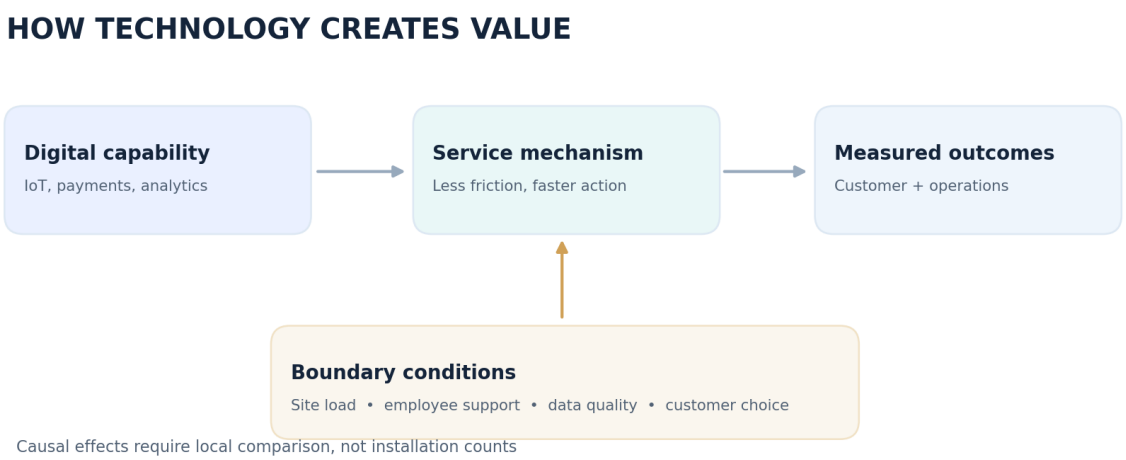


Figure 3. Proposed causal links and contextual conditions; hypotheses require empirical validation.

Table 2. Illustrative paired outcome scorecard for a hypothetical Saudi fuel station.

Measure	Illustrative baseline	Illustrative target	Direction of improvement
Mean approach to pump queue (min)	7.2	5.4	25.0% shorter
Completed transactions / operating hour	21.0	23.5	11.9% higher
Payment exceptions (% of attempts)	1.8	0.9	50.0% lower
Successful automatic reconciliation (%)	96.0	99.2	+3.2 percentage points
Complaints per 1,000 transactions	18	12	33.3% fewer
Pump availability (% of scheduled time)	97.0	98.5	+1.5 percentage points

Note: All values are illustrative assumptions, not observed Saudi results. Percent changes are computed from the illustrated baseline; percentage point changes are identified separately. Results require matching observation windows and consistent definitions.

The outcome layer is explicitly dual. Customer measures include perceived convenience, confidence in payment accuracy, waiting time experience, complaint resolution and repeat visits, where consent and robust measurement permit analysis. Operational measures include service time, throughput, exception frequency, dispenser uptime, reconciliation integrity and staff intervention load. These dimensions need not move together: a rapid but poorly explained transaction might improve throughput while diminishing trust. Grewal et al. (2023) separate employee and customer benefits of in-store technology, offering a useful rationale for monitoring tradeoffs. A credible performance review should report the pair of outcomes alongside unintended consequences rather than combining them into an opaque composite index.

The feedback layer supports controlled refinement. Performance dashboards should segment results by demand period, location, vehicle mix, site size and customer characteristics where appropriate and lawful. Urban sites may be constrained by lane availability; highway sites by demand spikes; neighbourhood stations by small operational teams. A central network benchmark can identify outliers but should not impose a universal target without local context. The framework therefore recommends a common measurement dictionary accompanied by station-specific operating assumptions. Its novelty lies less in a new algorithm than in an explicit translation from technology to service mechanism, measurable decision and bounded customer outcome.

9 Analytical illustration: Queueing, measurement and trade-offs

Queueing provides an accessible way to demonstrate the distinction between technical performance and customer impact. At a station with a single bottlenecked effective service channel, average waiting time is sensitive to the relationship between arrival and processing rates. Under a simple M/M/1 assumption, expected queue wait is $\lambda/[\mu(\mu-\lambda)]$, with λ representing hourly arrivals and μ the hourly service capacity; this model assumes independent memoryless arrivals and service times and is not a calibrated representation of a multi-dispenser forecourt. Table 3 applies the formula to two assumed capacities and three arrival rates. Its purpose is to show why a modest service speed improvement can have a disproportionate effect as utilisation rises.

Table 3. Illustrative queueing sensitivity under a single effective channel M/M/1 assumption.

Arrivals (λ, /h)	Baseline μ (/h)	Scenario μ (/h)	Baseline W_q (min)	Scenario W_q (min)	Shorter wait
12	30	36	1.33	0.83	37.5%
18	30	36	3.00	1.67	44.4%
24	30	36	8.00	3.33	58.3%

Note: Calculated, not observed: $W_q = 60 \times \lambda/[\mu(\mu-\lambda)]$ minutes; arrival rates λ = 12, 18, 24/h; service capacities μ = 30 and 36/h. Assumes steady state, one effective channel and exponential service/arrival distributions; not a validated multi-dispenser station model.

Actual stations generally require richer models. Parallel dispensers, variable vehicle turnaround times, fuel grade constraints, different payment preferences and lane conflicts violate the simplest queue model. An empirical evaluation would record individual arrival and service timestamps, then estimate distributions by vehicle class and demand band. A discrete event simulation could compare alternative staffing or lane management policies and validate predictions against held out site data. The underlying principle is to connect an identified intervention to the point at which service capacity changes, rather than to use a generic percentage improvement from a different industry as the forecast.

Measurement also requires attention to definitions. 'Waiting time' may mean arrival to pump, pump to payment or total dwell; 'uptime' may describe network connectivity or a dispenser ready for safe transactions. 'Customer satisfaction' may refer to one short survey, the most recent visit or long-term loyalty. Unstandardised definitions make comparisons misleading, especially when a network includes sites with different layouts. For the illustrative performance scorecard in Table 2, all values are hypothetical and are expressed in fixed units. Before implementation, operators should specify an observation window, treatment and comparison sites, thresholds for data completeness, and the practical meaning of a material change.

An important interpretation issue concerns selection. Customers who adopt a mobile app may already be more digitally confident and more loyal than nonusers. Comparing these two groups after launch does not identify the causal effect of the app. Similarly, a site receiving a sensor upgrade may also receive new supervisors or maintenance resources. A defensible evaluation should use matched comparison sites or phased adoption, collect pre-intervention baselines and assess whether trends differed before treatment. Short-term novelty effects should be separated from persistent behavioural change; where possible, customer surveys should be complemented by transaction and complaint records that do not depend on self-selection alone.

The financial case must not overwrite the service case. Savings from automatic reconciliation may be measurable in staff hours and fewer exceptions, yet they may be offset by integration, cybersecurity, maintenance and training expenditure. Customer benefits may also differ by segment: a commercial fleet operator may value reliable accounts and rapid invoices, whereas an occasional traveller prioritises directions, rest facilities and trustworthy payments. Retail technology research warns that new channels do not necessarily create uniform gains across contexts (Grewal et al., 2017; Alexander and Kent, 2020). Investment decisions should consequently compare separately the expected operational value, customer value, implementation risk and strength of supporting evidence.

10 Safety, privacy and governance

Safety is not merely another satisfaction attribute in petroleum retail. Dispensers, tanks and vehicle movements create risks that require established operating rules, staff training and fail-safe equipment. Digital monitoring may help detect deviations, but alerts must be tested for false positives, missed events and the possibility of distraction. A false alarm can obstruct work while a missed alarm creates false reassurance. System vendors should not be permitted to use the language of autonomous safety assurance unless performance has been validated under site-specific conditions and responsibility for intervention is explicit. Engineering demonstrations of connected station controls are useful for identifying architecture options but do not replace field certification or operational audits (Kumar et al., 2017; Jemat et al., 2024).

Customer data governance demands an equally concrete approach. A station that counts vehicles to estimate queues has different privacy exposure from one that collects number plates, associates visits with accounts and generates personalised offers. The latter requires rigorous purpose limitation, access control, retention management and oversight, along with compliance checks under the applicable Saudi legal framework. Privacy should be considered during system design rather than after deployment. Marketing frameworks describe how machine intelligence can support personalisation, but they also recognise the need for ethical constraints and managerial accountability (Davenport et al., 2020; Huang and Rust, 2021).

Cybersecurity introduces a third dependency. Payment terminals, edge devices and service dashboards may be linked through systems that were not originally designed as one network. A compromised integration can disrupt trading or expose customer records. Operators should maintain separation between safety critical control, payment information and analytics environments where feasible, with tested backups, access logs, incident response and vendor responsibility. The customer-facing consequence of a cybersecurity failure is often immediate: inability to pay, unavailable receipts or an unexplained interruption. Thus cybersecurity resilience belongs in the operational scorecard alongside conventional measures such as throughput and uptime.

Governance also determines fairness. Digital-first designs can exclude customers who use cash, lack smartphones, encounter accessibility difficulties or prefer personal assistance. A station can promote electronic channels without making safe ordinary service contingent on those channels. Research on automated retail and self-service suggests that technology readiness and the quality of frontline support shape acceptance (Pillai et al., 2020; Sharma et al., 2021). For Saudi sites that serve tourists, commercial drivers and local residents, basic multilingual clarity and accessible alternatives may provide greater social value than an extensive set of sophisticated but infrequently used digital functions.

11 Discussion: What the evidence establishes

The strongest conclusion is that customer experience and operational excellence are connected through particular service mechanisms, not through a single digitalisation variable. Information can improve a journey when it changes lane guidance, reduces avoidable error, supports recovery or makes a transaction easier to verify. It can improve operations when it enables timely intervention, less manual reconciliation or better use of capacity. Neither outcome follows automatically from technical installation. This distinction is consistent with the wider service literature's attention to service design, employee roles and customer participation (Ostrom et al., 2015; Larivière et al., 2017).

The petroleum-specific evidence suggests that connected tools can recognise vehicles, analyse traffic and help monitor safety practices in real settings. Yet the literature available for this review contains a limited number of station-level field tests, with concentration in non Saudi contexts and overlapping author groups. The 2024 book chapter offers an accessible description of a Mumbai deployment, while the earlier journal study documents related objectives (Purohit et al., 2024b; Purohit and Jain, 2021). Their contribution is proof of implementable processes, not generalisable claims about Saudi customer loyalty. Likewise, work on petroleum retail service quality measurement and changing consumer expectations helps identify the dimensions that a Saudi study should assess, without supplying a Saudi treatment effect (Purohit and Jain, 2020a, 2024).

Evidence from adjacent retail services provides both encouragement and caution. Technologies that support contactless transactions, mobile communication and customer insight can help match preferences to service design, but perceived intrusiveness, poor handoff and technical failures may undermine value (Verhoef et al., 2015; Pantano et al., 2023). Even immersive retail tools can widen an expectations gap if the physical service cannot deliver what the digital presentation implies (Farah et al., 2019). For a practical fuel station programme, this makes digital honesty a useful design criterion: display only information the operator can keep current, promise only service levels that can be delivered and provide an accountable recovery route when the promise is missed.

Saudi retail conditions should not be reduced to a claim of uniformly high digital readiness. The reviewed Saudi studies suggest substantial interest in data-driven service and mobile payment, but attitudes and capabilities vary by customer, organisation and context (Alhumaid and Alotaibi, 2025; Ali et al., 2024). Operators may also differ in site ownership, technology contracts and access to specialist staff. Implementation priorities should be grounded in data from the actual station network. For example, an investment in advanced loyalty segmentation would be premature if point-of-sale exception rates and pump availability remain poorly measured. Operational sequence matters because later analytical functions depend upon earlier transaction and asset data being trustworthy.

The proposed contribution to theory is a testable distinction between enabling capability and realised service improvement. We propose that data quality and staff response mediate the relationship between connected technology and operating reliability; that reduced friction and transparent recovery mediate the relationship between operational reliability and customer experience; and that privacy confidence and customer choice moderate the relationship between personalised engagement and trust. These propositions could be tested using multilevel datasets with observations nested within station, city and operator. Each hypothesis identifies a possible failure: technically accurate data without timely action, faster payment without clarity, or personalisation without permission.

A further customer-facing opportunity concerns the communication of alternative fuels and other service changes. Research on green fuel promotion in Indian retail outlets suggests that awareness and loyalty-related mechanisms can shape consumer responses, although these findings cannot be transferred quantitatively to Saudi purchasing patterns (Routray and Giri, 2024). Station-level communication should clarify availability, eligibility and practical use rather than presenting environmental claims as a substitute for product and service reliability.

The contribution to practice is a disciplined way to evaluate investment. Instead of celebrating a technology deployment as a performance result, station managers can report technical accuracy, staff action time, service recovery, customer effort and actual operational consequences. Process changes should be assessed against baseline levels and relevant comparison sites. Network-level data can then support targeted training and resource allocation. The dual-outcome framework offers a common language for service operations, customer experience, IT and risk teams without assuming that any one function can validate the whole customer journey on its own.

12 Managerial implementation priorities and future research

A staged programme should begin with a limited audit of observed friction: failed payments, unplanned pump stoppages, queues, poor signage, unresolved complaints and unexplained inventory differences. This baseline stage establishes data definitions, confirms instrument reliability and identifies the sites most suitable for a controlled pilot. The second stage tests one or two interventions with clear success thresholds, including non-financial safeguards. The third stage expands only when benefits persist across demand periods and staff can operate the technology safely. Wider scaling should follow an evaluation of data governance, resilience and total ownership costs, not a demonstration day result. Figure 4 expresses this sequence as a measurable delivery roadmap.

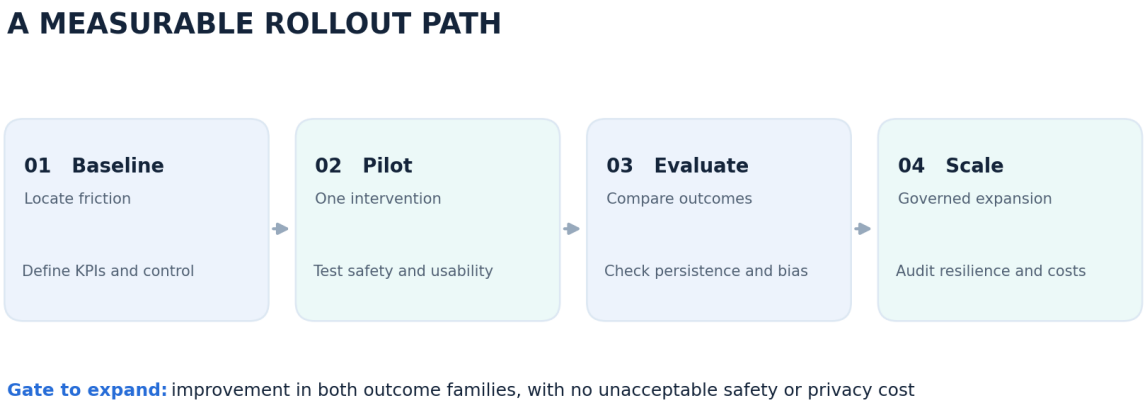


Figure 4. A staged testing and rollout process with explicit decision gates.

Research opportunities are comparatively specific. A multi-site Saudi study could estimate the impact of reliable digital receipts on payment disputes; compare dynamic lane guidance with conventional supervision at matched sites; or test whether an anonymous queue display improves perceived control. Another design could investigate whether customer-facing personalisation produces value after controlling for station convenience and brand familiarity. Field trials should report both

customer outcomes and staff workload to avoid concluding that a customer benefit is free of operational cost. A longitudinal design would show whether effects persist beyond an initial adoption surge.

Future work should also examine differences among urban, rural, highway and fleet-oriented stations. The same investment may be valuable in one format and wasteful in another. Network-level quasi-experiments could exploit staggered rollouts, while process mining might reveal where time is actually lost from arrival to settlement. Safety and privacy evaluations should be conducted alongside operational assessments rather than appended after them. Given the evidence gaps, the most useful future research will replace abstract claims about intelligence and sustainability with precise estimates of what changes, for whom, under which conditions and at what operational cost.

13 Limitations and conclusion

This review is limited by its purposive, cross-disciplinary scope and by the scarcity of directly comparable Saudi petroleum retail outcome studies. It does not claim an exhaustive record of every publication or a statistically pooled causal effect. Fuel-specific technical demonstrations are informative about feasibility, while surveys and conceptual studies explain plausible behavioural mechanisms; neither alone can establish counterfactual performance. Some source reports contain ambiguous denominator or satisfaction information, and overlapping publications require care when interpreting the quantity of independent evidence. The illustrative calculations are explicitly analytical examples, not a disguised new dataset.

Digital technologies can support better customer experience and operational excellence in Saudi petroleum retail, but only when they are connected to an identifiable service problem and a reliable mechanism for action. This review identifies four such mechanisms: reducing friction, improving visibility, creating proportionate engagement and protecting trust. It proposes an evaluation architecture that separates technical detection, employee response, customer perception and station outcomes. The priority for operators is therefore not maximum automation; it is a dependable and accountable service journey that technology helps deliver. For researchers, the priority is credible local evaluation capable of identifying both benefits and trade-offs across different Saudi station formats.

References

[1] Albarq A (2024). The emergence of mobile payment acceptance in Saudi Arabia: The role of reimbursement condition. *Journal of Islamic Marketing*, 15(6), 1632–1650. https://doi.org/10.1108/JIMA-02-2023-0052

[2] Alexander B, Kent A (2020). Change in technology-enabled omnichannel customer experiences in-store. *Journal of Retailing and Consumer Services*, 102338. https://doi.org/10.1016/j.jretconser.2020.102338

[3] Alhumaid MM, Alotaibi IS (2025). Artificial intelligence, big data, and their impact on improving marketing effectiveness and customer experience in the retail sector in the Kingdom of Saudi Arabia. *Jazan University Journal of Human Sciences*, 13(2). https://doi.org/10.37575/h/edu/22002

[4] Ali MA, Khan MA, Nabi MK, Alakkas AA (2024). Consumer adoption of mobile payment in the Kingdom of Saudi Arabia: An empirical study. *Journal of Law and Sustainable Development*, 12(2), e2452. https://doi.org/10.55908/sdgs.v12i2.2452

[5] Davenport T, Guha A, Grewal D, Bressgott T (2020). How artificial intelligence will change the future of marketing. *Journal of the Academy of Marketing Science*, 48, 24–42. https://doi.org/10.1007/s11747-019-00696-0

[6] Farah MF, Ramadan ZB, Harb DH (2019). The examination of virtual reality at the intersection of consumer experience, shopping journey and physical retailing. *Journal of Retailing and Consumer Services*, 48, 136–143. https://doi.org/10.1016/j.jretconser.2019.02.016

[7] Grewal D, Benoit S, Noble S, Guha A, Ahlbom CP, Nordfält J (2023). Leveraging in-store technology and AI: Increasing customer and employee efficiency and enhancing their experiences. *Journal of Retailing*, 99(4), 487–504. https://doi.org/10.1016/j.jretai.2023.10.002

[8] Grewal D, Roggeveen AL, Nordfält J (2017). The future of retailing. *Journal of Retailing*, 93(1), 1–6. https://doi.org/10.1016/j.jretai.2016.12.008

[9] Huang MH, Rust RT (2018). Artificial intelligence in service. *Journal of Service Research*, 21(2), 155–172. https://doi.org/10.1177/1094670517752459

[10] Huang MH, Rust RT (2021). A strategic framework for artificial intelligence in marketing. *Journal of the Academy of Marketing Science*, 49, 30–50. https://doi.org/10.1007/s11747-020-00749-9

[11] Jemat A, Sameon SS, Nazeri S, Roslan MFH (2024). IoT-based petrol station automation system. *AIP Conference Proceedings*. https://doi.org/10.1063/5.0198628

[12] Kumar PN, Kumaresan P, Sundaresan YB (2017). IoT-based retail automation of fuel station and alert system. *IOP Conference Series: Materials Science and Engineering*, 263, 042072. https://doi.org/10.1088/1757-899X/263/4/042072

[13] Kumar SCV, Agrawal R (2024). Developing customer convenience and experience through increased competency and efficiency: A strategic approach to retail operations mastery. *Heliyon*, 10(16), e36395. https://doi.org/10.1016/j.heliyon.2024.e36395

[14] Larivière B, Bowen D, Andreassen TW, Kunz W, Sirianni NJ, Voss C, Wünderlich NV, De Keyser A (2017). "Service encounter 2.0": An investigation into the roles of technology, employees and customers. *Journal of Business Research*, 79, 238–246. https://doi.org/10.1016/j.jbusres.2017.03.008

[15] Lemon KN, Verhoef PC (2016). Understanding customer experience throughout the customer journey. *Journal of Marketing*, 80(6), 69–96. https://doi.org/10.1509/jm.15.0420

[16] Ostrom AL, Parasuraman A, Bowen DE, Patrício L, Voss CA (2015). Service research priorities in a rapidly changing context. *Journal of Service Research*, 18(2), 127–159. https://doi.org/10.1177/1094670515576315

[17] Pantano E, Vannucci V, Marikyan D (2023). Gratifications in change of privacy? The response of four consumers' generational cohorts toward facial recognition technology in retail settings. *Journal of Consumer Behaviour*, 22(2), 288–299. https://doi.org/10.1002/cb.2124

[18] Pillai R, Sivathanu B, Dwivedi YK (2020). Shopping intention at AI-powered automated retail stores (AIPARS). *Journal of Retailing and Consumer Services*, 57, 102207. https://doi.org/10.1016/j.jretconser.2020.102207

[19] Purohit S, Jain AK (2020a). Evolution of fuel retail in India vis à vis Indian customer: Shift in consumer behaviour. *International Journal of Management*, 11(8), 199–207. https://doi.org/10.34218/IJM.11.8.2020.019

[20] Purohit S, Jain AK (2020b). Technological transition from analog to internet of things (IoT) on Indian petro retail's customer service. *Indian Journal of Science and Technology*, 13(42), 4364–4368. https://doi.org/10.17485/IJST/v13i42.1964

[21] Purohit S, Jain AK (2021). Leveraging IoT and AI for delivering tailor-made customer experiences in Indian petro retailing. *Indian Journal of Science and Technology*, 14(7), 604–609. https://doi.org/10.17485/IJST/v14i7.3

[22] Purohit S, Jain AK (2024). Development and validation of a scale for measuring petro retail service quality: A bilateral approach. *European Economic Letters*, 14(1), 213–227. https://doi.org/10.52783/eel.v14i1.1017

[23] Purohit S, Purohit S, Jain AK (2024a). Driving superior customer service in Indian petro retail through RFID innovation. In: *Business, Management and Economics: Research Progress*, Vol. 6, pp. 160–178. https://doi.org/10.9734/bpi/bmerp/v6/2713

[24] Purohit S, Purohit S, Jain AK (2024b). Transforming Indian petro retail: Enhancing customer experience through IoT and AI solutions. In: *Scientific Research, New Technologies and Applications*, Vol. 10, pp. 61–74. https://doi.org/10.9734/bpi/srnta/v10/3554

[25] Rese A, Ganster L, Baier D (2020). Chatbots in retailers' customer communication: How to measure their acceptance? *Journal of Retailing and Consumer Services*, 56, 102176. https://doi.org/10.1016/j.jretconser.2020.102176

[26] Routray M, Giri A (2024). Impact of green fuel promotion on customer buying behavior in Indian retail fuel outlets: A mix-method approach using fsQCA and NVivo. *Indian Journal of Marketing*, 54(11), 65–72. https://doi.org/10.17010/ijom/2024/v54/i11/174631

[27] Sharma P, Ueno A, Kingshott R (2021). Self-service technology in supermarkets—Do frontline staff still matter? *Journal of Retailing and Consumer Services*, 59, 102356. https://doi.org/10.1016/j.jretconser.2020.102356

[28] Verhoef PC, Broekhuizen T, Bart Y, Bhattacharya A, Dong JQ, Fabian N, Haenlein M (2021). Digital transformation: A multidisciplinary reflection and research agenda. *Journal of Business Research*, 122, 889–901. https://doi.org/10.1016/j.jbusres.2019.09.022

[29] Verhoef PC, Kannan PK, Inman JJ (2015). From multi-channel retailing to omni-channel retailing: Introduction to the special issue on multi-channel retailing. *Journal of Retailing*, 91(2), 174–181. https://doi.org/10.1016/j.jretai.2015.02.005

[30] Wirtz J, Patterson PG, Kunz WH, Gruber T, Lu VN, Paluch S, Martins A (2018). Brave new world: Service robots in the frontline. *Journal of Service Management*, 29(5), 907–931. https://doi.org/10.1108/JOSM-04-2018-0119