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Original Research Article

Advanced Process Automation and Distributed Control Systems for Improving Operational Efficiency in Saudi Arabia's Oil and Gas Industry

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Abstract: Process automation in petroleum facilities is frequently described as a route to efficiency, yet the mechanisms through which distributed control systems (DCS) improve performance remain insufficiently differentiated from supervisory analytics, instrumentation renewal and operational governance. This critical review examines contemporary evidence on regulatory control, distributed economic optimisation, field data acquisition, asset monitoring and cyber physical integrity, with particular attention to Saudi Arabia's upstream and processing assets. Thirty peer reviewed publications dated 2020–2025 were selected through targeted, DOI checked literature retrieval and evaluated according to the maturity of their evidence and the transferability of their findings. The synthesis identifies four interacting determinants of useful automation: trustworthy measurements, feasible constrained control, resilient information exchange and disciplined operator involvement. Simulation studies show how predictive algorithms can coordinate coupled process variables; field oriented investigations reveal the greater difficulty of sustaining gains when equipment deteriorates, communication becomes unreliable or operating modes change. A layered implementation framework is proposed that retains safety functions at the appropriate control level while enabling supervisory optimisation with auditable performance indicators. The review argues that Saudi deployment should prioritise measurable process outcomes, brownfield integration, cybersecurity and staff competence rather than treating digital connectivity as efficiency in itself.

Keywords: Distributed Control System, Advanced Process Control, SCADA, Operational Efficiency, Saudi Arabia, Oil and Gas, Reliability, Model Predictive Control.

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INTRODUCTION

Saudi Arabia's oil and gas system spans dispersed wells, injection networks, compression stations, processing plants and long distance pipelines. At each location, the efficiency question is operational rather than purely technological: can the facility maintain required throughput and product quality with fewer disturbances, less avoidable energy use and lower exposure to unsafe operating states? Digitalisation literature describes substantial

opportunities for improved coordination, but it also warns that fragmented ownership of data and weak management of change can dilute expected value [1, 2]. For these assets, automation must be judged against the physical variability of the process, not against the number of screens, tags or connected devices installed.

A DCS typically executes regulatory control, sequences, alarms and plant wide operator functions across distributed controllers. It differs from a supervisory control and data acquisition (SCADA) system, which often gathers information and provides supervisory access to geographically dispersed equipment. Remote terminal units (RTUs), programmable logic controllers and independent protective systems can coexist with both arrangements. Confusing these functions produces unrealistic design expectations: a cloud dashboard may offer useful diagnostics without being suitable for a fast pressure control loop, while a reliable local loop may operate safely even when its higher level connection is lost. The distinction is fundamental to evaluating automation claims in mature Saudi facilities.

Recent control research has moved beyond traditional set point tracking toward models that explicitly represent constraints and economic objectives. Petroleum production studies investigate gas lift allocation, electrical submersible pumps and natural gas compressors, whereas refinery studies consider interacting reactor regenerator subsystems [3–8]. These models establish technical possibilities but are not equivalent to verified reductions in Saudi operating expenditure. A critical review must therefore differentiate algorithmic success under controlled conditions from durable plant performance supported by maintenance records, independent measurements and operator acceptance.

This article brings these strands together through an operational efficiency lens. Rather than treating automation, artificial intelligence, digital twins and instrumentation as interchangeable innovations, it asks which engineering decisions each can improve, what evidence is available, and which dependencies restrict replication. The resulting argument is relevant to Saudi Vision 2030 because resource productivity, reliable industrial operations and technical capability are meaningful only when accompanied by transparent assessment of safety, resilience and environmental performance.

2. Aim, Objectives and Research Questions

The aim is to critically evaluate how advanced process automation and distributed control architectures can improve measurable efficiency in Saudi oil and gas operations without weakening process safety or control reliability. Four objectives guide the assessment: first, to distinguish the operational roles of field devices, DCS, SCADA and supervisory optimisation; second, to examine what contemporary studies demonstrate about constrained control and equipment reliability; third, to identify organisational, interoperability and cybersecurity conditions affecting implementation; and fourth, to develop an evaluation framework suitable for brownfield and greenfield projects.

The review addresses three research questions. RQ1 asks which control and monitoring functions have the clearest causal connection to production stability, energy intensity and asset availability. RQ2 asks how the strength of published evidence changes across simulation, hardware in the loop, laboratory and operating facility settings. RQ3 asks what minimum technical and governance conditions should be established before claims of efficiency improvement are generalised to Saudi installations. These questions deliberately exclude an unsupported assumption that every digitally connected asset is a smart or optimised asset.

3. REVIEW METHODOLOGY

A structured, critical narrative review design was chosen because the relevant literature uses heterogeneous technologies, performance measures and study settings. The targeted retrieval was completed using publisher article records, DOI linked bibliographic entries and scholarly indexing results. Search combinations paired oil and gas, upstream, refinery, compressor, SCADA or DCS with advanced process control, economic model predictive control, remote monitoring, predictive maintenance, digital twin, interoperability and operational technology security. Publication dates were limited to 2020–2025, and only scholarly articles with identifiable DOI records were included in the final reference set. The review does not claim exhaustive database coverage or a pooled effect estimate.

Selection favoured studies that described a physical system, a recognisable automation mechanism and an operational outcome or implementation limitation. Papers dealing only with corporate digital strategy were retained sparingly to contextualise governance; those without meaningful relevance to oil and gas, process control, instrumentation or cyber physical operations were excluded. Thirty sources were organised by control hierarchy, production optimisation, asset condition, data architecture and risk. The assessment considered setting, input data, degree of experimental validation, baseline comparator, constraints, claimed performance and possible transfer to geographically distributed Saudi assets.

Missing site measurements or unavailable counterfactuals were recorded as evidence limitations, not silently replaced with assumed benefits.

Synthesis was interpretive rather than statistical. First, technical mechanisms were compared within each theme. Second, findings from closely related studies were contrasted to locate disagreements or changes in assumptions. Third, cross cutting dependencies were mapped from instrument quality to control feasibility, decision execution and realised performance. Simulation and digital twin results were interpreted as demonstrations of method capability, while operational studies were weighted more strongly for deployment claims. Because selection was purposive and the sources span distinct equipment classes, the conclusions identify plausible intervention pathways rather than presenting general numerical efficiency percentages for Saudi Arabia.

4. Distributed Automation as an Operational Architecture

The functional architecture of an automated petroleum facility should be separated into measurement, direct control, supervision and enterprise analysis. Sensors and analysers provide pressure, temperature, flow, vibration, composition and valve position signals; local control equipment uses these signals to regulate actuators within deterministic deadlines. DCS servers organise operator interfaces, alarms, histories and engineering configuration, while SCADA and RTUs extend the view to remote wells or stations. Higher level tools can recommend targets or maintenance actions, but their usefulness depends on data validity and a clear route back to approved plant decisions. Figure 1 shows this hierarchy without implying that information should bypass protective layers.

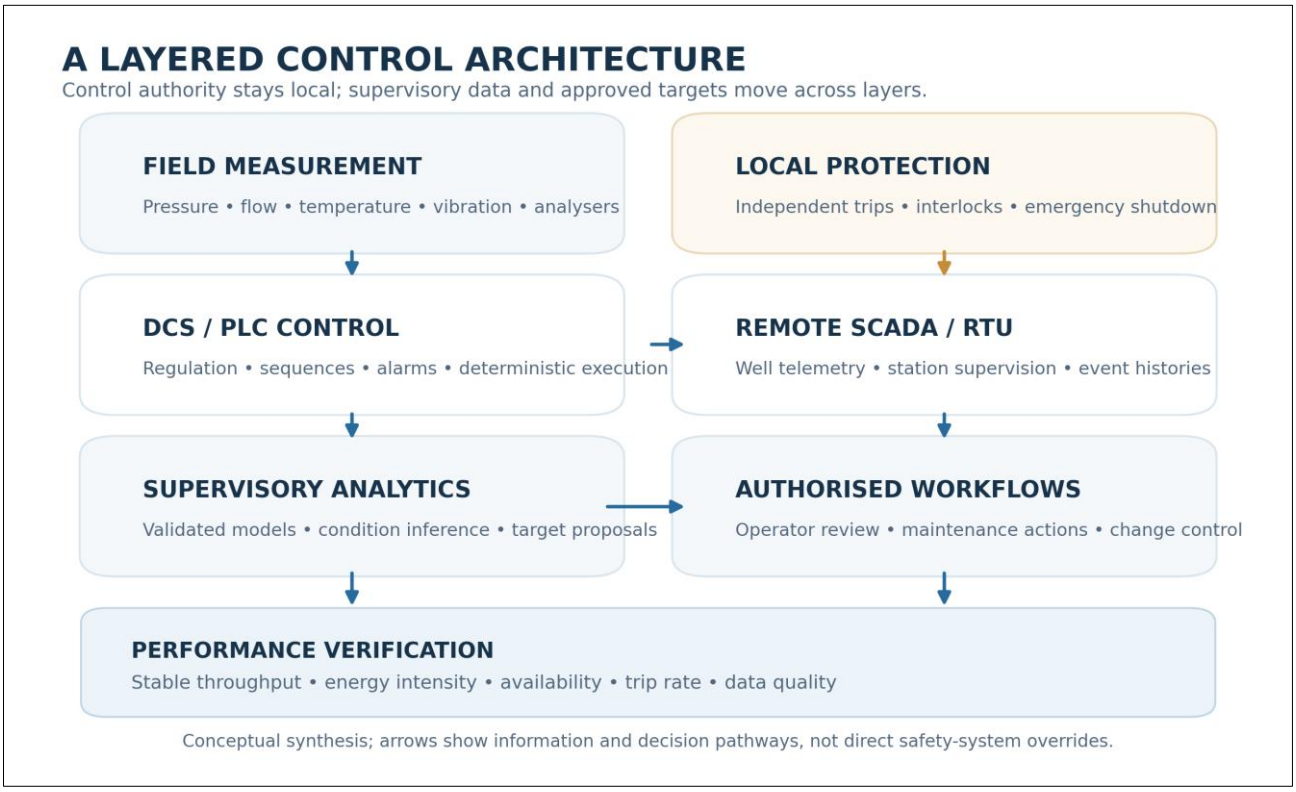


Figure 1: Functional separation of field measurement, protective systems, local control, remote supervision and decision support. Original conceptual diagram developed for this review

At the regulatory level, poor loop tuning, instrument drift and valve stiction can offset sophisticated analytics. A predictive controller cannot recover genuine observability from a failed transmitter merely because the data stream is stored at high frequency. Engineering teams should therefore treat calibration, signal diagnostics and instrument selection as performance interventions. When supervisory models are introduced, they require explicit descriptions of sampling intervals, sensor uncertainty, model update frequency and fallback behaviour. Production network studies demonstrate that meaningful uncertainty changes feasible operating decisions; nominal optimisation may select conditions that cannot be sustained when disturbances arrive [3].

DCS modernisation also changes work practices. Configuration migrations, alarm rationalisation, historian integration and human machine interface redesign may improve consistency, but can create temporary failure paths or new cognitive demands. System boundaries must be documented before commissioning, including the responsibilities of safety instrumented systems and emergency shutdown logic. Performance acceptance should encompass normal operation, transition between modes, sensor failures, loss of communications and manual intervention. Treating commissioning as a documentation exercise risks overlooking precisely the conditions that govern long term efficiency.

A useful distinction is that geographic distribution and computational distribution solve different problems. The first connects separated facilities; the second allocates control decisions across cooperating subsystems. A site may use one DCS for a compact processing plant while its wells communicate through SCADA, and an economic optimiser may coordinate several DCS managed units without replacing their local regulators. Project documentation should describe these boundaries in functional language and identify the owner of each set point. This prevents the mistaken assumption that an enterprise platform can assume all local control duties simply because it receives plant data.

5. Evidence from Advanced Control and Optimisation

Model predictive control (MPC) is attractive in oil and gas operations because it handles interacting variables and hard or soft constraints over a prediction horizon. Janatian and Sharma [3], examined uncertain gas lift allocation and showed why scenario based decisions can be less conservative than a worst case design while remaining more robust than nominal optimisation. However, the case relied on a represented production network; the practical inference is that uncertainty must be characterised before optimisation targets are accepted, not that every gas lift system will realise an identical economic gain.

Gas compression presents a related but distinct problem. Meira and colleagues [4], investigated implementable nonlinear predictive strategies for surge avoidance under non ideal gas behaviour. The contribution lies in incorporating operating constraints into controller design, a more credible safety rationale than maximising throughput alone. Gesser and co workers [5], examined an offshore compression system from dynamic modelling to infrastructure, indicating that controller performance depends on how supervisory and local functions are integrated. Together these studies support staged deployment, model verification and explicit compressor protection margins rather than autonomous pressure or speed changes without operator and engineering review.

Electrical submersible pump studies provide a test of implementability. Santana and colleagues [6], coupled nonlinear MPC with state estimation to address difficult to measure variables and changing thrust envelope limits. Their simulations show how a zone based formulation can preserve feasible control when fixed targets become inappropriate. The key limitation is that successful calculation under tested conditions does not establish sensor durability, operator workload or overall field economics. Embedded hardware experiments in the same area suggest that computation can be brought closer to equipment, but interface validation and long duration fault tolerance remain separate engineering obligations.

At the processing end, refinery control introduces coupled temperatures, catalyst circulation, yields and energy demands. Huang, Zheng and Li [7], developed a distributed economic predictive approach that explicitly addresses plant model mismatch in a fluid catalytic cracking unit. Related work on cooperative distributed control introduces safety oriented stability constraints, illustrating that economic objectives need not displace safe envelopes. Zumoffen and colleagues [8], approached an FCC fractionator benchmark through plant wide control structure design rather than replacing all loops with a single controller. This contrast matters: substantial improvement may result from better variable pairing and measured coordination before an expensive platform replacement is justified.

Across these studies, the substantive finding is conditional. MPC can calculate more informed responses to coupled processes than isolated proportional integral loops, particularly when disturbances and constraints are represented realistically. Yet the papers use different baselines, process models and experimental conditions, preventing an honest pooled estimate of economic benefit. Deployment plans should record the existing controller's performance first, identify binding constraints, quantify the value of proposed changes and require stable comparisons across equivalent operating windows. Without those steps, a favourable simulation trajectory may be mistaken for achieved operational efficiency.

The distinction between regulating variability and improving economic value warrants particular emphasis. A tighter pressure distribution may protect equipment and reduce off spec

operation, but an optimal energy target depends on the process network and the selected accounting boundary. Conversely, a controller may deliberately permit limited variation in one variable to secure a larger improvement elsewhere. Researchers should report constraint activity, actuator movement, robustness against model mismatch and evidence of performance degradation as carefully as a headline objective. Such reporting helps engineers distinguish a deployable design from a favourable operating scenario chosen after the fact.

6. Data Acquisition, Digital Twins and Remote Field Coordination

Oil field automation is complicated by geography. Remote production wells may communicate over mixed fibre, radio and satellite links with variable bandwidth, latency and interruption risk. Ramzey and colleagues [9], surveyed the integration of industrial internet technologies and edge computing in crude oil monitoring, emphasising continuous data availability and the management demands of a dispersed value chain. Edge processing can reduce dependency on a distant data centre for selected diagnostics, but control design must specify which decisions remain local during network failure. Supervisory architecture that assumes uninterrupted connectivity is unsuitable for critical field regulation.

Knebel and co authors [10], examined cloud and edge technologies for oil and gas digital twins and identified security, privacy and integration concerns as barriers to adoption. A digital twin is useful only when its purpose is stated precisely: visualisation, condition estimation, what if simulation and closed loop optimisation require different levels of synchronisation and model validation. A historical equipment model labelled as a twin should not be treated as a reliable live process model. Czachorowski and colleagues [11], show that offshore digital transformation also requires systems engineering, technology roadmaps and coordinated organisational change, not technology procurement alone.

Measurement reconciliation is equally important. Wells produce multiphase streams, and field instruments can be sparse, intermittently calibrated or located away from the variable a model seeks to estimate. Apparent improvements in dashboard responsiveness may therefore reflect faster reporting rather than better production decisions. Models should state how raw tags are checked for timestamp errors, unit conversion, missing intervals and inconsistent operating modes. Quality flags should travel with the value so that optimisation logic can distinguish measured, estimated and invalid data. Successful supervisory control begins with disciplined data stewardship, not a large volume of undocumented sensor records.

Where an organisation operates hundreds of wells, prioritisation is more realistic than immediate universal optimisation. A phased programme can select representative wells or stations, establish comparability of baselines, and then extend validated configurations to neighbouring assets. The decision to scale should depend on communication uptime, model accuracy under changing reservoir conditions, alarm quality and maintenance response time. A fleet wide platform can improve visibility while remaining operationally ineffective if recommendations are never reviewed or if data ownership is unresolved. Operational efficiency therefore requires a traceable connection between detection, decision, execution and verification.

7. Reliability, Process Safety and Cyber Physical Exposure

Predictive maintenance is relevant to distributed control because process instability often begins with deteriorating equipment rather than inadequate algorithms. Brahimi and colleagues [12], evaluated turbine monitoring methods using operational histories, while Yue and co authors [13], examined anomaly detection when fault examples are scarce and operating conditions shift. These investigations highlight a recurrent difficulty: a model trained under familiar loads can mistake legitimate transients for failure, or overlook degradation in an unrepresented regime. Maintenance predictions should consequently be checked against inspection evidence, machine physics and the cost of false alarms before they are embedded in work order prioritisation.

Luan and colleagues [14], explored a digital twin surrogate for gas turbine condition monitoring, linking online parameter changes to degradation indicators. Tao and co authors [15], combined dynamic Bayesian reliability modelling with a digital twin representation for subsea control modules. Yang and colleagues [16], investigated fault diagnosis for subsea production systems, where system behaviour changes gradually and labelled training examples may be scarce. These studies contribute different tools to a common problem, but none removes the need to document failure modes, equipment criticality, intervention thresholds and verification after maintenance. A warning that is not converted into a timely action does not improve availability.

Operational efficiency must also incorporate process safety. Alarms, permissives, interlocks and emergency shutdown functions have distinct purposes and should be designed and assessed accordingly. Efficiency targets must never be

interpreted as authorisation to disable protective actions or suppress alarms merely to reduce nuisance events. An optimisation algorithm should operate inside documented limits; independent protection remains effective even if the supervisory layer fails. Change control should capture software versions, controller parameters, loop ownership and the acceptance criteria used during factory and site tests. Any proposed modification that influences process hazards requires appropriate engineering review before implementation.

More connectivity also changes the threat model. Upadhyay and colleagues [17], investigated protection mechanisms for SCADA and connected devices using test bench methods; Xiao and co authors [18], analysed potential attack pathways in intelligent pipeline cyber physical systems. Mohammed and colleagues [19], studied network anomaly detection for oil and gas industrial environments, while Wali and co authors [20], examined stealth attacks against SCADA protocols. Together they demonstrate the importance of segmentation, asset inventories, access control, protocol monitoring and tested recovery procedures. They do not justify the claim that a single intrusion detection model can make a field network secure.

8. Operational Efficiency: Measurement and Evaluation

A defensible evaluation begins by specifying the outcome and counterfactual. Throughput, on spec production, equipment availability, compressor energy intensity, control variability, nuisance trip rate and operator response time measure different aspects of performance. A higher flow rate may increase wear or electricity consumption, while an apparent energy reduction may arise from processing lighter feedstock. Energy normalised and production normalised measures should therefore be reported alongside absolute values where practical. Ibrahim, Ashour and Gadalla [21], considered refinery energy optimisation, reinforcing the need to study unit interactions and operating conditions rather than isolated equipment values.

Table 1 links the principal automation mechanisms to suitable indicators and likely confounders. Its purpose is not to promise improvement, but to make project hypotheses testable. For each intervention, the facility should establish a baseline window covering representative operating modes, validate instruments, document production constraints and predefine acceptable safety limits. Where random assignment is unrealistic, engineering teams can compare matched periods or staggered deployments and disclose differences in feed, maintenance, ambient conditions and operator practice. Without these controls, annual production growth or a lower count of alarms cannot confidently be attributed to DCS modernisation.

Table 1: Operational efficiency outcomes and confounders for process automation interventions

Automation function	Primary outcome	Suggested KPI	Major attribution risk
Loop tuning and DCS control	Reduced process variability	Distribution of pressure / flow deviations	Sensor drift; feed variability
Supervisory constrained MPC	Fewer constraint breaches	Time within safe operating envelope	Changed setpoints or product slate
SCADA and RTU integration	Improved remote visibility	Usable data availability; event latency	Communications outages; tag mapping
Predictive condition monitoring	Timelier maintenance	Avoided failures; verified intervention lead time	Low fault prevalence; false alarms
Plant wide energy optimisation	Reduced resource intensity	Energy per tonne of on spec output	Throughput and ambient conditions

The environmental dimension requires similarly careful boundaries. Compressor electricity, fired heater duty, flaring events and leakage detection are meaningful metrics, but reductions must be separated from changes in plant utilisation. An efficient control system can stabilise throughput and reduce avoidable cycling, yet it can also push equipment toward more intensive operation. The relevant objective is not necessarily minimum instantaneous energy demand; it is the best achievable combination of stable output, resource use and safety under prevailing constraints. This point is especially important when presenting industrial automation as a contribution to national sustainability objectives.

Independent verification needs to survive both favourable and unfavourable outcomes. Trend archives should preserve raw measurements, controller mode changes, alarm histories, maintenance interventions and approved target revisions. Data aggregation can conceal transient problems; consequently, monthly averages should be complemented by event based analyses and distributions of variability. A performance claim becomes more persuasive when reviewers can

reconstruct the baseline, confirm the plant was comparable, and examine whether an improvement persisted beyond the initial tuning period. Such evidence also helps operations teams decide whether a technology should be replicated elsewhere.

Measurement planning also determines whether improvement is practically detectable. If the expected savings are smaller than instrument uncertainty or the natural variation between feed campaigns, an attractive result cannot be verified confidently. Before deployment, teams should calculate data completeness, sensor repeatability, minimum observation duration and the frequency of disruptive maintenance events. Where instrument replacements occur concurrently with a software upgrade, the evaluation should separate these changes or identify their combined contribution. This is particularly important for old facilities where the largest benefit may come from restoring measurement quality rather than implementing a more complex controller.

9. Implementation Implications for Saudi Facilities

Saudi operators face a combination of technically mature installations, remote well infrastructure and major new development projects. In a brownfield setting, a staged approach is preferable to a single enterprise wide conversion. First, perform a control system health assessment covering instrument calibration, loop performance, alarm loading, controller obsolescence and network availability. Second, select an intervention with a clear process constraint and verifiable output. Third, test interfaces in a representative environment, including failure and fallback cases. Fourth, commission with a defined handover and operator training plan. Finally, retain a post implementation evaluation period long enough to distinguish stable improvement from temporary operator attention.

Industrial automation must integrate human capability rather than eliminate it by assumption. Engineers need transparent explanations of recommendation logic; operators need unambiguous authority to accept, defer or reject supervisory set point changes. Maintenance teams require diagnostic information in a format that supports real action, and cybersecurity teams need visibility of changes to connected assets. Jirsa and colleagues [22], demonstrated how industrial components can be represented through interoperable digital descriptions, but interoperability does not automatically supply common governance or safe operating procedures. Table 2 turns these dependencies into explicit acceptance checks for a Saudi deployment programme.

Table 2: Suggested acceptance gates for staged DCS and automation implementation in Saudi oil and gas facilities

Programme stage	Minimum evidence required	Responsible owner	Decision rule
Baseline	Validated KPIs; representative operating periods	Operations and process engineering	Pause if sensors or comparisons are unreliable
Engineering design	Control philosophy; constraints; network boundaries	Automation and safety engineers	Reject unsafe overrides or undefined fallback
Integration test	FAT/SAT records; fault and communication tests	DCS vendor and independent tester	No deployment with unresolved critical failures
Pilot operation	Approved changes; trend archives; operator sign off	Operations and reliability teams	Extend only if benefits persist without new risk
Scale and support	Lifecycle ownership; patching; training; costs	Asset manager and cybersecurity lead	Stop rollout if ownership or support is unclear

Gas turbine and compressor applications illustrate why integration deserves equal status with algorithm development. Studies by Rubiales Mena and colleagues [23], and Jiang and co authors [24], use operational or physics informed signals to support condition assessment, but their transfer to another fleet depends on fuel composition, instrumentation, maintenance history and operating envelope. Yao and colleagues [25], examine maintenance prediction when sensitive data are limited, an obstacle likely to arise across contractors and asset owners. Data sharing constraints should be addressed through governance and validation plans rather than hidden through optimistic modelling assumptions.

Scaling decisions should also be connected to procurement and contractual accountability. Equipment vendors can deliver systems that satisfy factory specifications but leave unresolved data semantics, spare part support and responsibility for model updates. Owner operators should specify rights to historical data, change logs, interface descriptions, cybersecurity updates and independent acceptance testing. Service agreements should define the consequences of failed communication, changes to process configuration and model drift. These

contractual details are not administrative extras: they determine whether optimisation remains supportable after the original project team departs.

A proportionate business case should include continuing costs, not only initial installation expenditure. These costs encompass licensing, cybersecurity patches, specialist support, periodic recalibration, data storage and the time required to review model recommendations. Benefits should be tracked at the facility level and reconciled with process and maintenance records, avoiding double counting between improved availability and increased production. When an initial pilot fails to outperform the baseline, the result should inform system redesign rather than automatically trigger a wider rollout. Evidence led cancellation of an ineffective project is itself a productive use of engineering resources.

10. Research Gaps and Future Agenda

The literature contains more controller demonstrations than longitudinal assessments of integrated operating outcomes. High quality research should compare algorithms against a credible industrial baseline, use transparent disturbance scenarios and report failures as well as improvements. In particular, researchers should investigate how model uncertainty, sensor faults and communication delays interact over extended periods. Published studies often explore one of these factors while assuming the others are controlled. This separation limits the ability to predict real performance across geographically distributed petroleum assets.

A second gap concerns interfaces between technology layers. Supervisory models may identify better targets without specifying how those targets are authorised, constrained, logged and withdrawn. Belo and colleagues [26], document requirements challenges in digital twins for oil and gas production systems; their findings strengthen the case for explicit operational requirements and lifecycle accountability. Future research should test whether consistent data semantics, formal interface contracts and auditable operator approvals reduce project failure, and should quantify the additional engineering effort required to achieve these properties.

Third, performance research needs a clearer link between condition monitoring and decision economics. Failure detection accuracy is not a substitute for prevented downtime. Studies should include lead time, positive predictive value under realistic event prevalence, repair resource availability, and the cost of unnecessary interventions. Likewise, research on intelligent gas dehydration monitoring [27], suggests that useful models can focus on degradation state rather than attempting full autonomy. Practical research should explain which variables inform scheduling decisions and how those decisions remain robust when measurement quality deteriorates.

Finally, the distinction between technology transfer and local evidence remains significant. Broad reviews of industrial digitalisation and energy sector digital twins describe promising approaches [28–30], yet Saudi specific outcomes depend on climate, asset maturity, supply arrangements, workforce skills and the operating philosophy of each organisation. Collaboration between universities, plant operators and technology providers could generate anonymised benchmark datasets, reproducible hardware in the loop trials and long duration controlled evaluations. Carefully governed evidence sharing would be more valuable than additional unverified claims of percentage savings.

11. DISCUSSION

The synthesis offers a layered explanation of why advanced control sometimes improves operations and sometimes adds complexity without clear benefit. The first link is valid measurement: a controller can respond only to information it can trust. The second link is feasible optimisation: process constraints, uncertainties and protective boundaries determine which targets can be used. The third is reliable execution: interfaces, alarm management, operators and maintenance processes decide whether the recommendation changes actual plant behaviour. The final link is evaluation: only controlled comparison distinguishes useful intervention from coincident changes in demand or asset condition. Figure 2 represents these links and the evidence required at each transition.

This interpretation reconciles an apparent tension in recent research. Algorithms demonstrate convincing benefits under modelled disturbances, while transformation studies emphasise coordination, data ownership and changing workflows. Neither perspective is sufficient alone. A technically excellent supervisory controller may fail to produce durable value when sensors drift or recommendations are ignored. Conversely, strong procedures cannot compensate for a process that persistently violates constraints because its control structure is poorly designed. The most credible strategy is an iterative programme combining control engineering, asset reliability, operations research and organisational learning.

For Saudi Vision 2030, the relevant contribution is not the novelty of a digital label but the capacity to operate critical energy infrastructure

safely and efficiently with measurable knowledge transfer. Investment decisions should therefore favour interventions with transparent baselines, technically justified failure modes and a clear route to local staff competence. Published studies justify serious consideration of predictive control, condition monitoring and digital integration; they do not justify universal claims about efficiency percentages or guaranteed results across Saudi installations.

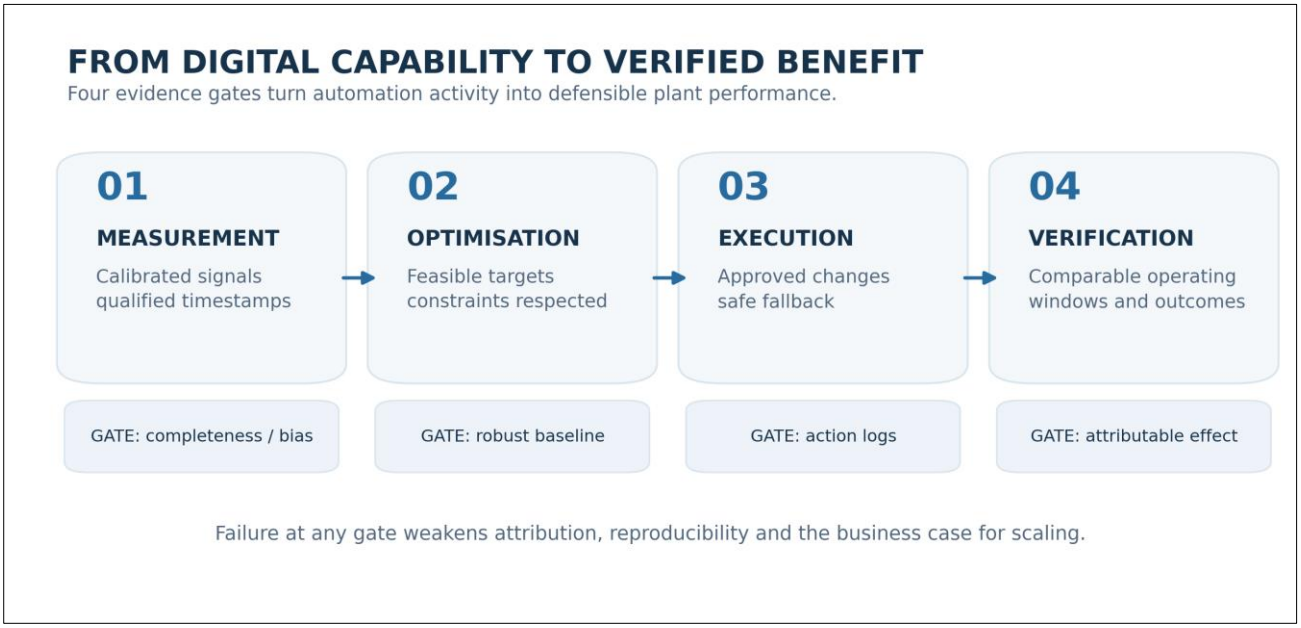


Figure 2: Evidence gates connecting measurement, constrained optimisation, operational execution and verified efficiency. Original conceptual diagram developed for this review

12. LIMITATIONS

This review is limited to a purposively selected body of thirty DOI identifiable papers published during 2020–2025. It does not represent exhaustive coverage of industrial standards, unpublished plant projects, vendor performance data or confidential operating records. The reference set includes simulation studies, methodological reviews, pilot evaluations and studies of assets outside Saudi Arabia, and these evidence types cannot be treated as equally generalisable. Because operational efficiency is reported through diverse measures, no common effect size or statistical meta analysis is presented. Proposed implementation steps are reasoned implications, not observations from a new Saudi field trial.

13. CONCLUSION

Advanced process automation and DCS integration can strengthen operational efficiency when they reduce unstable operation, coordinate constrained processes, support reliable equipment and shorten the path from credible data to accountable decisions. The contemporary evidence is strongest for specific control and monitoring mechanisms, and weaker for claims that broad digital transformation alone guarantees economic savings. Saudi operators should prioritise measurement integrity, protection boundaries, interoperable architectures, operator competence and robust before and after evaluation. A phased programme using carefully selected assets, explicit acceptance criteria and independently reviewed performance records offers a defensible way to transform technical potential into sustained operational outcomes. They accommodate changing operating modes, ageing equipment and organisational constraints.

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