Augmented Supply Chain Workforce Solutions for Saudi Arabia: Integrating ERP, Warehouse Management Systems and Digital Decision Support toward Vision 2030.

Abstract:

The transformation programme outlined in Saudi Arabia's Vision 2030 includes the logistics sector, industrial diversification, digital government, and human-capital development. Yet supply chain digitalisation leads to sustainable value only when enterprise systems improve how people understand situations, coordinate activities, and make decisions. This study considers an augmented workforce model based on enterprise resource planning (ERP), warehouse management systems (WMS), and digital decision support (DDS). It aims to demonstrate how these systems can be combined to enhance frontline execution, supervisory judgement, and cross-functional cooperation in Saudi supply chains. A systematic, targeted integrative review of literature published between 2020 and 2025 was conducted, starting with two existing Saudi-specific studies and concluding with 30 relevant sources. The synthesis brings together perspectives from human-centric Industry 5.0, digital transformation, warehouse technology and supply-chain resilience. Results show that ERP ensures transactional consistency and planning discipline, WMS converts plans into precise actions at specific locations, and DDS delivers predictive, prescriptive, and exception-management functions. These systems are more effective when workers are given role-based interfaces, training, decision-making authority, and feedback, rather than being treated as passive users of automation. The review proposes a human-in-the-loop architecture, a step-by-step implementation roadmap, and performance indicators geared toward the workforce and consistent with Vision 2030. It concludes that augmentation, not simply replacing people with technology, is the more realistic approach to achieving resilient, productive, and locally capable Saudi supply chains.

1. Introduction

Supply chains are currently being reorganised around continuous data, connected assets, and faster decisions. This shift is evident in manufacturing, distribution, retail, construction, and services, as volatility has made rigid planning and siloed execution increasingly costly. Accordingly, the literature on digital transformation regards supply chains not solely as a sequence of transactions but as information-rich operating systems whose performance depends on visibility, integration and responsiveness (Hanelt et al., 2021; Verhoef et al., 2021). Alquraish (2025) reaches a similar conclusion, stating that Saudi Arabia's digital transformation of its supply chains must sustain efficiency, resilience, and sustainability, while also accounting for force development as a necessary condition for socially sustainable implementation.

Enterprise resource planning systems, warehouse management systems and digital decision-support tools each have different roles but, when put together, provide a complementary contribution within this transformation. The ERP system integrates master data, procurement, finance, sales, production and planning into a single transactional core. The WMS then adds operational details to that core by carrying out tasks such as receiving, put-away, replenishment, determining inventory location, picking, packing and dispatch. Digital decision support – which includes analytics, artificial intelligence, optimisation and digital-twin functions – turns the accumulated data into forecasts, priorities, alerts, scenarios and recommended actions. When the systems are integrated, they can establish a closed information loop in which strategic demand is converted into warehouse activities, operational events cause corporate plans to be revised, and potential exceptions are identified before they lead to service failures. Research into digital supply chains shows that integration and visibility are key mediating factors between the adoption of Industry 4.0 and performance (Reaidy et al., 2024), and AI-based information processing can boost resilience, provided it is connected to collaborative and flexible capabilities (Reaidy et al., 2024).

The problem is that simply having a fully integrated system does not mean the workforce size increases. Nevertheless, warehouses and supply-chain environments still depend on people to deal with ambiguity, manage non-standard situations, negotiate trade-offs, preserve safety standards, and learn from disruptions. Research on Logistics 4.0 shows that obstacles to using these technologies include digital readiness, the availability of necessary skills, security concerns, financial restrictions, and the difficulty of integrating new tools into existing operations (Perotti et al., 2022). Studies that have focused on human elements also show that the character of the work changes when digital technologies redistribute cognitive demands, task ordering, and responsibility (Cimini et al., 2021). The example of augmented reality applications makes this particularly clear: even though visual guidance can reduce the need for searching and assist with picking, the benefits depend on the quality of the interface, the degree of acceptance, ergonomic factors and the way the work is designed in relation to the technology (Fang and An, 2020; Plakas et al., 2020).

For Saudi Arabia, this distinction is important because rapid investment within digital infrastructure is possible before operational procedures are in place and specialist skills are developed. Evidence on this issue, as supplied by Mgammal (2024), illustrates a wider principle concerning organisations: awareness, engagement, and preparation for change act as a mediating factor in how advanced technologies affect professional efficiency. Those who use the system have to understand it, trust the relevant outputs, and at the same time be able to deal with exceptional cases. A workforce strategy that depends entirely on automation may eliminate some manual tasks but will leave organisations with disjointed data, inadequate exception handling, and a reliance on a small number of specialists. In contrast, an augmentation strategy considers how technology can extend human perception, reduce unnecessary cognitive effort, standardise routine decisions, and allow human attention to concentrate on complex decisions.

Although previous reviews include some of the main points of this argument, they rarely merge these parts in the context of the Saudi workforce. Nasiri et al. (2020) explain how smart technologies affect digital supply-chain management; Aravindaraj and Rajan Chinna (2022) examine the applications of Industry 4.0 in warehouse management; and Alquraish (2025) connects digital transformation regarding resilience and sustainability in Saudi manufacturing. In contrast, research on human-centric Industry 5.0 argues that resilience, sustainability, and worker well-being should be treated as mutually dependent design objectives rather than separate outcomes (Ivanov, 2023; Lu et al., 2022). What is still missing, though, is an integrated review of how ERP, WMS, and decision support systems can work together to improve human work during both the planning and warehouse execution stages while additionally contributing to the Kingdom's objectives in localisation, capability building, and competitiveness.

On this basis, the review treats the augmented supply-chain workforce as a system-level capability. It focuses on the interactions between the various technology layers, the different types of worker roles and decision processes, rather than evaluating a specific software product. The analysis includes employees such as planners and buyers as well as warehouse operators, supervisors, inventory controllers and supply-chain managers. It also distinguishes automation and augmentation: automation means transferring a particular activity to a machine or an algorithm, while augmentation is intended to enhance a person's ability to sense, interpret, decide, or act. The paper then proposes an architecture based on a review of both approaches.

2. Objectives, Aim, and the Questions for Restudy

The study intends to develop an integration model that is focused on the workforce and which explains how ERP systems, WMS, and digital decision support can together improve supply-chain execution and the quality of decisions in Saudi Arabia. The review is based on four objectives. The first is to combine evidence on the individual and complementary roles of the three technology layers. The second objective is to identify how these systems support workers, for example by providing visibility, enabling cognitive offloading, managing exceptions, facilitating learning, and supporting interdepartmental collaboration. The third objective is to examine the implementation conditions particular to Saudi Arabia, including digital capability, workforce readiness, governance, localisation, and organisational change. The fourth objective is to convert the synthesis into a phased architecture, a performance framework, and a research agenda that is consistent with Vision 2030.

The review consists of three questions: RQ1 looks into how ERP, WMS and digital decision support interact to create an augmented supply-chain operating model; RQ2 looks at whhuman resource abilitiesties and human-in-the-loop design decisions cause the combining to result in gains in productivity, resilience as well as sustainability; and RQ3 examines the contextual conditions that Saudi organisations should take account of when scaling the model across their warehouses and wider supply networks. Unlike adoption reviews focused on technology, these questions focus on the relationship between workers and systems.

The analysis concentrates on the work system rather than the software platform. As a result, it examines the flow of information from enterprise planning through warehouse execution, how decisions are passed up the chain, and how employees interact with recommendations, alerts, and automated tasks. Workforce augmentation is seen as an extension of human abilities through digital tools, not simply as a way to substitute human labour. The predicted outcomes therefore include operational indicators including accuracy, cycle time, inventory visibility and toughness, as well as human-related measures such as decision confidence, skill depth, safety, learning, and the ability to handle exceptions. With this definition, the study is consistent with the concept of human-centric digital transformation. It prevents success from being considered achieved merely because productivity has increased due to hidden workloads, poor adoption, or a loss of operational knowledge.

3. Review Methodology

A focused systematic integrative review was selected since the research question covers information systems, operations management, warehousing, human factors and the Saudi transformation context; the approach therefore conforms to the transparency principle specified in PRISMA 2020 and makes use of thematic synthesis to integrate evidence that cannot be statistically pooled (Page et al., 2021).

The period under review spanned January 2020 to December 2025 so that all scholarly citations referred to in the text would fall within the time frame requested in this paper. The two cited articles served as seed studies: Alquraish (2025) presented a systematic review model on digital supply chains in Saudi Arabia, and Mgammal (2024) provided empirical evidence from Saudi Arabia on technology engagement, workforce change, and decision support. Additional sources were located through focused searches of the publisher's records and academic indexing databases associated with literature included in Scopus and Web of Science. The conceptual search strings were: (1) "enterprise resource planning" OR ERP; (2) "warehouse management system" OR WMS OR "smart warehouse" OR "warehouse 4.0"; (3) "decision support" OR analytics OR "artificial intelligence" OR optimization OR "digital twin"; (4) workforce OR worker OR operator OR "human-centric" OR augmentation; and (5) "Saudi Arabia" OR "Vision 2030" OR transportation OR supply chain. The searches combined at least one technology term with supply-chain or warehouse terms, while the Saudi-related terms were used in the contextual sub-search rather than being treated as a mandatory filter for all the global evidence sources.

To be included, a paper had to be published between 2020 and 2025 and make a direct contribution to at least one of the four areas of analysis: enterprise integration, warehouse digitalisation, digital decision support, or the human/workforce implications. Preference was given to peer-reviewed journal articles, systematic reviews, and studies based on experimental evidence and published in well-established journals in operations, information systems, and manufacturing. Papers that were specific to Saudi Arabia were included, provided they offered contextual evidence on digital supply chains, Industry 4.0, organisational capability, or workforce implications. The exclusion criteria removed items published before 2020; those that contained only technical algorithms with no link to operational or human aspects; applications not related to the supply chain and without transferable consequences for decision-making; duplicate records; and sources for which the bibliographic information could not be confirmed. The final core set of evidence consists of the thirty sources listed in the reference section.

The quality evaluation used five criteria: relevance to the review questions, clarity of construct definitions, transparency of the method, strength of the empirical or conceptual basis, and the extent to which the findings were transferable to supply-chain work. For reviews and conceptual papers, assessment focused on the transparency of their search procedure or theory. In contrast, empirical studies were judged on the clarity of their sample or application and on the plausibility of the relationships between the technology and the outcomes. Rather than treating low-transferability findings as evidence of universal effects, the authors used them to identify possible opportunities or design considerations. For example, studies on AR order-picking present insights into interface and cognitive-support mechanisms, while the accounting evidence from Saudi Arabia illustrates the general role of engagement and reskilling; in neither case do they claim that performance occurs in all Saudi warehouses.

The data were extracted using a structured coding sheet with six categories: the technology layer, the operational process, the human role, the augmentation mechanism, the performance outcome, and the implementation condition. For ERP systems, the coding focused on process integration, planning, data uniformity, and interdepartmental coordination. For evidence, the coding focused on inventory visibility, task orchestration, order picking, traceability, and human-machine interaction. For evidence related to decision-support systems, coding focused on prediction, anomaly detection, prioritisation, scenario analysis, and autonomous recommendations. The human outcomes included workload, skills, safety, decision quality, job redesign, adoption, and learning. The contextual codes consisted of data quality, cybersecurity, organisational readiness, regulation, and relevance to Saudi Vision 2030.

The procedure occurred in three stages. In the first stage, within-domain synthesis was used to identify the findings that were repeated in relation to ERP, warehouse digitalisation and AI-enabled decision support. In the second stage, cross-domain synthesis revealed the relations in which ERP provides a common transactional semantics, the WMS generates detailed execution data, and the decision-support applications produce actionable signals based on the two aforementioned sources. In the third stage, a human-centric synthesis examined the various points at which workers act as decision makers, exception owners, trainers, maintainers and recipients of system guidance. This is why the paper includes two conceptual figures and two tables. Since the framework has now been developed, it is interpretative rather than causal: it outlines the mechanisms supported by the convergent literature. It indicates zones where further empirical testing in Saudi Arabia is required.

4. The conceptual foundations: from automation to augmentation

The foundation of workforce augmentation lies in digital transformation, information processing, and human-centred production. Digital transformation entails more than installing software because it changes organisational routines, how information moves, and the logic of value creation (Hanelt et al., 2021; Verhoef et al., 2021). Nasiri et al. (2020) see smart technologies as key enablers of digital supply-chain management. Still, the degree of their contribution depends on how organisations combine technology with their managerial capabilities. For this review, technology is viewed as an enabling resource whose effect is achieved through the redesign of work, rather than as a standalone factor affecting performance.

Ivanov (2023) supports the view that Industry 5.0 is geared towards humans, describing it as aiming for resilience, sustainability, and a human-focused approach, while Lu et al. (2022) point out the need for manufacturing systems that incorporate human needs and capabilities into sophisticated digital environments. Ghobakhloo et al. (2023) reach the same conclusion, arguing that inclusive sustainable manufacturing needs a strategic emphasis on people, institutions, and technology rather than a narrow automation strategy. When this principle is extended to supply chains, it implies that a digitally mature warehouse is not necessarily the one with the fewest number of workers; instead, it is the one in which the routine physical and informational tasks are appropriately shared between humans and machines, human decision making is available when uncertainty occurs, and the lessons drawn from exceptional situations result in better future operations.

A second ground for the automation-augmentation paradox is provided by Raisch and Krakowski (2021), who show that artificial intelligence can assume some managerial responsibilities while also assisting with others, leading to mutual dependence between automation and augmentation. In warehouses and planning scenarios, the paradox occurs whenever algorithms optimise a route, prioritise an order, or detect a risk. Still, a person remains responsible for accounting for local constraints. When conditions are stable and repetitive, complete automation is preferable; however, augmentation becomes more valuable when the tasks involve novel disruptions, multiple objectives, social coordination or poor data.

ERP, WMS, and DDS can be regarded as different layers in the allocation of cognition. ERP establishes organisational memory through common master data, transaction rules, and integrated plans. As Lukyanova et al. (2022) point out, ERP configuration affects supply chain coordination across a variety of organisational scenarios, while Qureshi (2022) links ERP implementation to sustainable supply-chain management and stresses the organisational conditions linked to adoption. WMS provides a more direct understanding of the current situation by displaying stock locations, task queues and warehouse events. Perotti et al. (2022) identify procedure optimisation as one of the main advantages of logistics 4.0 in warehousing, but they also note readiness, security, and economic issues. Likewise, Aravindaraj and Rajan Chinna (2022) find that smart warehousing can improve monitoring, process efficiency and risk management. Still, it is constrained by a lack of skilled workforce and by the existing facilities.

The third stage of DDS is interpretation and forecasting. Studies on AI and big data show that better information-processing skills can increase resilience by enabling pattern identification, prediction, and more rapid response (Bahrami and Shokouhyar, 2022; Zamani et al., 2023).

Digital twins put this concept into practice by linking operational data with simulation and scenario-testing models (Wang et al., 2022). However, algorithms can provide poor recommendations if the data are incomplete, the objectives are misdefined, or operating conditions change. For this reason, the augmented workforce approach uses human-in-the-loop control: the systems handle data aggregation, pattern recognition, and routine optimisation; workers then examine exceptions, supply relevant contextual knowledge, approve important trade-offs, and feed learning back into the system rules.

It results in five methods of augmentation. By improving visibility, the effort required to search for and coordinate information decreases because relevant state information becomes available; cognitive offloading entails transferring necessary calculations, memory-demanding checks, and repetitive sequences to systems. Decision compression reduces the time interval between detecting a deviation and choosing a response. Guided execution turns complex procedures into role-specific instructions for the location where the work is being carried out. Lastly, learning amplification records exceptions and outcomes so organisational knowledge is not confined to individual experience. Together, these mechanisms show that integration may improve both operational performance and workforce capability when governance and training are designed alongside the technology.

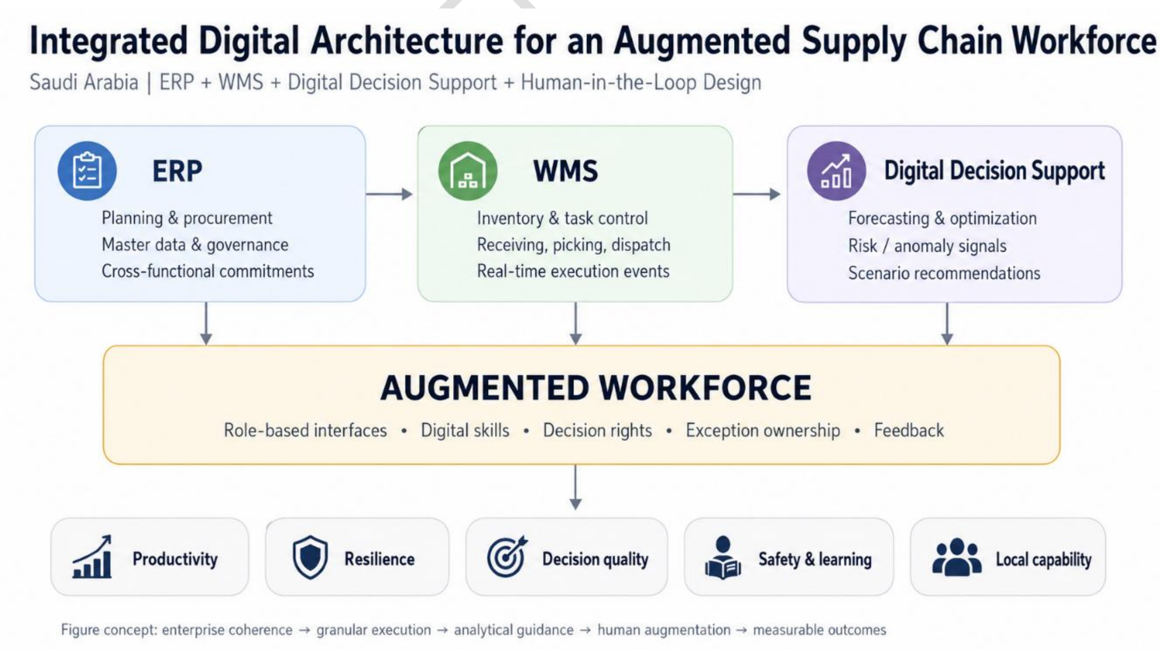

Figure 1. Integrated ERP-WMS-DDS architecture for workforce augmentation.

5. Integrated ERP-WMS-DDS Architecture for Workforce Augmentation

The proposed architecture begins by making ERP the central element for planning and governance. It gives planners, buyers, the finance teams and operations managers a shared representation of demand, supply, orders, suppliers, costs and commitments. The value it offers the workforce is not just in speeding up the entry of transactions; standardised data definitions reduce the amount of reconciliation work required, common workflows make the responsibilities clearer, and integrated planning makes the upstream and downstream effects more obvious. As AlMulhim (2021) points out, digital technologies contribute to achieving smart supply-chain performance by improving organizational capabilities, and the evidence from the Saudi Industry 4.0 initiative shows that the benefits of technology are greater when process and lean practices are aligned rather than when these practices are introduced as separate tools (Ghaithan et al., 2021). It is for this area that subsequent improvements depend.

The WMS turns the company's intentions into actions within the warehouse by allocating storage locations, managing stock status, determining the sequence for replenishment and picking, and maintaining records of goods movements at a level of detail that an ERP system is generally unable to manage efficiently. This level of detail affects how operators and supervisors carry out their tasks since task priorities might now be changed dynamically instead of having to be passed on through paper lists or informal instructions. As stated in the studies on Logistics 4.0, warehouse process optimisation, real-time visibility and technology-enabled coordination are considered the main benefits, although it is also pointed out that the quality of adoption depends on compatibility, workforce readiness and security (Perotti et al., 2022). The systematic review by Aravindaraj and Rajan Chinna (2022) also stresses the importance of having skilled personnel and up-to-date infrastructure. The augmented model therefore sees WMS screens, scanners and mobile devices as interfaces for the workers, more than as data-capture terminals.

At the level of the operator, digital guidance is able to cut down on the cognitive effort that is unnecessary while still permitting local judgment. Fang and An (2020) illustrate how wearable augmented reality can help with manual order picking by offering spatial information and therewith reducing the mental strain resulting from having to find items in crowded areas. Plakas et al. (2020) provide an account of the lessons gained from a real industrial AR application that was used in the context of order picking, showing how virtual instructions can support repetitive warehouse tasks in actual operations. Ponis et al. (2020) take a human-oriented approach by combining AR with gamification and looking at questions of work efficiency and employee contentment. They do, nevertheless, put forward a design principle: the WMS should supply the right amount of context to the worker at the moment when action is taken, using the least intrusive interface suitable for the task.

DDS is placed both above and to one side of ERP and WMS in order that it can decide what should draw attention. The forecasting models can detect possible imbalances in demand or in inventory; optimisation may be applied to the sequencing of replenishment, labour and transport; anomaly detection can point out anomalous transactions; and the scenario tools can be used to compare the responses to a disruption. Belhadi et al. (2024) show that AI-enabled information processing contributes to supply-chain resilience plus performance inside dynamic situations, while Qader et al. (2022) link Industry 4.0 capabilities with resilience plus performance. Reaidy et al. (2024) also indicate that integration and visibility function as mediators of the relationship between Industry 4.0 and supply-chain performance. It is essential that the recommendations be fed back into the ERP and WMS workflows so that the people responsible can take action on them.

A human-in-the-loop approach is therefore essential. Automation is appropriate for decisions that are routine and rest on explicit rules and reliable data—for example, creating a replenishment task when stock falls below a specific level. In cases where there is greater uncertainty, the system can offer suggestions: the DDS can rank various allocation alternatives during a shortage, while the planner chooses the right course of action after considering customer importance, contractual obligations, and local constraints. As Mgammal (2024) shows in a work setting in Saudi Arabia, awareness of technology, the degree of one's engagement and preparation for change all have an impact on how AI affects work outcomes; the key point is that the value of decision support comes from knowledgeable involvement rather than just being exposed to it.

Integration also establishes a continuous feedback loop in which the ERP system transmits information about demand, orders, and policy parameters to the WMS; the WMS then sends back data relating to inventory, productivity, and any exception events; the DDS makes use of both of these data streams to generate risk signals and recommendations; the workers implement them, reject them or modify them; and the data on the results are then used to update the future models and operating rules. Problems that keep occurring—such as difficulties at a specific location, variations from suppliers, or delays in picking—become structured signals rather than being dealt with as separate incidents. Perano et al. (2023) state that digitalization and process integration is able to enhance supply-chain performance, while Spieske et al. (2023) suggest that the post-disruption future of Industry 4.0 as well as resilience depends on capabilities that go beyond those of individual technologies.

The design additionally contributes in support of resilience and sustainability since, in the event of a disruption, integrated data indicates the location of the inventory, which orders are at risk and what substitution alternatives are still available. Even though AI-driven decision support can evaluate the different options more quickly, it is still up to human teams to make the decisions concerning safety, customer commitments and regulatory requirements. Alquraish (2025) points out that the digital transformation occurring in Saudi Arabia achieves resilience through better visibility and anticipatory capabilities, but it also requires workforce development in order to avoid adverse social effects. Similarly, Yusuf and Lytras (2023) connect Saudi digitalisation with competitive sustainability in the context of Vision 2030.

The technology-to-workforce relationship is explained in Table 1 and the integrated architecture is illustrated in Figure 1. Daily operations will stay unclear if ERP is used without a WMS; it is possible to optimize the warehouse at a local level but at the same time disconnect it from enterprise-level priorities if a WMS is used without ERP; and if DDS is used in the absence of reliable operational data it will produce complicated but useless recommendations. Conversely, integration alone, without a redesign of the workforce, will only accelerate the existing problems. The augmented model therefore associates each technology layer with specific user roles, training, decision-making authority and feedback procedures. Hence, the approach changes from one of 'installing and adopting' to 'integrating, redesigning, learning and scaling'.

Table 1. Technology layers and workforce-augmentation mechanisms

Layer	Core digital role	Workforce augmentation	Representative decisions	Primary outcomes
ERP	Shared planning, master data and transaction governance	Reduces reconciliation; exposes cross-functional consequences; standardizes routine workflows	Purchase priorities, allocation commitments, plan changes, approval routing	Data consistency, coordination, planning discipline
WMS	Granular inventory and warehouse task orchestration	Delivers point-of-work instructions; reduces search effort; structures exceptions	Put-away, replenishment, pick sequence, wave release, dispatch exception	Accuracy, cycle time, inventory visibility, safer execution
DDS	Analytics, AI, optimization and scenario support	Compresses decision time; prioritizes attention; provides evidence for uncertain choices	Risk alerts, labor balancing, shortage allocation, anomaly review, scenario selection	Resilience, forecast quality, exception resolution, decision quality

Layer	Core digital role	Workforce augmentation	Representative decisions	Primary outcomes
Human interface / automation	Mobile, scanners, AR, AGVs/cobots and workflow interfaces	Connects system guidance to physical action while preserving accountable human oversight	Accept/override recommendation, escalate exception, confirm safe execution	Adoption, learning, ergonomic fit, calibrated autonomy

6. Saudi Arabia: Vision 2030 Implementation Roadmap

Saudi Arabia is concerned; the framework should be seen as the background of Vision 2030's shared emphasis on diversification, logistical competitiveness, digital development, and human capital development. The objective is not to go in for a general idea of a "light warehouse", but to set up rating systems that strengthen local capabilities. The structure in question must be modular: the fundamental ERP governance should be standardized, the WMS should be established on a site-by-site basis, and prioritized in line with decisions that provide the greatest operational value.

Workforce readiness is the first implementation condition; digital interfaces change knowledge requirements, and supervisors and operators need to adapt. As Cimini et al. (2021) note, Logistics 4.0 results from both task content and human requirements, and Lu et al. (2022) support human-centered systems in which worker capability is regarded as a design variable. Saudi organisations should therefore draw up role-based skill matrices before making their final decisions on automation; for instance, a warehouse operator will need scanning skills, the ability to identify exceptions and safe interaction with automated equipment, while a supervisor will need to be able to interpret dashboards and to balance workloads and a planner will need to have skills in scenario analysis and in questioning models.

A further requirement is organizational absorptive capacity, defined as the capacity to acquire, interpret and apply new knowledge. According to Abourokbah et al. (2023), digital capability is linked to agility, resilience and inventiveness performance, showing that the value of technology depends on the organization's overall capacity. In practice, Saudi companies ought to set up multi-functional product teams comprising individuals from supply-chain operations, IT, data management, finance, human resources and cybersecurity; otherwise the ERP, WMS and analytics systems will be left as separate technical projects with conflicting data definitions.

The third requirement is data governance. If the item masters, the locations, the units of measure, the supplier attributes and the transaction timestamps are to be trusted, then a decision-support layer must be relied upon. Governance should specify who is responsible for the key data objects, establish validation rules, monitor the rate of exceptions and handle the various versions of the models. Cybersecurity must be included because linking the warehouses increases the attack surface, and operational disturbances may have physical consequences. According to the model provided by Alquraish (2025), regulatory uncertainty and digital risk act as contextual moderators, while Azmi et al. (2022) point out that emerging digital technologies in Saudi supply chains require attention to resilience and governance rather than simply focusing on technological newness.

A fourth requirement is phased investment, meaning that firms first achieve visibility and ensure their processes are stable before proceeding to autonomous optimization. In the first phase, clean master data, standardised processes and reliable integration between the ERP and WMS are established. The second phase introduces execution, real-time dashboards, and exception handling. In the third phase, predictive systems are introduced for demand, labor, inventory, and disruption. In the fourth phase, prescriptive optimization and a cautiously limited amount of automation are included, provided data quality and process maturity align. This approach aligns with the digital-transformation literature's emphasis on organizational change and capability building (Hanelt et al.). It helps minimize the risks of applying advanced AI to processes that have not yet been stabilized.

Performance measurement should also consider the workforce. Even though traditional warehouse KPIs such as inventory accuracy, order-cycle time, picks per hour and service level are still necessary, they alone are not sufficient. The framework contains measures such as decision latency, exception-resolution time, the percentage of recommendations that are accepted or overridden, training completion, cross-skill coverage, digital error rates, safety events, and the proportion of recurring exceptions eliminated as a result of learning. These are measures that enable us to distinguish between authentic augmentation and simple work intensification. When productivity increases but the number of overrides, fatigue or safety incidents rises, the technology may be shifting the load rather than improving the system.

Moreover, the implementation should provide for localization and make it easy to acknowledge and transfer. As Mgammal (2024) continues, adaptation and training are required due to the professional changes caused by AI. In conjunction with the human-centered approach that is at the heart of Industry 5.0, this makes it possible to follow a vision of the modernization of the digital supply chain that results in the establishment of higher-value jobs as well as greater operational proficiency. Table 2 presents this approach as a step-by-step roadmap, and Figure 2 shows the closed learning loop that connects system intelligence, worker action, and organizational outcomes.

Table 2. Phased implementation roadmap and workforce-oriented performance measures

Phase	**System priority**	**Workforce action**	**Governance checkpoint**	**Illustrative KPIs**
1. Foundation	ERP master data, process standards, stable ERP-WMS interfaces	Map roles; establish digital skill baselines; nominate super-users	Data ownership, access control, process accountability	Master-data error rate; inventory accuracy; process adherence
2. Connected execution	Real-time WMS, mobile workflows, exception visibility	Train operators and supervisors on point-of-work interfaces and escalation	Cybersecurity, device safety, interface usability	Cycle time; exception-resolution time; digital error rate; safety events

Phase	System priority	Workforce action	Governance checkpoint	Illustrative KPIs
3. Decision augmentation	Predictive analytics, alerts, scenario support	Build model literacy; define accept/override/escalate decision rights	Model validation, bias review, traceable recommendations	Decision latency; recommendation acceptance/override; service risk detected early
4. Scaled autonomy	Optimization, digital twins, bounded automation and feedback learning	Cross-skill teams; continuous improvement; develop local analytics/automation capability	Model drift, change control, human fallback, auditability	Recurring exceptions eliminated; skill depth; resilience recovery time; productivity

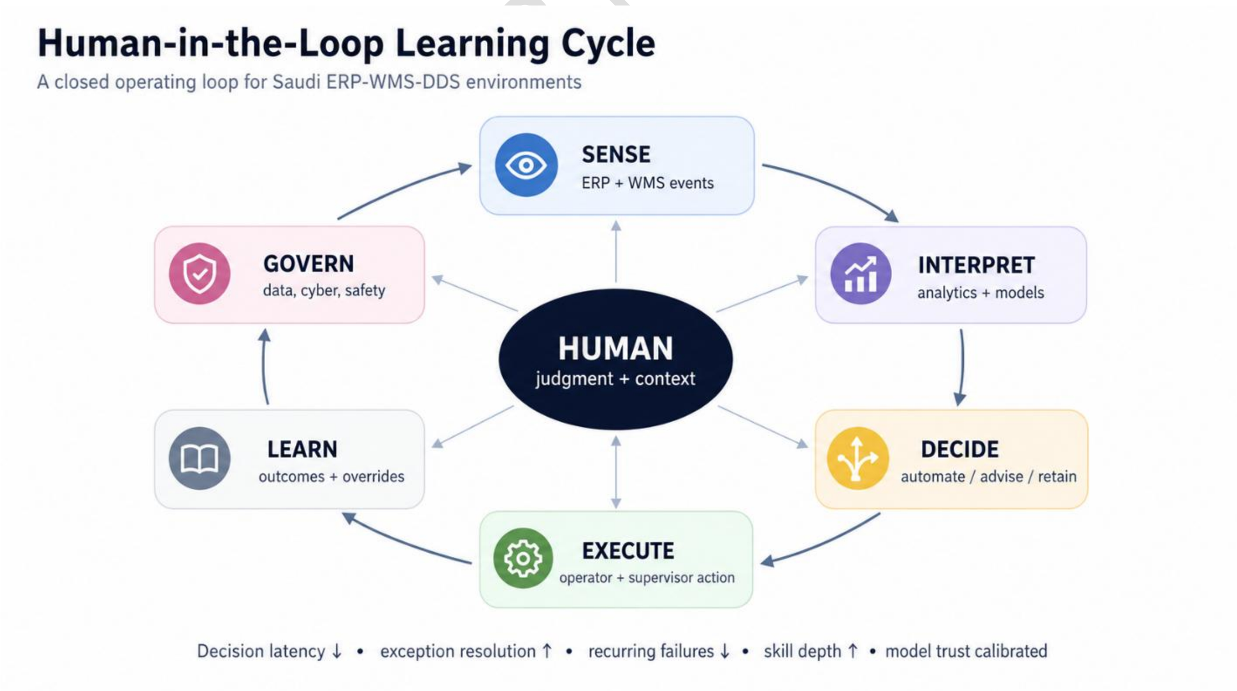

Figure 2. Human-in-the-loop learning cycle.

7. Discussion, Research Agenda and Limitations

The synthesis proposes three main propositions. The first is that the value of ERP, WMS and DDS is multiplicative not additive, since integration is important because each of the layers provides information or control which the others do not. The second proposition is that augmentation is a process of building capabilities: faster systems lead to better outcomes only when workers have the right interfaces, skills, and decision-making authority. The third point is that, in the Saudi case, workforce development becomes a strategic outcome in itself, not simply an adoption issue; digitalization can enhance resilience and sustainability, but only if organizations refrain from creating new dependencies on divided data, opaque models, or scarce external expertise.

This also points to a range of research questions. Studies of Saudi Arabia should involve a comparison of warehouses that have different levels of integration, investigate whether the depth of digital skills mediates the relationship between system use and performance, and look at the situations in which human interventions either improve or reduce the quality of decisions. It is especially important to carry out longitudinal research since the initial increases in productivity may fail to take into account factors such as learning, fatigue, staff turnover or model drift. Comparing the sector across healthcare, retail, manufacturing, and project logistics would help establish which aspects of the architecture are generalizable. Furthermore, subsequent research should assess bilingual interface design, local training routes and governance arrangements for generative or agentic AI as these tools move into supply-chain control environments.

The review does have some limitations; although it is based on thirty sources, this body of evidence is selective rather than complete, and the variety of study designs makes it impossible to estimate quantitative effects. A number of the findings relating to human augmentation come from international warehouse or production settings and therefore need to be validated in Saudi Arabia. Furthermore, technologies change more rapidly than the time it takes for publications to be produced. To address these limitations, the framework is presented as a testable synthesis rather than evidence that every technology will produce the same result in every organization.

8. Conclusion

Transforming Saudi Arabia's supply chains requires more than connected software; it needs staff able to use connected information to act more quickly, consistently, and with better judgment. This review explains how ERP, WMS, and digital decision support can together form a coherent augmentation stack. ERP establishes data collection and planning across the entire enterprise, WMS turns these plans into specific warehouse operations, and DDS spots patterns, risks, and options that warrant attention. When these levels are combined with role-based interfaces, training, governance, and the right to make decisions with human monitoring, automation can take over routine tasks while enabling employees to focus on exceptions, coordination, and continuous improvement.

With regard to Vision 2030, it is essential that productivity and capability development are planned and designed in tandem. It is more reliable to take a step-by-step approach that starts with data quality and process stability, before moving on to visibility, prediction, and bounded autonomy, than to go with a technology-driven method. The suggested architecture and roadmap provide Saudi organizations with a practical basis for evaluating where human decision-making should be kept, where computerized guidance should be introduced, and where routine decisions can be automated. Future empirical studies should test these mechanisms in different sectors of Saudi Arabia and monitor both operational and workforce outcomes over time. The strategic aim is to achieve an adaptive supply chain in which digital systems improve local expertise, organisational learning and toughness rather than simply replacing manual activities.

References

Alquraish, M. (2025). Digital transformation, supply chain resilience, and sustainability: A comprehensive review with implications for Saudi Arabian manufacturing. Sustainability, 17, 4495. https://doi.org/10.3390/su17104495

Mgammal, M. H. (2024). The influence of artificial intelligence as a tool for future economies on accounting procedures: Empirical evidence from Saudi Arabia. Discover Computing, 27, 20. https://doi.org/10.1007/s10791-024-09452-7

Nasiri, M., Ukko, J., Saunila, M., & Rantala, T. (2020). Managing the digital supply chain: The role of smart technologies. Technovation, 96, 102121.

Hanelt, A., Bohnsack, R., Marz, D., & Antunes Marante, C. (2021). A systematic review of the literature on digital transformation: Insights and implications for strategy and organizational change. Journal of Management Studies, 58, 1159-1197. https://doi.org/10.1111/joms.12639

Verhoef, P. C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Dong, J. Q., 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

Raisch, S., & Krakowski, S. (2021). Artificial intelligence and management: The automation-augmentation paradox. Academy of Management Review, 46, 192-210. https://doi.org/10.5465/amr.2018.0072

Ivanov, D. (2023). The Industry 5.0 framework: Viability-based integration of the resilience, sustainability, and human-centricity perspectives. International Journal of Production Research, 61, 1683-1695. https://doi.org/10.1080/00207543.2022.2118892

Lu, Y., Zheng, H., Chand, S., Xia, W., Liu, Z., Xu, X., Wang, L., Qin, Z., & Bao, J. (2022). Outlook on human-centric manufacturing towards Industry 5.0. Journal of Manufacturing Systems, 62, 612-627. https://doi.org/10.1016/j.jmsy.2022.02.001

Ghobakhloo, M., Iranmanesh, M., Foroughi, B., Tirkolaee, E. B., Asadi, S., & Amran, A. (2023). Industry 5.0 implications for inclusive sustainable manufacturing: An evidence-knowledge-based strategic roadmap. Journal of Cleaner Production, 417, 138023. https://doi.org/10.1016/j.jclepro.2023.138023

Cimini, C., Lagorio, A., Pirola, F., & Pinto, R. (2021). How human factors affect operators' task evolution in Logistics 4.0. Human Factors and Ergonomics in Manufacturing & Service Industries, 31, 98-117. https://doi.org/10.1002/hfm.20872

Perotti, S., Bastidas Santacruz, R. F., Bremer, P., & Beer, J. E. (2022). Logistics 4.0 in warehousing: A conceptual framework of influencing factors, benefits and barriers. The International Journal of Logistics Management, 33, 193-220. https://doi.org/10.1108/IJLM-02-2022-0068

Aravindaraj, K., & Rajan Chinna, P. (2022). A systematic literature review of integration of Industry 4.0 and warehouse management to achieve Sustainable Development Goals (SDGs). Cleaner Logistics and Supply Chain, 5, 100072. https://doi.org/10.1016/j.clscn.2022.100072

Ponis, S. T., Plakas, G., Agalianos, K., Aretoulaki, E., Gayialis, S. P., & Andrianopoulos, A. (2020). Augmented reality and gamification to increase productivity and job satisfaction in the warehouse of the future. Procedia Manufacturing, 51, 1621-1628. https://doi.org/10.1016/j.promfg.2020.10.226

Plakas, G., Ponis, S. T., Agalianos, K., Aretoulaki, E., & Gayialis, S. P. (2020). Augmented reality in manufacturing and logistics: Lessons learnt from a real-life industrial application. Procedia Manufacturing, 51, 1629-1635. https://doi.org/10.1016/j.promfg.2020.10.227

Fang, W., & An, Z. (2020). A scalable wearable AR system for manual order picking based on warehouse floor-related navigation. The International Journal of Advanced Manufacturing Technology, 109, 2023-2037. https://doi.org/10.1007/s00170-020-05771-3

Lukyanova, I., Haddud, A., & Khare, A. (2022). Types of ERP systems and their impacts on the supply chains in the humanitarian and private sectors. Sustainability, 14, 13054. https://doi.org/10.3390/su142013054

Qureshi, M. R. N. M. (2022). Evaluating enterprise resource planning (ERP) implementation for sustainable supply chain management. Sustainability, 14, 14779. https://doi.org/10.3390/su142214779

AlMulhim, A. F. (2021). Smart supply chain and firm performance: The role of digital technologies. Business Process Management Journal, 27, 1353-1372. https://doi.org/10.1108/BPMJ-12-2020-0573

Ghaithan, A., Khan, M., Mohammed, A., & Hadidi, L. (2021). Impact of Industry 4.0 and lean manufacturing on the sustainability performance of plastic and petrochemical organizations in Saudi Arabia. Sustainability, 13, 11252. https://doi.org/10.3390/su132011252

Yusuf, N., & Lytras, M. D. (2023). Competitive sustainability of Saudi companies through digitalization and the circular carbon economy model: A bold contribution to the Vision 2030 agenda in Saudi Arabia. Sustainability, 15, 2616. https://doi.org/10.3390/su15032616

Azmi, N. A., Sweis, G., Sweis, R., & Sammour, F. (2022). Exploring implementation of blockchain for the supply chain resilience and sustainability of the construction industry in Saudi Arabia. Sustainability, 14, 6427. https://doi.org/10.3390/su14116427

Bahrami, M., & Shokouhyar, S. (2022). The role of big data analytics capabilities in bolstering supply chain resilience and firm performance: A dynamic capability view. Information Technology & People, 35, 1621-1651.

Qader, G., Junaid, M., Abbas, Q., & Mubarik, M. S. (2022). Industry 4.0 enables supply chain resilience and supply chain performance. Technological Forecasting and Social Change, 185, 122026.

Zamani, E. D., Smyth, C., Gupta, S., & Dennehy, D. (2023). Artificial intelligence and big data analytics for supply chain resilience: A systematic literature review. Annals of Operations Research, 327, 605-632.

Reaidy, P., Alaeddini, M., Gunasekaran, A., Lavastre, O., & Shahzad, M. (2024). Unveiling the impact of Industry 4.0 on supply chain performance: The mediating role of integration and visibility. Production Planning & Control, 1-22. https://doi.org/10.1080/09537287.2024.2440454

Belhadi, A., Mani, V., Kamble, S. S., Khan, S. A. R., & Verma, S. (2024). Artificial intelligence-driven innovation for enhancing supply chain resilience and performance under the effect of supply chain dynamism: An empirical investigation. Annals of Operations Research, 333, 627-652. https://doi.org/10.1007/s10479-021-03956-x

Perano, M., Cammarano, A., Varriale, V., Del Regno, C., Michelino, F., & Caputo, M. (2023). Embracing supply chain digitalization and unphysicalization to enhance supply chain performance: A conceptual framework. International Journal of Physical Distribution & Logistics Management, 53, 628-659.

Wang, L., Deng, T., Shen, Z. J. M., Hu, H., & Qi, Y. (2022). Digital twin-driven smart supply chain. Frontiers of Engineering Management, 9, 56-70.

Spieske, A., Gebhardt, M., Kopyto, M., Birkel, H., & Hartmann, E. (2023). The future of Industry 4.0 and supply chain resilience after the COVID-19 pandemic: Empirical evidence from a Delphi study. Computers & Industrial Engineering, 181, 109344.

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., McGuinness, L. A., Stewart, L. A., Thomas, J., Tricco, A. C., Welch, V. A., Whiting, P., & Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ, 372, n71. https://doi.org/10.1