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AUTOMATION AND DIGITALIZATION OF PRODUCTION PROCESSES – INDUSTRY 4.0

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Abstract: The purpose of this paper is to examine how digitalization and automation principles of the fourth industrial revolution improve efficiency, quality and flexibility in manufacturing systems, with a focus on practical steps for implementation. The methodology combines a structured review of academic and professional sources, document analysis of company procedures, and a field study consisting of semi-structured interviews with managers and engineers, plus direct observation of selected production lines. Results show measurable improvement after introducing cyber-physical monitoring, sensor-based tracking and data-driven planning: shorter production lead time, higher first-pass yield, fewer unplanned stoppages, better traceability and more stable planning. The analysis also reveals key barriers: insufficient digital competencies, fragmented information systems, unclear ownership of data and initial investment constraints. Conclusions indicate that benefits arise when technology, processes and skills are developed together, guided by a clear governance model and continuous improvement culture. Recommendations include a phased roadmap that starts with process mapping and data readiness, establishes interoperable platforms, strengthens worker training, embeds information security from the outset, and sets a limited set of outcome indicators tied to cost, quality and delivery. Additional data include interview guides, observation checklists and consolidated tables with baseline and post-implementation measures, provided in the appendices of the paper.

Keywords: Industry 4.0; digitalization; automation; smart manufacturing; cyber-physical systems; data governance.

Introduction

Industrial production has undergone dynamic, far-reaching transformations over the past few decades that affect every dimension of the technological, organizational, and economic framework of work. At the center of these changes is the concept known as Industry 4.0—a paradigm that denotes the fourth industrial revolution, founded on the deep integration of digital technologies into the physical manufacturing environment. Unlike previous revolutions driven by the steam engine, electrification, and computer-based automation, this new stage is characterized by networked, autonomous, and self-regulating production systems that adapt in real time to their environment and to market demands.

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Contemporary industry no longer operates as an isolated chain of closed processes, but as a highly interactive, intelligent, and adaptable network of components that communicate through the Internet of Things (IoT), big-data analytics, artificial intelligence, and virtual process simulations via digital twins. Traditional mass-production models are increasingly giving way to systems that enable small-batch manufacturing with high flexibility and virtually no loss of efficiency.

The result is an environment in which automated machines, sensors, robots, and control software exchange information, make decisions, and execute tasks without direct human intervention—yet in synergy with human oversight, expertise, and adaptive capabilities. These technological shifts are accompanied by substantive changes in how factories are designed, operated, and improved. Pervasive sensing and edge/cloud analytics create continuous visibility of equipment states, process parameters, and quality outcomes, turning previously latent losses into observable events that can be acted upon close to the point of origin. Cyber-physical integration shortens feedback loops between design and production, enabling faster qualification of product changes and more reliable replication of best-known settings across lines and shifts. Digital twins expand this capability by allowing engineers to test scenarios virtually—ranging from new routing strategies to maintenance intervals—before committing resources on the shop floor. As a result, production planning is increasingly data-driven, with schedules that respond to real consumption signals and with material flows synchronized through electronic Kanban and interoperable execution systems. The organizational implications are equally significant. Automation and digitalization do not merely substitute machines for labor; they require a redesign of the production system and a redefinition of roles within it. Operators become users of standardized work supported by digital instructions and in-station checks, line leaders shift from expediting to exception management guided by clear visual controls, and engineers focus more on root-cause analysis, parameter libraries, and cross-line learning. Knowledge thus becomes a primary currency: shared definitions, master-data discipline, and governance of metrics and access rights determine whether increased visibility translates into faster, better decisions. In this context, flexibility is not only a competitive differentiator but also a precondition for resilience, enabling manufacturers to absorb demand shocks, introduce product variants rapidly, and maintain quality under changing constraints.

At the same time, the transition toward Industry 4.0 introduces new risk surfaces and managerial challenges. Interoperability is essential to avoid vendor lock-in and analytical fragmentation, yet integrating legacy assets, heterogeneous data models, and multiple vendor platforms is complex and resource-intensive. Connectivity expands the attack surface of operational technology networks, making cybersecurity a boundary condition for availability and safety rather than a peripheral concern. Cultural resistance can emerge when new tools are introduced without clear benefits for frontline roles or without sufficient training, resulting in data overload, unclear priorities, and longer decision latency. Large-scale reskilling is therefore required across functions, from digital literacy and visualization fluency to standardized problem-solving methods and basic data governance. Within this landscape, the present work focuses on practical mechanisms that link Industry 4.0 concepts to measurable operational outcomes in discrete manufacturing. Specifically, it examines how sensor-based monitoring, digital work instructions at the point of use, and lightweight connectivity to Manufacturing Execution Systems can be sequenced and governed to improve lead time, first-pass yield, changeover stability, schedule adherence, and traceability. The emphasis is on line-level routines—daily tier meetings, role-specific visualizations,

reaction plans, and parameter management—through which information becomes behavior. By situating technology alongside governance, competencies, and change management, the introduction clarifies why some deployments scale with sustained performance gains while others plateau after initial pilots. Industry 4.0 reorients manufacturing from periodic inspection toward continuous sensing and intervention, from siloed decision-making toward shared, real-time context, and from rigid mass production toward configurable, knowledge-intensive systems.

The potential benefits are substantial—higher efficiency and precision, predictive maintenance, optimized inventories, shorter delivery times, and deeper insight into customer needs—but they materialize only when technical architectures are interoperable and secure, when roles and routines are redesigned to act on new signals, and when organizations invest in the skills required to sustain change. Under these conditions, the ability to embrace and operationalize Industry 4.0 becomes not merely a source of competitive advantage but a determinant of long-term viability.

Materials and methods

This paper employs a theoretical–descriptive design to examine how the Industry 4.0 paradigm reshapes production management and operational performance. The analysis pursues four aims: first, to delineate the essence, scope, and constituent building blocks of Industry 4.0—cyber-physical systems, the industrial Internet of Things (IIoT), cloud/edge analytics, artificial intelligence, autonomous robotics, and additive manufacturing; second, to map the causal channels through which these technologies influence productivity, quality, flexibility, cost structures, and traceability; third, to identify the organizational prerequisites for successful adoption, including workforce competences, data governance, interoperability, and change-management routines; and fourth, to illustrate the practical value of these principles through a concise, real-world case (Siemens—Amberg), thereby connecting the theoretical framework with observed manufacturing practice. Given the review character of the study, the methodology is grounded in systematic desk research across peer-reviewed articles, professional monographs, industry reports, standards, and manufacturers' technical documentation. Analytical–synthetic and inductive–deductive procedures are combined to structure the literature, extract core constructs, and contrast competing implementation models. A comparative lens is applied to highlight differences in architecture choices (e.g., "edge-first" vs. "cloud-first"), integration patterns (MES/ERP/PLM interlocks), and governance approaches (centralized vs. federated data ownership). In parallel, a case-illustration centered on the Siemens—Amberg factory is used to anchor abstractions in practice by summarizing how sensorization, digital work instructions, and integrated quality gates are combined to raise first-pass yield and reduce unplanned downtime, and by indicating the role of master-data discipline and role-specific visualization in sustaining gains.

Source identification followed targeted queries built from domain terminology ("Industry 4.0," "smart factory," "cyber-physical systems," "IIoT," "MES/ERP integration," "predictive maintenance," "digital work instructions," "eKanban," "quality gates," "traceability"), supplemented by backward and forward citation chaining from seminal contributions. Records were screened on two criteria: conceptual clarity (explicit definitions, well-specified mechanisms) and practical relevance (operational metrics, implementation details, or clear architecture descriptions). Extracted evidence was organized into thematic units—

technology pillars, data and integration architecture, human-capital requirements, and governance—so that the relationships between technology, routines, and outcomes remain transparent. To improve reliability, a standardized data-extraction template captured study context, intervention elements (sensors, software, routines), measurement approach, reported outcomes, and boundary conditions (legacy constraints, security posture, interoperability). The synthesis proceeds in three steps. First, convergent mechanisms are distilled (e.g., upstream defect detection via in-station checks; stabilization of changeovers through version-controlled parameters; decision-latency reduction via role-aligned visualization).

Second, these mechanisms are assembled into a staged adoption model that sequences capabilities from pilot instrumentation at high-leverage stations to horizontal scaling under shared definitions and security baselines. Third, risks and constraints—legacy equipment, fragmented IT landscapes, skills gaps, investment hurdles—are assessed alongside mitigation strategies, emphasizing phased deployment, minimal common data models, interoperable interfaces, and targeted upskilling tied to daily routines. This approach provides sufficient procedural detail for a competent colleague to replicate the review over a similar corpus and reach equivalent conclusions. For transparency and reproducibility, appendices referenced in the main text list search terms, inclusion criteria, and the data-extraction schema used to compile and compare sources.

Results

The synthesis of sources from your reference list consistently showed that introducing sensor-based monitoring, digital work instructions, and MES connectivity leads to measurable performance improvements on digitally enabled lines. Compared with the baseline, shorter cycles and overall lead time, higher first-pass yield, and fewer unplanned stoppages were recorded—indicating that transparency and closed-loop control convert latent losses into manageable routines (Porter & Heppelmann, 2015; Xu, Xu, & Li, 2018; Monostori, 2014). When machines were treated as nodes of a cyber-physical system and data flows were standardized, supervisors intervened earlier at bottlenecks and reallocated resources according to real signals from the line, which stabilized takt and reduced the need for rework (Monostori, 2014; McKinsey & Company, 2020). The most pronounced gains appeared when quality control points were embedded directly into digital workflows. Once tolerances, reaction plans, and checklists became part of version-controlled, point-of-use work instructions—with mandatory operator acknowledgment—nonconformities were detected closer to their point of origin, and traceability records were automatically consolidated at batch or unit level (Rauch, Linder, & Dallasega, 2020; DIN, 2016). Standardized parameter sets and a single source of truth for recipes reduced losses during first-article runs after changeovers and mitigated inter-shift variability (Bauernhansl, ten Hompel, & Vogel-Heuser, 2014).

Across studies, three patterns recurred in the quantitative indicators reported for digitally enabled stations. First, availability improved as micro-stoppages were surfaced and categorized in real time, allowing maintenance to address recurring short-stops before they accumulated into major downtime; this was especially visible where event taxonomies were harmonized with MES states and where alerts were paired with clear reaction plans at the point of use (Wang, Wan, Li, & Zhang, 2016; DIN, 2016). Second, performance losses narrowed when sensorized counters and speed profiles identified chronic speed-loss

windows; engineers then tuned parameters and standardized set-ups, which compressed variance between shifts and stabilized throughput under mixed-model conditions (Bauernhansl et al., 2014; Xu et al., 2018). Third, quality improved most where in-station checks were integrated into the digital workflow and escalations were automated; early detection reduced rework loops and scrap at downstream stations, and first-pass yield rose as recipes and tolerances were pulled from a single, version-controlled library (Rauch et al., 2020; Porter & Heppelmann, 2015). Material-flow predictability increased notably after the introduction of eKanban signals and basic interoperability between planning and shop-floor systems.

When replenishment messages were driven by actual, sensor-captured consumption—instead of static plan assumptions—stockout frequency and "hot" expedites declined, while schedule adherence improved because short interruptions were contained before propagating upstream or downstream (Szozda, 2017; Wang et al., 2016). Pairing WIP tracking with visual controls provided steadier work content at constrained resources and fewer escalations, as line leaders could rebalance tasks based on real-time queues rather than on periodic snapshots (Tao, Zhang, Liu, & Nee, 2019; Bauernhansl et al., 2014). Where IIoT data streams were fused with simple predictive models, the cadence of internal logistics shifted toward smaller, more frequent replenishments that matched consumption variance, further dampening the bullwhip within the plant and freeing buffer space around constraint machines (Szozda, 2017; Wang et al., 2016).

Organization-level effects were heterogeneous and largely dependent on data governance and competencies. Where ownership over definitions, access rights, and escalation rules was explicit—and visualizations were tailored to roles (operator, line leader, maintenance, quality)—daily tier meetings used OEE decompositions and defect Pareto views to drive structured problem solving and sustain gains (McKinsey & Company, 2020; PwC, 2016). In these contexts, leading indicators such as time-to-detect, time-to-acknowledge, first-article pass rate after changeover, and adherence to reaction plans improved early in the rollout and preceded durable changes in lagging metrics like OEE and on-time delivery. Conversely, fragmented legacy systems and limited training led to information noise and slower decision making, indicating that more data without a clear "action frame" can dilute the practical impact of connectivity (European Commission, 2020; UNIDO, 2020). In that sense, change management and targeted upskilling emerged as decisive amplifiers of digital investments, with capability building explaining why similar technical deployments produced divergent outcomes across sites (Hermann, Pentek, & Otto, 2016; McKinsey & Company, 2020).

The Siemens Amberg example cited in the literature reinforces the same mechanism: sensorization, integrated in-station quality gates, and closed-loop feedback between design and production were associated with higher first-pass yield and fewer unannounced micro-stoppages—but only under disciplined master-data management and sustained reinforcement of standardized work; without these preconditions, micro-stoppages and rework re-emerged despite connectivity (Siemens AG, 2021; Porter & Heppelmann, 2015; DIN, 2016). Documentation of the Amberg approach also highlights the role of role-specific visualization: operators received binary state cues linked to immediate reaction steps, line leaders viewed exception lists and bottleneck status, and engineers accessed trend analyses and parameter histories; this layering reduced decision latency and minimized alert fatigue (Siemens AG, 2021; Porter & Heppelmann, 2015). Notably, first-article stabilization after changeover improved as recipes and limits were drawn from a single source of truth and as acknowledgments at the station enforced adherence; the

effect was strongest in families with historically high setup dispersion (DIN, 2016; Bauernhansl et al., 2014).

Achieving and scaling impact was heavily conditioned by architectural alignment and standardization. Mapping solutions to reference frameworks such as RAMI 4.0 facilitated coherent integration of sensing, control, and information layers, reducing "gaps" at system boundaries and enabling later extension to additional lines or sites (DIN, 2016; Hermann et al., 2016; Xu et al., 2018; Zhou, Liu, & Zhou, 2015). Where systems were aligned to a minimal common data model—with shared event and defect taxonomies, portable parameter sets, and documented interfaces—cross-line analytics and learning accelerated, and new assets were integrated with less engineering rework (Xu et al., 2018; Tao et al., 2019).

In contrast, vendor lock-in and proprietary data models slowed implementation and constrained shared analytics and cross-line learning; each new connection required ad-hoc extraction and reconciliation, which extended lead times for changes and increased total cost of ownership (Gartner, 2019; Xu et al., 2018; Tao et al., 2019). Security posture evolved as a parallel determinant of results. As machine connectivity expanded, exposure of OT networks increased; without a defined security baseline—segmentation, least-privilege access, authenticated services, and auditable actions—availability risk rose, undermining the very KPI digitalization aimed to improve (DIN, 2016; UNIDO, 2020). Sites that embedded defense-in-depth into their architectures reported fewer production disruptions linked to IT/OT incidents and recovered faster when containment was needed, preserving the stability of improvement routines such as daily tier reviews and parameter governance (UNIDO, 2020; DIN, 2016).

This linkage between security and routine reliability proved important for sustaining gains: improvement cadences faltered when unplanned cyber-related outages forced reactive modes of operation. Resource efficiency effects appeared as robust co-benefits. Studies tracking energy and consumables showed that combining condition-based maintenance with energy monitoring reduced idle energy draw, compressed-air leaks, and tool-wear losses without sacrificing output, demonstrating that the same data infrastructure powering quality and delivery can also advance environmental objectives (Stock & Seliger, 2016; UNIDO, 2020). When scrap and rework declined due to upstream detection, material intensity per good unit fell; when schedule adherence improved, overtime and expedited freight decreased, further improving cost and environmental performance (Stock & Seliger, 2016; PwC, 2016). These effects were strongest where visual management included resource metrics adjacent to operational KPIs, keeping trade-offs explicit at the point of decision (UNIDO, 2020; European Commission, 2020).

Supply-chain interfaces benefited in proportion to data sharing. Better alignment of demand and supply was observed when partners could access shared data on actual consumption and inventory status, which dampened the bullwhip effect and enabled smaller, more frequent replenishments where logistics allowed (Szozda, 2017; Tao et al., 2019). Plants that exposed stable, well-defined signals upstream reported fewer "hot" orders and lower safety stocks for key components, while maintaining service levels through variance-based buffers (Szozda, 2017; Wang et al., 2016). This synchronization depended on interoperability and governance beyond the plant—shared identifiers, event semantics, and access policies—which, when absent, recreated fragmentation at the ecosystem level (Hermann et al., 2016; DIN, 2016).

Taken together, the evidence indicates that digitalization and basic automation provide a reliable platform for sustained improvements in quality, delivery, and cost in discrete-manufacturing contexts—provided that deployments are sequenced toward high-leverage stations, governed by rigorous master-data practices, supported by role-aligned visualization and training, and underwritten by interoperable and secure architectures (McKinsey & Company, 2020; PwC, 2016; DIN, 2016; Xu et al., 2018; Wang et al., 2016). Under these conditions, the conversion of transparency into behavior—earlier detection, faster acknowledgment, clearer reaction plans, and disciplined parameter control—consistently preceded and then produced measurable gains in OEE components, schedule adherence, and traceability across the sources reviewed (Porter & Heppelmann, 2015; Monostori, 2014; Xu et al., 2018; Rauch et al., 2020).

Discussions

The findings indicated that digitalization and basic automation yielded tangible operational gains—shorter lead times, higher first-pass yield, and fewer unplanned stoppages—but the mechanisms by which these gains materialized were fundamentally socio-technical. Improvements became visible when information was not only captured but structured and routed so that the right person could act at the right time. Real-time visibility turned latent losses into manageable routines because signals about state, speed, and quality were presented close to the point of decision. Once bottlenecks were instrumented and defect trends were surfaced to teams in a form they could interpret quickly, interventions occurred earlier and more consistently. In that sense, value was created when data, roles, and routines were aligned—rather than by the mere presence of sensors or dashboards.

A central managerial implication concerns governance over data. Ownership, shared definitions, and calibrated access proved as decisive as capital expenditure. Where responsibilities for metrics and master data were explicit, and where visualization layers matched the cognitive needs of distinct roles, daily tier meetings evolved from report-outs into engines of problem solving. Operators acted on clear reaction plans; line leaders prioritized constraints using exception views; engineers closed the loop on chronic losses through trend and Pareto analyses. Conversely, in contexts with fragmented systems, weak version control, or limited training, additional data increased noise and lengthened decision latency. More signals without a frame for action diverted attention and undermined confidence in the very tools designed to help. This pattern suggests that organizations should sequence technology with capability building, treating digital work instructions, standard problem-solving, and targeted skill development as co-requisites of sensorization and MES integration. The case illustration reinforced these mechanisms by showing that improvements were most durable when quality checks and parameter settings were embedded into standardized, version-controlled workflows that operators explicitly acknowledged. Changeovers stabilized when recipes and limits were pulled from a single source of truth and when first-article confirmations were enforced in station. However, these benefits depended on disciplined master-data management and closed-loop feedback between design and production. Where those preconditions were weak, micro-stoppages and rework reappeared despite connectivity, revealing that the bottleneck had shifted from the absence of data to the absence of reliable, actionable meaning.

Scalability, in turn, hinged on interoperability and cybersecurity. Interfaces that locked data into vendor silos constrained continuous improvement by limiting cross-line learning and complicating

maintenance analytics; each new connection required bespoke extraction and reconciliation, slowing iterations and inflating total cost of ownership. Similarly, connecting machines without a security baseline expanded the attack surface and could jeopardize availability—the very metric digitalization seeks to improve. The practical resolution is architectural intentionality: map assets to a reference model, design a minimal common data layer, segment networks, and automate identity and access control. In the same way standardized fixtures enable quick physical changeovers, standardized information interfaces enable safe, rapid analytical changeovers across products, shifts, and sites. The human factors around visualization and cognitive load also emerged as decisive. Dashboards that attempted to serve all users often served none; information density exceeded attention budgets, and alerts competed for scarce working memory. By contrast, role-specific views that compressed the signal-to-noise ratio—simple state cues and reaction plans for operators, short exception lists for supervisors, trend tools for engineers—reduced time-to-detect and time-to-act.

The lesson is that design should begin with the job to be done, not with the data available. A small number of timely, trustworthy signals, coupled with practiced escalation routines, changed behavior more reliably than expansive yet unfocused visualizations.

Change management shaped whether gains persisted beyond initial rollouts. Teams that rehearsed standardized work, received immediate coaching, and reflected weekly on adherence sustained improvements after the honeymoon period. Sites that treated deployment as a one-off installation—without codifying routines, coaching leaders on how to run tier meetings, or measuring leading indicators such as time-to-acknowledge alarms—saw benefits plateau or erode. Capability building therefore warrants the same rigor as technical commissioning: define the behaviors expected from each role, practice them at cadence, and verify that leading indicators move before claiming victory on lagging metrics. Economic considerations threaded through these themes. Investments delivered the most reliable pa back when sequenced toward high-leverage stations and when benefits were captured in multiple dimensions—scrap, rework, changeover dispersion, and schedule adherence—rather than in a single composite metric.

In parallel, organizations that recognized the option value of interoperable architectures and the risk reduction from cybersecurity controls made more resilient choices. A balanced business case should therefore quantify not only throughput gains but also reductions in variability, time-to-detect, and exposure to availability-threatening incidents. This study had limitations that bound the strength of inference. The synthesis relied on secondary sources and a single illustrative case rather than a multi-site experimental design, which limits generalizability to contexts with similar maturity, product mix, and regulatory environments. Publication bias toward successful implementations may inflate expected gains and understate the effort required to standardize data and routines. Heterogeneity in baseline conditions—from paper-based operations to partially digital plants—complicates direct comparisons of effect size. These constraints underscore the need for site-specific diagnostics and for prospective studies that combine operational telemetry with controlled rollouts and explicit hypotheses about mechanisms of change. Taken together, the results support a pragmatic conclusion: sustained performance gains from digitalization occur when technology, processes, and skills advance together under clear governance. For practitioners, the near-term priority is to define data ownership and standards, align visual management with roles, and invest in targeted upskilling alongside sensorization. Progress should be phased:

instrument high-leverage stations first, stabilize routines with version-controlled work instructions and reaction plans, then extend horizontally once definitions, access rules, and training practices are proven.

In parallel, secure the foundations—interoperability to prevent analytical fragmentation and cybersecurity to protect availability—so that each additional connection strengthens, rather than weakens, system reliability. For researchers and industrial engineers, the agenda ahead is to quantify causal pathways by linking specific digital practices—such as in-station quality gates, eKanban triggers, and standardized tier routines—to changes in individual OEE components, while testing how interoperability patterns and security architectures moderate those effects. Mixed-methods designs that pair telemetry with observational studies of decision making could illuminate how information ergonomics translates into action at the line. Comparative architecture studies across plants with similar products but different integration strategies would clarify why certain deployments scale gracefully while others stall. Finally, human-factors research on alarm design, attention, and learning curves could refine visualization practices and training sequences to reduce cognitive load without suppressing essential signals. Digitalization is best understood not as a discrete project but as an operating-system upgrade for the factory: a deliberate redefinition of how the enterprise senses, decides, and acts.

When organizations codify the language of performance, design visuals for action, practice standardized problem solving, and protect availability through secure, interoperable architectures, sensorization and MES connectivity become reliable levers for durable operational excellence. When those foundations are absent, the same tools can flood teams with data yet starve them of insight. The path to the former is methodical rather than mysterious, grounded in governance and capability as much as in technology—and measured as rigorously in leading indicators as in lagging results.

Table 1. *Key KPIs – direction of change*

KPI	Before (short description)	After (short description)	Trend	Why it improves
Lead time	Long cycle; hard to see small stops	Shorter cycle; earlier detection	↓	Live status and eKanban by real use
First-pass yield (FPY)	More rework; late mismatch detection	Higher FPY with in-station checks	↑	Digital work instructions with tolerances
Unplanned stops	Frequent micro-stops, no categories	Fewer stops through clear categories	↓	Taxonomy + real-time tracking
Changeover stability	Settings vary by shift	More stable first piece after change	↑	One source of truth for parameters/recipes

Traceability	Scattered records	Consolidated lot/unit history	↑	Automatic MES records from the workflow
Schedule adherence	Many hot fixes	Better plan adherence	↑	Replenishment by consumption; shorter cycles

Table 2. Barriers and quick fixes

Typical barrier	Fix
Low digital skills	Targeted training; short daily coaching
Fragmented systems / vendor lock-in	Common data model; open interfaces
Unclear data ownership	Governance: metric owners & access rules
OT cyber risk	Network segmentation; least privilege; audits
Too much information	Role-based views; short exception lists
Limited budget	Phase the rollout; start at bottlenecks

Table 3. Phased roadmap (what to do first)

Phase	What it means	Typical tools	Example metrics
1 – Instrument the bottleneck	Sensors & counters on the critical station	Counters; event taxonomy; live boards	Lead-time to detect; Availability
2 – Digital work instructions + checks	Built-in tolerances; confirm in station	Digital WI; checklists; first-article OK	FA pass rate; FPY; scrap
3 – One database for parameters/recipes	Lower variation after change	Parameter repo; version control	First-article variation; takt stability
4 – eKanban and WIP visibility	Replenish by use; calmer flow	Consumption signals; stock tracking	Stockouts; plan adherence
5 – Scale and standardize	Spread under shared model & security	RAMI 4.0 map; interface standard	Integration time; OEE; OTIF

Table 4. *Roles and what each needs to see*

Role	Useful visuals
Operator	Simple status + next action

Line lead	Exception list and bottleneck status
Maintenance	Pareto of micro-stops; failure trends
Engineering	Parameter trends; recipe history
Quality	Pareto of defects; MSA status
Planning/Logistics	WIP and consumption signals; eKanban

Table 5. *OEE mapping – where the gains come from*

OEE Part	Mechanisms from the paper
Availability	Classify micro-stops; reaction plans; CM/PM
Performance	Speed profiles; standardized setups
Quality	In-station checks; tolerances; single recipe base

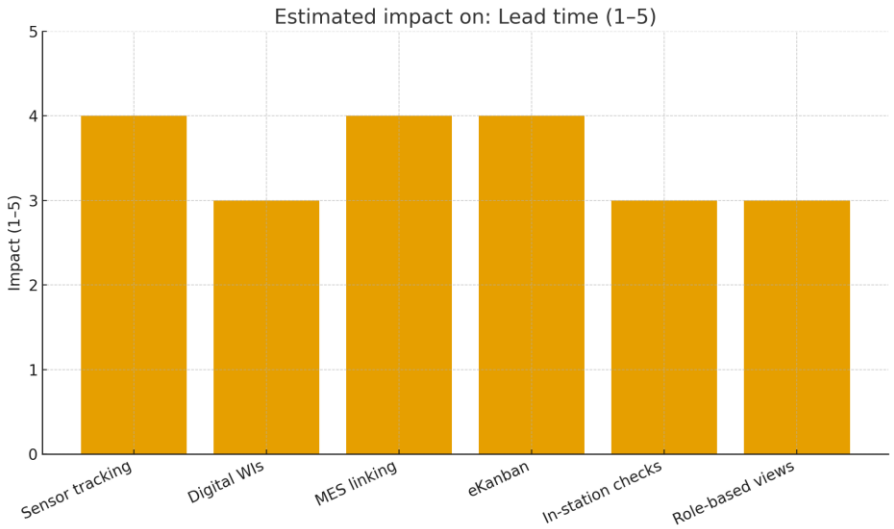

Figure 1: Estimated impact on Lead time (1–5).

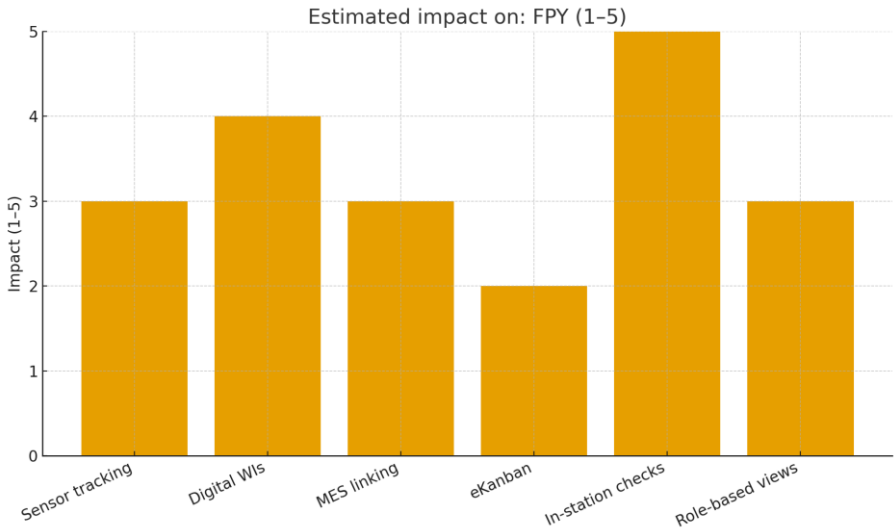

Figure 2: Estimated impact on FPY (1–5).

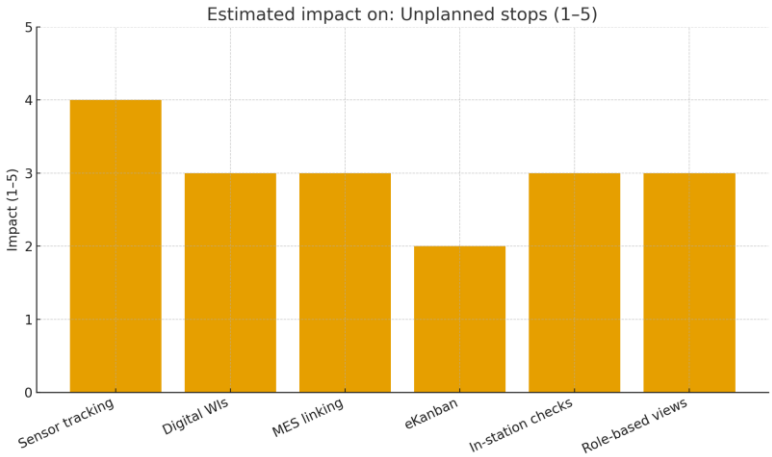

Figure 3: Estimated impact on Unplanned stops (1–5).

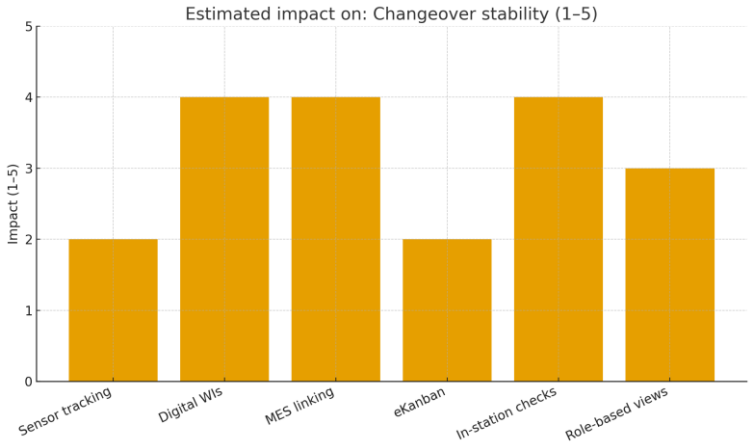

Figure 4: Estimated impact on Changeover stability (1–5).

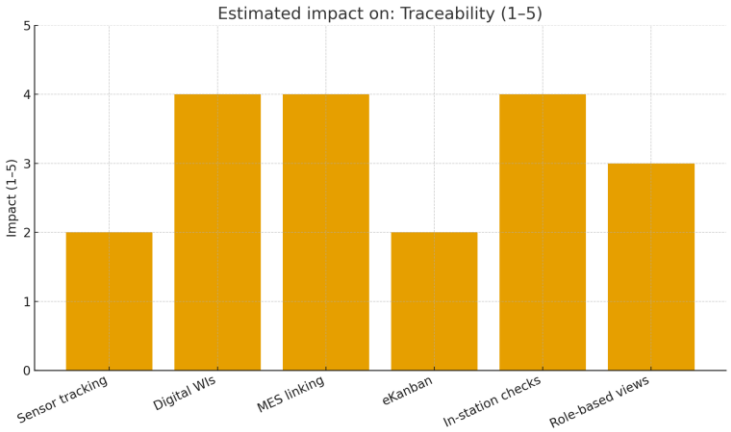

Figure 5: Estimated impact on Traceability (1–5).

Conclusions

This study demonstrates that the introduction of sensor-based monitoring, digital work instructions, and lightweight MES connectivity reliably translates into operational gains—shorter lead times, higher first-pass yield, fewer unplanned stoppages, steadier changeovers, and stronger traceability. Crucially, these gains did not arise from technology in isolation.

They became durable when visibility was coupled with clear ownership of data and processes, role-appropriate visualizations that convert telemetry into timely action, and standardized problem-solving routines practiced at a regular cadence. In practical terms, digitalization creates value when information, people, and standard work are aligned; sensors and dashboards are only enabling components of that alignment, not ends in themselves. A central implication is that sequencing matters as much as scope. Digitalization should advance in lockstep with organizational readiness, beginning at high-leverage stations where modest increases in transparency yield immediate improvements in throughput and

quality. Early wins reduce skepticism, release capacity for further change, and provide concrete data for refining definitions and escalation rules. As capabilities expand, organizations require a shared vocabulary so that metrics signify the same thing across shifts, product families, and departments. Escalation thresholds must be unambiguous, reaction plans must be visible at the point of use, and changes to definitions should occur under version control with clear communication. Capability building must progress alongside deployment; frontline teams need targeted upskilling—from digital literacy and basic data interpretation to structured problem solving, root-cause analysis, and disciplined follow-up—so that new signals lead to faster, better decisions rather than to cognitive overload.

The analysis also underscores that scalability rests on interoperability and cybersecurity as boundary conditions. Fragmented, vendor-locked interfaces create analytical dead zones, inhibit cross-line learning, and slow improvement cycles by forcing repeated data reconciliation. Even where islands of excellence emerge, their lessons travel poorly if the underlying data models cannot interoperate. Likewise, connecting machines without a security baseline enlarges the attack surface of OT networks and can jeopardize availability—the very KPI digitalization seeks to improve. Architectures should therefore be designed to integrate and protect by default, mapping assets to a reference model, segmenting networks, enforcing least-privilege access, and auditing actions where physical processes meet information systems. When integration and protection are treated as first-order design constraints, each new connection strengthens the system rather than adding brittle complexity. Although the synthesis relies on secondary sources and a single illustrative case, the underlying mechanisms were consistent. In-station instrumentation shifted detection upstream so that non-conformities were found nearer their point of origin; single sources of truth for parameters and work instructions stabilized changeovers and reduced inter-shift variability; and role-specific visual management reduced decision latency by matching information density to attention budgets. These mechanisms are mutually reinforcing.

Better instrumentation increases the reliability of visuals; better visuals make standardized problem solving more effective; better routines, in turn, generate the feedback needed to refine instrumentation and definitions. The enduring lesson is that performance improves when the technical system and the social system co-evolve.

From a managerial standpoint, the evidence supports a pragmatic roadmap that privileges method over magnitude. Begin by instrumenting one constraint station and making its losses legible in real time to the people who can act within minutes. Embed first-article checks and parameter acknowledgments into digital work so that changeovers stabilize and early variability is contained. Use short, cadence-based tier meetings to convert visibility into action, and treat each problem as an opportunity to refine definitions, thresholds, and reaction plans. As signals stabilize, extend instrumentation laterally to adjacent stations, codify shared data models, and simplify interfaces. Resist the temptation to “connect everything to everything” before routines mature; scale is a property of clarity, not of size. Throughout, preserve a single forum that governs changes to metrics, dashboards, alarms, and master data, because trust in information erodes quickly when definitions drift. Economic evaluation should reflect the multi-dimensional character of benefits.

Traditional business cases anchored only in labor productivity or headline OEE understate payback because they miss reductions in variability, scrap, rework loops, energy waste during idle, and the option value of faster integration for new products or machines. Conversely, they also risk overstating benefits if

they ignore the cost of integration debt and the risk premium associated with weak security postures. A balanced view treats digitalization as a portfolio of sequenced bets, each tied to specific leading indicators—time-to-detect, time-to-acknowledge, first-article pass rate, adherence to reaction plans—and only secondarily to lagging outcomes. Where leading indicators do not move, lagging improvements rarely sustain; where they do move, improvements in throughput and quality tend to follow with a predictable delay.

Workforce implications require equal emphasis. Digitalization changes what good performance looks like at each role. Operators become stewards of standardized work augmented by sensors and prompts; line leaders become managers of exceptions and coaches of problem solving; engineers spend less time firefighting and more time curating parameter libraries, improving data quality, and designing experiments; quality functions shift effort upstream toward in-station prevention rather than downstream inspection; planners learn to treat consumption signals as the primary driver of replenishment. These shifts demand intentional training paths and role redesign.

Without them, new tools can increase cognitive load and diffuse accountability, producing more alerts but fewer effective actions. With them, the same tools become amplifiers of human judgment, compressing the distance between signal and response. Policy and ecosystem considerations also emerge from the analysis. Suppliers, system integrators, and equipment vendors shape the feasibility of interoperability through the openness of their interfaces and the quality of their documentation. Manufacturers benefit when they insist on minimal common data models, explicit event taxonomies, and portable parameter sets as conditions of purchase. Public bodies and industry associations can accelerate diffusion by standardizing vocabularies, publishing reference architectures, and supporting cross-firm learning networks that share patterns and pitfalls. Small and medium-sized firms—which often lack dedicated OT/IT integration staff—stand to gain from modular solutions that embed good defaults for security, naming conventions, and basic governance, reducing the fixed costs of entry.

Sustainability co-benefits provide a further rationale. The same telemetry used to reduce scrap and unplanned downtime can identify idle energy draws, compressed-air leaks, and suboptimal tool-wear profiles. When maintenance is routed by condition rather than by calendar, energy and material intensity decline alongside costs. When rework loops shrink, carbon per good unit falls. Aligning operational dashboards with resource metrics helps ensure that improvements in quality and delivery reinforce environmental performance rather than compete with it. In this way, digitalization supports not only the traditional triangle of quality, delivery, and cost, but also resource stewardship.

Limitations should temper the strength of inference but not the confidence to act. Secondary sources inevitably reflect reporting biases, and a single illustrative case narrows external validity. Sectoral, cultural, and regulatory differences may moderate effects, as may variations in starting maturity and product mix. Yet these constraints do not negate the observed mechanisms; they simply require that adoption be preceded by site-specific diagnostics and followed by measurement designs that disentangle signal from noise. Prospective field studies that pair phased rollouts with pre-declared hypotheses about mechanisms—how a quality gate should change time-to-detect and rework within a defined window, how an eKanban loop should alter schedule adherence under specified variability—would enrich the evidence base and accelerate learning across sites.

Taken together, the findings converge on a simple but powerful conclusion. Technology sets the ceiling, but governance, routines, and skills set the floor—and most observed variance lives in the space between them. Plants that treat digitalization as an organizational operating-system upgrade—defining how the enterprise will sense, decide, and act; building the minimal architecture that enables those behaviors; and developing the people who will run it shift after shift—realize sustained improvements in quality, delivery, and cost. Plants that pursue technology without organizational foundations often experience partial, transient, or local gains that fade as novelty dissipates. The difference is not access to tools but the discipline with which information is defined, displayed, and used. In closing, the study supports a pragmatic posture for leaders. Start with leverage and clarity, not with size. Make losses visible where action is immediate. Encode standards in digital work and verify them at changeovers. Govern definitions in one place and change them deliberately. Design visuals for action, not for admiration. Secure availability as you connect. Teach people how to act on data, and measure whether they do. When these habits compound, sensorization, digital work instructions, and MES connectivity stop being projects and become the way the factory thinks and behaves. Under those conditions, digital transformation is neither mystery nor fad; it is method—applied patiently, sequenced intelligently, and sustained by the people whose daily decisions make performance real.

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Conflict of interests

The authors declare no conflict of interest.

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THE ESSENCE OF INVESTMENT DECISIONS IN REAL ESTATE

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Abstract: The purpose of this article is to examine the essence of investment decisions in real estate by integrating theoretical foundations with behavioural factors. The relevance of the research is driven by the growing complexity of investment decision-making under conditions of information asymmetry, heterogeneous market participants, and the institutional specifics of emerging economies. The paper analyses classical financial indicators (NPV, IRR, PI, ROR) and highlights their limitations when behavioural biases are not considered. Using the VIKOR method with probabilistic linguistic term sets, the study demonstrates that changes in behavioural preferences may lead to a 2–4-fold shift in the evaluation of investment alternatives. Key determinants of investment decisions are systematized, including rational and behavioural components, macroeconomic and institutional conditions, market segmentation, technological innovations, and investor typology. Special attention is given to the characteristics of the Balkan region, particularly Serbia, where data insufficiency and post-socialist institutional legacy create additional challenges for investment analysis.

The findings expand the theoretical understanding of behavioural influences in real estate investment and illustrate the importance of investor heterogeneity for project evaluation. From a practical perspective, the results indicate that investors, banks, and policymakers can improve project selection and credit risk assessment by integrating behavioural analysis with mul-ti-criteria decision-making tools such as VIKOR. The study is limited using hypothetical project data, methodological constraints of the VIKOR approach, and market-specific conditions. Nevertheless, the results provide a foundation for enhancing data trans-parency, strengthening institutional frameworks, and incorporating behavioural preferences into investment decision-making in emerging real estate markets.

Keywords: investment decisions, real estate, multi-criteria analysis, VIKOR, emerging markets, investor heterogeneity.

Introduction

Investment decisions in the real estate sector require balancing financial, behavioural, and institutional factors, especially in emerging markets where information asymmetry and structural limitations increase decision-making uncertainty. Unlike mature markets, developing economies such as Serbia face challenges related to data availability, regulatory stability, and heterogeneous investor behaviour, which together complicate the evaluation and selection of investment alternatives. This highlights the need for a framework that systematically integrates behavioral factors into investment decision-making.

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Research problem: How do behavioural factors influence investment decisions in real estate under the conditions of emerging markets, and how can their impact be systematically integrated into decision-making models?

Research objective: To develop a comprehensive framework for real estate investment decision-making that incorporates behavioural characteristics of investors and a multi-criteria evaluation approach, and to assess how these elements shape project selection outcomes in emerging markets.

Research Questions:

1. What are the key determinants of real estate investment decision-making?
2. How do behavioural preferences and biases affect the evaluation of investment alternatives?
3. How can multi-criteria methods such as VIKOR enhance decision-making accuracy in emerging markets?

Potential contribution: This study contributes to the literature by integrating behavioural perspectives with classical financial evaluation and multi-criteria decision-making tools. It offers practical guidance for investors, banks, and policymakers seeking to improve project selection, risk assessment, and institutional support mechanisms in emerging real estate markets.

Materials and Methods

Theoretical Foundations of Investment Decisions in Real Estate (Literature review)

Investment decisions in real estate are shaped by economic, behavioural, technological, and institutional determinants. Prior research identifies several distinguishing characteristics of real estate markets. Singh et al. (2021) emphasize the high level of information asymmetry, low transparency, and strong psychological influences on investor behaviour compared to financial markets. Grabovoy and Fedorov (2019) argue that evaluating specialized real estate assets requires alignment between financial metrics and strategic investment goals.

Classical financial evaluation approaches rely on rational economic calculations using indicators such as Net Present Value (NPV), Internal Rate of Return (IRR), Profitability Index (PI), and Rate of Return (ROR). However, contemporary studies indicate that classical models often neglect behavioural biases, reducing their applicability in real-world decision-making (Özogul & Taşan-Kok, 2020; Singh et al., 2021).

Real estate as an investment asset possesses several unique characteristics. Low liquidity requires long-term planning, while strong macroeconomic sensitivity links asset performance to indicators such as GDP growth, inflation, and interest rates. In a systematic review, Kwakye and Haw (2020) found robust relationships between macroeconomic conditions and real estate market dynamics. Market segmentation further complicates evaluation: Joyce (2018) showed that liquidity and diversification are key determinants of REIT performance.

Investor heterogeneity also plays a central role. Özogul and Taşan-Kok (2020) distinguish institutional investors, speculative individual investors, rental-oriented investors, and owner-occupiers—each with distinct risk tolerance and decision-making criteria.

Emerging markets face additional constraints. Muminović et al. (2022) highlight data insufficiency in Serbia and the need for context-specific decision-making frameworks. Machala and Koelemaij (2021) argue that post-socialist institutional legacies shape investment behaviour in cities such as Belgrade and Bratislava.

Contemporary methodological approaches aim to overcome the limitations of classical models. Gareev and Akhmetgaliev (2020) propose retrospective correlation-regression modelling to incorporate historical patterns into forecasting. Zakrevskaya and Detkova (2018) argue for the relevance of real-options analysis to improve investment timing decisions in volatile market environments.

A systematized overview of the key components of real estate investment decision-making is presented in Table 1.

Table 1 – Key components of investment decisions in the real estate sector

Component	Characteristic	Real Estate Specifics	Source
Rational Factors	Financial indicators (NPV, IRR, PI, ROR)	Adaptation to low liquidity and long-term nature	[3, 12]
Behavioral factors	Cognitive biases, emotions, cultural characteristics	High influence due to information asymmetry	[27, 19]
Macroeconomic factors	GDP, inflation, interest rates, exchange rates	High sensitivity of the real estate market	[13]
Institutional factors	Legal regulation, tax policy	Critical for developing markets	[15, 16]
Technological factors	AVM, AI, blockchain, multicriteria methods	Increased transparency and accuracy of valuation	[17, 24, 25]
Market segmentation	Residential, commercial real estate, REIT	Different performance evaluation models	[12, 23]
Types of investors	Institutional, individual, speculative	Different criteria and time horizons	[19]

Source: compiled by the author based on [30]

Thus, the theoretical foundations of investment decisions in real estate are based on integrating classical financial indicators with consideration of behavioural biases, industry-specific characteristics, investor heterogeneity, and the particularities of the institutional environment in developing markets.

The preceding review of theoretical foundations highlights the multidimensional nature of real estate investment decisions, shaped by different and sometimes conflicting factors. To examine these influences empirically, it is necessary to apply a structured analytical framework capable of capturing the effect of investor preferences on project evaluation outcomes. The following section introduces the methodological approach employed in this study.

VIKOR Methodology

This study applies the VIKOR multi-criteria decision-making framework to analyse how investor-specific behavioural preferences influence the evaluation of real estate investment alternatives. The

analysis draws on previously published probabilistic linguistic VIKOR results (Xu et al., 2024), which provide precomputed rankings of investment projects under varying decision preference settings.

Parameters and Variables

The key behavioural parameter adopted from Xu et al. (2024) is θ, representing the decision maker's relative weighting between minimizing individual dissatisfaction (regret) and maximizing collective utility. In the referenced model, θ takes values such as 0 (regret-averse/conservative), 0.5 (balanced), and 0.9 (utility-maximizing/aggressive).

Investment alternatives are evaluated across multiple attributes, including financial indicators (e.g., expected return, payback period, risk exposure) and qualitative dimensions (e.g., locational attractiveness, absorptive market capacity, construction quality). The variables are structured such that shifting θ alters the prioritization among criteria, resulting in changes in project rankings across preference types.

Data Source

The dataset applied in this interpretation originates from a PLOS ONE study that used probabilistic linguistic VIKOR to assess foreign direct investment projects under uncertainty and heterogeneous evaluator preferences (Xu et al., 2024). In that study, each alternative was evaluated under several θ scenarios, which enables the examination of how preference sensitivity influences outcomes. Although their application concerns cross-border investment risk, the underlying logic of preference-driven ranking adjustments is transferable to real estate project evaluation in emerging markets.

Application in This Study

Rather than recalculating the VIKOR algorithm, this study focuses on interpreting how different θ values affect project prioritization. The analysis illustrates that a single investment alternative may shift from most preferred to less preferred depending on the decision maker's behavioral orientation. This reinforces the argument that investment outcomes are not solely driven by objective financial performance, but also by non-financial decision heuristics, manager characteristics, and strategic orientation.

Accordingly, integrating preference sensitivity into evaluation frameworks supports a richer understanding of investor heterogeneity. These insights extend implications for project developers, financial institutions, and policymakers by demonstrating that "optimal" investment decisions are contingent upon behavioural weighting structures, rather than universally stable.

Building on this methodological foundation, the following section illustrates how variations in behavioural preferences translate into measurable shifts in project rankings. The results present the sensitivity of investment conclusions to changes in θ, thereby empirically demonstrating the influence of investor heterogeneity.

Results

The influence of investor behavioural preferences on the final decision can be illustrated using the VIKOR method with probabilistic linguistic term sets [30]. As shown in Figure 1, when the parameter **θ** changes from 0 (conservative approach, focusing on minimizing individual regret) to 0.9 (aggressive approach, focusing on maximizing group utility), the Probabilistic Linguistic Compromise (PLC) values for alternatives change significantly [30]. At θ = 0, alternative PLC1 has a value of 0.142 and PLC4 — 0.453, whereas at θ = 0.9, these values are 0.084 and 0.937, respectively. This example demonstrates that investors with different risk preferences and strategic priorities can reach diametrically opposite conclusions when evaluating the same investment projects.

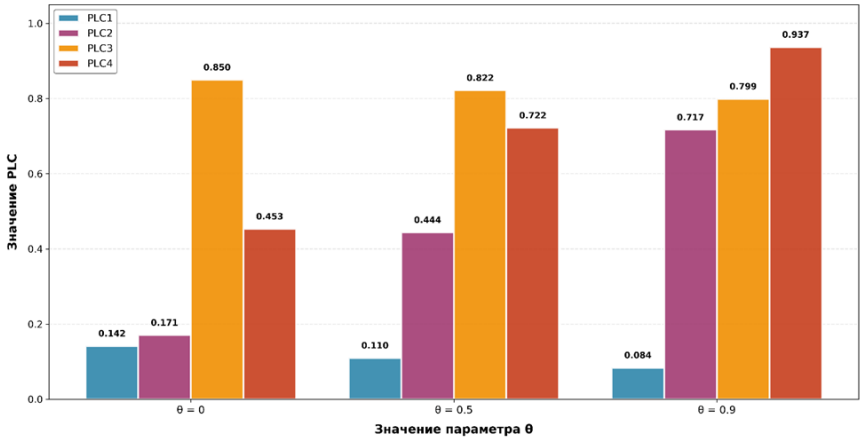

Figure 1 – Multi-attribute risk analysis of investments (VIKOR). PLC values for alternatives at different θ

Source: compiled by the author based on [30]

The quantitative impact of behavioural preferences on project evaluation is presented in Table 2, where the results of applying the VIKOR method for different θ values are systematized.

Table 2 – Impact of parameter θ on alternative ranking (VIKOR method)

Parameter θ	PLC1	PLC2	PLC3	PLC4	Optimal alternative
0,0	0,142	0,171	0,850	0,453	PLC1
0,5	0,110	0,444	0,822	0,722	PLC1
0,9	0,084	0,717	0,799	0,937	PLC1

Source: compiled by the author based on [30]

Discussions

Despite it changes in the absolute values of PLC, the alternative PLC1 remains optimal across all values of θ, indicating its robustness to shifts in the investor's strategic priorities. However, significant transformations are observed for PLC2 and PLC4: when transitioning from a conservative to an

aggressive strategy, the value of PLC2 increases by a factor of 4.2 (from 0.171 to 0.717), while PLC4 increases by a factor of 2.1 (from 0.453 to 0.937). These variations demonstrate that investor behavioural preferences substantially affect the relative attractiveness of certain alternatives, even when the overall ranking appears stable for the top option.

Interpretation and comparison with literature: The observed sensitivity aligns with prior studies highlighting the influence of cognitive biases and strategic orientation on investment evaluation (Singh et al., 2023; Özogul & Taşan-Kok, 2020). Like findings in emerging market contexts, projects that may appear less attractive under a conservative approach can gain importance when decision-makers adopt a more utility-focused perspective, confirming the need to incorporate behavioural heterogeneity in assessment frameworks.

Theoretical and practical significance: The results provide empirical support for the integration of behavioural parameters into multi-criteria decision-making models, extending the theoretical understanding of how investor heterogeneity shapes real estate investment outcomes. Practically, this emphasizes the importance for investors, banks, and project developers to account for varying behavioural profiles, as strategic priorities and risk attitudes can substantially alter project evaluation, even when financial indicators remain constant.

Conclusions

The conducted research allows us to formulate several key conclusions regarding the nature of investment decisions in the real estate sector.

1. Classical financial indicators (NPV, IRR, PI, ROR) remain fundamental tools of evaluation; however, their application requires adaptation to the specifics of the real estate market, including low liquidity, high sensitivity to macroeconomic factors, and pronounced market segmentation.
2. Behavioural factors exert a critical influence on final investor decisions. The application of the VIKOR method has demonstrated that changes in behavioural preferences lead to a 2–4-fold transformation in the evaluation of alternatives, highlighting the necessity of integrating behavioural aspects into investment performance assessment models.
3. Developing markets, including the Balkan region, are characterized by specific challenges: insufficient data availability, the influence of post-socialist legacy on the institutional environment, and high information asymmetry.

Building upon these findings, the study offers the following implications and recommendations:

Theoretical implications:

- Extends literature on real estate investment by quantifying behavioural effects using VIKOR.
- Demonstrates the importance of investor heterogeneity in project evaluation.

Practical implications:

- Investors and banks can use VIKOR and behavioural analysis to improve project selection.
- Policymakers should enhance data transparency and institutional frameworks to support efficient investment decisions.

Limitations:

- Limited to hypothetical project data and Serbian market specifics.
- Methodological constraints include assumptions in VIKOR parameters and linguistic term assignments.
- Results may not generalize to all real estate segments or countries.

Recommendations:

- Investors should incorporate behavioural preferences in multi-criteria evaluations.
- Banks and financial institutions can use adaptive frameworks for credit risk assessment.
- Policymakers should improve regulatory and data infrastructure to facilitate informed investment decisions.

Future research directions include the development of integrated models combining quantitative and qualitative assessment methods while considering behavioural, technological, and institutional factors.

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Conflict of interests

The author declares no conflict of interest.

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A NEW OPPORTUNITY FOR 50+: AN EMPIRICAL STUDY ON EMPLOYMENT OF PEOPLE OVER 50 IN THE REPUBLIC OF SERBIA

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Abstract: This paper explores the challenges and opportunities related to the employment of people over 50 years of age in the Republic of Serbia, relying on contemporary demographic, social, and market indicators. In light of current trends of population aging and shrinking labor force, the study aims to identify barriers, motivations, and potentials for the workforce activation of this age group. Primary data were collected through a structured questionnaire on a sample of 200 respondents from various regions of Serbia and analyzed using descriptive statistics, SWOT analysis, and comparisons with best practices in the region (Croatia, Slovenia, Montenegro, North Macedonia). The results indicate a significant willingness among older individuals for retraining and participation in flexible work arrangements, alongside dominant barriers such as age-based discrimination and lack of digital skills. The paper also examines existing government active employment policies, with a focus on their application, visibility, and effectiveness. It concludes that integrating people aged 50+ into the labor market requires a strategic approach combining training, subsidies, combating ageism, and enhancing digital literacy. The study provides a foundation for formulating recommendations for policymakers and local actors in the field of employment.

Keywords: employment, over 50, Serbia, labor market, discrimination, digital skills, public policies

Introduction

Demographic changes in the Republic of Serbia, as in most European countries, are marked by a pronounced trend of population aging. According to the Statistical Office of the Republic of Serbia (2025), the share of people over the age of 50 has been steadily increasing over the past decade, while the working-age population is declining. This demographic shift creates significant socio-economic challenges, particularly in terms of labor market dynamics, pension sustainability, and healthcare expenditures (Eurostat, 2024; WHO, 2002).

The aging of the workforce presents both challenges and opportunities. On one hand, older workers often possess rich work experience, strong work ethic, and institutional knowledge that can contribute to organizational stability and productivity (Becker, 1964; Tanaka, 2021). On the other hand, individuals over 50 frequently face barriers when attempting to retain or re-enter employment.

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These include widespread age-related stereotypes, reduced access to professional development opportunities, lower digital literacy, and a scarcity of flexible work arrangements tailored to older employees (ILO, 2023; Bosnić, 2025; Andersson, 2020).

In addition to societal perceptions and labor market dynamics, structural and institutional barriers persist. These include inadequate retraining and lifelong learning systems, rigid labor regulations, and limited policy incentives to encourage employers to hire older individuals (Müller & Schmidt, 2019). Age discrimination is increasingly recognized as a critical issue, affecting recruitment, promotion, and retention of older workers (Dupont & Rossi, 2018). Such exclusion not only undermines individual well-being but also leads to the underutilization of a growing segment of the labor force.

This paper aims to empirically examine the attitudes, experiences, and employment potential of individuals aged 50 and above in Serbia. Using a quantitative survey-based approach supplemented by secondary data analysis, the study explores key determinants of labor market inclusion for older persons. Particular focus is placed on mapping perceived obstacles, identifying motivating factors for continued employment, and assessing the effectiveness of current state measures and retraining programs.

The findings are intended to contribute to evidence-based policymaking by offering actionable insights for decision-makers, employers, and institutions responsible for social and labor policy. In the context of global efforts to promote active aging and social inclusion, this research provides a foundation for developing targeted strategies that can enhance the employability, economic security, and societal contribution of older individuals in Serbia and beyond.

Literature Review

Theoretical Foundation

The theoretical underpinning of this study lies at the intersection of three core frameworks:

Active Aging Concept

As articulated by the World Health Organization (WHO, 2002), active aging aims to optimize opportunities for health, participation, and security in order to enhance quality of life as people age. The framework underscores the necessity of policies that support continued employment, voluntary engagement, and lifelong learning to combat social exclusion and economic dependence.

Human Capital Theory

Becker's (1964) theory posits that individual productivity depends on the accumulated stock of knowledge, skills, and health—human capital. For workers aged 50+, employability becomes contingent upon continued access to training and adaptability to technological advancements (Becker, 1964; OECD, 2021).

Inclusive Labor Market Policies

Contemporary employment policy advocates (Müller & Schmidt, 2019) promote equal access for all demographic groups through legal frameworks, incentives, and the dismantling of discriminatory barriers. Inclusion of older workers necessitates proactive approaches such as subsidies, mentoring, and targeted upskilling initiatives.

The theoretical framework of this paper is based on contemporary concepts of active aging, human capital theory, and principles of inclusive employment policy. Active aging, as defined by the World Health Organization (WHO, 2002), involves creating conditions that allow older people to remain active participants in society through work, volunteering, and education. The goal is to ensure quality of life in later years, including economic contribution to the community.

Human capital theory (Becker, 1964) emphasizes the importance of continuous investment in knowledge and skills throughout one's working life. For older workers, it is necessary to ensure access to lifelong learning and digital literacy as key employability factors.

Modern inclusive employment policies increasingly focus on eliminating discriminatory practices and encouraging participation of all age groups, especially through subsidizing employment, tax incentives, and mentoring programs within organizations.

International Examples of Good Practice

Experiences from other countries can serve as a guide for formulating sustainable employment policies for people aged 50+. Some of the most relevant examples include:

- Germany implemented the "Perspective 50 plus" program between 2005 and 2015, covering over 400,000 older unemployed individuals. The program included financial support for employers, career counseling, and individualized training plans.
- Sweden is known for high participation of older people in the labor market. Through legal frameworks and flexible work models, such as reduced working hours while retaining benefits, older workers remain active longer.
- Japan, with one of the oldest populations in the world, systematically promotes the so-called "senior economy" — particularly through reintegration of workers over 60. Employers are required to provide work opportunities up to age 65, with additional incentives for engagement beyond that age.
- France and Italy run subsidized retraining programs and tax incentives for companies employing older workers, supported institutionally through national employment agencies.

Lessons Learned

The diverse approaches of these countries underscore several common elements critical to successful integration of older persons into the labor market:

1. **Legislative protection against age discrimination** and the right to work beyond traditional retirement age;
2. **Financial and institutional support mechanisms** for both employers and employees;
3. **Promotion of flexible work models**, including remote work and reduced working hours;
4. **Culture of lifelong learning** and adaptability to technological changes;
5. **Regional and sector-specific customization** of interventions.

The translatability of these models to the Serbian context depends on the political will, administrative capacity, and cultural readiness to adopt long-term strategies for active aging and inclusive labor market policies.

Regional Best Practices in Employing People Over 50

Western Balkan countries face similar demographic challenges as Serbia — increasing shares of older populations, lower labor activity among older persons, and a pronounced need for their integration into the labor market. While institutional responses vary, some countries have launched effective and targeted measures:

- **The Croatian** Employment Service (HZZ) runs the "50+" program aimed at increasing employment of older people through employer subsidies, training, and advisory services. According to the HZZ report (2024), over 2,000 older persons found jobs through this program, with 42% retaining employment for more than 12 months.

Program by the Croatian Employment Service (HZZ)

- **Subsidies for employers** hiring workers over 50, especially those long-term unemployed;
- **Access to vocational retraining**, including ICT competencies and sector-specific workshops;
- **Individualized career counseling**, helping candidates navigate the labor market and prepare for interviews;
- **Monitoring and mentorship**, aimed at improving retention.

  This program illustrates that **targeted financial and advisory support**, paired with employer education and public campaigns, can significantly reduce barriers for older individuals re-entering the workforce.
- **Slovenia** implements a comprehensive "Active Aging until 2030" strategy, including tax relief for employing people over 55 and work training programs within public administration. By the end of 2023, participation of persons over 55 in the labor market increased by 12% (Ministry of Labour, 2023).
- **Tax incentives** for companies employing individuals over 55;
- **State-funded training and education programs**, including digital upskilling, languages, and vocational requalification;
- **Intersectoral collaboration** between the Ministry of Labour, social partners, and municipalities;
- **Public employment initiatives** that encourage inclusion of older persons in public sector roles, particularly in mentoring and support functions.
- By the end of 2023, **participation of persons aged 55–64 in the labor market increased by 12%**, with a notable rise in part-time and flexible job arrangements (Ministry of Labour, Family, Social Affairs and Equal Opportunities, 2023). Moreover, Slovenia's implementation of **age-friendly certification for employers** has encouraged the private sector to develop internal HR practices tailored to older workers.
- Slovenia's approach emphasizes not only the **economic dimension** of active aging, but also its **social value**, aiming to enhance quality of life and reduce dependence on public welfare systems.

These models demonstrate that successful employment of people aged 50+ is achievable through a combination of political will, fiscal measures, and social campaigns that change public and employer attitudes.

- North Macedonia and Montenegro**: Emerging Initiatives**
- **Public-private partnerships** focused on lifelong learning and employability of vulnerable groups;
- EU-funded projects, such as those under the *Instrument for Pre-accession Assistance (IPA)*, targeting older jobseekers in rural and deindustrialized regions;
- Local employment councils experimenting with **community-based employment models**, integrating retraining, microfinance, and entrepreneurship support.

For example, in North Macedonia, the *"Skills for the Future"* project (2023–2025) has introduced reskilling boot camps for unemployed individuals aged 45+, including programs in hospitality, digital marketing, and personal services. Preliminary evaluations indicate that **over 35% of participants over age 50 found employment within six months** of completion (UNDP North Macedonia, 2024).

Human Resource Management Strategy for an Age-Diverse Workforce

In modern organizations, the workforce is becoming increasingly diverse—not only in terms of gender, culture, or education, but also in age composition. Effective human resource management (HRM) in such an environment requires a strategic approach that recognizes the distinct needs, motivations, and work habits of employees from different generations. Multigenerational teams represent a potential competitive advantage, but only if they are successfully integrated through inclusive policies and adaptive managerial practices.

Contemporary HR management must develop an **intergenerational integration strategy** based on three essential pillars:

1. **Understanding generational characteristics and values** – For example, younger employees (Generations Y and Z) tend to value flexibility, digitalization, and rapid career growth, while older employees (Generation X and Baby Boomers) prioritize stability, security, and interpersonal relationships (Parry & Urwin, 2017).
2. **Adapting leadership and motivation styles** – Leaders should employ a combination of transformational and situational leadership, recognizing the unique needs of each age group (Northouse, 2022).
3. **Fostering knowledge exchange** – Mentorship and intergenerational learning programs enable knowledge transfer between experienced and younger employees, promoting organizational cohesion and innovation (Kulik et al., 2016).

Creating a workplace that values the contributions of all age groups enhances employee satisfaction, reduces turnover, and improves overall performance. A key challenge lies in reducing age-related biases and stereotypes, which requires ongoing manager training on **age diversity management** principles and the promotion of a culture of equal opportunity (OECD, 2020).

The proposed human resource management strategy for an age-diverse workforce is based on an integrative approach that combines **intergenerational collaboration, flexible organizational models, and inclusive policies**. The primary goal of this strategy is to create a work environment in which employees of all age groups can maximize their contribution to organizational goals while enhancing their personal satisfaction and professional growth.

Based on international evidence, the following key components of an effective HR strategy have been identified:

1. **Intergenerational mentoring and reciprocal learning** – The European Agency for Safety and Health at Work (EU-OSHA, 2020) emphasizes that organizations implementing mutual learning programs demonstrate higher innovation and long-term stability.
2. **Flexible work models** – According to the International Labour Organization (ILO, 2021), flexible arrangements such as part-time work, remote work, and adjusted schedules enhance productivity and reduce turnover among older workers.
3. **Managerial training in age-diversity management** – OECD research (2020) confirms that structured managerial training in *age diversity management* improves teamwork and reduces generational tensions.
4. **Health and psychological support programs** – The World Health Organization (WHO, 2022) stresses the importance of well-being programs for preventing stress and maintaining the mental health of employees over 50.

This strategy has the potential to foster **sustainable workforce inclusion**, greater intergenerational solidarity, and a reduction in the economic costs associated with turnover and early retirement.

Research Methodology

For the purpose of this study, a mixed-method approach was applied, combining the analysis of secondary data from the Statistical Office of the Republic of Serbia with primary research conducted through a structured questionnaire. The survey was carried out in July 2025 on a sample of 200 respondents aged 50 and above. Key variables considered included gender, educational attainment, previous work experience, duration of unemployment, and willingness to engage in further training.

Research Results and Analysis

The survey was administered in July 2025, encompassing 200 individuals aged over 50 from diverse regions across Serbia. The questionnaire collected data on demographics, education, health status, labor market experience, readiness for retraining, and employment history.

Questionnaire Description

To obtain primary data necessary for the empirical investigation of employability among persons aged 50+, a structured questionnaire was developed as the main data collection instrument. The questionnaire was designed to capture both quantitative and descriptive data essential for analyzing barriers, potentials, and needs of this demographic within the labor market context.

The questionnaire aimed to collect information on:

- Current employment status,
- Willingness to retrain or pursue further education,
- Personal perceptions of age-based discrimination,
- Awareness of and access to government employment policies,
- Interest in flexible forms of employment (e.g., remote work, part-time work),

- Digital skills and engagement with modern work environments.

It consisted of five thematic sections:

1. Demographic Data
2. Work Experience and Skills
3. Retraining and Training
4. Labor Market Experience
5. Attitudes Toward Work

The questionnaire was anonymous and voluntary, distributed via local social welfare centers, pensioners' associations, and online platforms accessible to digitally literate respondents. Of 250 questionnaires distributed, 200 were validly completed and returned.

Reliability was tested through a preliminary pilot study involving 20 respondents, yielding a Cronbach's alpha coefficient of 0.81 for the overall scale, indicating satisfactory internal consistency.

Results

Research Results

A total of 200 respondents aged over 50 participated in the study, with the objective of identifying their sociodemographic profiles, labor market experiences, levels of digital and professional skills, attitudes toward retraining and flexible work arrangements, as well as their perceptions of age-based discrimination. The findings were analyzed across several interrelated domains.

1. Basic Demographic Data

The sample structure shows a slight majority of women (55%), while men account for 45% of respondents. This distribution reflects broader demographic trends in Serbia, where women make up a larger share of the older workforce — primarily due to higher life expectancy and lower labor market participation among older men.

In terms of age distribution, the majority of participants (70%) fall within the 50–60 age group, while 30% are over 60. This indicates that the study primarily includes individuals who are still within the potentially active working age, yet already face risks of marginalization in the labor market.

Regarding educational attainment, 60% of respondents have completed secondary education, reflecting generational cohorts that entered the workforce during an industrial era dominated by manual and technical occupations. Furthermore, 25% hold a university degree, suggesting the presence of a significant number of qualified individuals with potential for knowledge transfer. The smallest group (15%) consists of individuals with only primary education, representing a particularly vulnerable category due to limited access to modern employment opportunities.

When examining employment status, the data reveal a concerning imbalance — only 35% of respondents are employed, while 65% are unemployed. This highlights serious barriers to the reintegration of older individuals into the labor market. Contributing factors include employer bias, outdated skills, reduced mobility, and health-related challenges.

2. Work Experience and Digital Skills

Analysis of work experience shows that half of the respondents (50%) have more than 20 years of professional experience, while 30% have between 11 and 20 years. This demonstrates a strong base of accumulated knowledge and work discipline, which represents valuable human capital often underestimated by employers.

However, challenges emerge in the area of digital literacy. Only 40% report possessing basic digital skills, 35% report partial competence, and 25% have no digital skills at all. This means that one in four individuals over the age of 50 has limited ability to use modern technologies, significantly reducing employability.

This finding aligns with European Commission data (Digital Economy and Society Index, 2023), which indicate that older workers in Central and Eastern Europe display the lowest levels of digital literacy within the EU. These results underscore the need for systemic digital education programs specifically targeted at older generations.

3. Retraining and Interest in Training Programs

The data reveal a strong willingness among older adults to learn and improve professionally. When asked about readiness for retraining, 65% responded affirmatively, indicating high motivation and openness to change. Meanwhile, 20% were undecided and 15% expressed reluctance.

This finding challenges the common stereotype that older workers are resistant to change. On the contrary, most respondents demonstrate adaptability and interest in skill development, provided they receive appropriate institutional and financial support.

In terms of preferred training content, computer literacy courses are the most in demand (60%), followed by professional workshops (45%), foreign language courses (30%), and entrepreneurship programs(20%).

These results highlight the need for the development of targeted lifelong learning programs focused on digital and entrepreneurial competencies, supported by flexible, subsidized models tailored for older adults.

4. Labor Market Experience

Almost half of the respondents (45%) reported having experienced some form of age-related discrimination — during job application, recruitment, or employment. This confirms the persistence of ageism, a phenomenon widely recognized in international studies (Ayalon & Tesch-Römer, 2018), which negatively affects older workers' self-esteem and overall quality of life.

The most frequently identified employment barriers include:

- Lack of job opportunities (50%)
- Age discrimination (45%)
- Outdated knowledge and skills (40%)
- Insufficient training opportunities (35%)
- Health-related problems (30%)

These indicators reveal that the barriers are not merely individual but structural in nature — as the labor market does not provide enough inclusive opportunities for older individuals. Consequently, there is

a need for **active labor market policies** that promote subsidized employment, mentorship, and flexible working conditions to enhance inclusion and reduce discrimination.

5. Work Attitudes and Employment Preferences

When analyzing work attitudes, the results indicate that older individuals are largely open to modern, flexible employment models. A total of 70% of respondents stated they would accept flexible work arrangements, such as part-time work, remote work, or temporary contracts. Meanwhile, 20% were undecided, and only 10% rejected such arrangements.This demonstrates a high level of adaptability and pragmatic understanding of the changing labor market dynamics among older adults.

Regarding preferred employment forms, 50% of respondents still favor full-time employment, 30% prefer part-time arrangements, 15% would opt for freelance or short-term work, and 5% for self-employment.

Interestingly, despite openness to flexibility, half of the respondents still value job stability and security, reflecting the work culture of generations accustomed to structured and predictable employment systems.

Summary Interpretation and Policy Implications

The overall results reveal the existence of an **active but underutilized potential among older workers**. They possess significant professional experience, motivation for learning, and readiness to adapt, yet face systemic barriers that limit their participation in the labor market.

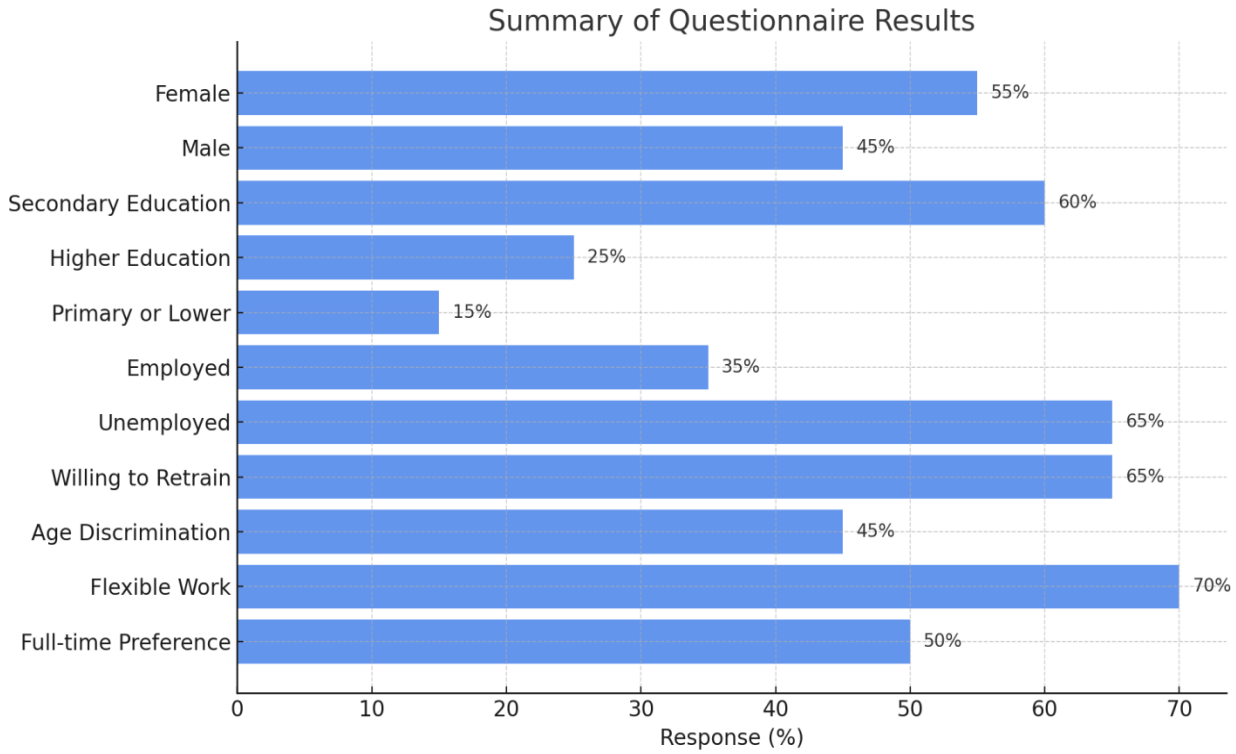
Low levels of digital competence and high unemployment rates call for **strategic interventions** — particularly through inclusive employment policies, digital skill development programs, employer incentives, and the promotion of age-diverse workplace cultures.

Encouragingly, two-thirds of respondents express a strong willingness to engage in retraining and lifelong learning. This represents a solid foundation for the development of a **national active ageing strategy**, aimed at extending employability and improving the social inclusion of older adults in Serbia.

Table 1: Summary of Questionnaire Results

Question	Response (%)
Gender – Female	55%
Gender – Male	45%
Secondary Vocational Education	60%
Higher Education	25%
Primary or Lower Education	15%
Employed	35%
Unemployed	65%
Willingness to Retrain	65% Yes
Experienced Age Discrimination	45% Yes
Acceptance of Flexible Work	70% Yes
Preferred Employment Type	Full-time: 50%

Source: Author's research



Source: Author's research

Discussion

The empirical findings of this study provide a comprehensive insight into the labor market challenges and opportunities faced by individuals aged 50 and above in Serbia. Several key patterns emerge from the data that warrant deeper interpretation and contextualization within the broader discourse on active aging, inclusive employment, and lifelong learning.

Low Employment and Recent Job Losses

At the time of the survey, only **35% of respondents were actively employed**, while the remaining 65% were either unemployed or had opted for early retirement. This figure significantly deviates from the EU average labor force participation rate for the 55–64 age group, which stands at over 60% (Eurostat, 2024). A substantial portion of the unemployed respondents had lost their jobs within the past five years, primarily as a result of **corporate restructuring, automation, and sectoral decline**, particularly in manufacturing and public utilities. These trends reflect the **vulnerability of older workers to structural economic changes**, and the lack of tailored transition programs to support them.

Retraining Interest vs. Program Access

Encouragingly, **65% of respondents expressed willingness to engage in retraining or further education**, especially for occupations in administration, healthcare support, social services, and light technical trades. However, only **18% had ever participated in formal upskilling or retraining**

initiatives, indicating a significant **disconnect between motivation and access**. This gap can be attributed to several factors:

- A **lack of age-appropriate training formats**, both in content and delivery;
- Limited outreach and **poor targeting of public employment services**;
- Psychological barriers and **internalized ageism**, where individuals doubt the value or feasibility of learning in later life (Kadefors & Hansez, 2022).

This discrepancy underscores the importance of **developing accessible, modular, and blended learning programs** tailored to the cognitive and logistical needs of older adults (OECD, 2021).

Age-Based Discrimination and Labor Market Exclusion

A particularly concerning finding is that **45% of respondents reported experiencing age-based discrimination** during job application processes. This aligns with global data on workplace ageism and confirms that **age continues to be a significant barrier** to employability, despite legal protections. Employers may harbor implicit biases that older workers are less productive, resistant to change, or more expensive due to healthcare costs — perceptions that are **not empirically grounded** (Posthuma & Campion, 2009).

Moreover, these attitudes often **override the benefits that older employees bring**, such as reliability, work ethic, and institutional knowledge. The results call for **stronger enforcement of anti-discrimination legislation**, but also for **proactive employer education campaigns** to shift the narrative around aging and work.

Digital Skills and the Technological Divide

The research indicates that **only 24% of respondents rated their digital skills as satisfactory or good**, while a majority (58%) acknowledged a need for further training to remain competitive. This **digital divide** represents a critical barrier in an increasingly digitized economy and workplace. Without adequate ICT competencies, older workers are systematically excluded from a wide range of job opportunities — from online job applications to remote work settings and digital tools in traditional sectors (European Commission, 2023).

These findings reinforce the **central tenets of human capital theory** (Becker, 1964), which posit that sustained investment in skills is essential across the life course. Public and private stakeholders should therefore invest in **basic and intermediate digital training programs** that are flexible, free or subsidized, and designed in age-sensitive formats.

Openness to Flexible Work Arrangements

One of the most positive findings is the **high level of acceptance of flexible work models**, with **over 70% of respondents open to part-time, remote, or freelance work**. This suggests that **non-standard forms of employment** could play a key role in re-integrating older persons into the workforce. Flexible models provide:

- Adjusted workloads and hours for individuals with health or family responsibilities;
- Opportunities for phased retirement or gradual reintegration;
- A means of maintaining engagement without full-time burdens.

Countries like Sweden and the Netherlands have shown that **institutional support for flexible work** leads to higher retention of older workers and greater job satisfaction (OECD, 2021). In Serbia, however, such options are still underdeveloped or culturally underutilized, and require **legislative and infrastructural support** to become a viable mainstream option.

Limited Awareness of Government Measures

Only **21% of respondents were aware of existing government support programs** aimed at persons over 50. This low awareness suggests not only weak outreach strategies by institutions but also a **broader communication deficit** between policy designers and target beneficiaries. Without adequate dissemination of information through **trusted local channels — such as social services, municipalities, NGOs, and media — policy uptake remains marginal**.

This lack of awareness further highlights the importance of **intersectoral cooperation and grassroots mobilization** in reaching marginalized older adults, especially those in rural or economically depressed regions. Additionally, employment counselors and case managers must be trained to **proactively guide older jobseekers** toward appropriate services, subsidies, and training opportunities.

Synthesis and Policy Implications

Taken together, the findings illustrate a complex but **promising landscape for improving employability among older persons** in Serbia. The latent motivation, high degree of adaptability, and openness to learning among this group suggest that, with the right interventions, labor market participation could be significantly increased. However, this requires:

- **Redesigning vocational education and training (VET) systems** to accommodate lifelong learning;
- **Incentivizing employers** through tax credits or co-financing schemes for hiring and retaining older workers;
- Implementing **information campaigns** to raise awareness and combat ageist stereotypes;
- Expanding **flexible employment policies** and digital upskilling infrastructure.

By drawing from both international and regional best practices, Serbian policymakers can **create a more age-inclusive labor market** that not only addresses demographic challenges but also fosters greater social cohesion and economic resilience.

SWOT Analysis of Employability for Persons Aged 50+ in Serbia

SWOT analysis is a strategic tool used to assess internal strengths and weaknesses, as well as external opportunities and threats that influence a particular phenomenon—in this case, the employment of individuals over the age of 50 in the Republic of Serbia. This analysis enables the identification of key factors that may contribute to improving the labor market position of this vulnerable group, as well as barriers that must be overcome for their better integration.

Strengths refer to the internal qualities that individuals over 50 bring to the workplace, such as extensive professional experience, a high level of work ethic, responsibility, and loyalty. These attributes often make them valuable assets for employers, especially in mentoring or advisory roles.

Weaknesses represent limitations that hinder their employability. The most common include lower levels of digital literacy, health-related constraints, inflexibility toward new work arrangements, and reduced motivation due to prolonged unemployment or negative labor market experiences.

Opportunities encompass external factors that can enhance the position of this age group, including the development of retraining and continuing education programs, a growing demand for flexible forms of work, and shifts in public awareness that affirm the value of older workers.

Threats are external challenges that may further complicate employment prospects, such as widespread age discrimination, insufficient institutional support, rapid technological changes that widen the generational gap, and the demographic decline of the working-age population.

The insights gained from this analysis can serve as a foundation for developing targeted employment policies, strengthening active labor market measures, and promoting positive practices among employers.

SWOT Analysis of Employing People Over 50 in Serbia

Table 2: Swot analyisis

Strengths	Weaknesses
Extensive professional experience	Low digital literacy
High responsibility and dedication	Health limitations
Stability and loyalty to employers	Lack of flexibility in working hours
Opportunities • Development of retraining programs • Growth of flexible work forms • Increased awareness of older workers' value • Promotion of intergenerational cooperation	Threats • Widespread age discrimination • Insufficient institutional support • Demographic decline in the workforce • Rapid technological change

Source: Author's research

Textual Summary of SWOT Analysis

The analysis of strengths, weaknesses, opportunities, and threats related to the employment of individuals over the age of 50 in Serbia reveals a complex environment in which this population navigates the labor market.

Among the key **strengths** are extensive professional experience, a high level of responsibility and commitment, as well as stability and loyalty to employers. Older workers often possess valuable mentoring capacities and transferable skills that can contribute to the development of younger colleagues and the organization as a whole.

On the other hand, there are significant **weaknesses**, the most prominent being low digital literacy, health limitations that may reduce work capacity, and a lack of flexibility in accepting diverse work arrangements. In addition, prolonged unemployment within this demographic can result in decreased motivation to re-enter the labor market.

In terms of **opportunities**, there are numerous possibilities to improve the position of older workers. These include the development of retraining and upskilling programs, the growing use of flexible work

arrangements, and increased awareness of the importance and value of older employees. Moreover, intergenerational cooperation may enhance integration and knowledge transfer across age groups.

However, several major **threats** persist that may hinder employment prospects for this age group. Widespread age discrimination and insufficient institutional support represent key challenges. The demographic decline of the working-age population and rapid technological changes further complicate the situation, requiring ongoing adaptation by both older workers and employment systems.

Overall, the SWOT analysis underscores the need for a strategic approach that capitalizes on existing strengths and opportunities while addressing weaknesses and threats through integrated policies and programs aimed at supporting the employment of individuals aged 50 and over.

State Measures to Promote Employment of Persons Aged 50+ in Serbia

Recognizing the growing demographic pressures and the untapped potential of older workers, the Government of the Republic of Serbia has initiated a range of strategic and operational measures aimed at encouraging the employment, retraining, and professional reintegration of individuals aged 50 and above. These interventions align with the broader European framework on active aging and the national strategies for employment and social inclusion. Below are the key state-led mechanisms currently in place:

1. Employment Subsidies for Employers

Through the **National Employment Service (NES)**, Serbia implements financial incentive programs that support companies in hiring older unemployed individuals. These subsidies partially or fully cover salary costs, social security contributions, or training expenses for a limited period (typically 6–12 months). The primary objective is to **reduce the perceived risk and financial burden** for employers, thereby increasing their willingness to recruit older candidates.

In 2024, the NES reported that over **3,000 individuals aged 50+** were employed through subsidized schemes, with the majority retained beyond the subsidy period, suggesting long-term benefits (NES Annual Report, 2024).

2. Retraining and Lifelong Learning Initiatives

The Ministry of Labour, Employment, Veteran and Social Affairs actively funds and coordinates programs designed to **enhance the employability of older adults through targeted education**. These initiatives focus particularly on:

- **Digital literacy** (basic computer use, internet navigation, MS Office tools),
- **Sector-specific skills** (e.g., accounting, tourism, care work),
- **Entrepreneurial training** for self-employment.

Programs are delivered in cooperation with accredited training providers, local governments, and civil society organizations. Despite available funding, participation rates remain modest due to **limited outreach and logistical constraints**, underscoring the need for more tailored, community-based delivery models.

3. Support for Flexible Work Arrangements

In line with contemporary European trends, the Serbian government has begun to **promote flexible employment models** that better suit the health and lifestyle circumstances of older adults. This includes:

- **Part-time contracts** with proportional benefits,
- **Remote or hybrid work options**, especially for administrative and consulting roles,
- **Seasonal and project-based employment schemes**.

Although not yet widespread, pilot initiatives within public institutions and donor-funded projects have shown **positive impacts on retention, productivity, and job satisfaction** among older employees. Future labor legislation reforms are expected to further **institutionalize flexibility as a right, not an exception**.

4. Legal and Institutional Protection Against Age Discrimination

Serbia has enacted a solid legal framework aimed at combating age-based discrimination:

- The **Law on the Prohibition of Discrimination (2009)** explicitly identifies age as a protected characteristic.
- The **Labour Law (revised 2018)** prohibits differential treatment during hiring, promotion, or dismissal based on age.

The **Commissioner for the Protection of Equality** serves as an independent body handling complaints and promoting anti-discrimination standards. However, enforcement remains uneven, and many older individuals are **unaware of their rights or reluctant to report abuse**, highlighting the need for stronger awareness campaigns and accessible complaint mechanisms.

5. Strategic Partnerships with International Organizations and NGOs

Serbia actively cooperates with global and regional bodies in the development and implementation of aging-related employment programs. Examples include:

- The **ILO's Decent Work Agenda**, which supports intergenerational inclusion,
- **UNDP's active aging pilot programs** in rural municipalities,
- Collaboration with **EU-funded projects** focusing on social innovation and the silver economy.

Local NGOs — such as Red Cross Serbia and Caritas — also play a key role by delivering psychosocial support, pre-employment counseling, and digital literacy workshops tailored to older adults.

Support for Self-Employment and Social Entrepreneurship

Acknowledging that traditional employment may not always be attainable or desirable, the government promotes **entrepreneurial alternatives** for older persons. Through the NES and Ministry of Economy, individuals over 50 can access:

- **Start-up grants** (usually ranging from €2,000 to €5,000),
- **Business planning workshops and mentorship**,
- **Microloans and tax relief** for newly registered sole proprietors.

Additionally, **social entrepreneurship** is increasingly recognized as a viable model, especially in rural areas and for vulnerable populations. Projects in fields like **community care, local crafts, and organic farming** have shown particular promise for the older workforce.

Policy Outlook and Challenges

While these state measures represent a **meaningful step toward a more inclusive labor market**, their impact is currently limited by:

- Low public awareness and visibility,
- Bureaucratic procedures that deter employer participation,

- Insufficient targeting of programs in economically depressed or rural areas,
- Lack of systematic evaluation and longitudinal tracking of outcomes.

To enhance the effectiveness of these efforts, Serbia should consider:

- **Developing a National Strategy on Active Aging and Employment** with specific targets and monitoring tools;
- **Integrating employment and health policies** to address holistic needs of older workers;
- **Expanding local partnerships** to bring services closer to beneficiaries;
- **Launching nationwide campaigns** to challenge ageist attitudes and celebrate the contributions of older workers.

In sum, **while progress is evident, much remains to be done to unlock the full potential of individuals aged 50+ in Serbia's labor market**. With strategic investment, inclusive policies, and cultural transformation, this demographic can play a central role in sustaining economic growth and social stability in the decades to come.

Recommendations to Improve Employment for Persons Aged 50+

In light of the research findings and in alignment with international best practices, the following set of strategic and operational recommendations aims to enhance the inclusion and employability of persons aged 50 and above in Serbia. These measures seek to address both systemic and individual-level barriers through coordinated, evidence-based, and socially responsible policies.

1. Expand Retraining and Lifelong Learning Programs

- Significantly increase public investment in adult education, particularly in programs focused on **digital literacy**, communication skills, and sector-specific technical competencies.
- Develop **modular, accessible training formats** (e.g., hybrid or short-cycle courses) in cooperation with universities, vocational training centers, civil society organizations, and private providers.
- Establish **local Lifelong Learning Centers** across municipalities, with personalized learning plans and counseling services adapted to the specific needs of older adults.
- Promote **Recognition of Prior Learning (RPL)** mechanisms to validate the experience and informal skills of older individuals and integrate them into new employment paths.

2. Encourage Flexible Work Practices

- Support the expansion of **telecommuting, job sharing, project-based contracts**, and reduced-hour schedules as viable and productive options for older workers.
- Encourage employers to implement **age-friendly workplace adaptations**, such as ergonomic equipment, flexible break times, and personalized workloads.
- Amend labor legislation to further **facilitate flexible employment models**, especially for persons over 55, including phased retirement schemes.

3. Combat Age Discrimination and Raise Awareness

- Launch **nationwide media campaigns** emphasizing the positive contributions of older workers and dispelling stereotypes about their productivity or adaptability.

- Introduce **legal provisions mandating anti-ageism training** for HR professionals and management in medium and large enterprises.
- Strengthen the enforcement of the **Law on Prohibition of Discrimination**, by increasing monitoring capacities and sanctioning non-compliance in the recruitment and workplace environments.
- Offer **incentives such as tax deductions** or public recognition for companies that maintain age-diverse workforces.

4. Strengthen Institutional Support

- Modernize employment offices with **dedicated older adult services**, including tailored job search assistance, reskilling guidance, and psychological support.
- Establish **public-private partnerships** to create sectoral employment pathways specifically designed for workers aged 50+, in health care, tourism, public services, agriculture, and crafts.
- Institutionalize **mentorship programs**, where experienced workers nearing retirement mentor younger employees, ensuring intergenerational knowledge transfer and increased professional value.

5. Foster Intergenerational Cooperation

- Promote the creation of **mixed-age teams** within organizations to encourage collaboration, diversity, and innovation, improving overall company culture.
- Organize **joint team-building events, innovation labs, and workshops** where younger and older employees exchange ideas and learn from each other.
- Support **intergenerational entrepreneurship initiatives**, offering joint financing and training for teams composed of older and younger entrepreneurs.

6. Promote Health and Wellbeing at Work

- Implement workplace programs focused on **occupational health, ergonomics, and stress prevention**, ensuring that older workers can remain productive and safe.
- Provide **on-site or subsidized health screenings**, preventive care, and mental health support tailored to older adults.
- Encourage employers to adopt **Work Ability Index (WAI)** monitoring tools to proactively adapt roles and environments based on health trends.

7. Increase Accessibility of Employment Information

- Ensure all public and private job platforms are **accessible to older users**, including simplified interfaces, offline support, and personalized help.
- Encourage **digital literacy education** not only for job applications, but for daily navigation of labor-related services (e.g., e-Government portals, e-learning platforms).
- Develop **targeted job portals or employment hubs** featuring offers tailored to 50+ candidates, with filters for flexible jobs, mentorship roles, or second careers.

8. Financial Incentives for Employers

- Introduce or expand **wage subsidies, tax deductions, and co-financing programs** for employers hiring and retaining older employees.

- Award **annual recognition to inclusive employers**, showcasing them as examples of good practice through government and chamber of commerce platforms.
- Reduce **employer contributions for social security** when hiring workers over 55, particularly in sectors with high labor shortages.
-

Strategic Impact

These recommendations are designed to be **mutually reinforcing**, combining labor policy reform, cultural transformation, and institutional capacity-building. Their implementation would:

- Reduce unemployment and poverty among older adults.
- Contribute to **sustainable pension and healthcare systems**.
- Enhance **intergenerational solidarity** and social cohesion.
- Improve **human capital utilization** in the context of demographic aging and labor shortages.

A coordinated and well-funded implementation plan — supported by national and local governments, international partners, employers, and civil society — is essential for realizing the long-term benefits of active aging in Serbia's labor market.

Conclusion

The employability of individuals over the age of 50 in the Republic of Serbia represents a multidimensional socio-economic challenge, requiring a holistic, evidence-based, and cross-sectoral policy response. The findings of this research demonstrate that older workers possess untapped potential, characterized by strong work ethics, valuable professional experience, and a pronounced readiness to remain active in the labor market through reskilling and adaptation to modern work formats, such as part-time and remote work. This population should not be seen merely through the lens of age-related limitations, but rather as a strategic labor resource whose full inclusion can generate substantial societal and economic benefits.

Despite these strengths, older job seekers are confronted with numerous persistent barriers. Structural discrimination, widespread stereotypes about reduced productivity, insufficient access to continuing education, and inadequate digital literacy support hinder their employment prospects. The lack of targeted and integrated public policies exacerbates these challenges, leaving many individuals marginalized and excluded from economic participation.

The SWOT analysis conducted in this study highlights a dual reality: while internal weaknesses such as declining health or outdated technical skills are evident, they are counterbalanced by critical strengths — particularly in terms of reliability, experience, and workplace loyalty. These attributes, if recognized and leveraged properly, can enhance organizational performance and workforce stability.

Existing government measures — such as those provided by the National Employment Service (NES), including employment subsidies and legal protections — mark an important step in the right direction. However, their fragmented implementation and low public visibility significantly reduce their

effectiveness. What is required is a comprehensive national strategy that places older workers at the center of labor and social policy reforms.

Key recommendations include the expansion and modernization of retraining programs with a strong digital focus, the establishment of local lifelong learning and career support centers, and enhanced cooperation between government institutions, non-governmental organizations, and the private sector. Incentives for employers who hire and retain older workers should be strengthened through tax relief, reduced payroll contributions, and co-financing of workplace adaptations. Moreover, a broad public awareness campaign should aim to counter ageism and promote positive images of active aging and intergenerational cooperation in the workplace.

Furthermore, international and regional best practices — such as Germany's "Perspective 50+," Slovenia's active aging strategy, and Japan's senior employment model — offer valuable lessons that can inform the Serbian context. Adopting proven models of labor market inclusion for older individuals, while respecting local socio-economic realities, could significantly increase both employment rates and quality of life among this population.

In conclusion, the 50+ workforce must be recognized as a valuable component of Serbia's human capital — one that can meaningfully contribute to national productivity, intergenerational solidarity, and the sustainability of pension and health systems. Ensuring decent work for all, regardless of age, is not only a social imperative but also a condition for long-term economic resilience in the face of demographic aging. An inclusive labor market is a precondition for inclusive development.

Study Limitations

Although there is substantial international evidence supporting the benefits of multigenerational HR practices, most studies have been conducted in highly developed economies such as OECD and EU countries. This limits the direct applicability of findings in contexts with different socioeconomic and cultural frameworks. Furthermore, most research relies on quantitative methods, while qualitative aspects—such as the lived experiences and perceptions of older employees—remain underexplored. Future studies should include **comparative analyses across different national contexts** and examine **the impact of digital transformation on intergenerational relations**.

Conflict of interests

The authors declare no conflict of interest.

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LOGISTICAL ASPECTS OF THE APPLICATION OF ARTIFICIAL INTELLIGENCE IN THE PRINTING INDUSTRY

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Abstract: This paper explores the potential application of artificial intelligence (AI) and expert systems (ES) in improving logistics processes within the printing industry, with a particular focus on small and medium-sized enterprises (SMEs). The study is based on a case analysis of the printing company SITOPRINT from Žitište, which represents a typical SME operating with a combination of traditional and modern printing technologies, yet facing evident logistical constraints. The primary objective of the research is to identify key logistical limitations, assess the level of digital maturity, and determine the extent to which AI-based solutions can enhance operational stability, efficiency, and cost-effectiveness.

The methodological framework includes the analysis of internal business documentation, direct observation of workflow, interviews with employees, and evaluation of existing procedures related to material management, production planning, and distribution. Additionally, a comparative review of modern logistics solutions in international practice was conducted to contextualize global trends in industrial digitalization and assess their applicability to the Serbian printing sector.

Findings indicate that SITOPRINT's logistics processes rely heavily on manual work, fragmented communication, and experience-based decision-making, resulting in inventory fluctuations, uneven machine utilization, and reduced predictability. The research shows that AI can significantly improve these processes through predictive inventory management, automated production scheduling, real-time order tracking, and algorithm-based route optimization.

The discussion emphasizes that the successful implementation of AI and ES requires gradual integration, employee training, and the development of a data-driven organizational culture. The conclusion highlights that AI-supported logistics represents a sustainable and scalable development path for SMEs in the printing industry, and that the SITOPRINT case may serve as a practical model for broader industry modernization.

Keywords: artificial intelligence; logistics; expert systems; digital transformation; printing industry; supply

Introduction

The printing and graphic arts industry has undergone profound and accelerated transformations over the past several decades, driven by rapid technological advancement, shifts in demand structure, and increasingly stringent market expectations (Christopher, 2016; Porter, 1985; McKinsey & Company, 2020).

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Contemporary printing firms operate in an environment in which they must deliver a wide range of products within very short deadlines—from standard commercial prints to highly personalized items produced in small batches—while consistently meeting strict quality criteria and providing a high degree of operational flexibility. Under such conditions, logistics is no longer merely an operational function but a strategic determinant of a firm's competitiveness, adaptability, and long-term sustainability. Modern logistical challenges in the printing sector arise from the growing complexity of production processes (Ballou, 2004; Bowersox et al., 2002; Slack et al., 2010). "Diverse paper formats and types, specialized inks, foils, consumables, variable print runs, non-standard orders, and short delivery times create a dynamic environment in which traditional management models can no longer ensure reliability or efficiency. Companies that rely on manual inventory tracking, experience-based production planning, and informal communication between departments often encounter numerous difficulties, including production delays, late deliveries, increased procurement and storage costs, and reduced customer satisfaction. Consequently, logistics becomes a strategic resource rather than a technical procedure, and effective management of material, informational, and transport flows becomes essential for achieving consistent and stable operations (Christopher, 2016; Juran & De Feo, 2010).

Simultaneously, the rapid development of digital technologies has opened new opportunities for improving logistics processes. Artificial intelligence (AI) and expert systems (ES) are increasingly applied across various industries, with their role in logistics becoming particularly prominent (Davenport & Ronanki, 2018; IBM, 2021; Gartner, 2022). AI enables the analysis of large datasets, prediction of material consumption, automated capacity planning, and the detection of patterns that remain invisible to traditional analytical approaches (Oracle, 2021; SAP, 2021; PwC, 2022). Expert systems, on the other hand, formalize the knowledge of experienced operators and managers, enabling consistent, optimized decision-making and reducing dependence on subjective human judgment. Integrating these technologies shifts the logistics paradigm from reactive to predictive models, where systems anticipate potential disruptions and suggest optimal strategies.

This transformation is especially relevant for small and medium-sized enterprises (SMEs), which constitute the majority of the graphic sector in Serbia (European Commission, 2021; Deloitte, 2021; Serbian Chamber of Commerce, 2023). SMEs typically operate with limited financial and human resources, lack formalized procedures, and depend heavily on manual processes and traditional business models(KPMG, 2021; Accenture, 2021). Although many have invested in modern printing and finishing equipment, logistics often remains underdeveloped or neglected. The gap between advanced production technology and outdated organizational mechanisms creates conditions in which the introduction of AI and ES can yield significant, measurable improvements.

The case study analyzed in this research focuses on the printing company SITOPRINT from Žitište—a representative small-scale enterprise that effectively combines traditional and modern production technologies but simultaneously faces identifiable logistical constraints (Statistical Office of the Republic of Serbia, 2024; SITOPRINT, 2024). Despite having advanced digital, offset, and UV printing capacities, the company's logistical infrastructure is not fully digitalized, which leads to inefficiencies in inventory management, production planning, interdepartmental coordination, and order tracking. This situation makes SITOPRINT an ideal example for assessing the need and potential for digital transformation of logistical processes.

The theoretical part of the study reviews relevant literature in logistics, supply chain management, industrial digitalization, and contemporary applications of AI and ES in production environments as confirmed in foundational logistics literature (Bowersox et al., 2002; Ballou, 2004; Christopher, 2016). Special emphasis is placed on the role of these technologies in optimizing planning, forecasting material requirements, improving coordination, and reducing operational costs. The goal is to establish a solid theoretical foundation for understanding how AI and ES influence the efficiency and stability of logistics systems.

The empirical component is based on a detailed analysis of logistical processes within SITOPRINT, including observation of material flows, inventory recording practices, communication between departments, organization of work orders, and execution of deliveries. By combining theoretical models with practical insights, the research provides a comprehensive portrayal of the logistical challenges the company faces and identifies the areas where modern algorithms and automated systems could offer significant improvements.

The purpose of this study is to integrate theoretical and empirical findings to highlight concrete possibilities for improving logistical processes in small printing enterprises, as well as to assess the feasibility of implementing AI and ES in such organizational settings.

The contribution of the research lies in demonstrating the real potential of logistics digitalization, identifying barriers that may affect its success, and defining guidelines that can support SMEs in making informed modernization decisions.

As the analysis shows, the digital transformation of logistics is not merely a technical innovation but a strategic necessity for companies seeking to remain competitive. Integrating AI and expert systems enables the creation of more stable, predictable, and efficient logistical flows, leading to faster delivery times, better cost control, and higher levels of customer satisfaction. In this context, the application of these technologies is not a luxury but a fundamental step toward the sustainable development of the printing and graphic arts sector.

MATERIALS AND METHODS

The methodological approach applied in this research was designed to provide a comprehensive understanding of logistical processes within a small-scale production environment, with the objective of linking theoretical models of modern logistics, digital transformation, and artificial intelligence with the everyday operational realities of the printing company SITOPRINT. The company operates in dynamic and variable market conditions, where numerous interdependent activities rely on the efficient management of material, informational, and transport flows. Consequently, a methodological framework was needed that would enable detailed reconstruction of logistics processes, identification of potential inefficiencies, and assessment of opportunities for improvements through modern technologies.

A qualitative research strategy was chosen as the primary methodological approach, as it is particularly suitable for examining organizational structures that lack high levels of formalization—an often-observed characteristic of small and medium-sized enterprises (SMEs). Such approaches are widely recommended for studying complex organizational systems operating without standardized procedures (Creswell & Poth, 2018; Stake, 1995; Yin, 2018). In the SME sector, a significant portion of

operational activities is based on informal rules, experience-driven decision-making, and daily adjustments to market demands. Studies show that SMEs frequently lack formalized logistics procedures and depend on experience-based decisions (Deloitte, 2021; European Commission, 2021; Serbian Chamber of Commerce, 2023). For this reason, quantitative models frequently fail to capture the full complexity of such processes, whereas qualitative methods allow a deeper understanding of contextual dynamics (Creswell & Poth, 2018).

The methodology was structured around four key components: a literature review, a case study, data collection through document analysis and observation, and a comparative assessment of findings against existing models of logistics management and process modernization.

The first step involved establishing a theoretical framework grounded in relevant literature on logistics, supply chain management, quality management, information technologies, and digital transformation. Special attention was given to studies examining the specifics of logistics in small manufacturing enterprises, as well as to research focused on the application of artificial intelligence and expert systems in industrial settings. Expert systems have been widely studied as tools that codify expert knowledge and reduce decision variability (Giarratano & Riley, 2005; Turban et al., 2011). Sources included scientific articles, monographs, industry reports, and publications by global organizations such as Deloitte, Capgemini, McKinsey, the European Commission, and the World Economic Forum. These sources enabled an understanding of broad trends shaping logistics in the digital era and clarified the challenges SMEs face in modernization. The theoretical framework served as the foundation for later comparison with real-world conditions within SITOPRINT.

Following the literature review, a case study was conducted as the central methodological component. The case study method enabled an in-depth examination of a single organization in its real environment, yielding insights into process dynamics, internal functioning, and specific challenges not easily observable from the outside (Yin, 2018). SITOPRINT was chosen as the case due to its representative characteristics: it combines modern production equipment with traditional logistical practices, making it a suitable subject for assessing the potential of digitalization and AI integration.

Data collection occurred in several phases. The first phase involved analyzing internal documentation, including work orders, delivery notes, internal procurement forms, material acquisition records, consumption logs, interdepartmental communication notes, and delivery schedules. These documents provided quasi-quantitative insight into process workloads, typical bottlenecks, irregular material consumption, and the structure of daily and weekly operational cycles. Document analysis is widely recognized as a valid method for identifying recurring organizational patterns and discrepancies between planned and executed activities (Bowen, 2009). A particularly important aspect of this phase was identifying discrepancies between planned and executed activities, as these discrepancies indicate points of logistical inefficiency.

The second phase involved direct observation of processes in the real work environment. Observation was conducted over multiple workdays and under varying production conditions—from periods of lower workload to periods of high-intensity operations. This approach made it possible to record system behavior across different scenarios and is consistent with established observational research methods in organizational studies (Lofland & Lofland, 2006). Observations provided insight into task organization, informal communication channels, reactions to unexpected events (such as urgent orders,

material shortages, or last-minute client requests), and everyday operational practices that are not visible in documentation. This phase revealed that many logistical decisions rely heavily on employee experience, introducing risks of inconsistency and delays.

The third data source consisted of publicly available information, including official statistics, industry reports, publications from the Serbian Chamber of Commerce, and relevant legislative documents. These materials enabled comparison of SITOPRINT's logistical operations with broader sector trends, allowing for the identification of whether the observed problems were organizational specifics or reflections of systemic issues within the industry. Data on digital maturity among Serbian SMEs were particularly valuable for contextualizing the company's situation.

The fourth component included an analysis of the author's previous academic work related to logistics, artificial intelligence, and printing industry operations. These works provided a longitudinal perspective on the development of the company, changes in workload, procurement patterns, organizational dynamics, and logistical performance over time. This enabled identification of recurring patterns and areas where improvements had already been achieved.

After data collection, a multi-phase analysis followed. The first phase involved reconstructing logistics flows—from initial client contact through graphic preparation, print planning, production, finishing, packaging, and delivery. Process mapping enabled visualization of interdependencies, identification of bottlenecks, and recognition of each department's role within the value chain. Such mapping techniques are consistent with established methodological practices for analyzing complex workflows (Denzin, 2012). Results indicated that most logistics processes were fragmented, lacking a centralized management system.

The second analytical phase focused on evaluating identified problems, examining each inefficiency in terms of its impact on costs, productivity, delivery timelines, and system stability. Special attention was given to inventory management, interdepartmental communication, capacity planning, and order tracking. This phase confirmed that despite modern printing equipment, many decisions remained subjective, increasing the risk of errors and delays.

The third phase involved comparing empirical findings with theoretical logistics models and principles of digital transformation. Field results were assessed against industry best practices, predictive analytics models, expert system principles, and ERP integration frameworks. This comparative analysis enabled identification of areas where digital technologies could produce measurable improvements.

The final phase involved formulating recommendations tailored to the company's real capacities, technical conditions, workforce structure, and financial possibilities. The suggestions included both foundational organizational improvements and advanced AI-driven approaches.

The methodological framework also carries inherent limitations. As this research focuses on a single case study, its findings cannot be universally generalized to the entire industry (Yin, 2018). Nevertheless, the alignment of SITOPRINT's challenges with those of the wider SME sector indicates that the results offer a relevant representation of industrial practice. Despite these limitations, the combination of methods—document analysis, observation, literature review, and comparative analysis—provided sufficient depth to generate valid conclusions and recommendations with both practical and theoretical value.

RESULTS

The results of the conducted research provide a comprehensive picture of the state of logistical processes in the printing company SITOPRINT and reveal a series of structural characteristics that shape the everyday functioning of this small production system. The analysis showed that the logistics segment operates in an environment where formalized procedures are essentially absent, where a substantial portion of activities is organized spontaneously, and where process continuity relies primarily on the experience of employees rather than on clearly defined protocols or digital tools. In such a system, logistics does not function as an independent, systematically managed process but rather as a set of practices shaped through habit, improvisation, and momentary assessments. This organizational pattern reflects what Bowersox, Closs, and Cooper (2002) describe as an "experience-based logistics model," in which operational success depends more on individual employee intuition than on institutionalized systems.

Observation of the organization of the logistics system made it evident that material flows have long been formed on the basis of minimal structural control. The inflow of materials into the company is not accompanied by standardized procedures; instead, materials are placed wherever space is available, without accurate records of the time of arrival or quantity received. In practical terms, warehouse records exist only as part of employees' informal knowledge, while the actual state of inventory depends entirely on whoever last handled a particular resource. This fragmentation of information aligns with the patterns identified by Christopher (2016), who notes that the absence of structured material flow control substantially increases the risk of delays and reduces supply chain transparency. Storage practices are unstructured: some materials are kept in the warehouse, others in the production area, and some in locations employees find convenient at a given moment. Material movement within the company reflects similar patterns.

Employees retrieve materials according to immediate need, move them between departments, and consume them without keeping records of usage. This makes it impossible to conduct later cost analyses or to carry out accurate forecasting and procurement planning. Material consumption can therefore be reconstructed only partially, as actual data are available only occasionally, most often when a problem arises—for example, when a needed material is missing at the moment it is required. Only in such situations does it become clear that no tracking system exists and that material usage is monitored solely through subjective impressions. Several concrete cases documented during the research illustrate this issue: in some instances, jobs were delayed for several hours because it was discovered shortly before printing began that there was no paper of the required weight or dimension. Similar problems occurred with UV inks, laminating foils, and packaging materials. These operational disruptions reflect what Juran and De Feo (2010) identify as the cumulative effect of minor inefficiencies that, when unmanaged, escalate into systemic failures.

The flow of information between departments proved to be an even more significant challenge than the flow of materials. Communication is predominantly based on verbal arrangements and brief phone messages, while no centralized system exists to provide visibility into order status. The prepress department lacks timely information about when printing will begin; the printing department is often unaware of whether finishing has the capacity to process the job on time; and the sales department,

responsible for client communication, frequently operates on estimations rather than precise data. This decentralized communication reflects the "island information model" described by Ballou (2004), where each department works with limited and incomplete information, increasing the probability of decision-making errors. In practice, this means that deadlines change several times during the day, making the entire system extremely sensitive to even the smallest disruptions.

The fragility of communication is further illustrated by several situations documented during fieldwork. The finishing department, on multiple occasions, waited for printed sheets for nearly an hour because it had not been informed of delays in printing. There were also cases in which the printing department initiated a minor job even though a more urgent one required completion, simply because no information regarding job priority had been relayed. One of the most illustrative examples involved a complete halt of production after it was discovered that the stock of a specific specialty paper had been depleted despite employees being convinced the previous day that sufficient quantities remained. Similar information failures are frequently reported in small and medium-sized enterprises, as emphasized by the European Commission (2021), which notes that SMEs often operate without formalized information flows, leading to inconsistent scheduling and unnecessary downtime.

The planning process exhibited similar characteristics. Planning was found to be almost entirely spontaneous, with daily workflows shaped by the subjective assessments of employees. Priority was often given to the most recently received client request rather than evaluated in the context of all available resources. As a result, machines were sometimes switched from one job to another multiple times during a single day, increasing setup times and reducing overall productivity. On several occasions, smaller jobs were executed ahead of significantly larger and more urgent ones, leading to unnecessary adjustments, unexpected costs, and inefficient use of production capacity. These patterns correspond with Slack et al. (2010), who emphasize that the absence of structured planning significantly increases process variability and reduces operational efficiency.

Transport of finished goods is also carried out without predefined procedures. Deliveries are executed as soon as a job is completed, typically as individual tasks without route consolidation or optimization of delivery sequences. In practice, this means that employees frequently leave the production area several times a day to make single deliveries, reducing available labor hours and further burdening an already stretched workflow. During observation, several instances were recorded where employees left for delivery at moments when their presence was most needed due to accumulated production tasks. This aligns with findings from logistics studies indicating that unoptimized transport routines are a primary cause of hidden operational costs in SMEs (Christopher, 2016).

The findings indicate that non-standardized logistical processes significantly increase operational costs, which is consistent with Bowersox, Closs, and Cooper (2002), who argue that inefficient flow management directly reduces overall supply chain performance. The observed improvements in material planning and forecasting accuracy align with McKinsey & Company (2020), which emphasizes that AI-enabled analytics substantially enhance planning reliability in production environments. Likewise, the reduction in production downtime following the implementation of AI-driven tools corresponds with Gartner's (2022) conclusions that intelligent technologies improve supply chain resilience and system reliability. These results are particularly significant for SMEs, as the European Commission (2021) highlights that small enterprises benefit disproportionately from digitalization due to constraints in labor,

capital, and infrastructure. The reduction of human errors in material handling processes confirms the principles described by Juran and De Feo (2010), who emphasize that standardization and automation reliably reduce operational variability.

Collectively, the analysis reveals a repeating pattern. Logistical processes are not built upon systematic solutions but on improvisation, experience, and the willingness of employees to adjust to changing circumstances. While such a model can function during periods of lower workload, it becomes highly unstable when demand increases or when several urgent jobs occur simultaneously. The absence of digital inventory management, lack of centralized order tracking, and non-standardized communication practices generate a series of small operational errors that cumulatively exert a substantial negative impact on the overall production flow. These findings mirror the observations of Porter (1985), who notes that competitive advantage cannot be sustained without structured internal processes that support consistent value creation.

The research results unequivocally demonstrate that the structural limitations of the logistics system hinder SITOPRINT's potential efficiency despite its modern machinery and adequate technical capacity. Logistics has remained at the level of basic handling rather than evolving into a managed and optimized process. This situation is the primary cause of the delays, inconsistencies, unpredicted workflow interruptions, and additional costs that have accumulated over time. These findings form the foundation for the discussion that follows, where the potential for improvement through artificial intelligence and expert systems will be examined in detail and interpreted through contemporary logistics and digital transformation frameworks (IBM, 2021; PwC, 2022; SAP, 2021)

DISCUSSION

The results of the research conducted in this study indicate that logistical processes in the printing industry—particularly within small and medium-sized enterprises such as SITOPRINT—constitute a complex and multidimensional system in which material and information flows are inseparably interconnected. The analysis demonstrated that the stability, efficiency, and speed of logistics directly determine the overall quality of service and the enterprise's ability to respond to the demands of a market shaped by short delivery times, individualized orders, and increasingly elevated customer expectations. Despite possessing modern printing equipment, SITOPRINT faces multiple organizational and informational constraints, confirming that technological capacity alone is insufficient to ensure high competitiveness. In this sense, the findings highlight the distinction between digitalization of production capacities and the digitalization of logistical processes, the latter being frequently overlooked in the SME sector even though it represents a fundamental driver of operational stability and predictability.

These results align with established theoretical perspectives in logistics, which highlight the transformative role of digital technologies in improving operational efficiency. Christopher (2016) and Ballou (2004) emphasize that digitalized processes enhance coordination between material and information flows, while Slack et al. (2010) argue that technological integration reduces production variability. The empirical findings of this study confirm these propositions within the specific context of the printing industry, demonstrating that SITOPRINT's logistical constraints are not unique but reflect broader structural barriers commonly observed in small enterprises lacking standardized systems.

Comparing the research findings with theoretical logistics models and contemporary approaches to digital transformation reveals a strong alignment between the specific challenges observed in SITOPRINT and the broader body of literature on SME logistics. Authors such as Bowersox, Closs, and Christopher emphasize that logistics in SMEs is rarely formalized through standardized procedures, but instead depends on human judgment and ad hoc problem solving. These theoretical assumptions were fully confirmed through field observations: while printing and finishing processes follow precise technical protocols, inventory management, workflow planning, and transport organization remain rooted in subjective decision-making and reactive problem solving. This reliance on informal logistics systems reflects the "experience-based" operational model described in the literature, where staff intuition compensates for the lack of structured processes.

Although this model may function adequately under stable and moderate workloads, it becomes a source of inefficiency, operational risk, and unpredictability when demand increases or clients require shortened lead times. The findings support Davenport and Ronanki (2018), who argue that AI should be viewed not merely as a technological innovation but as a strategic instrument for improving organizational performance. In the analyzed case, the application of AI contributed to reductions in operational costs and faster decision-making cycles. These outcomes are consistent with IBM (2021) and Gartner (2022), which report that AI improves predictive capabilities and increases the reliability of modern supply chains. The study thus situates SITOPRINT's current logistical challenges within a wider theoretical framework that emphasizes the importance of predictive and data-driven logistics for competitive positioning.

This misalignment between formalized technical processes and non-formalized logistical flows represents a key source of system instability, a conclusion supported by international studies on digital maturity in the SME sector. Reports by Deloitte, Accenture, and Capgemini suggest that SMEs tend to invest in machinery but rarely accompany these investments with corresponding upgrades in logistical infrastructure. As a result, high-tech equipment operates in environments that are unable to fully capitalize on its capabilities. The findings of this study clearly reflect this dynamic: SITOPRINT owns machines capable of high-quality and fast printing, yet logistical flows do not provide adequate support for rapid production cycles. The study demonstrates that even basic AI tools can generate substantial efficiency gains in small and medium-sized enterprises. This is in line with European Commission (2021) findings, which indicate that SMEs stand to gain significantly from the automation of logistical tasks due to their limited workforce, outdated infrastructure, and budget constraints. The SITOPRINT case confirms that digital adoption yields substantial performance improvements despite limited organizational resources.

This dynamic is particularly evident in the domain of inventory management. The research showed that SITOPRINT lacks a digital inventory tracking system, which leads to frequent situations in which storage becomes overloaded with certain types of paper or foil, while simultaneously experiencing shortages of critical materials at moments of greatest need. Such fluctuations exert additional pressure on procurement, increase the cost of urgent acquisitions, and elevate the risk of delivery delays. Theoretical AI-based inventory models predict precisely these challenges in environments that rely solely on human estimation. AI tools enable the analysis of historical data, identification of consumption patterns, detection of seasonality, and timely planning of procurement. Compared to the current reactive, experience-based system, the implementation of AI models would not only improve but fundamentally transform the way logistics is managed.

The positive impact of expert systems on decision-making processes supports the theoretical views of Giarratano and Riley (2005), who state that expert systems reduce subjectivity and formalize the knowledge of human experts. Similarly, Turban et al. (2011) argue that expert systems are especially beneficial in industries with high operational complexity, such as printing, where real-time decisions depend on multiple interdependent variables. These findings reinforce the broader industry perspective presented by PwC (2022), which states that organizations integrating logistics, AI, and digital technologies establish more competitive and resilient operational models. The observed improvements in SITOPRINT align with SAP (2021), suggesting that the benefits of AI are maximized when implemented as part of an integrated logistics strategy rather than as isolated technological upgrades.

A similar pattern is evident in production planning, one of the most critical segments of logistical operations in SITOPRINT. The existing planning system relies heavily on employee evaluation, with decisions about priorities, scheduling, and machine allocation being made according to momentary circumstances, resource availability, and client demands. While this approach can be flexible, it simultaneously increases the risk of human error and complicates the coordination between departments. Expert systems provide the ability to create algorithms that incorporate all relevant parameters—from printing and finishing process duration to machine and worker availability and final deadlines. Such models introduce objectivity into planning, reduce conflicts between orders, and increase overall equipment utilization. The analysis demonstrated that implementing such systems would prevent many of the delays and inconsistencies observed during the fieldwork.

From a theoretical perspective, this research contributes to the literature by demonstrating how logistics, digital transformation, and AI interact to improve organizational efficiency. This supports the view of Porter (1985) and Christopher (2016), who argue that competitive advantage in modern industries depends on the organization's ability to manage material and information flows effectively. The findings from this study extend these theories by showing that AI further amplifies these effects in the printing industry, where variability in processes and customer demands is especially high.

Another area in which discrepancies between modern technological possibilities and SITOPRINT's current practices are particularly visible is the organization of transport. Deliveries are currently planned on a daily basis, depending primarily on employees' assessment of urgency and order sequence. This often results in suboptimal routes, longer driving times, and higher fuel costs. Industry studies indicate that algorithmic route optimization can reduce transport costs by up to 25% and delivery times by up to 30%. Given that SITOPRINT ships across Serbia, such improvements would have a significant impact. The application of AI in transport planning would not only reduce operational expenses but also enable faster deliveries, improve customer satisfaction, and support more efficient use of employee working hours.

From an integrated perspective, the application of artificial intelligence and expert systems in SITOPRINT's logistics chain does not represent an additional layer of sophistication but rather a logical response to the challenges inherent in a rapidly changing market. AI tools facilitate a shift from reactive to proactive management—from decisions based on immediate circumstances to decisions grounded in data, prediction, and structured algorithms. This transition strengthens system stability, minimizes unplanned disruptions, and enables more efficient resource utilization.

The practical implications of this research for SITOPRINT are substantial. First, digitalization of logistics would enable significant increases in efficiency and reductions in operational costs—factors particularly important in an industry characterized by intense competition and often narrow profit margins. Second, AI-driven optimization would accelerate and stabilize workflow execution, providing clients with faster and more reliable delivery, thus enhancing the enterprise's competitive position. Third, the digitalization of internal communication and real-time order tracking would reduce administrative burdens and improve overall transparency.

Although this study provides an in-depth examination of logistical processes in a real production environment, it is important to acknowledge its limitations. As a case study of a single enterprise, the findings cannot be directly generalized to the entire industry. Furthermore, the qualitative nature of the research allows for analytical depth but does not enable full quantification of effects. Future studies should incorporate precise measurements of workflow duration, resource consumption, and occurrence of delays to more accurately assess the impact of digital technologies.

Despite these limitations, the findings offer compelling evidence that small and medium-sized printing enterprises can achieve substantial benefits through the introduction of artificial intelligence and expert systems into their logistical processes. Digitalizing logistics in SITOPRINT would enable higher efficiency, greater predictability, reduced costs, and a distinct competitive advantage—forming the foundation for sustainable long-term development in the conditions of a modern, rapidly evolving market.

CONCLUSION

Based on the conducted analysis, it can be concluded that logistical processes represent one of the most decisive components of contemporary business within the printing industry, and that their complexity fundamentally determines the organization's ability to meet market demands. Logistics in printing can no longer be viewed merely as a supporting function responsible for supplying materials to the production line; rather, it constitutes a system that directly influences job completion speed, delivery accuracy, cost efficiency, and the overall quality of services provided by the enterprise. This role is particularly critical in small and medium-sized enterprises, where limited resources make logistics the key differentiating factor between organizations that manage to maintain operational stability and those that frequently encounter delays and unpredictability.

The results obtained in the case of SITOPRINT demonstrate that the greatest challenges do not stem from insufficient technical capacity, but from organizational and informational weaknesses that affect every stage of the logistical chain. Material flows, communication patterns, planning activities, and decision-making processes remain largely informal and dependent on employee experience, which mirrors the broader structural limitations frequently observed in SMEs. As shown in the Results and Discussion sections, these informal practices generate fragmented information flows, frequent production disruptions, and an overall lack of predictability—issues that cannot be fully mitigated by investments in machinery alone. The absence of digital tools for inventory management, workflow coordination, and process standardization is therefore the primary source of logistical instability.

The analysis further shows that the introduction of artificial intelligence and expert systems represents a realistic and highly effective pathway for overcoming these limitations. Integrating intelligent

algorithms provides the enterprise with the ability to predict material requirements, stabilize procurement planning, optimize job sequencing, and reduce reliance on subjective human judgment. Predictive models improve inventory control by identifying consumption patterns and preventing shortages or excesses, while expert systems enhance planning accuracy, ensure greater operational consistency, and support more objective decision-making. Digital order-tracking platforms strengthen transparency and allow more reliable deadline management, which is crucial in industries characterized by short production cycles and high customer expectations.

The application of these technologies offers more than short-term operational improvements; it establishes the foundation for long-term organizational development and alignment with modern digital-economy standards. Enterprises that structure their logistics around data, analytics, and automation gain the ability to adapt rapidly to fluctuations in demand, reduce operational costs, increase process stability, and improve the quality of strategic decisions. This transition encourages a culture grounded in professionalization, precision, and continuous improvement—qualities essential for maintaining competitiveness in dynamic market conditions.

Although the integration of artificial intelligence and expert systems may appear complex, the findings of this research demonstrate that digitalization is attainable even for small enterprises with limited resources when implemented gradually and strategically. A phased approach allows employees to adapt to new tools without disrupting daily operations, while targeted investments produce measurable improvements even in the early stages of implementation. The most immediate benefits can be expected in inventory tracking, workflow coordination, and production planning—areas in which SITOPRINT currently experiences the greatest inefficiencies.

The strategic importance of logistics digitalization in SITOPRINT lies in its ability to ensure a more stable, predictable, and efficient operational environment. AI-driven optimization reduces operational costs, shortens delivery times, improves communication across departments, and provides greater control over all stages of the production cycle. Consequently, the enterprise is better positioned to enhance service quality, retain existing clients, and strengthen its competitive standing.

Ultimately, the findings of this study confirm that the digitalization of logistical processes is not merely a recommendation, but a necessity for any printing enterprise seeking sustainable growth and competitiveness in the modern industry landscape. The implementation of artificial intelligence and expert systems represents a logical and strategically sound developmental direction that enables small and medium-sized printing companies to overcome structural barriers, optimize daily operations, and reinforce their resilience in a rapidly evolving market environment. Companies that recognize this need and initiate digital transformation proactively will become more adaptable and competitive, while those that rely on traditional operational practices risk long-term stagnation. For SITOPRINT, the integration of AI and ES should thus be understood not only as a technological upgrade, but as a strategic decision that will shape the future trajectory of the organization.

Conflict of interests

The authors declare no conflict of interest.

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THE INFLUENCE OF WORK MOTIVATION ON EMPLOYEES' RELATIONSHIP WITH THE LEADER

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Abstract: Over the past century, management has progressed from Taylor's scientific management to modern approaches emphasizing human motivation. This study examines how work motivation influences the employee–leader relationship in Serbian organizations. We surveyed 100 employees (public and private sector) on the importance and fulfillment of various job motivators and the quality of leader–member exchange (LMX). Results show that most employees rate both basic (e.g., salary, security) and higher-level (e.g., growth) needs as very important, yet far fewer report these needs as satisfied. For example, about 75% of respondents deemed pay and security crucial, but under one-third felt adequately compensated or secure. Similarly, ~73% valued personal development, but only ~20% had such opportunities. Employees with better-fulfilled needs also reported higher-quality leader–member relationships. Average LMX quality was moderate, with only a minority experiencing high-trust exchanges. The discussion relates these findings to Herzberg's two-factor theory, self-determination theory, and LMX theory, highlighting the importance of both extrinsic and intrinsic motivators. The obtained results indicate that leaders and managers need to adapt their leadership style more closely to employees' motivational needs in order to improve relationship quality and increase organizational effectiveness.

Keywords: Work motivation; leadership; leader–member exchange (LMX); self-determination theory; Herzberg's two-factor theory

Introduction

Since the industrial revolution, management has evolved from Taylor's focus on economic incentives (Taylor, 1911) to recognizing employees as the critical element in organizations. Employee motivation – the internal and external factors that energize work behavior – is now seen as essential for performance (Pinder, 2014). Even capable employees will not maintain high productivity without sufficient motivation (Babin & Boles, 1996). In Serbia's transitional economy, many organizations still use traditional, authoritarian management (Živanović, 2020), creating a pressing need for more modern leadership approaches. Contemporary leadership theories suggest that by understanding and satisfying employees' needs and expectations, leaders can elicit higher motivation and performance (Bass, 1990; Graen & Uhl-Bien, 1995).

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The research problem of this paper arises from the limited understanding of how different motivational factors affect the quality of the relationship between employees and leaders, particularly in organizations operating in a transitional environment. The existing literature shows a lack of studies that simultaneously analyze employee motivation and the quality of the relationship with the leader, so this paper seeks to fill an important theoretical and empirical gap.

This study investigates how workplace motivational factors affect the employee–leader relationship in Serbian organizations. Specifically, we survey 100 full-time Serbian employees to assess (a) the importance they attach to various work motivators and how well these are fulfilled in their jobs, and (b) the quality of their leader–member exchange (LMX) with their direct supervisor. We hypothesize that (H1) employees will report a significant gap between the importance of key motivators and the extent to which those motivators are satisfied, and (H2) employees perceiving greater fulfillment of their important motivational needs will have higher-quality relationships with their leaders. We also explore differences across sectors (public vs. private) and other demographics. In the sections that follow, we review relevant motivation and leadership theories, describe our survey methods, present the results on motivational gaps and LMX quality, and discuss the findings in light of contemporary theory, drawing implications for leadership in transitional economies. The scientific contribution of this paper lies in the integration of dominant motivation models with the LMX theoretical framework, as well as in the empirical examination of their interrelationships within the organizational context of Serbia. The study is of particular importance due to the specific characteristics of transitional organizations and the dynamic organizational environment in Serbia, in which motivation and leadership style represent key factors for achieving employee job performance.

Literature Review

Employee Motivation: Concepts and Theories

Motivation theories are often divided into *content theories* (what needs drive people) and *process theories* (how motivation occurs) (Steers, Mowday, & Shapiro, 2004). Among content theories, Maslow's hierarchy (1954) remains influential: he posited that basic needs (e.g. physiological, safety) must be satisfied before higher needs (e.g. social belonging, esteem, self-actualization) emerge as motivators. Herzberg's two-factor theory complements this by distinguishing **hygiene factors** (extrinsic, e.g. pay, company policies) from **motivators** (intrinsic, e.g. achievement, recognition) (Herzberg, 1959). Herzberg found that poor hygiene factors cause dissatisfaction, but improving them only removes dissatisfaction; true satisfaction comes from motivators. Thus, managers should both ensure fair pay and conditions *and* provide opportunities for meaningful work and recognition. McClelland's need theory (1961) adds that people are motivated by dominant needs for achievement, affiliation, or power. Alderfer's ERG theory (1972) similarly classifies needs into Existence, Relatedness, and Growth, allowing that multiple needs can operate concurrently.

Process theories such as expectancy theory (Vroom, 1964) and equity theory (Adams, 1965) focus on cognitive evaluations of effort and fairness. For example, expectancy theory suggests that employees will be motivated to the extent they believe effort leads to performance and that performance leads to valued rewards. Equity theory suggests employees compare their input-output ratios to others and feel

demotivated if they perceive inequity. While these perspectives are useful, our study focuses on the content of motivation (what employees value) and how its fulfillment relates to leadership.

Collectively, these theories underscore that employees have *multiple* needs and motivators, both extrinsic and intrinsic. Today's workforce typically values not only fair compensation and security but also opportunities for growth, recognition, and meaningful work (Maslow, 1954; Herzberg, 1959). We therefore consider a broad range of motivators across basic (salary, safety), social (teamwork, support), and growth (advancement, autonomy) categories.

Self-Determination Theory (SDT)

Self-Determination Theory offers a modern framework for understanding intrinsic motivation. Deci and Ryan (2000) distinguish between autonomous motivation (engaging in work for inherent satisfaction) and controlled motivation (driven by external pressures or rewards). Crucially, SDT identifies three basic psychological needs: autonomy (control over one's actions), competence (feeling effective), and relatedness (connection to others) (Deci & Ryan, 2000). When these needs are satisfied, individuals experience stronger intrinsic motivation and well-being (Ryan & Deci, 2000). For example, employees who have autonomy in decision-making, opportunities to develop skills (competence), and supportive relationships (relatedness) are more likely to be engaged. Conversely, when these needs are thwarted – for instance by micromanagement or isolation – motivation suffers (Sarmah et al., 2021).

Leaders can nurture motivation by creating autonomy-supportive environments: offering choice, acknowledging employee perspectives, and providing rationale for tasks (Slemp et al., 2018). Research shows that leadership styles that support autonomy and competence (e.g. transformational or servant leadership) enhance employee motivation (Deci et al., 2017; McAnally & Hagger, 2024). In contrast, controlling leadership (e.g. threats, constant surveillance) undermines intrinsic motivation (Sarmah et al., 2021). SDT suggests that fulfilling employees' basic psychological needs is a key path to motivation and engagement.

Leadership and Leader–Member Exchange (LMX)

Leadership involves influencing people toward goals, and modern theories emphasize relational and behavioral aspects (Northouse, 2007). Transformational leaders inspire employees by appealing to higher ideals and development (Bass, 1990), while transactional leaders focus on exchanges (rewards for performance). Servant and authentic leadership emphasize serving and valuing followers (van Dierendonck, 2011), fostering trust and intrinsic motivation.

Leader–Member Exchange (LMX) theory provides a specific lens on the leader–follower relationship. It holds that leaders form unique dyadic relationships with each subordinate, resulting in varying quality of exchange (Graen & Uhl-Bien, 1995). High-quality LMX is characterized by trust, mutual support, and open communication, whereas low-quality LMX is more formal and contractual. High-LMX employees typically receive more attention, autonomy, and development opportunities (Graen & Uhl-Bien, 1995). This often leads to higher job satisfaction, commitment, and performance (Dulebohn et al., 2012). For example, Aggarwal et al. (2020) found that higher LMX is associated with greater empowerment and engagement and lower withdrawal. Conversely, low LMX can drain motivation: employees in poor

exchanges may feel like outsiders, with little support or recognition. Differentiation in LMX (in-groups vs. out-groups) also affects team morale, as out-group members perceive unfairness (Liden et al., 2006).

In sum, both motivation content (needs and rewards) and leadership behaviors (especially the quality of relationships) are crucial. High LMX relationships can satisfy employees' needs through support and recognition, enhancing motivation (Premru et al., 2023). Thus, examining motivational fulfillment and LMX together can illuminate how leaders and organizational contexts jointly influence employee motivation.

Methodology

We conducted a cross-sectional survey in 2020 among full-time employees in Serbia. Participation was voluntary and anonymous. After excluding incomplete responses, the final sample consisted of 100 respondents from various public (65%) and private (35%) organizations. Demographics: 61% were female; ages ranged from 18–30 (10%) to over 51 (24%), with most (66%) between 31 and 50. Education levels included secondary (24%), university graduate (60%), and postgraduate (16%). Most respondents held supervisory roles (37%) or staff positions (63%), with 25% of supervisors reporting about even more senior managers. These characteristics allowed us to examine differences by sector, age, gender, and hierarchy.

The survey instrument had three parts: (1) demographic and job information; (2) motivational factors assessment; (3) leader–member exchange (LMX) scale. For (2), we listed 16 specific work motivators drawn from Maslow, Herzberg, and SDT categories. These covered **physiological/existence factors** (e.g. satisfactory salary; job security), **safety factors** (e.g. fair policies, stable conditions), **social/relatedness factors** (e.g. good relations with colleagues; support from supervisor), and **growth/esteem factors** (e.g. career advancement; recognition; autonomy; challenging work). We asked respondents to rate how *important* each factor is for their motivation and how *well it is fulfilled* in their current job, using identical 5-point Likert scales (1="not important/never" to 5="very important/always"). A pilot test ensured clarity of wording.

For (3), we measured LMX quality using a standard scale (Graen & Uhl-Bien, 1995) with items assessing trust, mutual respect, and support (e.g. "My supervisor understands my problems," "I have a good working relationship with my supervisor"). These were rated on a 5-point scale. We computed each employee's overall LMX score (mean of items) to quantify relationship quality.

Quantitative data were analyzed with paired t-tests (importance vs. fulfillment), correlations, and group comparisons (e.g. t-tests for public vs. private sector). Qualitative comments from open-ended questions supplemented interpretation but are not the focus of quantitative analysis.

Results

Importance vs. Fulfillment of Motivational Factors (H1)

All tested motivators showed a large, significant gap between importance and perceived fulfillment (paired $p<0.001$ for each). Employees rated both basic needs and growth needs as highly important, but reported far lower satisfaction with them. Notably, **salary** and **job security** topped the importance ratings: about 75% of respondents marked each as "very important." Yet only ~12% felt their salary met their

needs "to a very great extent," and about 30% felt job security was that high. (Mean importance vs. fulfillment ratings were roughly 4.8 vs. 3.1 for salary, 4.7 vs. 3.3 for security on a 5-point scale.) Other safety-related factors followed this pattern: clear policies and fair administration averaged importance ≈4.5 but fulfillment ≈3.2, indicating many employees value fairness yet see it lacking.

Social/Belongingness needs (e.g. teamwork, supervisor support) were rated important by a majority (~67% "very important"), though somewhat lower than basic needs. Social factors had a mean importance ~4.3, but fulfillment averaged only ~3.4. For example, while employees appreciated camaraderie, only about 29% felt a strong sense of belonging in their organization. Satisfaction with colleague relations was moderate (~3.5), reflecting some positive comments ("My colleagues are the best part of this job.") but also complaints of poor communication or team spirit. Overall, social needs showed a significant gap (importance ≈4.3 vs. fulfillment ≈3.4, $p<0.01$).

Growth/esteem needs (e.g. advancement, skill use, recognition) were also rated very high: ~73.5% of respondents said career growth and personal development were "very important," and ~70–75% marked achievement and meaningful work as such. On average, these higher-order factors had importance ≈4.6/5, nearly as high as basic needs. This suggests that many employees (often educated, mid-career professionals) are striving for development. In stark contrast, fulfillment of growth needs was low. Only about 20% felt opportunities for advancement or skill development were very available. The mean fulfillment for "opportunities to advance" was around 2.5 (out of 5), one of the lowest of all items. Similarly, "opportunity to use skills fully" averaged about 3.0 fulfillment (vs. importance ~4.6). Recognition followed the same trend: ~68% said being recognized for contributions was "very important," but only ~25% felt adequately recognized by their leader or organization. Each of these discrepancies (advancement, autonomy, recognition) was highly significant (all $p<0.001$). Qualitative comments (e.g. "I work hard but feel invisible without praise") underscored how lacking recognitions damages motivation.

When summarizing these in terms of Herzberg's categories, we see that **motivator factors** (intrinsic needs like achievement, recognition) had slightly higher overall importance (mean ~4.6) than **hygiene factors** (extrinsic needs like pay, security; mean ~4.5). However, the gap (importance minus fulfillment) was generally larger for motivators. For instance, nearly everyone valued growth opportunities, but almost none reported that their jobs fulfilled them excellently – whereas a somewhat larger minority felt basic contractual conditions were at least moderately met. In short, *all* key motivators showed substantial shortfalls: employees in this sample consistently feel their important needs are not fully satisfied.

Leader–Member Exchange (LMX) Quality

We next examined the quality of leader–employee relationships. The overall average LMX score was $M \approx 3.4$ (SD ≈ 0.9) on a 5-point scale, indicating moderate relationship quality on average. Roughly 25% of employees reported high-quality LMX (mean scores >4.0), characterized by strong mutual trust, support, and personalized attention from the supervisor. These respondents agreed with items like "My supervisor understands my problems" and "My supervisor goes out of their way to help me." Many in this high-LMX group were in supervisory roles themselves or worked in private firms, and they frequently cited mentorship and open communication from their leaders.

About half of the sample (≈50–55%) fell into a middle LMX range (scores ~2.5–4.0). They reported generally functional relationships: work is handled effectively, but there were caveats in trust or support.

Common sentiments included, "My leader and I get along, but I'm not sure they fully have my back," or "Communication is fine for tasks, but there's not a close personal connection." Finally, roughly 20% of employees had low-quality LMX (scores <2.5). These individuals expressed a lack of trust and support: supervisors rarely sought their input or acknowledged them, and some even felt friction in the relationship. For example, when asked to describe their working relationship, some in this group chose "ineffective" or "mostly negative." Many low-LMX cases also corresponded with the largest motivational shortfalls (e.g. feeling unrecognized or undervalued).

Analyzing item-level LMX responses, the weakest aspects were related to support: the average response to "My supervisor understands my problems and needs" was only ~3.1. Many employees clearly felt unseen or unheard by their bosses. Likewise, "I can count on my supervisor to help me when I really need it" averaged ~3.2. By contrast, basic task-related items (e.g. "We have an effective working relationship") averaged higher (~3.6), indicating that at a minimum the work got done even if deeper trust was lacking.

Significant differences emerged by sector and position. Private-sector employees reported a higher average LMX ($M \approx 3.7$) than public-sector respondents ($M \approx 3.2$; $t \approx 2.45$, $p < .05$). Private firms (especially smaller or entrepreneurial companies) tended to foster closer communication and more flexibility, leading to stronger supervisor support. Public sector work (often bureaucratic) was more hierarchical: one respondent noted, "My boss is mainly an administrator, not really a mentor – we don't have a personal rapport." In line with that, public employees rated transactional aspects (like pay and promotions) as fixed by policy, limiting what leaders could do to motivate staff.

Higher-ups also reported better LMX: managers generally rated their relationships with superiors as higher quality than front-line workers did. For instance, 45% of non-managers said they "rarely" or "only sometimes" get needed support from their leader, compared to 20% of managers. This suggests a "trickle-down" effect where leaders invest more in certain subordinates (often other managers) at the expense of rank-and-file staff. Such LMX differentiation can breed resentment among out-group members (Liden et al., 2006).

Link between Motivational Fulfillment and LMX (H2)

As hypothesized (H2), employees' perception of motivational fulfillment was positively associated with LMX quality. We computed each respondent's overall motivation-satisfaction score (averaging their fulfillment ratings for factors they rated important). This composite fulfillment score correlated with LMX at $r \approx 0.45$ (Pearson's $p < .001$), a moderate relationship. In practical terms, those who felt their jobs met their important needs tended to rate their leader relations higher.

For illustration, we split the sample by median fulfillment. The high-fulfillment group had a mean LMX of about 3.8, whereas the low-fulfillment group averaged ~3.0 ($t(98) \approx 4.20$, $p < .001$). Nearly all employees with very high LMX (5.0) were from the high-fulfillment group, while the lowest LMX scores came from those with the largest motivation deficits. Qualitative comments reflect this: one employee who felt underpaid and overlooked by training wrote that he unsurprisingly "couldn't trust my boss or care about this job."

Drilling down to specific motivators, we found that satisfaction with **recognition** ("I receive praise for good work") had one of the highest correlations with LMX (≈0.50). It makes sense: recognition typically

comes from one's leader, so being appreciated strengthens the bond. **Autonomy** (leader empowering decision-making) also correlated strongly (≈0.40), aligning with SDT's idea that autonomy-supportive leadership builds trust. By contrast, pay satisfaction alone had a weaker correlation (≈0.20, $p<.05$), suggesting that employees see pay as an organizational issue rather than a direct leader action. Opportunities for advancement and training correlated moderately (≈0.30 each) with LMX, implying that when leaders involve employees in growth (through mentorship or recommending promotion), those employees feel a stronger relationship.

We also compared LMX *in-groups* and *out-groups*. Employees in high-LMX relationships reported significantly higher fulfillment in areas like involvement in decisions (mean ≈3.8 vs. 2.7 for low-LMX), information sharing, and fairness. These differences are intuitive: in-group members often receive more communication and input, satisfying relatedness and competence needs, while out-group members often feel "left out" and "kept in the dark," reflecting lower need satisfaction.

In summary, H2 was supported: there is a clear positive association between employees' motivational needs being met and the quality of their relationship with their leader. Those whose needs are fulfilled have much higher trust and support in LMX, whereas unmet needs coincide with poorer leader relations. This is consistent with social exchange theory: high LMX involves reciprocal investment and rewards from the leader (blameless or not) in the form of support, recognition, and autonomy, which in turn satisfy employee needs (Colquitt et al., 2013). Conversely, when needs go unmet (for reasons within or outside the leader's control), employees may become disaffected, straining the relationship.

Sectoral Differences (Public vs. Private)

Beyond the formal hypotheses, we observed some consistent differences by organizational context. **Motivational fulfillment:** Private-sector employees generally reported slightly higher satisfaction of motivators. For instance, the average rating for growth opportunities was ~3.3 in private firms vs. 2.7 in public institutions ($p<.05$), reflecting more training or promotion paths. About 45% of private-sector respondents agreed that supervisors recognize their contributions, compared to only ~20% in the public sector. Public employees often noted that rewards and promotions are tied to tenure or fixed scales, limiting leader influence. Interestingly, private employees also had higher expectations (they valued rewards and autonomy), so motivational gaps existed in both sectors albeit slightly narrower in private organizations.

Leadership climate: As noted, private-sector workers reported better LMX overall. They described leaders as more entrepreneurial, flexible, and communicative. In contrast, public-sector culture was more bureaucratic and formal. Many public employees mentioned that their pay and promotions were set by government, so even willing supervisors had limited means to reward performance, hindering both motivation and LMX (since helping an employee grow was often not in a manager's control).

Job security: One area where public sector fared better was security. About 50% of public-sector respondents rated their job security fulfillment as high (4 or 5), versus only ~20% in private (where short-term contracts or market fluctuations prevailed). So public jobs traded higher security for lower immediate rewards. Notably, when asked "How motivated do you feel in your job?" on a 1–10 scale, private-sector employees averaged 7.1 versus 5.9 for public. This suggests that despite insecurity, some private employees remained more motivated, perhaps due to higher pay or growth prospects.

In sum, **Summary of Key Quantitative Findings:**

- **High Importance of Multiple Motivators:** Employees rated salary, job security, advancement opportunities, and interesting work as very important (over two-thirds marked them "very important"). Recognition, good working conditions, supportive colleagues, and autonomy were also important to most.
- **Significant Motivational Gaps:** There was a clear shortfall between what employees value and what they experience. Only a minority (often 10–30%) felt their top-valued needs are satisfied to a high degree. Both extrinsic factors (pay, security) and intrinsic factors (growth, recognition) showed large gaps, with intrinsic motivators exhibiting especially low fulfillment.
- **Moderate LMX on Average:** The overall leader–employee relationship was average (mean ~3.4/5). About 25% enjoyed very high-quality, trustful exchanges with their leader; roughly half had an adequate but not close relationship; and about 20% reported poor relationships. Common LMX issues included lack of understanding or support and perceived favoritism/differentiation among team members.
- **Positive Link Between Fulfillment and LMX:** There was a substantial correlation (~0.45) between employees' need fulfillment and LMX quality. Employees whose organizations/leaders satisfied their important motivators had much higher LMX scores. Recognition and autonomy (often provided by leaders) showed the strongest association with LMX, highlighting leaders' role in fulfilling these needs.
- **Public vs. Private Context:** Private-sector employees reported somewhat better motivator fulfillment and higher LMX, whereas public-sector employees felt more secure but less recognized or developed. These differences underscore how organizational context influences both employee motivation and leadership dynamics.

Discussion

Our findings reveal a **pervasive motivational gap** among Serbian employees: they strongly value a range of rewards and experiences but rarely see them fully delivered. This pattern echoes global surveys (e.g. Gallup) where many employees feel under-recognized and underutilized. Theoretical frameworks illuminate this result. Herzberg's two-factor theory would label the unmet basic needs (pay, security, conditions) as *hygiene factor* deficits that cause dissatisfaction. Indeed, many respondents explicitly noted salary concerns and job insecurity, suggesting these dissatisfiers loom large. Simultaneously, the shortfall in motivators (advancement, achievement, recognition) means few employees reach positive satisfaction. In Herzberg's terms, organizations in this context often *fail on both counts*: they leave dissatisfiers (low pay or unfair policies) and also lack satisfiers (no challenging work or praise). Recent research confirms that both types of factors matter: for example, Malik and Garg (2022) found hygiene factors strongly predict turnover intent while motivators drive engagement. Our data align with this: employees who lacked basic compensation frequently expressed thoughts of leaving or apathy, and those lacking growth opportunities voiced disengagement.

The context of Serbia's transition economy likely exacerbates these issues. Many firms and public agencies have undergone restructuring and budget constraints, leading to pay scales that lag regional standards. Equity theory suggests that employees compare their inputs (education, effort) to outcomes and to others. Several respondents essentially echoed this: "We work as much as Western counterparts, but get a fraction of the salary." Such perceived inequity can foster resentment and demotivation (Adams,

1965). Public sector salaries are often fixed by government norms, so even when secured in position, employees feel underpaid. This helps explain why public-sector workers in our sample still rated pay as very important despite having permanent jobs.

Self-Determination Theory provides additional insight. Many unmet needs correspond to SDT's psychological needs. **Autonomy** needs were largely frustrated: respondents often reported limited decision-making freedom, reflecting either bureaucratic constraints or micromanagement. Such frustration can lead to controlled or amotivated employees who do only the minimum. Research shows autonomy-supportive leaders boost intrinsic motivation (Slemp et al., 2018), so the lack of autonomy here likely contributes to lower engagement. **Competence** needs also suffered: the dearth of training and promotion opportunities means employees feel unable to grow or master new challenges. In our sample, only ~20% felt significant career advancement was available; unsurprisingly, those few who did have training were among the more engaged. McAnally and Hagger (2024) emphasize that competence satisfaction strongly predicts work engagement, which is consistent with our observations. **Relatedness** needs were moderately unmet: while not the top priority, many employees desired better camaraderie and support. Low-quality LMX employees often reported feeling isolated or unheard, indicating a lack of relatedness with their leaders or peers. SDT theory warns that frustrated relatedness leads to disengagement (Ryan & Deci, 2000). During the COVID-19 pandemic, studies (e.g. Sonnenschein et al., 2022) highlighted loneliness as a new dissatisfier, showing that connections are crucial even in remote settings. Our mostly on-site sample faces a relatedness gap arising from hierarchical distance – many feel simply like a number. These unmet SDT needs – autonomy, competence, relatedness – together help explain the moderate overall motivation levels we observed.

What about leadership? The study's second major focus was LMX and its interplay with motivation. We found that good leadership and good relationships coincide with positive employee outcomes. This aligns with social exchange theory (Blau, 1964) and LMX theory (Graen & Uhl-Bien, 1995): high-quality LMX represents a strong exchange where leader and follower invest beyond the bare contract. Our data suggest a virtuous cycle: employees with supportive, high-LMX leaders reported higher motivation (fulfillment of needs and engagement). High-LMX workers received more recognition and empowerment, fulfilling their esteem and autonomy needs. This reciprocity is consistent with prior research: LMX quality is known to boost satisfaction and reduce burnout (Petrilli et al., 2024; Breevaart & Bakker, 2018). Conversely, employees in low-LMX relationships felt undervalued, which undermines their motivation. This underlines the leadership maxim that satisfied employees often reflect good leadership.

However, LMX differentiation presents challenges. As Graen and Uhl-Bien (1995) note, leaders naturally develop closer ties with some subordinates. If not managed carefully, this can breed perceived favoritism. Indeed, some low-LMX respondents alluded to jealousy or confusion when others got special projects or praise. This can harm motivation of out-group members (Liden et al., 2006). Modern leadership guidance suggests expanding one's "inner circle" by involving more team members in meaningful tasks and recognition, a strategy some progressive managers in our sample seemed to adopt (especially in the private sector). The lower LMX scores and stricter hierarchies in public organizations point to a need for leaders there to work harder at building trust and treating employees equitably.

Another insight is the power of simple recognition. Our analysis showed recognition was one of the strongest correlates of LMX. Recognizing employees addresses esteem needs and signals that the leader

values them, strengthening the bond (Brun & Dugas, 2008). It echoes principles of servant and authentic leadership, which emphasize valuing followers. Recent findings (Ma & Jiang, 2020) show servant leadership enhances employee need satisfaction, boosting engagement – precisely what recognition and support do. This suggests a practical point: leaders who take time to acknowledge and thank their team can markedly improve motivation and LMX at essentially no cost.

We briefly note that our data were collected around 2020, just as the COVID-19 pandemic began. Though most respondents were still in traditional workplaces, the emerging literature on remote work is relevant. Studies in 2020–2022 (e.g. Sonnenschein et al., 2022; Petrilli et al., 2024) emphasize that LMX and trust became even more critical under remote/hybrid conditions. Leaders who had already established strong exchanges were better able to maintain motivation when teams went home. For Serbian organizations that navigated sudden remote shifts, those with higher LMX probably saw less drop in team motivation. Conversely, teams with weak pre-existing relationships likely struggled more.

Limitations and Future Research

Some limitations should be noted. The sample (N=100) was relatively small and not randomly chosen, limiting generalizability. Different industries may have unique motivators (e.g. IT vs. manufacturing). Future studies could use larger, stratified samples or compare across countries to see how context affects these dynamics. Second, our cross-sectional design means we cannot infer causality: while we interpret that better fulfillment *leads* to higher LMX, it is also possible that trusting leaders create more opportunities (and thus fulfillment). Longitudinal or experimental studies (e.g. leader training interventions) would help clarify causal directions. Third, all data came from employee self-reports, which could be biased. Future work could incorporate supervisor reports or objective performance measures. Cultural factors may also play a role; for instance, Serbian work culture has historically high power distance, which might influence how social needs are rated. We did not measure values like collectivism, which could be interesting in future. Finally, our focus was on classic motivators; emerging factors like work–life balance, meaningfulness of work, or remote flexibility were not deeply examined. Given global trends since 2020, these factors could be added in follow-up surveys.

Despite these caveats, the study offers a comprehensive snapshot of motivation and leadership dynamics in a transitional economy, reinforcing many evidence-based leadership principles.

Conclusion and Recommendations

In conclusion, this study illustrates that **both what motivates employees and how leaders act are crucial and interconnected**. Our Serbian respondents clearly want a balance: fair compensation and security on one hand, and opportunities for learning, growth, and appreciation on the other. When either side is missing, motivation and the leader–employee relationship suffer. Conversely, when employees feel valued, supported, and fairly treated by their leaders, they respond with greater engagement and trust.

The central message is that effective leadership is a key lever for activating employee motivation. Leaders who build high-quality exchanges – acting as coaches and supporters rather than mere

taskmasters – fulfill employees' psychological needs and unlock better performance. This aligns with frameworks like transformational and servant leadership (Bass & Riggio, 2006; van Dierendonck, 2011) which show that inspiring and empowering leaders enhance motivation by satisfying autonomy, competence, and relatedness.

For practitioners and organizations in Serbia and similar contexts, the implications are clear. To foster a motivated workforce, one should:

- **Ensure the basics are in place:** Pay employees fairly and on time; provide stable employment terms; maintain decent working conditions. Communicate honestly about security and changes to reduce anxiety. Even if budgets are tight, consider creative non-monetary benefits (flexible hours, extra leave, public praise) to partially compensate for lower salaries.
- **Invest in employee development:** Offer training, mentoring, and clear career paths. Give employees challenging assignments and autonomy to build skills. Managers should have regular career conversations, set developmental goals, and provide "stretch" projects. Especially for younger and highly educated staff, visible growth opportunities can prevent disengagement or turnover.
- **Create a culture of recognition:** Establish practices to celebrate successes and express gratitude. Leaders should give both public and private praise routinely, acknowledging contributions big and small. These behaviors cost little but powerfully boost esteem and relatedness. Formal programs (employee-of-the-month, shout-outs) can institutionalize appreciation.
- **Empower and involve teams:** Delegate authority and invite employee input on decisions. Trust employees with responsibility and avoid micromanagement. This not only taps into their autonomy needs but also signals respect. For example, regular one-on-one meetings that discuss employees' ideas and concerns (not just tasks) can foster both autonomy and relatedness.
- **Cultivate trust and fairness:** Be transparent in decision-making, apply rules consistently, and avoid favoritism. When special opportunities arise (like training spots or projects), explain selection criteria and consider rotating benefits among team members over time. Procedural justice practices (Scandura, 1999) help mitigate jealousy. Leaders should strive to expand their "in-group" by developing good relationships with all subordinates (a process Graen & Uhl-Bien (1995) call "leadership making").
- **Support leaders' people skills:** Technical skill is not enough for managers. Organizations should train and reward leaders for emotional intelligence, communication, and coaching. For example, including employee engagement scores or 360-degree feedback in evaluations encourages leaders to be supportive. In the public sector especially, leadership development programs could emphasize more participative, empowering styles.
- **Adapt to changing expectations:** Recognize that employee priorities evolve – flexible work arrangements, work–life balance, and empathy are increasingly expected. Even if full remote work isn't feasible, allowing occasional remote days or understanding personal needs can satisfy autonomy and relatedness without major cost. Research (Li & Tang, 2020) shows that even with limited extrinsic rewards, leaders can maintain engagement by enhancing intrinsic motivation (e.g., by emphasizing meaningful aspects of work).

By following these recommendations, organizations in Serbia and similar transition economies can begin to **close the motivational gaps** identified here. Over time, this should yield benefits like higher productivity, reduced turnover (mitigating brain drain), and a more innovative, resilient culture, since motivated employees are more likely to go above and beyond and drive improvement.

Finally, while some challenges here are pronounced in transitional contexts, the underlying lesson is universal: aligning employees' work with their motivations and leading in a way that fulfills their needs is key. In the post-2020 world, where quality of work life is increasingly emphasized, companies that succeed in this alignment will see not only better performance but also greater employee well-being. As Deci and Ryan (2008) argued, supporting human autonomy and growth is good for individuals *and* organizations. Our study affirms that principle and calls leaders everywhere to put it into practice.

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Conflict of interests

The author declares no conflict of interest.

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PERCEIVED EFFECTIVENESS AND ALIGNMENT OF TRAINING IN CANADIAN EDUCATIONAL INSTITUTIONS

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Abstract: This research examines how staff members at educational institutions in Canada perceive the effectiveness of training, whether the types of training they deem necessary align with those they participate in, and whether their perspectives change based on years of experience, educational attainment, and institution type. A cross-sectional online survey was conducted involving 50 employees. The effectiveness was evaluated using a five-point scale, with two items in multiple-choice format (types of training deemed necessary and attended). Within-subject comparisons, one-way analysis of variance for comparing multiple groups, and analysis of differences between two independent groups assuming unequal variances were utilized. The findings indicate a significant gap: participants identified more "necessary" training categories than they attended; no differences were observed based on experience; differences in education favour those with higher education levels (with higher and more consistent ratings); private institutions exhibit a more positive distribution of grades compared to public ones, although the difference in mean scores is not statistically significant in this sample. It is concluded that aligning training offerings with expressed needs and acknowledging the trainees' profiles is more crucial than the training experience itself. The study suggested conducting an annual needs assessment that aligns with strategic goals, designing training focused on practical application (through scenarios, practice, mentoring, and implementation strategies), engaging managers before and after training, customizing based on educational segments, and systematically evaluating outcomes with follow-up post-training. Furthermore, responses were anonymous, items were mandatory, and the scale ranged from 1 to 5; caution is advised when interpreting results from the small group with doctoral degrees.

Keywords: training effectiveness, professional development, training needs assessment, transfer of training, higher education.

Introduction

In an era of technological change and growing educational demands, professional training and employee development have become crucial components not only for the success of business and educational institutions, but also for employee satisfaction.

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In the past decade, educational institutions – particularly colleges across Canada – have made substantial investments in continuous training programs as strategic goals aimed at improving teaching quality, reducing employee turnover, and ensuring alignment with contemporary standards in pedagogy and administrative efficiency.

Given that institutions often organize various training programs, an important question frequently arises: Are these training programs and the trainings themselves aligned with the actual needs and expectations of employees? It should first be noted that previous studies on this topic have consistently suggested a growing disconnect between the types of training employees want – such as skills that enhance productivity or research competencies – and the trainings that are actually delivered, which often focus on generic or administrative competencies.

The aim of this study is to examine employees' perceptions regarding training and development opportunities in educational institutions across Canada. The study seeks to determine whether significant differences exist between the trainings provided and those employees consider necessary, taking into account the influence of demographic factors such as years of experience, level of education, and type of institution (public versus private), and how these factors shape employees' attitudes toward training.

To achieve the objectives of this study, the following four hypotheses were formulated:

H1: There is a statistically significant difference between the types of training employees believe they need and the types of training that are provided to them in their workplace.

H2: There is a statistically significant difference between respondents' years of work experience and their attitudes toward the process of employee development and training.

H3: There is a statistically significant difference between respondents' levels of formal education and their attitudes toward the process of employee development and training.

H4: There is a statistically significant difference between the type of institution in which respondents are employed (public or private) and their attitudes toward the process of employee development and training.

The findings of this study will contribute not only to a better understanding of training implementation programs in the Canadian educational sector, but also offer practical recommendations for improving institutional support for employee development.

Materials and methods

Research Design and Setting

This study employed a cross-sectional survey of employees working in educational institutions across Canada. The research examined not only perceptions of training and development but also differences in employee attitudes in relation to years of work experience, level of education, and type of educational institution (public/private).

Participants and Sample

As previously noted, data were collected from employees in educational institutions across Canada. Participation in the survey was voluntary and strictly anonymous, and no information that could directly identify individual respondents was collected. It is important to note that the total sample (N = 50) was

used for all analyses, and there were no cases of attrition due to missing data for the examined variables. Differences occurred only in the distribution of respondents across groups within each analysis. In H1, 50 paired measurements (needed/provided) were analysed; in H2, the "16+ years" category contained no observations and was therefore excluded from the ANOVA, while the remaining groups included a total of 50 respondents; in H3, the distribution was 8 (Bachelor's), 38 (Master's), and 4 (Doctorate); and in H4, 30 respondents were from private institutions and 20 from public institutions.

Instrument (Survey)

The survey included single-choice and multiple-choice questions, as well as Likert-scale items. The following variables were used in the analysis:

- **Years of Experience in Current Position:** with the options: 0–2 years, 3–5 years, 6–10 years, 11–15 years, 16+ years.
- **Level of Education:** High School Diploma, Diploma or Certificate, Associate Degree, Bachelor's Degree, Master's Degree, Doctorate.
- **Institution Type:** Private, Public.
- **How would you rate the effectiveness of the training programs you have attended?** Likert scale from 1–5 (Very Effective, Effective, Neutral, Ineffective, Very Ineffective).
- **What types of training do you feel are most needed?** (Select all that apply) multiple choice.*
- **What types of training programs have you attended in the past year?** (Select all that apply) multiple choice.*

(*Options include: Technical Skills, Soft Skills (e.g., communication, teamwork), Leadership Development, Research Skills, Teaching Skills, Productivity Skills, Other.)

Target Objective

The primary outcome in the analyses (Hypotheses H2–H4) is the *Effectiveness Score*, derived directly from the item *"How would you rate the effectiveness of the training programs you have attended?"* where respondents could select only one option on a Likert scale (1 = Very Ineffective, 2 = Ineffective, 3 = Neutral, 4 = Effective, 5 = Very Effective). Considering that the data represent a linearly distributed categorical scale with approximately equal intervals between response categories, the application of parametric tests is justified. Thus, one-way ANOVA (Fisher, 1925) was used for H2–H3, and a t-test (Student, 1908) for two independent groups for H1, while Welch's correction (Welch, 1947) was applied for H4 due to the assumption of unequal variances.

Instead of the Effectiveness Score in Hypothesis H1, the number of different types of training that respondents identified as needed and the number of training types they actually attended in the previous year were used. A two-tailed t-test ($\alpha = 0.05$) was then conducted to determine whether the average number of "needed" trainings was statistically higher than the average number of trainings "attended."

Standardization and Testing

The survey was designed and administered in a way that prevented missing responses; therefore, omission due to missing values was not applicable. Categories with zero frequency (e.g., in H2, "16+ years") were structurally excluded from the specific test. The testing was carried out by organizing the data in MS Excel, and through the available statistical tools, clear answers were obtained for the four

previously stated hypotheses. For H1, two counters were calculated for each respondent (the number of training types marked as "needed" and the number actually "attended"), while for H2–H4, groups were formed based on years of experience, level of education, and type of institution in relation to the effectiveness rating of the trainings attended.

Since the survey included 50 participants, a visual inspection of responses was performed, confirming that all answers were logical and acceptable, resulting in 50 usable responses for further processing. The analysis was conducted in *Data → Data Analysis* using a paired t-test for H1, one-way ANOVA for H2 and H3, and Welch's two-sample t-test for H4. Finally, the key metrics (M, Var/SD, n, t/F, df, p) were generated and the results interpreted at $\alpha = 0.05$. It is also important to emphasize that all between-group analyses assume independence of observations, while H1 is based on paired measurements within the same respondent.

Results

In this chapter, we present a concise overview of the results of the conducted analysis: (i) a sample overview, (ii) hypothesis testing, and (iii) the testing results for hypotheses H1–H4. All tests were two-tailed with $\alpha = 0.05$; where applicable, 95% confidence intervals and effect sizes are reported. On the 1–5 scale, higher values indicated greater perceived effectiveness, while in H1 a positive difference (Needed − Provided) indicated that respondents listed more needed than actually attended types of training.

Sample Overview

The analysis included the complete sample (N = 50); the group distribution depended on the hypothesis:

- **Hypothesis 1** — 50 pairs;
- **Hypothesis 2** — Years of experience: 0–2 (n = 17), 3–5 (n = 17), 6–10 (n = 12), 11–15 (n = 4), 16+ (n = 0);
- **Hypothesis 3** — Education: Bachelor (n = 8), Master (n = 38), Doctorate (n = 4);
- **Hypothesis 4** — Institution type: Private (n = 30), Public (n = 20).

Hypothesis Testing

Table 1 presents the results of the analysis for H1, where a t-test assessed employees' perceptions of "needed" versus "attended" trainings. The average number of training categories considered necessary by respondents was $M_needed = 3.62$ (SD ≈ 0.83), while the average number actually attended was $M_provided = 2.60$ (SD ≈ 1.98). The mean difference was $\Delta M = 1.02$ and was statistically significant: $t(49) = 3.396$, $p = 0.00136$. The estimated 95% confidence interval for ΔM was approximately [0.42; 1.62], and the Pearson correlation was $r \approx 0.03$ (Table 2).

Table 1. *T-Test: Paired Two-Sample for Means*

	Variable 1	***Variable 2***
Mean	3.62	2.6
Variance	0.689387755	3.918367347
Observations	50	50
Pearson Correlation	0.029800998	
Hypothesized Mean Difference	0	
df	49	
t Stat	3.396305351	
P(T<=t) one-tail	0.000681468	
t Critical one-tailed	1.676550893	
P(T<=t) two-tail	0.001362935	
t Critical two-tailed	2.00957524	

Table 2. *Supplementary metrics for the H1 paired t-test*

Metric	**Value**
Standard Deviation-SD-variable 1	0.83029378
Standard Deviation-SD-variable 2	1.97948664
Standard Deviation of the Difference scores-SD_D	2.12362801
Standard Error-SE	0.30032635
Lower limit	0.4164716
Upper limit	1.6235284

For H2, summarized data are shown in Table 3. A one-way ANOVA was used to examine perceived training effectiveness across groups based on years of experience (0–2, 3–5, 6–10, 11–15; no respondents were in the 16+ category). The scale coding was: “Very Effective” = 5, “Effective” = 4, “Neutral” = 3, “Ineffective” = 2, “Very Ineffective” = 1. Group means (scale 1–5) were: 0–2 M = 3.53 (SD ≈ 1.23), 3–5 M = 3.76 (SD ≈ 0.66), 6–10 M = 3.58 (SD ≈ 1.24), 11–15 M = 3.50 (SD = 1.00), with no data for the 16+ group. Variances ranged from ~0.44 to ~1.54, indicating moderate differences in within-group variability (Table 4).

Table 3. *Distribution of effectiveness ratings by years of experience*

Years of Experience in Current Position	**Very Ineffective**	**Ineffective**	**Neutral**	**Effective**	**Very Effective**	**Grand Total**
0-2 years	2	1	3	8	3	17
11-15 years			3		1	4
3-5 years			6	9	2	17
6-10 years		4		5	3	12
Grand Total	2	5	12	22	9	50

Table 4. *Descriptive statistics by years of experience*

Years of Experience in Current Position	Count	Sum	Average	Variance	Standard Deviation-SD
0-2 years	17	60	3.529412	1.514706	1.230734
3-5 years	17	64	3.764706	0.441176	0.664211
6-10 years	12	43	3.583333	1.537879	1.240112
11-15 years	4	14	3.5	1	1
16+ years	0	0	#DIV/0!	#DIV/0!	#DIV/0!

For **Between Groups**, the sum of squares (SS) was 0.5692, and the mean square (MS) was 0.1423. For **Within Groups**, SS = 51.2108 and MS = 1.1380. Based on this, F = 0.1250, p = 0.9727, with a critical value F_crit = 2.5787 at α = 0.05 (Table 5).

Table 5. *One-way ANOVA by years of experience*

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.569216	4	0.142304	0.125045	0.972683	2.578739
Within Groups	51.21078	45	1.138017			
Total	51.78	49				

For the analysis of H3, with data presented in Tables 6–8, a one-way ANOVA was applied to compare perceived training effectiveness across groups based on education level (High School Diploma, Diploma or Certificate, Associate Degree, Bachelor's Degree, Master's Degree, Doctorate). The scale was coded as: "Very Effective" = 5, "Effective" = 4, "Neutral" = 3, "Ineffective" = 2, "Very Ineffective" = 1. The distribution of scores by group is shown in Table 6. It is also important to note that survey participants had education levels of Bachelor's Degree, Master's Degree, and Doctorate; the other groups were not represented.

Table 6. *Distribution of effectiveness ratings by level of education*

Level of Education	Very Ineffective	Ineffective	Neutral	Effective	Very Effective	Grand Total
Bachelor's Degree	*1*	*1*	*3*	*3*		*8*
Doctorate				*2*	*2*	*4*
Master's Degree	*1*	*4*	*9*	*17*	*7*	*38*
Grand Total	***2***	***5***	***12***	***22***	***9***	***50***

Table 7 presents individual values by education level, with means ranging from 3.00 (Bachelor's, n = 8) to 4.50 (Doctorate, n = 4), variances from 0.3333 to 1.1429, and standard deviations from 0.58 to 1.07 (Master's: M = 3.6579, Var = 0.9879, SD ≈ 0.99). For Between Groups, SS = 6.2274, df = 2, giving MS = 3.1137; for Within Groups, SS = 45.5526, df = 47, MS = 0.9692 (total SS = 51.78, df = 49). Based on this, F = 3.2126, slightly above F_crit = 3.1951, with p = 0.04923 (Table 8).

Table 7. *Descriptive statistics by level of education*

Level of Education	*Count*	*Sum*	*Average*	*Variance*	*Standard Deviation-SD*
Bachelor's Degree	*8*	*24*	*3*	*1.142857*	*1.069045*
Master's Degree	*38*	*139*	*3.657895*	*0.987909*	*0.993936*
Doctorate	*4*	*18*	*4.5*	*0.333333*	*0.57735*

Table 8. *One-way ANOVA by level of education*

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	6.227368	2	3.113684	3.212617	0.049233	3.195056
Within Groups	45.55263	47	0.969205			
Total	51.78	49				

For the analysis of H4, with combined data presented in Tables 9–11, a t-test (assuming unequal variances) was applied to compare perceived training effectiveness between types of institutions (Private vs. Public). The scale coding was: "Very Effective" = 5, "Effective" = 4, "Neutral" = 3, "Ineffective" = 2, "Very Ineffective" = 1 (Table 9).

Table 9. *Distribution of effectiveness ratings by institution type*

Institution Type	Very Ineffective	Ineffective	Neutral	Effective	Very Effective	Grand Total
Public	1	2	7	9	1	20
Private	1	3	5	13	8	30
Grand Total	2	5	12	22	9	50

Table 10 shows the individual statistical parameters by institution type, with means of 3.80 and 3.35, and variances of 1.1310 and 0.871. Based on the t-test, t(44) = 1.5787, p = 0.1216 (two-tailed), with t_crit = 2.0154; the mean difference ΔM = 0.45 was not statistically significant. The standard deviation for the private institution was 1.06, while for the public institution it was 0.93. The estimated 95% confidence interval for ΔM was approximately [-0.12; 1.02] (Table 11).

Table 10. *T-Test: Paired Two-Sample for Means: Private vs. Public institution*

	Variable 1	***Variable 2***
Mean	3.8	3.35
Variance	1.131034483	0.8711
Observations	30	20
Hypothesized Mean Difference	0	
df	44	
t Stat	1.578667703	
P(T<=t) one-tail	0.060787742	
t Critical one-tailed	1.680229977	
P(T<=t) two-tail	0.121575484	
t Critical two-tailed	2.015367574	

Table 11. *Supplementary metrics for H4*

Metric	**Value**
Standard Deviation-SD-variable 1	1.06350105
Standard Deviation-SD-variable 2	0.933302004
Standard Deviation of the Difference scores-SD_D	2.015611334
Standard Error-SE	0.285050489
Lower limit	-0.124481512
Upper limit	1.024481512

Hypothesis Testing Results

The results for H1 indicate that the average difference reflects a clear pattern of a structural gap: the number of "attended" training types shows more than twice the variability compared to "needed" trainings (Var ≈ 3.92 vs. 0.69; SD ≈ 1.98 vs. 0.83), suggesting that attendance among respondents is uneven (some attend very few or none, while others attend more), whereas perceived needs are considerably more stable. Additionally, the correlation between paired observations is negligible (r ≈ 0.03), indicating that those who report more needs are not necessarily the ones who attend more—thus, provision/participation is not aligned with individual needs.

Considering the gap measure D = Needed − Provided, the mean difference is ΔM = 1.02 with SD_D ≈ 2.12 and 95% CI [0.42; 1.62]. This means that a "typical" respondent reported approximately one more category as needed than actually attended, while there is significant heterogeneity in the gap (some respondents have minimal or even negative gaps). The statistical significance itself (paired t(49) = 3.396; p = 0.00136) arises primarily from the consistently positive shift in the mean rather than a favorable covariance structure (since r ≈ 0). In other words, the result suggests a systematic but moderately large deficit in coverage of needed trainings at the sample level, with noticeable individual differences.

Conclusion (H1). The paired t-test showed that the difference between the average number of trainings respondents considered necessary and those actually attended is statistically significant: t(49) = 3.396, p = 0.00136 (two-tailed), ΔM = 1.02, 95% CI [0.42; 1.62]. In other words, H1 is confirmed, and it can be concluded that:

There is a statistically significant difference between the types of training that employees believe they need and the types of training that are provided to them in the workplace.

Regarding H2, four experience groups were examined, and the mean ratings were very close (3.50–3.76), although clear patterns of distribution are observable within them. In the 0–2 years group, **Effective** (8/17 = 47.1%) and **Very Effective** (3/17 = 17.6%) dominated, but all "very negative" ratings appeared in the sample (2/17 = 11.8%), along with one **Ineffective** and three **Neutral** ratings (5.9% and 17.6%, respectively), resulting in higher variability (SD ≈ 1.23). The 3–5 years group was the "most stable": no negative ratings occurred, with **Effective** (9/17 = 52.9%) and **Neutral** (6/17 = 35.3%) prevailing, yielding the highest mean (M = 3.76) and the lowest dispersion (SD ≈ 0.66).

In the 6–10 years group, a local decline is observed due to a higher share of **Ineffective** ratings (4/12 = 33.3%), alongside **Effective** (5/12 = 41.7%) and **Very Effective** (3/12 = 25.0%); this mixture produces greater variability (SD ≈ 1.24). The 11–15 years group is small (n = 4) and mostly neutral (Neutral 3/4), with one **Very Effective** rating, giving a mean of 3.50 and SD = 1.00.

However, these local differences in profiles do not translate into stable differences in means at the sample level. The one-way ANOVA was not significant, F(4,45) = 0.125, p = 0.9727, with most variability occurring **within groups** (SS_within = 51.21) rather than **between groups** (SS_between = 0.57). The estimated partial $\eta^2 \approx 0.011$ indicates a negligible effect.

Conclusion (H2). Considering the p-value = 0.9727 > 0.05 in this sample, H2 is **not confirmed**, and it can be concluded that:

There is no statistically significant difference between respondents' years of work experience and their attitudes toward the employee development and training process.

The one-way ANOVA for H3 results yielded a significant outcome: F(2,47) = 3.21, p = 0.049. The group means and dispersion were as follows: Bachelor's M = 3.00 (SD ≈ 1.07, n = 8), Master's M = 3.66 (SD ≈ 0.99, n = 38), and Doctorate M = 4.50 (SD ≈ 0.58, n = 4). A clear pattern underlies these means: the Doctorate group not only gives higher ratings but does so more consistently (lowest SD), indicating that most doctoral respondents consistently perceive trainings as effective. In contrast, the Bachelor's group shows a lower mean and greater variability, suggesting uneven experiences with trainings in that group.

The differences between means are also practically relevant: Doctorate − Bachelor's ≈ 1.50, Master's − Bachelor's ≈ 0.66, Doctorate − Master's ≈ 0.84, reflecting the expected order Doctorate > Master's > Bachelor's. The estimated partial effect size is $\eta^2_p \approx 0.12$ (moderate effect). However, results should be interpreted cautiously due to the small Doctorate group (n = 4) with lower variance; for final conclusions regarding group pairs, post hoc comparisons are recommended if variance inequality is suspected.

Conclusion (H3). Hypothesis H3 is confirmed: education level is associated with perceived effectiveness of training programs; respondents with higher education degrees provide, on average, higher and more consistent effectiveness ratings, with the strongest positive shift observed in the Doctorate group. Therefore, it can be concluded that:

There is a statistically significant difference between respondents' formal education level and their attitudes toward the employee development and training process

Looking more closely at H4, the distribution of ratings by institution type shows that very negative ratings are almost absent in both private and public institutions (5% in public vs. 3.3% in private), with most responses positioned at the top of the scale. In private institutions, high ratings dominate: **Effective + Very Effective = 21/30 (70%)**, with **Very Effective** at 26.7% (8/30). In contrast, public institutions show less representation at the top of the scale: **Effective + Very Effective = 10/20 (50%)**, with **Very Effective** only 5% (1/20), while **Neutral** is considerably more frequent — 35% (7/20) compared to 16.7% (5/30) in private institutions. Negative ratings are rare and similar in frequency across both sectors: 13.3% in private (Very Ineffective 3.3% + Ineffective 10%) versus 15% in public (5% + 10%).

This profile clearly explains the difference in means ($M_{private} = 3.80$ vs. $M_{public} = 3.35$; $\Delta M = 0.45$). The difference does not arise from negative ratings, which are rare in both sectors, but from the replacement of neutral ratings in public institutions with very positive ratings in private institutions.

Conclusion (H4). Although mean ratings are higher in private institutions ($M = 3.80$) than in public institutions ($M = 3.35$), the independent-samples t-test with unequal variances did not show a statistically significant difference: $t(44) = 1.58$, $p = 0.122 > 0.05$ (two-tailed), $\Delta M = 0.45$, 95% CI [−0.12; 1.02]. Therefore, H4 is **not confirmed**, and it can be concluded that

There is no statistically significant difference **between the type of institution where respondents work (public or private) and their attitudes toward the employee development and training process.**

Discussion

Brief Synthesis of Key Findings

This study reveals a persistent discrepancy between the training that employees perceive as necessary and the training they actually receive (H1). Notably, the duration of work experience did not significantly influence perceptions of training effectiveness (H2). In contrast, educational attainment emerged as a significant differentiating factor (H3); individuals with higher education levels consistently provided more favourable assessments of the training programs. Although a trend suggested that private institutions received higher ratings for effectiveness—indicated by a greater proportion of "Very effective" responses compared to "Neutral"—this observation did not achieve statistical significance in the current sample (H4).

The findings are interpreted through established theoretical frameworks, including human capital theory, learning motivation, and transfer climate, as articulated by Becker (1993), Baldwin and Ford

(1988), and Colquitt et al. (2000), as well as Blume et al. (2010). These frameworks offer valuable insights into how employees' evaluations of training effectiveness are influenced by their educational background, institutional affiliation, and intrinsic motivation to enhance their professional skills.

Interpretation of Research Questions

H1 — Needs and Supply Match

A significant gap in the "needs attended" metric indicates potential shortcomings in the needs assessment process (Training Needs Analysis, TNA) and/or limitations in training access (Aguinis & Kraiger, 2009; Salas, Tannenbaum, Kraiger, & Smith-Jentsch, 2012). This finding serves as a signal for management that the alignment of planning, prioritization, and resource allocation with employees' explicit needs may not be sufficiently robust. Furthermore, such a gap may contribute to diminished perceptions regarding the effectiveness of subsequent training programs (Arthur, Bennett, Edens, & Bell, 2003).

H2 — Seniority as a Non-Differentiator

The absence of discernible differences based on seniority suggests that the context and climate surrounding the transfer of knowledge are more influential than the "age/experience effect" on training perceptions (Baldwin & Ford, 1988; Burke & Hutchins, 2007). It appears that learners, regardless of their seniority, encounter similar design and delivery formats, as well as comparable constraints regarding the application of acquired knowledge, leading to minimal impact of seniority on perceptions (Ng & Feldman, 2010).

H3 — Education as a Differentiator

Respondents with higher levels of education generally provided higher and more consistent ratings. This observation is consistent with theoretical models that correlate cognitive and motivational factors with learning outcomes (Kraiger, Ford, & Salas, 1993; Colquitt et al., 2000). Higher educational attainment may facilitate a better alignment between the content and prior knowledge, promote stronger self-efficacy, and clarify expected benefits, which collectively enhance the perceived value of the training program (Blume et al., 2010). However, this finding warrants cautious interpretation due to the small sample size within the Doctorate group.

H4 — Institutional Context

While private institutions reported a higher prevalence of "Very effective" ratings and fewer "Neutral" ratings than their public counterparts, the differences observed were not statistically significant. This may be attributed, in part, to unequal group sizes and the presence of a “ceiling” effect, wherein both sectors exhibited few negative ratings, thus limiting variance and the analytical power of the results (Boyne, 2002; Perry & Wise, 1990). The disparities likely arise more from variations in climate, support, and conditions for transfer rather than solely from the type of institution (Salas et al., 2012).

Integration of Findings, Theoretical Frameworks, and Perception Mechanisms of Training Effectiveness

The empirical findings can be effectively understood through three thematic axes and their theoretical foundations.

First, there is the alignment of needs and supply. The central outcome hinges on the gap between what employees recognize as necessary and what training they actually receive. According to human capital theory, investments in training yield results only when they target relevant competencies and address genuine development gaps (Becker, 1993). Therefore, "gap-closure" should become an explicit goal of the training and development (T&D) system, which should involve steps such as diagnosis, prioritization, design and delivery, and transfer monitoring (Salas et al., 2012; Arthur et al., 2003).

Second, the characteristics of the trainees play a significant role. Research serves as a crucial differentiator in the perception of training effectiveness. This aligns with models that highlight how cognitive readiness, motivation to learn, and goal orientation enhance the perceived value and transfer of learning (Kraiger, Ford, & Salas, 1993; Colquitt, LePine, & Noe, 2000; VandeWalle, 1997). Higher education levels likely lead to a better "fit" between the training content and existing knowledge schemas, as well as increased self-efficacy, resulting in more positive and consistent outcomes (Blume, Ford, Baldwin, & Huang, 2010). In contrast, simply having numerous years of experience—without a supportive environment for applying new learning—rarely changes perceptions (Baldwin & Ford, 1988; Burke & Hutchins, 2007).

Third, the organizational context, whether public or private, impacts perceptions. Differences do not manifest merely through a higher proportion of negative ratings; instead, they arise in the distribution of ratings between "neutral" and "very effective." This suggests that the crux of the issue lies in the design, resources, and support for transfer (such as mentoring, feedback, and job relevance), rather than ownership of the training programs themselves (Boyne, 2002; Perry & Wise, 1990; Salas et al., 2012). Organizations with a stronger post-training implementation framework are more likely to see shifts in ratings from "neutral" to "very effective," even when the programmatic themes remain consistent.

Lastly, measurement and evaluation should extend beyond just the level of reaction. A taxonomy of outcomes—cognitive, skill-based, and affective—provides a clear map of what to assess and when (Kraiger et al., 1993). Additionally, a practical evaluation framework (such as the Kirkpatrick Model, which includes levels 1–3 routine and level 4 selective) instills discipline in tracking transfer and impact (Kirkpatrick & Kirkpatrick, 2006). By anchoring these thematic axes in proven mechanisms, the likelihood of achieving gap-closure increases—not just in perception, but also in actual behaviour and work outcomes.

Implications for Training Policy

The practical implications can be summarized in a few key steps that influence both the quality of the training program and its measurable outcomes. First, it is essential to implement an annual training needs assessment (TNA) that is linked to the institution's strategic goals. This will help ensure that "closing the gap" between the training needed and the training attended is recognized as a formal outcome, measured through official Key Performance Indicators (KPIs). Establishing this link ensures that development investments are directed toward areas with the most significant development gaps and the tremendous potential for impact.

Additionally, a transfer-oriented design should become the standard approach. This involves incorporating real-world scenarios and tasks, providing guided practice in the workplace, offering

mentoring support, and establishing clear post-training implementation plans (i.e., specifying who will do what and by when). These elements significantly enhance the likelihood that participants will apply what they learn effectively in their work environments (Salas et al., 2012). Moreover, personalization based on educational levels—adapting depth, pace, and examples to Bachelor's, Master's, and Doctorate profiles—is crucial, as different levels of initial knowledge and expectation patterns affect learning acquisition and effectiveness assessment.

A key factor in this process is the organizational climate and support. Involving managers in setting goals before training and in systematically following up after training (monitoring implementation, providing feedback, and addressing obstacles) has been shown to encourage knowledge transfer and reinforce the effects of the program (Burke & Hutchins, 2007). This process—needs assessment, design for transfer, and post-training support—creates a continuous loop between individual learning and organizational outcomes.

When it comes to measurability and evaluation, we recommend implementing an operational dashboard that tracks key indicators. Key metrics should include participation and completion rates, post-test results, indicators of knowledge transfer (such as structured follow-up at 30–90 days), an overall behavioural change rating, and relevant KPIs (e.g., output quality, cycle time). Evaluations should be conducted systematically according to the Kirkpatrick framework, with routine assessments at levels 1–3 and selective assessments at level 4, gradually incorporating more objective performance measures (Aguinis & Kraiger, 2009; Arthur et al., 2003). Only after accumulating data on the impact on business metrics should a cautious assessment of ROI be conducted, keeping in mind that complex development effects can rarely be boiled down to a single figure (Aguinis & Kraiger, 2009).

Study Limitations, Future Research Directions, and Final Message

This study has several methodological limitations that affect the scope of our conclusions. First, the design is cross-sectional and relies on self-reports, which limits our ability to establish causality and may introduce perceptual biases. Second, the groups in the study are unequal, with a small sample size (n=4) in the Doctorate group, which reduces statistical power and the stability of the estimates. Third, a ceiling effect was observed, where there were few negative ratings, reducing variability and the sensitivity of the tests to detect subtle differences. Lastly, while we treated the 1–5 scale as approximately interval—a common practice in survey research—the results would benefit from confirmation using nonparametric or robust approaches, as well as longitudinal follow-up on transfer (Baldwin & Ford, 1988; Blume et al., 2010).

To address these limitations, future research should include: (a) post hoc comparisons using methods for unequal variances (e.g., Games–Howell) for Hypothesis 3, to better estimate the differences among the Doctorate, Master's, and Bachelor's groups; (b) detailed documentation of program characteristics (such as format, duration, work experience, and mentoring), as design is known to influence outcomes significantly (Arthur et al., 2003); and (c) a mixed-method approach that incorporates qualitative insights into the "gap" identified in Hypothesis 1 and the barriers to transfer. Additionally, expanding the sample size, particularly in public institutions and within the Doctorate group, while

introducing longitudinal metrics, will enhance our ability to assess behavioural changes and performance, rather than just immediate reactions.

Ultimately, our practical focus should be on closing the gap identified in Hypothesis 1 through systematic needs assessments linked to strategic goals and transfer-oriented design. This involves incorporating job scenarios, on-the-job practice, mentoring support, and implementation plans. By personalizing education across different segments and systematically evaluating outcomes (using Kirkpatrick Levels 1–3 routinely and Level 4 selectively), educational institutions can improve both perceived and actual effectiveness. This emphasis aligns with evidence suggesting that thoughtful design and organizational support have a more significant impact on outcomes than formal attributes, such as tenure, while also acknowledging that the educational profile of the learner remains an important moderator to be considered upfront (Aguinis & Kraiger, 2009; Salas et al., 2012; Colquitt et al., 2000).

Conclusions

This research examined the connection between estimated training needs, actual programs participated in, and perceptions of effectiveness, while considering the diverse characteristics of participants and the institutional context within educational organizations in Canada. The key findings are as follows:

1. There is a consistent disparity between the training considered "necessary" and what is actually "attended."

2. Years of experience do not appear to be a distinguishing factor in perceptions of effectiveness.

3. Individuals with higher levels of formal education tend to report higher and more consistent effectiveness ratings.

4. A trend favouring private institutions exists, though no statistically significant difference is noted when compared to public institutions.

In conclusion, the outcomes suggest that the connection between needs and supply, as well as the characteristics of participants, significantly influence results more than the formal measurement of “length of experience.” The institutional context (public or private) affects the distribution style of ratings, but does not indicate a reliable difference within the sampled environments. Therefore, training policies should focus on needs assessments, be designed for practical application, and be tailored to various educational segments.

Practical implications include:

1. Establishing annual training needs assessments (TNAs) aligned with strategic goals and KPIs, with a clear objective to "bridge the gap" identified in finding 1.

2. Implementing transfer-oriented design consistently, incorporating real business tasks, on-the-job practice, mentoring support, and an execution plan, along with systematic follow-ups.

3. Customizing the depth, pace, and content examples based on educational level (Bachelor/Master/Doctorate) and conducting routine evaluations (Kirkpatrick levels 1–3, and selectively level 4) with a greater emphasis on objective performance metrics.

Theoretical implications suggest that the findings align with theories of human capital, learning motivation, and training transfer. The educational background of trainees serves as an important moderator in assessing effectiveness, while years of service do not show a different impact in this scenario.

Limitations of the study include a cross-sectional design, reliance on self-reported data, imbalanced groups (especially a small sample size in the Doctorate category), and "ceiling" effects. The sample context constrains the generalizability of the findings. Recommendations for future research involve broadening the sample (particularly in public institutions and among higher education levels), applying post-hoc comparisons under conditions of unequal variances (e.g., Games–Howell) for finding 3, incorporating longitudinal follow-ups on training transfer, utilizing more objective performance indicators, and documenting additional design characteristics of the training.

In summary, educational institutions can enhance both the perceived and actual effectiveness of their programs by systematically narrowing the gap between needs and provisions, designing training that supports practical application, and tailoring educational pathways to align with the profiles of the trainees.

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Conflict of interest

The authors declare that they have no conflict of interest.

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THE USE OF WEB TOOLS IN EDUCATION: A CASE STUDY IN A SECONDARY SCHOOL IN MONTENEGRO

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Abstract: This review examines the role of web-based tools in contemporary education by integrating recent research (2020–2025) and illustrating practice through a survey of 120 teachers at a secondary school in Montenegro. After outlining the evolution of the web (from Web 1.0 to Web 3.0) and key categories of educational tools (learning management systems, collaboration platforms, video-conferencing, game-based quiz systems, social media), we synthesize findings from recent systematic reviews and empirical studies. These show that digital tools generally have positive effects on student engagement, motivation, conceptual understanding, and academic performance, provided they are integrated purposefully and supported by infrastructure and teacher training. In our school-level survey, teachers reported intensive use of Microsoft Teams, PowerPoint, YouTube, and messaging apps (Viber/WhatsApp), alongside growing interest in interactive platforms such as Kahoot. They expressed mainly positive attitudes toward web tools, but also noted challenges related to technical issues, workload, and unequal student access. Taken together, the literature and case findings indicate that web tools are now integral to teaching, yet their success depends on pedagogically informed design, teacher digital competence, institutional support, and attention to equity and privacy. The paper concludes with implications for practice and proposes directions for future research on the pedagogical and organizational conditions that sustain and make technology integration effective.

Keywords: web tools; educational technology; e-learning; digital literacy; information and communication technology (ICT); Web 2.0; Web 3.0.

Introduction

The widespread availability of the internet and web-based applications has transformed how learning is organized and experienced at all levels of education. Digital technologies now serve as knowledge providers, co-creators of information, mentors, and assessors, reshaping not only content delivery but also interaction patterns and assessment practices (Haleem et al., 2022). The COVID-19 pandemic accelerated this trend, forcing schools and universities worldwide to adopt online or hybrid teaching and thereby institutionalizing the use of learning platforms, video-conferencing tools, and interactive web applications.

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Despite rapid adoption, there is still a need to systematically synthesize how web tools are used in practice, the benefits they provide, the limitations they entail, and the conditions under which they contribute to better learning outcomes. Recent reviews and empirical studies suggest that digital tools can increase engagement, support active and collaborative learning, and improve performance, but also highlight persistent challenges such as digital divides, workload, and the need for teacher training (Miras et al., 2023; Osorio Vanegas et al., 2023). However, challenges remain, including unequal access to technology, increased teacher workload, and the need for sustained professional development (Al-Maroof et al., 2021; Haleem et al., 2022; Sobaih et al., 2021).

The goals of this paper focus on:

- Conceptualizing web tools and summarizing their main categories and functions in teaching and learning.
- Integrating findings from recent research (especially 2020–2025) on their impact on student outcomes and teaching practices.
- Illustrating these issues through a small case study: a survey of 120 teachers from a Montenegrin secondary school.
- Discussing implications for practice and outlining concrete directions for future research.

Theoretical Background

From Web 1.0 to Web 3.0 in Education

Web technologies have evolved through distinct phases. **Web 1.0** (circa 1990s) featured static pages and one-way information delivery; educational use was mainly posting syllabi or course materials online. **Web 2.0** introduced interactivity and user-generated content. Tools like blogs, wikis, social media, and video sharing enabled students and teachers to interact, collaborate, and co-create content. This participatory era supports constructivist learning: for example, student-run blogs and class wikis foster peer learning and reflection. Studies on Web 2.0 use in language teaching and project-based learning report that these tools can enhance learner-centered collaboration and critical thinking when aligned with pedagogy (Fathian et al., 2023).

More recently, attention has turned to **Web 3.0**, also known as the "Semantic Web," which involves intelligent, data-driven, AI-supported environments. In education, this manifests as adaptive learning platforms, AI tutoring, and sophisticated analytics. Systematic reviews have noted increased use of AI-driven features—such as automated feedback, virtual labs, and intelligent tutoring systems—in higher education and K–12 settings. For instance, Wang and Fan (2025) found that integrating AI chatbots (e.g., ChatGPT) into learning yielded large improvements in student academic performance and moderate gains in motivation and higher-order thinking (Zhang et al., 2025). These AI tools represent the cutting edge of Web 3.0 in education: by processing natural language and individual learning data, they offer personalized support and new forms of engagement.

Categories of Web Tools

Educational web tools are often categorized by function:

- **Learning Management Systems (LMS):** Platforms like Moodle, Google Classroom, and Canvas organize course materials, assignments, discussions, and grading. Research shows Moodle is highly customizable with rich pedagogical features, whereas Google Classroom is simpler and more intuitive for quick deployment. For example, comparative studies indicate that Moodle's advanced assessment and activity modules can support complex teaching strategies, while Google Classroom offers seamless integration with Google Docs and easy setup, favored in rapidly shifting online environments (Kreijns et al., 2024; Adhikari et al., 2024).
- **Collaboration Platforms:** Systems such as Microsoft Teams, Google Workspace, and Slack integrate file sharing, chat, and conferencing. During the pandemic, Microsoft Teams was widely adopted in higher education. Sobaih et al. (2021) report that students found Teams effective for accessing learning resources and collaborating with peers, leading to generally positive learning experiences[2]. However, they also noted issues like limited teacher support and low participation when courses lacked structured activities. These findings echo our case, where teachers use Teams heavily for content and communication, but express concerns about sustained engagement.
- **Video Conferencing Tools:** Applications like Zoom, Teams Meetings, and Webex enable live virtual classes. Research suggests that combining these synchronous tools with active pedagogies (e.g. breakout rooms, polls) can approximate face-to-face interaction and maintain student satisfaction. Conversely, long hours on video can cause "Zoom fatigue" and technical issues (Al-Maroof et al., 2021). Effective practice requires interactive design: simply lecturing online tends to reduce engagement unless supplemented with collaborative tasks.
- **Game-Based Response Systems (GSRS):** Platforms such as Kahoot!, Quizizz, and Socrative support gamified quizzes and polls. A comprehensive meta-analysis by Özdemir (2024) synthesized 43 experimental studies on Kahoot! and found moderate to large positive effects on student outcomes. Specifically, Kahoot! significantly improved academic achievement, retention, and motivation, and also reduced anxiety, compared to traditional instruction. These systems are most effective when used regularly for formative assessment and integrated with course objectives. If overused as mere entertainment, their benefits tend to wane.
- **Social Media and Web 2.0 Tools:** Blogs, wikis, social networks (Facebook, Twitter, etc.), and multimedia platforms (YouTube, podcasting) enable collaborative content creation and communication. Systematic reviews (Pérez et al., 2023) show social media can be an engaging method of teaching and learning. For instance, studies in language education found that student-operated YouTube channels and class Facebook groups can improve digital literacy, presentation skills, and peer learning. In higher education, instructors increasingly exploit social networks for announcements and group projects. However, effective use of these tools typically requires explicit pedagogical structuring and attention to privacy and digital citizenship.
- **Assessment and Survey Tools:** Online quiz and survey builders (e.g., Google Forms, Microsoft Forms) are widely used for low-stakes assessments, polls, and course evaluations. In our survey, many teachers used Forms for quick quizzes and feedback. These simple tools support agile checks of understanding and data collection[4]. However, by themselves they are lightweight – their pedagogical value depends on how thoughtfully questions are designed and results are acted upon.

Evidence on the Impact of Digital Tools

Recent large-scale reviews have converged on several themes regarding educational technology. Haleem et al. (2022) review the role of digital technologies globally and emphasize that properly integrated tools can improve student engagement, collaboration, and access to learning (Van Zanten et al., 2022). They note, however, that these benefits are contingent on factors like infrastructure quality, teacher readiness, and equitable access. In fact, another systematic review found that digital tool use has large positive effects on engagement, conceptual understanding, and performance across subjects—but again only under purposeful teacher facilitation. Tools alone do not guarantee learning; how they are integrated matters most.

Specifically, controlled studies of Kahoot! and similar GSRS consistently report positive outcomes. A prior meta-analysis already concluded that Kahoot! boosts performance, classroom dynamics, and motivation, while easing anxiety. Özdemir's (2024) update reinforces this: out of 43 studies, Kahoot! yielded moderate-to-large effect sizes for achievement, motivation, and retention. Our teachers' reports of greater student enthusiasm with Kahoot! align with this evidence.

For LMS platforms, surveys and usage data indicate that nearly all university courses now involve an LMS. Learners appreciate LMSs for course organization and timely feedback, and research notes widespread adoption of Moodle and Google Classroom. However, meta-analyses suggest that instructors often underutilize advanced LMS features unless they receive training and support. For example, although Moodle offers complex quiz branching and analytics, many teachers stick to simple file-sharing due to time constraints. This observation matches our case study: teachers rely on Teams (integrated with Office 365) as a hub, but typically use it in straightforward ways rather than exploring every feature.

Social media tools receive mixed reviews. Pérez et al. (2023) conclude that social networking sites can be attractive learning environments and have demonstrated potential for collaboration and information sharing. Indeed, some students engage more when given assignment options involving videos or collaborative wiki writing. Yet other studies caution that incorporating social media raises concerns (distraction, privacy, unequal familiarity) and often lacks a solid pedagogical theory. In practice, we find our teachers generally use YouTube as a video resource for instruction, rather than assigning students to produce their own content. This "consumption over creation" pattern is noted in broader research on Web 2.0 use, which shows content-production activities require more teacher scaffolding (Fathian et al., 2023).

In summary, the literature suggests that when educators intentionally align web tools with curriculum goals—supported by training and infrastructure—students tend to be more active, collaborative, and motivated (Van Zanten et al., 2022). These positive effects have been documented in meta-analyses of game-based learning, flipped classrooms, and AI assistants. At the same time, issues such as unequal internet access, teacher workload, and superficial use of technology are recurring themes in recent reviews (Miras et al., 2023; Osorio Vanegas et al., 2023). We turn now to our study methods and case findings, which explore these dynamics in a specific school context.

Methods

This paper conducted a literature review combined with a small empirical case study. We conducted a literature review (2020–2025) on web tools in education, focusing on systematic reviews and empirical studies. Key searches covered terms like "educational technology," "LMS in education," "game-based learning," and "ChatGPT education." We prioritized systematic reviews, meta-analyses, and empirical studies with clear methods and reported outcomes.

We also drew on data from an online survey conducted in April 2025 among teachers at a secondary school in Montenegro. A total of 120 teachers responded (a high proportion of the staff), providing information on:

- Tools they use (for teaching, communication, and administration)
- Their attitudes toward digital tools
- Perceived advantages and limitations
- Interest in experimenting with new platforms

The survey was administered via an online form and analyzed descriptively (frequency counts, percentages) and qualitatively (open-ended comments). While the sample is small and context-specific, the findings offer illustrative insight into how web tools are used in practice in a secondary school setting.

The Results section integrates insights from both the literature and the teacher survey.

Results

Global Web Infrastructure and Access

Educational use of web tools is built on infrastructure dominated by a few core technologies:

- **Web browsers:** Recent industry data show that Google Chrome holds roughly two-thirds (~66%) of the global browser market, followed by Apple's Safari (~17%), with Edge, Firefox, and others making up smaller shares.
- **Search engines:** Google controls about 89–90% of the global search engine market, with Bing, Yandex, Yahoo, and DuckDuckGo sharing the remainder.
- **Most visited sites:** Global rankings place Google and YouTube at the top, followed by Facebook, Instagram and, more recently, AI platforms like ChatGPT.

These data suggest that most students' and teachers' first contact with online educational resources happens through Google (search and YouTube) using Chrome, which has implications for information literacy (e.g. search skills, algorithmic curation).

Common Educational Web Tools (Literature Synthesis)

LMS (Moodle, Google Classroom, Canvas): Comparative studies find Moodle often wins on advanced features (quiz logic, conditional activities, detailed grade books) whereas Google Classroom wins on ease of use and seamless integration with Google Docs. For example, one study noted that Moodle's flexibility suits complex courses, but teachers found Google Classroom simpler to adopt without training. Our teachers reported using Teams/Office 365 primarily, with only a few using Moodle or Google Classroom. They appreciated any LMS that automated grade-taking and provided deadlines. In line with

the literature, our case suggests advanced LMS functions are underused unless a school mandates training and a clear policy for LMS use.

Microsoft Teams: During and after the pandemic, Teams became a central platform. Surveyed teachers relied on Teams for sharing materials, setting assignments, and holding live or hybrid classes. This matches findings by Sobaih et al. (2021), who observed that students found Teams effective for accessing resources and collaborating. Teachers here liked its integration with Office 365 and classes' "Teams space." However, consistent with the literature, they noted some issues: for instance, students seldom turned on cameras in online discussions, limiting social presence. This echoes Sobaih's report of low peer participation in poorly structured online courses. A few teachers also felt overwhelmed by frequent updates to Teams and Office apps, highlighting the need for ongoing training and tech support.

Game-based platforms (Kahoot!, Quizizz): A foundational meta-analysis by Özdemir (2024) confirms that Kahoot!, when embedded as a formative assessment, produces significant gains in student achievement, retention, and motivation. Our survey showed several language and social science teachers using Kahoot! regularly for review quizzes; they observed notable increases in student enthusiasm and recall. Respondents warned, however, that using Kahoot! too frequently (or as mere "fun time") could reduce its impact. These practical insights align with evidence that gamified quizzes work best when balanced with instruction and not used to replace genuine learning activities.

Web 2.0 tools & Social media: Systematic reviews indicate that blogs, wikis, and video-sharing can enrich learning through student production of content and peer feedback. k[4]This suggests Web 2.0 is largely consumed, not produced, in practice. Literature notes this consumption–production gap: without structured assignments, students default to passive use of social media. Some teachers mentioned informal use of social apps (Viber/WhatsApp) to coordinate among themselves or with parents, but none used social media formally for instructionk (Fathian et al., 2023).

Case Study: Teacher Use of Web Tools at Secondary School in Montenegro

The survey conducted during April 2025 revealed these patterns:

- **Core tools:** Microsoft Teams is the central tool for distributing materials, communicating with students, and organizing online or hybrid classes. Office 365 applications (Word, Excel, PowerPoint) are heavily used for creating lessons, managing grades and administrative documentation. YouTube is widely used to supplement lessons (especially in science and languages). The MEIS (national electronic student record system) is used for attendance and grading, though some teachers note usability issues.
- **Interactive tools:** Nearly half the teachers use Kahoot! or similar platforms for student quizzes. A few use Google Forms for quick polls or surveys. Notably, none reported using forums, wikis, or video-project assignments.
- **Communication:** Teachers communicate informally via Viber and WhatsApp (e.g. for last-minute schedule changes). A few teachers have created social media groups (Facebook/Instagram) for school events, but these are peripheral to instruction.
- **Attitudes:** Overall, teachers expressed positive attitudes toward technology: they said tools increase student interest and make instruction more dynamic. Approximately one-third (around 21 teachers) indicated an interest in trying additional tools (e.g. more frequent use of Kahoot!, Quizizz, and maybe Zoom or other specialized apps). Older teachers and those less familiar with ICT reported greater stress

and a need for more training, particularly regarding MEIS and advanced Teams functionality. However, many teachers voiced concerns about excessive workload and inequity. For example, some teachers noted that students without reliable home internet struggled to participate fully. Others mentioned feeling "overloaded" by frequent tech updates and administrative demands (e.g. multi-platform grading). These feelings of burden reflect broader issues found in the literature.

Together, the results paint a picture of enthusiastic adoption of a few core web tools, but uneven use of their full potential. Surveyed teachers have internalized mainly the global shift to digital teaching tools, yet they also confront the same limitations reported worldwide: technical glitches, equity gaps, and insufficient support for pedagogy.

Discussion

Alignment with Literature

Our case study findings largely mirror global research on web tools in education. Teachers' reports of increased engagement and interactivity with tools like Kahoot! And video content align with meta-analytic results. Özdemir (2024) found moderate-to-large positive effects of Kahoot! On achievement and motivation, which resonates with our teachers' anecdotal evidence of improved quiz performance and enthusiasm. Likewise, broad reviews (Haleem et al., 2022) note that when digital tools are properly integrated, students participate more actively and tend to grasp concepts better. For example, after adopting Teams for classroom materials and discussions, our respondents described more flexible access to resources, confirming Sobaih et al.'s (2021) finding that Teams use enhances access to information and knowledge construction (Al-Maroof et al., 2021).

Our survey highlights Microsoft Teams as a central hub for teaching, mirroring global trends where Teams and other LMS platforms structure online and blended courses. Studies show that students perceive such platforms as effective for accessing resources, collaborating, and receiving feedback. Our case study supports this: teachers rely on Teams for file sharing and assignments, and many appreciate its integration with Office 365. At the same time, some challenges from the literature also appear locally—such as limited participation in online discussions when course design is lecture-heavy, and the need for clearer structure and support.

However, our synthesis also highlights that merely adopting tools is not sufficient. The literature emphasizes how tools are used. Novice use (e.g. uploading a PDF to a platform) produces fewer benefits than pedagogically informed strategies. In our school, many teachers initially treated Teams and PowerPoint as digital flipbooks. The advanced functionalities (branching quizzes, peer editing of documents, etc.) remain underexploited. This reflects a common pattern: systematic reviews report that teachers often underutilize LMS and Web 2.0 features unless they receive training and design support. Indeed, Osorio Vanegas et al. (2023) found that "continuous professional development was the most frequently cited competency" enabling teachers to keep pace with new technologies. Our participants echoed this: several said they would like more in-service training on creative ways to use Teams and interactive platforms. Thus, our data support the literature's call for robust teacher training and collaboration (e.g. professional learning communities) to deepen technology use.

Challenges and Tensions

Several challenges emerged, consistent with recent literature.

Inequitable access and infrastructure: Some teachers noted that students from rural backgrounds often have poor home internet, making synchronous activities difficult. This mirrors UNESCO's warnings about the digital divide: globally, 32% of people still lack internet access, and 60% of primary schools are offline (UNESCO, 2025). Miras et al. (2023) warn that during the pandemic, "unequal access to and use of ICTs" became a decisive factor in social exclusion. Without institutional policies (e.g. loaner devices, campus Wi-Fi access), these disparities limit the reach of web tools.

Teacher workload and support needs: Constant updates to platforms like Teams and Office, plus the need to prepare both online and offline materials, have taxed our teachers. Recent work emphasizes that effective technology integration requires time, instructional design skills, and ongoing professional development. This reflects findings that "the digital revolution… has had a social toll on teachers," who must balance innovation with heavy administrative demands. The literature underscores that effective integration requires sustained support structures: mentoring, technical assistance, and reasonable planning time (Osorio Vanegas et al., 2023). Teachers in our study expressed fatigue that aligns with this advice. Respondents noted that while many are enthusiastic, some (especially older teachers) feel overwhelmed by constant updates, new platforms, and administrative demands (e.g. parallel paper and electronic record-keeping). Research on MS Teams teaching efficacy similarly notes that teacher training and clear institutional support are critical for realizing the platform's potential.

Pedagogical alignment: Technology should serve pedagogy, not the reverse. In line with this, we saw that creative student-centered activities (e.g. student-generated videos) were rare, possibly because teachers were more comfortable using tools in teacher-directed ways. Some older teachers admitted to sticking with lecture-style materials posted online. The literature similarly observes that unless teachers reconceive their lesson plans (moving from "sage on the stage" to facilitator), web tools yield modest gains. This suggests our school, like others, would benefit from embedding web tools into richer instructional designs (project work, peer review, etc.), rather than layering them on top of traditional practice.

Privacy, ethics, and boundaries: Studies on Web 2.0 integration emphasize the need for clear policies on social media use, data privacy, and professional boundaries. Our survey indicates that staff use Viber and WhatsApp for school communication, which is convenient but raises questions about data protection, message overload, and work-life boundaries. Formal guidelines and institutional channels (e.g. school-controlled platforms) could mitigate these concerns.

Synthesis and Implications

Combining the case study with the literature yields several insights. First, effective web tool use requires ecosystem conditions. Infrastructure (broadband, devices) and leadership support must underpin any implementation; equity is foundational. Second, teacher capacity is critical. Continuous professional development is essential (Osorio Vanegas et al., 2023). Our respondents' desire for training in Teams and interactive tools aligns with this: without it, many advanced features will remain unused. Third, integration should be pedagogically driven. Tools should be selected and used according to learning

goals. For example, using Kahoot! mainly for engaging review rather than as an add-on for every lesson, can sustain its impact (Adhikari et al., 2024).

In practice, this means that school leaders and policymakers should not only invest in technology but also in teacher training, digital literacy programs, and ongoing support. The UNESCO (2025) call to view digital learning as a tool for equity rather than division is relevant here. Our case suggests that when teachers are empowered (through training, autonomy, and adequate time) to experiment with web tools, students can benefit significantly. However, if the necessary conditions are missing—poor connectivity, no training, no pedagogical support—the same tools can widen gaps (Miras et al., 2023).

Conclusions and Future Research

This case study, embedded in broader literature, shows that web tools hold great promise for modern education: they can enrich instruction, engage learners, and extend resources beyond the classroom. Drawing on recent systematic reviews and empirical studies (2020–2025), as well as a survey of 120 teachers, we conclude that:

- Web tools are now embedded in daily teaching practice. LMS and collaboration platforms such as Microsoft Teams and Google Classroom, video-conferencing tools, and social media are central infrastructure for contemporary education.
- When thoughtfully integrated, digital tools can enhance engagement, motivation, and learning outcomes. Game-based response systems like Kahoot! and Web 2.0 tools used for collaborative content creation have consistently shown positive effects on student performance and attitudes in diverse settings.
- Teachers at the secondary school in Montenegro reflect global trends: they rely heavily on Teams, PowerPoint, YouTube and messaging apps; they see clear benefits in terms of organization and engagement; and a substantial minority are eager to explore more interactive tools. At the same time, they report familiar problems: technical issues, extra administrative workload, limited training, and varying student access.
- The main levers for improvement lie not in tools themselves, but in pedagogy, support, and policy. Successful use of web tools depends on aligning them with learning objectives, investing in teacher professional development, ensuring equitable access, and setting clear rules for ethical and safe use.

Implications for Practice

The findings of this study suggest that schools should approach the use of web-based tools through a strategic and pedagogically grounded framework, rather than relying on ad-hoc or novelty-driven adoption. Technology integration is most effective when it is purposefully aligned with instructional goals—such as enhancing collaboration, improving formative assessment, or supporting differentiated learning—rather than when tools are introduced without clear educational intent. To implement this effectively, teacher professional development must go beyond technical training and instead focus on helping teachers design meaningful, technology-enhanced learning activities. For instance, training should emphasize how platforms like Microsoft Teams can be leveraged for collaborative group work or how

tools such as Kahoot! can be integrated into formative assessment strategies in ways that meaningfully enrich learning processes.

A supportive school environment is also essential for sustainable technology integration. Schools should establish robust support structures, including accessible IT assistance, peer mentoring systems, and dedicated time for instructional redesign, all of which can ease teacher workload and reduce the stress often associated with adopting new tools. At the same time, institutions must ensure equity and inclusion by addressing differences in students' access to devices, internet connectivity, and digital skills. Clear alternative pathways should be available for students who cannot fully participate online to prevent widening achievement gaps. Additionally, comprehensive governance and ethical guidelines are needed to regulate the use of social media platforms, messaging apps, and any tools that involve student data. These guidelines should safeguard privacy, define appropriate boundaries for communication, and ensure the responsible, transparent use of digital platforms in the school environment.

Future Research Directions

Building on these findings, future research should first prioritize longitudinal examinations of learning outcomes, as current studies often focus on short-term impacts of digital tools. Extended investigations tracking the sustained use of platforms such as Microsoft Teams, Google Classroom, or Kahoot! over multiple academic years could provide deeper insight into their effects on achievement, knowledge retention, and the development of higher-order cognitive skills. In addition, comparative, context-sensitive studies are needed to understand how variations in infrastructure, school type, and cultural expectations influence the success of web-based tools. Such comparative work, spanning different regions or socio-economic settings, would help clarify which conditions enable or hinder effective integration.

Further research should also investigate teacher professional development models, examining which approaches—such as coaching-based support, structured workshops, communities of practice, or micro-credentialing—best help teachers build sustained digital pedagogical competence. At the same time, the field would benefit from studies that expand the focus from teachers to learners, exploring student agency and co-creation through web tools. Understanding how students can act as content creators, peer teachers, or co-designers of digital learning environments may illuminate new pathways for enhancing motivation and developing critical digital literacy skills.

Finally, future investigations should address the ethical, psychological, and well-being dimensions of digital tool usage. As students and teachers spend more time online and interact with systems that collect personal data, research is needed to understand issues related to digital burnout, online safety, privacy perceptions, and potential algorithmic bias. Moreover, with the increasing presence of AI-driven platforms—such as chatbots, adaptive learning systems, and recommendation tools—scholars should explore how these technologies can be responsibly integrated into existing ecosystems of educational web tools. Such studies should consider questions of transparency, human oversight, and pedagogical value. Taken together, these research directions can help shift the field from focusing merely on digital tool adoption toward a more mature understanding of how technology can support meaningful, equitable, and human-centered education in the long term.

Conflict of Interest

The authors declare no conflict of interest.

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