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DIGITAL TRANSFORMATION NEEDS ASSESSMENT IN MANUFACTURING SMES: AN INDUSTRY TECHNOLOGY INTENSITY PERSPECTIVE

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Abstract:
The digital transformation of manufacturing SMEs is a strategic priority of the EU's Digital Decade agenda, yet technology-intensity-differentiated evidence on SME DT profiles remains largely absent from the literature. This exploratory, quantitative study analyzes needs assessment data from 71 manufacturing SMEs in Romania's Centru Region, collected through FIT EDIH. Following Eurostat's industry technology-intensity classification, firms are assigned to two analytical groups: high and medium-high tech industries (Group A, n=12) and medium-low and low tech industries (Group B, n=59). The study aims to provide technology-intensity-differentiated evidence on DT needs, barriers, technology priorities, expected outcomes, and anticipated EDIH service demand, and to generate actionable intelligence for FIT EDIH service design. Descriptive and bivariate methods – Welch t-tests, ANOVA, Pearson and Spearman correlations – are applied. Industry technology intensity differentiates DT profiles, yet planning capacity and technology identification (each cited by two-thirds of SMEs regardless of group) establish a sector-agnostic pre-adoption bottleneck. SMEs recognizing DT as urgent but not yet acting record the lowest technology ambition alongside the highest anticipated service demand. Anticipated service demand is uniformly distributed across DT approach stages. These findings support a dual-dimension intake protocol – assessing industry technology intensity and DT approach stage independently – enabling differentiated yet universally accessible EDIH support.

Key words: *digital transformation, EDIH, industry technology intensity, manufacturing SMEs, needs assessment*

1. Introduction and Theoretical Background

Digital transformation in EU manufacturing SMEs: the needs assessment imperative

The digital transformation (DT) of manufacturing SMEs is among the most consequential yet least resolved challenges facing European regional economies. Across the EU, SMEs – which account for 99.8% of all enterprises, 53.6% of real value added, and 65.1% of employment (Schulze Brock et al., 2025) – face structural DT adoption challenges that large-firm frameworks and approaches consistently underestimate (Mittal et al., 2018; Moeuf et al., 2018). The EU's Digital Decade policy Programme targets 90% of SMEs at basic digital intensity (European Parliament and Council of the European Union, 2022), yet in 2024 only 74% had reached that level - while for large businesses it stood at 98% (Eurostat, 2025); moreover, this aggregate gap conceals a significant geographical divide between northern and western EU Member States (exhibiting substantially higher SME digital intensity) and their southern and eastern counterparts (Eurofound et al., 2025). Compounding both the aggregate gap and its geographical unevenness, EU SME digitalization is typically driven by reactive necessity rather than strategic planning, with external pressures – e.g., labor shortages, supply chain disruptions, or crisis conditions - acting as catalysts for tool adoption rather than structured transformation (Eurofound et al., 2025).

Industry 4.0 frames digital transformation as the integration of cyber-physical systems, Internet of Things, cloud computing and advanced analytics into interconnected, data-driven production architectures as the foundation of competitive manufacturing (Liao et al., 2017); Industry 5.0 broadens this agenda, positioning human-centered technology integration, systemic resilience, and environmental sustainability as co-equal objectives alongside operational efficiency (European Commission, 2021). For manufacturing SMEs, however, translating this agenda into firm-level action is contingent on a prior understanding of where each firm actually stands – its digital baseline, capability gaps, technology priorities, and readiness to invest – a prerequisite that neither the Industry 4.0/5.0 frameworks nor aggregate policy monitoring instruments are designed to fulfil.

Research consistently identifies financial, human capital, and organizational barriers to DT in manufacturing SMEs (Frank et al., 2019; Ghobakhloo & Iranmanesh, 2021; Moeuf et al., 2018; Müller et al., 2018; Sony & Naik, 2020), but their severity, interaction, and relative priority vary substantially across manufacturing sub-sectors, firm sizes, and regional contexts (Ghobakhloo et al., 2022; Veile et al., 2019) - a heterogeneity that aggregate barrier taxonomies and monitoring instruments cannot capture. Structured, population-level needs assessment – systematically mapping digital baselines, barrier configurations, technology priorities, and transformation readiness – is the analytical prerequisite for any differentiated, evidence-based response to this heterogeneity.

The technology-intensity gap in SME DT needs evidence

A persistent limitation of the Industry 4.0 SME literature is that it has documented this heterogeneity without providing the analytical tools to operationalize it: maturity models, readiness frameworks, and barrier taxonomies are routinely constructed at the aggregate SME level (Battistoni et al., 2023; Mittal et al., 2018; Moeuf et al., 2018), collapsing firms whose production technologies, supply chain architectures, regulatory environments, skill requirements, and competitive dynamics differ fundamentally (Frank et al., 2019; Veile et al., 2019) – a tendency reflected even in the most recent DT strategy frameworks, which continue to be grounded primarily in large-firm cases (Wurm et al., 2025). A pharmaceutical component manufacturer and a furniture producer may share legal SME status, but their DT entry points, technology ambitions, infrastructure prerequisites, and support needs are structurally distinct and demand correspondingly differentiated interventions.

Eurostat's technology-intensity classification stratifies manufacturing industries by R&D expenditure intensity into high-tech, medium-high-tech, medium-low-tech, and low-tech categories (Eurostat, 2022), providing an operationally tractable basis for differentiating manufacturing SME populations at the industry level. Absorptive capacity theory (Cohen & Levinthal, 1990) offers a theoretical rationale for why this industry-level classification matters for DT needs assessment: industries characterized by higher technology intensity may be expected to exhibit greater aggregate prior technological knowledge (insofar as sustained sector-level R&D investment generates shared knowledge stocks) which shapes the knowledge base of firms operating within them and, by extension, their capacity to recognize, assimilate, and apply new digital technologies.

The industry-level classification may thus serve as an approximate proxy for the differential absorptive capacity that conditions DT adoption starting points across firm populations – an extension of the absorptive capacity firm-level framework to the industry level that, while not without limitations, is consistent with sector-level applications of knowledge dynamics in the innovation literature. Concretely, higher-technology-intensity industries tend to exhibit greater prior exposure to advanced technologies, deeper technical skill stocks, and more complex supply chain integration requirements (Frank et al., 2019; Veile et al., 2019); lower-technology-intensity industries more frequently face hardware-layer modernization as a prerequisite to software or platform investment, and operate with leaner managerial and technical capacity. Despite its analytical utility, the industry-level classification has been rarely applied as a stratifying variable in empirical DT barrier and needs research, leaving technology-intensity-differentiated evidence on manufacturing SME DT profiles largely absent from the literature – a gap this study directly addresses.

The EDIH instrument and the role of needs assessment in lagging regions

The capacity of manufacturing SMEs to adopt and benefit from digital technologies is shaped not only by firm-level characteristics but by the regional innovation system in which they operate (Tödtling & Trippl, 2005). In lagging or peripheral regions (characterized by thin knowledge infrastructures, limited technology intermediaries, and structural distance from European innovation centers) SMEs face compounded adoption barriers that firm-level interventions alone cannot overcome.

Romania's Centru Region (NUTS2 code RO12) exemplifies this context. Classified as a less developed region under EU Cohesion Policy 2021–2027 (CCRE-CEMR, 2023), the region records a GDP per capita at 70% of the EU average (ADR Centru, 2024) and is classified as an Emerging- innovator on the Regional Innovation Scoreboard 2025 – ranked 240th among the (281) EU regions, with innovation performance at 33.6% of the EU average (European Commission, 2025a). Its manufacturing sector accounts for 28.9% of regional employment (nearly double the EU average of 15.6%) (European Commission, 2025a) and spans industries including automotive, food processing, metalworking, textiles, wood processing and furniture, construction materials, aeronautics, and pharmaceuticals and medical devices (ADR Centru, 2024). SMEs account for 99.7% of the region’s 84,105 active enterprises and, in terms of employment, represent 73% of regional workforce in industry, construction, and services (ADR Centru, 2024). Romania’s distance from the EU digital frontier compounds the regional challenge: cloud technology adoption by firms stood at 15.52% versus an EU average of 38.97%, AI adoption at 3.1% versus 13.48%, and basic digital skills at 27.7% of the population versus 55.56% across the EU (European Commission, 2025b).

European Digital Innovation Hubs (EDIHs) have been established under the Digital Europe Programme as a dedicated instrument to support regional SME digitalization, providing access to technology testing infrastructure, expertise networks, and services including support for accessing funding, pre-investment testing, digital skills development, and identification of suitable technology suppliers (European Parliament and Council of the EU, 2021). FIT EDIH – Futures of Innovation Technologies, the European Digital Innovation Hub serving the Centru Region – operates within this mandate, targeting manufacturing SMEs across the region's diverse industrial base (European Commission, 2022). Structured digital maturity assessment is central to the EDIH intake process, operationalized through instruments such as the Open Digital Maturity Assessment Tool (Open DMAT), which systematically profiles firms across dimensions including digital business strategy, digital readiness, data governance, and AI readiness (European Commission, 2023).

The present study focuses on the manufacturing sub-population, extending an initial cross-sectoral needs assessment – covering manufacturing, e-health, and smart city organizations across 321 entities in the region (Ogrean et al., 2024) – with deeper, technology-intensity-stratified analysis. Effective tailoring of EDIH support, however, depends on granular, empirically grounded intelligence about the actual composition of the regional SME population – its heterogeneity in DT approach, challenge structure, technology priorities, and service demand. Without this intelligence, intake protocols risk systematic miscalibration: delivering road-mapping services to firms that need awareness-building first, or deferring technology identification support to firms that are urgently motivated but lack the technology vision to act.

Research gaps, objectives, and contributions

Despite the growing policy prominence of EDIHs, academic literature on the topic remains limited and fragmented (Toma-Constantin et al., 2025) – and empirical research on how firms engage with and demand EDIH services at the intake level is largely absent. Three specific and interrelated gaps motivate this study. First, technology-intensity-differentiated evidence on DT barriers, needs, technology priorities, expected outcomes, and service demand within regional manufacturing SME populations is absent from the literature. Second, the internal DT approach heterogeneity of lower-technology-intensity SMEs has not been mapped at a granularity sufficient to inform differentiated EDIH service responses. Third, whether anticipated demand for EDIH services varies with DT approach stage (a question with direct implications for service access architecture) has not been empirically examined.

The study pursues two objectives: to provide technology-intensity-differentiated evidence on DT needs, challenges, expected outcomes, and technology priorities within a regional manufacturing SME population; and to generate empirically grounded intelligence for FIT EDIH's service design and prioritization in Centru Region Romania.

Three contributions follow. First, the study provides empirical evidence that industry technology intensity differentiates DT profiles in practically meaningful ways, while identifying a sector-agnostic pre-adoption bottleneck (reflecting insufficient operational planning capacity and technology scanning capability) that justifies universal first-contact EDIH intervention regardless of industry type. Second, it documents the internal DT approach heterogeneity of lower-technology-intensity SMEs at a granularity that industry classification alone cannot provide (including an urgency paradox in which the most urgently motivated firms exhibit the lowest technology ambition alongside the highest anticipated EDIH service demand). Third, it shows that anticipated EDIH service demand is uniformly distributed across DT approach stages, challenging threshold-based service access logic and supporting a parallel-track architecture from first contact.

2. Methodology

Research design and context

The study adopts an exploratory survey design, oriented toward pattern identification and hypothesis generation rather than confirmatory testing of pre-specified propositions. Although responses were accumulated progressively, no temporal comparisons are made, and each firm’s data represents a single-point-in-time DT profile.

The study draws on a self-administered structured questionnaire developed by FIT EDIH for operational needs assessment purposes and hosted on FIT EDIH’s webpage (FIT EDIH, 2023); responses recorded between 27 June 2023 and 7 February 2025 were included in this analysis. The instrument's quantitative format enables systematic inter-group comparison and produces findings in a form directly usable for EDIH service design and prioritization. SMEs accessed the questionnaire independently or following direct contact by FIT EDIH representatives, yielding 71 complete responses from manufacturing SMEs operating in Romania’s Centru Region. Respondents were classified by NACE Rev. 3 division (INSSE, 2025) and assigned to Eurostat's technology-intensity categories (Eurostat, 2022), producing two analytical groups: high and medium-high technology industries (Group A, n=12, 16.9%) and medium-low and low technology industries (Group B, n=59, 83.1%). The access channel introduces a self-selection mechanism (SMEs reached via FIT EDIH’s webpage may be more digitally aware than the broader regional manufacturing population) which constrains generalisation to the full regional SME population.

Survey instrument

The questionnaire was developed by FIT EDIH through an iterative internal process aimed at capturing the DT needs, challenges, technology priorities, and service expectations of manufacturing SMEs in the region. Multiple revision rounds refined item coverage and phrasing to ensure relevance to the operational realities of the target population. The instrument was administered in Romanian; face validity was assessed through FIT EDIH advisor review and a pilot with five manufacturing SME managers.

The instrument comprised seven sections: (1) SME's current digital operational baseline – captured on a three-point ordinal scale (paper-based processes, office suite operations, or cloud-based and integrated platform operations); (2) SME's approach to digital transformation – captured on a seven-point scale anchored at "DT is not necessary for our firm" and "DT is already underway - based on a comprehensive plan"; (3) strategic challenges – thirty items distributed across five organizational areas (Production and Operations, Market and Customers, Human Resources, Financial, and Management and Internal Processes), with respondents selecting exactly two items per domain; (4) technology relevance – seventeen technologies rated on a four-point scale (1 = not at all relevant; 4 = relevant to a large extent) for the firm's DT plans over the next one to three years; (5) department prioritization – respondents selecting exactly three priority departments for DT investment from a list of nine; (6) expected DT outcomes – ten items rated on a four-point importance scale (1 = not at all important; 4 = very important); (7) anticipated usefulness of FIT EDIH services – four service categories rated on a four-point scale (1 = not at all useful; 4 = very useful): support for accessing funding, test before investing, digital skills development, and identification of suitable technology suppliers.

Analytical approach

Analysis proceeded in two stages, both executed in Microsoft Excel. The first comprised descriptive statistics – frequencies, percentages and means – computed for the full sample and separately by group. The second comprised four sets of bivariate analyzes: Welch t-tests with Cohen’s d on all technology relevance, DT outcome expectations, and EDIH service usefulness items to test inter-group differences; one-way ANOVA with η^2 on a Technology Ambition Index (mean of all 17 technology items) across DT approach stages, supplemented by Pearson r between DT approach stage and the index; Spearman rank-order correlations (computed by applying Pearson correlation to RANK.AVG-transformed scores) across all 17 technology items to identify technology co-demand clusters; and Pearson r between DT approach stage and each EDIH service usefulness item to test whether anticipated service demand varies with DT approach stage. All findings are interpreted as indicative rather than confirmatory, consistent with the exploratory design, single-region scope, and small Group A size; statistical significance is reported alongside effect sizes, with primary inferential weight resting on the consistency and magnitude of descriptive patterns.

3. Results/findings

Sample composition

Table 1 presents the distribution of the 71 manufacturing SMEs by NACE division and Eurostat technology-intensity category. SMEs operating in high and medium-high technology industries (Group A - H/MH-tech) account for 12 organizations (16.9% of the sample), while SMEs in medium-low and low technology industries (Group B - L/ML-tech) account for 59 organizations (83.1%).

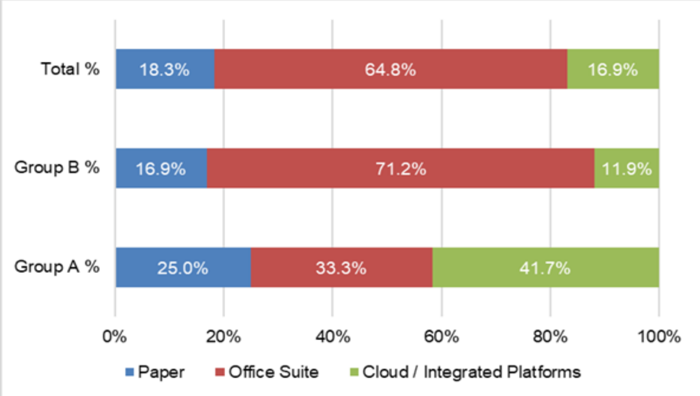
Table 1. SMEs in the sample - by NACE division and technology intensity

NACE Divisions	Industries	No of SMEs	Tech intensity (%)
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	1	High-tech industries 2.8%
26	Manufacture of computers, electronic and optical products	1	
27	Manufacture of electrical equipment	4	Medium-high-tech industries 14.1%
28	Manufacture of machinery, equipment, and other unclassified mechanical devices	5	
29	Manufacture of road transport vehicles, trailers, and semi-trailers	1	
22	Manufacture of rubber and plastic products	7	Medium-low-tech industries 28.2%
23	Manufacture of other non-metallic mineral products	1	
25	Metal construction industry and manufacture of metal products (excluding machinery, equipment, and installations)	11	
33	Repair, maintenance, and installation of machinery and equipment	1	
10	Food industry	10	Low-tech industries 54.9%
13	Manufacture of textile products	3	
14	Manufacture of clothing	2	
15	Tanning and finishing of leather; manufacture of travel goods, leather goods, harnesses, and footwear; fur preparation and dyeing	3	
16	Wood processing, manufacture of wood and cork products (except furniture); manufacture of straw and other woven vegetable materials	4	
18	Printing and reproduction of recorded media	4	
31	Manufacture of furniture	9	
32	Other industrial activities	4	

Digital operational baseline

The two industry groups differ substantially in their current operational modalities (Figure 1). In Group A, 41.7% of SMEs conduct their primary operations through cloud-based or integrated platforms (ERP, CRM), while 33.3% use office suites and 25.0% rely primarily on paper-based processes. In Group B, 71.2% rely on office suites as their primary operational backbone, 16.9% on paper, and only 11.9% on cloud or integrated platforms.

Figure 1. Current operational activities baseline by group
Group A (H/MH-tech ind., n=12); Group B (ML/L-tech ind., n=59); Total (n=71)

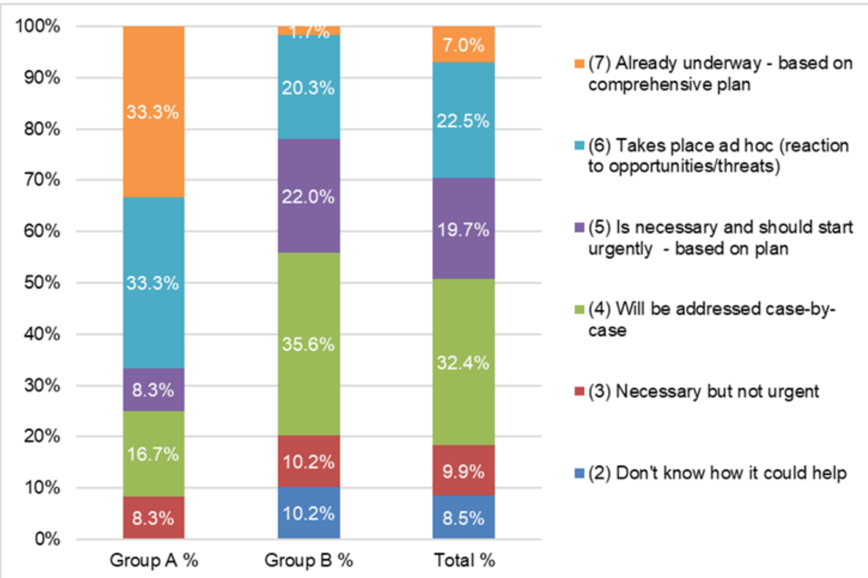


Approach to digital transformation (DT)

On the seven-point DT approach scale - from "DT is not necessary" (1) to "DT is already underway based on a comprehensive plan" (7) - Group A records a mean of 5.67 against Group B's 4.37 (Figure 2). No SME in either group selected code 1.

The two groups differ markedly in their distribution across active and inactive stages (codes 2-5 capture SMEs that have not yet initiated DT in any form; codes 6-7 capture those already in motion): within Group A, 66.6% are already active, 33.3% through ad hoc engagement (code 6) and 33.3% executing a comprehensive plan (code 7). Group B is predominantly inactive: 78.0% have not yet initiated DT, distributed across intent-to-act case-by-case (code 4, 35.6%), urgently motivated but not yet acting (code 5, 22.0%), passive recognition (code 3, 10.2%), and pre-awareness (code 2, 10.2%). Only 1.7% of Group B has a comprehensive plan underway, against 33.3% of Group A.

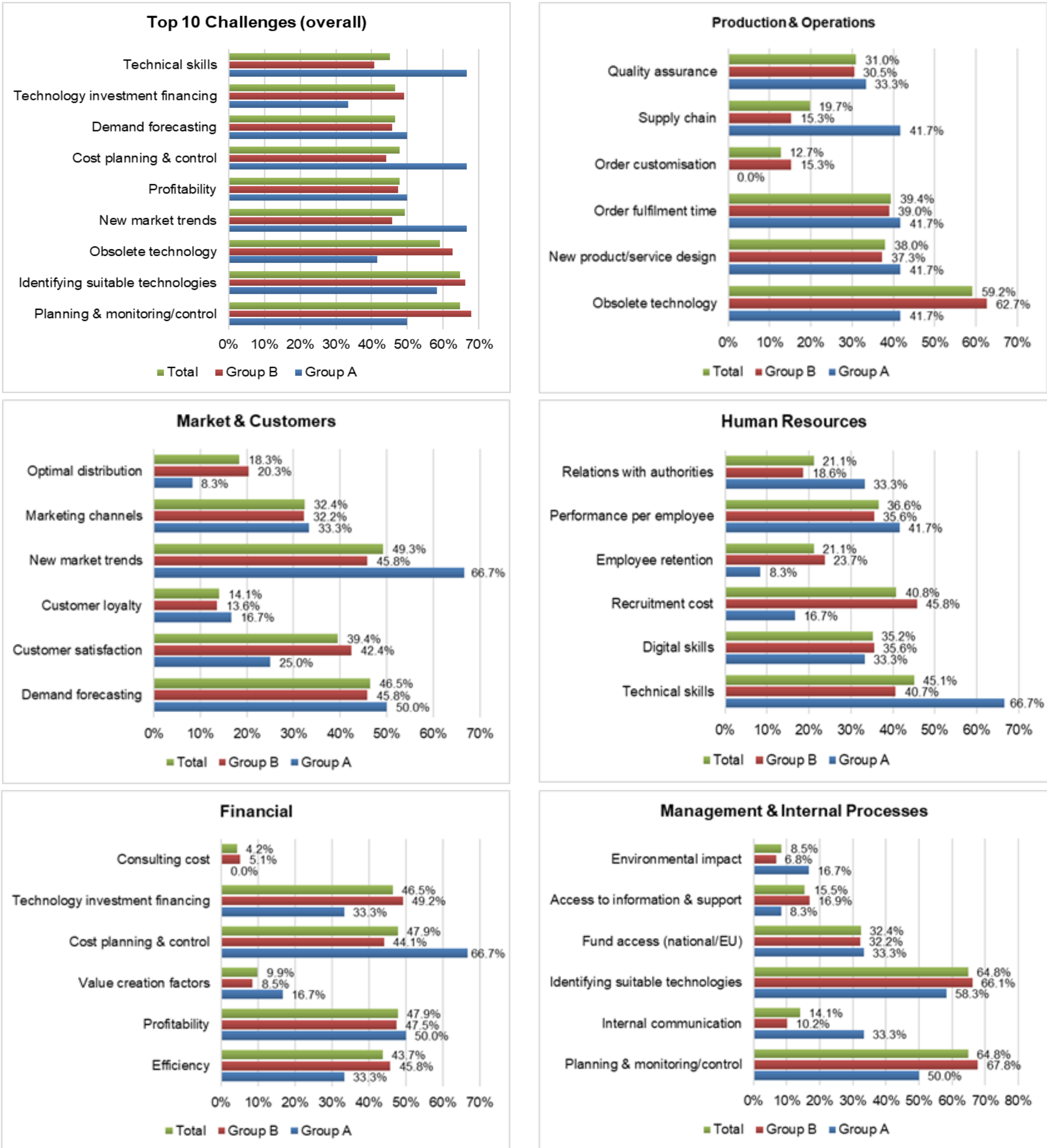
Figure 2. Approach to DT by group



Strategic challenges by organizational area

The challenge profiles differ both within and across the five organizational areas (Figure 3).

Figure 3. Strategic challenges - % of SMEs selecting each item (2 per area)



Production and Operations. Obsolete technology is the most widely cited production challenge overall (Total: 59.2%) and the largest inter-group divergence in this area: 62.7% of Group B vs. 41.7% of Group A (gap: −21.0 pp). Supply chain is the second-most cited challenge for Group A (41.7%) but ranks fifth for Group B (15.3%), a gap of 26.4 pp. Order fulfilment time (A: 41.7%, B: 39.0%) and New product/service design (A: 41.7%, B: 37.3%) are broadly comparable across groups. Order customization is cited exclusively by Group B (15.3%).

Market and Customers. New market trends is the highest-cited challenge in this area for both groups and produces the largest inter-group gap: A: 66.7% vs. B: 45.8% (+20.9 pp). Demand forecasting ranks second and converges closely across groups (A: 50.0%, B: 45.8%). Customer satisfaction is more widely cited in Group B (42.4% vs. 25.0%, −17.4 pp). Marketing channels are nearly identical (A: 33.3%, B: 32.2%). Optimal distribution is cited more by Group B (20.3% vs. 8.3%).

Human Resources. Technical skills is the most cited HR challenge for Group A (66.7%) and the largest Group A excess in this domain (+26.0 pp vs. B: 40.7%). Recruitment cost is the primary HR challenge for Group B (45.8%) and the largest Group B excess (−29.1 pp vs. A: 16.7%). Employee retention is more widely cited by Group B (23.7% vs. 8.3%). Digital skills (A: 33.3%, B: 35.6%) and Performance per employee (A: 41.7%, B: 35.6%) are broadly comparable.

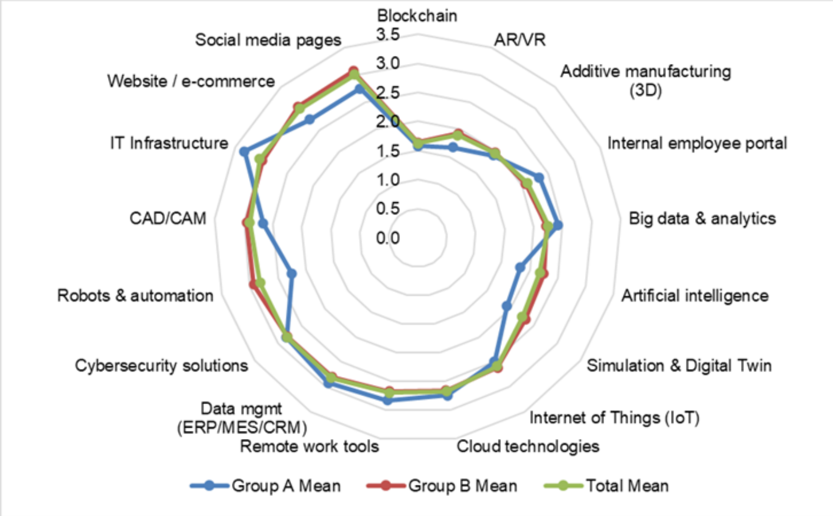
Financial. Cost planning and control is the highest-cited financial challenge for Group A (66.7%), producing the largest Group A excess in this domain (+22.6 pp vs. B: 44.1%). Profitability is the most widely cited challenge in Group B (47.5%) and converges closely with Group A (50.0%, gap: +2.5 pp). Technology investment financing is more widely cited by Group B (49.2% vs. 33.3%, −15.9 pp), as is Efficiency (45.8% vs. 33.3%, −12.5 pp).

Management and Internal Processes. Planning and monitoring/control (Total: 64.8%) and Identifying suitable technologies for modernization (Total: 64.8%) are the two highest-cited challenges in the entire dataset, shared across both groups: A: 50.0% and 58.3%; B: 67.8% and 66.1% respectively. Internal communication is cited by 33.3% of Group A but only 10.2% of Group B (+23.1 pp). Fund access is nearly identical across groups (A: 33.3%, B: 32.2%).

Technology relevance

The three highest-scoring technologies overall are IT infrastructure (M=3.04), Social media pages (M=3.01), and Website/e-commerce (M=3.00) (Figure 4). Group A rates IT infrastructure highest of all technologies (M=3.33 vs. B: 2.98, +0.35). Group B rates Robots and automation notably higher than Group A (M=2.93 vs. 2.25, −0.68), the largest single inter-group difference. CAD/CAM (M=2.90) and Data management systems (M=2.82) rank fourth and fifth overall. The lowest-scoring technologies are Additive manufacturing (M=1.97), AR/VR (M=1.89), and Blockchain (M=1.63), with minimal inter-group differences in all three.

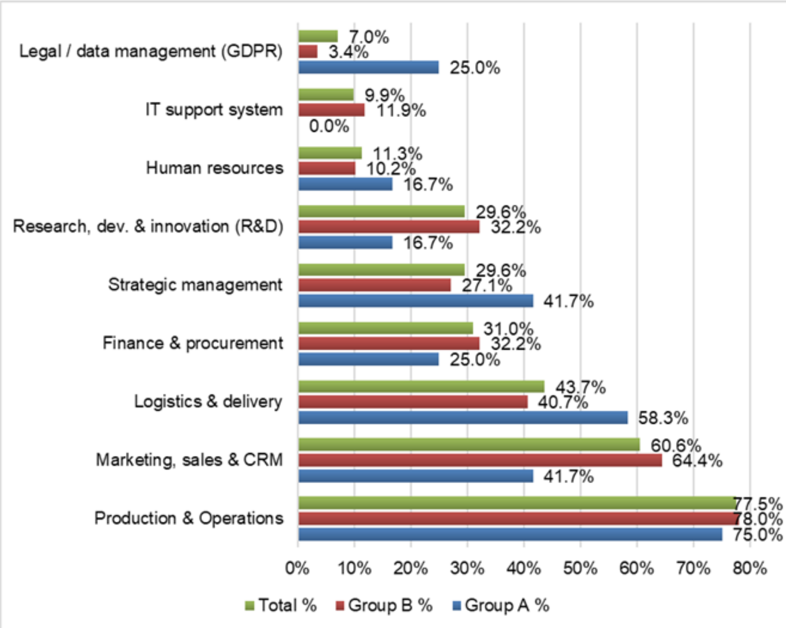
Figure 4. Technology relevance for next 1-3 Years – mean scores by group



Department prioritization

Production and Operations leads department prioritization for both groups (A: 75.0%, B: 78.0%; Total: 77.5%) (Figure 5). Marketing, sales and CRM ranks second overall (Total: 60.6%) with a notable inter-group gap (B: 64.4% vs. A: 41.7%, −22.7 pp). Logistics and delivery ranks third overall (Total: 43.7%) and is cited substantially more by Group A (58.3% vs. 40.7%, +17.6 pp). Finance and procurement (Total: 31.0%), Strategic management (Total: 29.6%), and R&D and Innovation (Total: 29.6%) follow, with R&D cited more by Group B (32.2% vs. 16.7%). Legal and data management (incl. GDPR) is cited by 25.0% of Group A but only 3.4% of Group B (+21.6 pp).

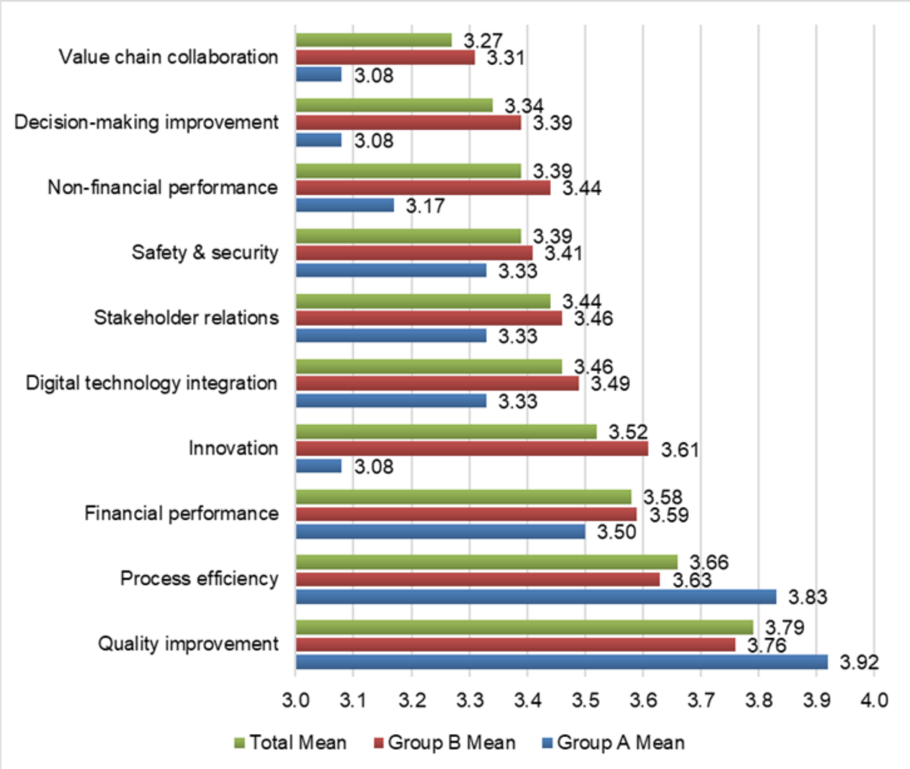
Figure 5. Department prioritization for DT by group - % selecting (3 per respondent)



Expected DT outcomes

Quality improvement and Process efficiency rank first and second for both groups (Figure 6). Group A (M=3.92 and 3.83); Group B (M=3.76 and 3.63). Innovation ranks third for Group B (M=3.61) but eighth for Group A (M=3.08), producing the largest inter-group gap (−0.53 points). Financial performance ranks third for Group A (M=3.50) and fourth for Group B (M=3.59). Group B rates eight of the ten outcomes higher than Group A; Group A leads only on Quality improvement (+0.15) and Process efficiency (+0.21).

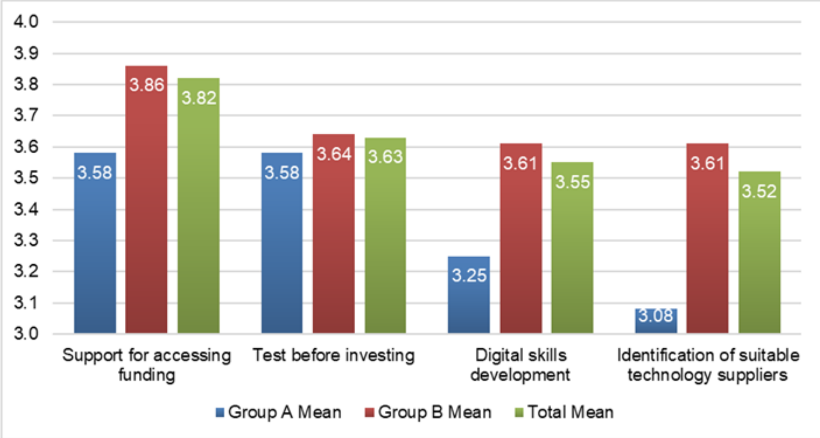
Figure 6. Most important DT outcomes – mean scores by group



Expected usefulness of FIT EDIH services

When asked to rate the expected usefulness of four FIT EDIH services for their own DT journey, respondents across the full sample score all four items above 3.50 (Figure 7). Support for accessing funding ranks highest overall (M=3.82), followed by Test before investing (M=3.63), Digital skills development (M=3.55), and Identification of suitable technology suppliers (M=3.52). Group B rates all four services higher than Group A. The largest gaps are on Identification of suitable technology suppliers (B: 3.61 vs. A: 3.08, −0.53 points) and Digital skills development (B: 3.61 vs. A: 3.25, −0.36 points). Test before investing shows the smallest inter-group difference (B: 3.64 vs. A: 3.58, −0.06 points).

Figure 7. Interest for EDIH services – mean scores by group



Analytical findings

Technology demand clusters. Spearman rank-order correlations across all 17 technology relevance items identify three coherent co-demand clusters – groups of technologies rated highly together by the same firms, visible as dark diagonal blocks in the correlation matrix, with technologies reordered so cluster members are adjacent (Table 2): a physical-digital integration cluster linking IoT, CAD/CAM, and Digital Twin (strongest pair: IoT x Digital Twin, r=0.81); an advanced digital backbone cluster linking Cloud, Cybersecurity, Big data, and AI (all six intra-cluster pairs r=0.65-0.80); and a customer-facing digital cluster linking Website and Social media (r=0.75). All values shown are significant at p<0.001. Four cross-cluster pairs also exceed r=0.70, most notably IoT x Cybersecurity (r=0.74) and IoT x AI: r=0.73).

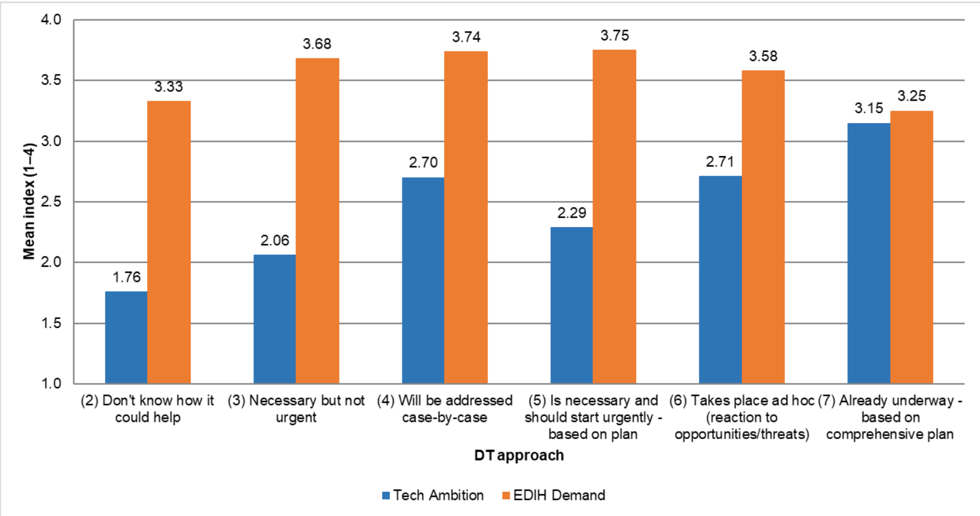
Table 2. Spearman r correlation matrix - technology relevance items (n = 71)

		Physical-digital			Digital backbone				Customer-facing									
Cluster	Technology	IoT	CAD/CAM	Digital Twin	Cloud	Cybersecurity	Big data	AI	Website	Social media	Robots	IT Infra	Remote work	Int. portal	Data mgmt	Add. mfg	AR/VR	Blockchain
Physical-dig	**IoT**	1	0.55	**0.81**	**0.71**	**0.74**	0.63	**0.73**		0.51	0.56		0.57		0.58	0.60	0.61	0.53
	CAD/CAM	0.55	1	**0.74**	0.52	0.51	0.41	0.47			0.58				0.44	0.64		0.41
	Digital Twin	**0.81**	**0.74**	1	0.67	0.64	0.52	**0.70**	0.41	0.50	0.69		0.47		0.53	0.68	0.64	0.59
Digital backbon	**Cloud**	**0.71**	0.52	0.67	1	**0.80**	0.65	**0.75**	0.43	0.47	0.52	0.54	0.67	0.44	0.58	0.60	0.64	0.55
	Cybersecurity	**0.74**	0.51	0.64	**0.80**	1	**0.74**	**0.77**	0.41	0.56	0.54	0.51	0.55	0.43	0.59	0.56	0.53	0.48
	Big data	0.63	0.41	0.52	0.65	**0.74**	1	0.69	0.46	0.54	0.52	0.56	0.47	0.61	0.60	0.46	0.44	0.49
	AI	**0.73**	0.47	**0.70**	**0.75**	**0.77**	0.69	1	0.50	0.54	0.59		0.55	0.46	0.42	0.58	**0.71**	0.61
Custon	**Website**			0.41	0.43	0.41	0.46	0.50	1	**0.75**	0.53			0.44	0.48	0.43		0.45
	Social media	0.51		0.50	0.47	0.56	0.54	0.54	**0.75**	1	0.53		0.44	0.50	0.53	0.51		0.50
Ungrouped	Robots	0.56	0.58	0.69	0.52	0.54	0.52	0.59	0.53	0.53	1				0.55	0.55	0.53	0.44
	IT Infra				0.54	0.51	0.56					1	0.50	0.47				0.50
	Remote work	0.57		0.47	0.67	0.55	0.47	0.55		0.44		0.50	1	0.47	0.46	0.55	0.52	0.40
	Int. portal				0.44	0.43	0.61	0.46	0.44	0.50		0.47	0.47	1	0.46	0.45		0.43
	Data mgmt	0.58	0.44	0.53	0.58	0.59	0.60	0.42	0.48	0.53	0.55		0.46	0.46	1	0.54		0.44
	Add. mfg	0.60	0.64	0.68	0.60	0.56	0.46	0.58	0.43	0.51	0.55		0.55	0.45	0.54	1	0.57	0.43
	AR/VR	0.61		0.64	0.64	0.53	0.44	**0.71**			0.53		0.52			0.57	1	0.47
	Blockchain	0.53	0.41	0.59	0.55	0.48	0.49	0.61	0.45	0.50	0.44	0.50	0.40	0.43	0.44	0.43	0.47	1

Note. Values displayed where |r|≥0.40 (all p<0.001); bold where r≥0.70. Bordered blocks indicate co-demand clusters: Physical-digital integration (IoT, CAD/CAM, Digital Twin); Advanced digital backbone (Cloud, Cybersecurity, Big data, AI); Customer-facing digital (Website, Social media).

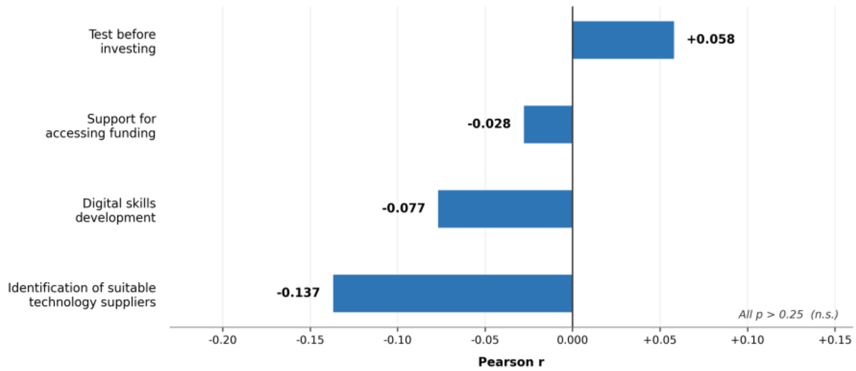
Technology ambition by DT approach. A one-way ANOVA on a Technology Ambition Index (mean of all 17 technology relevance items per respondent) across the DT approach stage (Figure 8) yields $F(5,65)=3.803$, $p=0.004$, $\eta^2=0.226$. The index rises from 1.76 among SMEs with low DT awareness ("Don't know how it could help") to 3.15 among firms already executing a comprehensive DT plan ("Already underway – based on comprehensive plan") and is positively correlated with DT approach treated as continuous (Pearson $r=+0.350$, $p=0.003$). SMEs recognizing urgent need but not yet having initiated action ("Is necessary and should start urgently - based on plan", n=14) – record a Technology Ambition Index (M=2.29) markedly lower than SMEs already engaging ad hoc (M=2.71) and those executing a comprehensive plan (M=3.15), despite their stated urgency and the highest EDIH Demand Index in the sample (M=3.75).

Figure 8. Technology Ambition Index & EDIH Demand Index by DT approach



Estimated/anticipated EDIH service usefulness and DT approach. Pearson correlations between the DT approach stage (six categories treated as continuous) and each of the four EDIH service items are all non-significant (r range: −0.137 to +0.058; all $p>0.25$); Anticipated EDIH service usefulness is uniformly distributed (Figure 9).

Figure 9. Pearson r: DT approach stage x Anticipated EDIH service usefulness



Group differences – formal tests. Welch t-tests on all technology relevance, DT outcome expectations, and EDIH service usefulness items confirm statistical significance for two inter-group differences: robots and automation (Group A: M=2.25 vs. Group B: M=2.93; p=0.044, d=0.63) and identification of suitable technology suppliers (Group A: M=3.08 vs. Group B: M=3.61; p=0.023, d=0.91). Two further differences approach but do not reach the conventional α=0.05 threshold: innovation (Group A: M=3.08 vs Group B: M=3.61; p=0.075, d=0.79) and digital skills development (Group A: M=3.25 vs Group B: M=3.61; p=0.081, d=0.66). All remaining inter-group differences are non-significant (all p>0.10). Given Group A's small size (n=12), non-significant results should not be interpreted as evidence of equivalence (Table 3).

Table 3. Group comparison - Welch t-Tests

Item	Scale (1-4)	Group A Mean	Group B Mean	t	p	d	Sig.
Statistically significant (p < 0.05)							
Robots & automation	Technology relevance	2.25	2.93	-2.172	0.044	0.63	*
Identification of suitable technology suppliers	EDIH service usefulness	3.08	3.61	-2.555	0.023	0.91	*
Borderline (0.05 ≤ p < 0.10) - indicative only							
Innovation	DT outcome expectations	3.08	3.61	-1.937	0.075	0.79	.
Digital skills development	EDIH service usefulness	3.25	3.61	-1.875	0.081	0.66	.
Non-significant (p > 0.10) - selected items shown; 20 further items all p > 0.12							
IT infrastructure	Technology relevance	3.33	2.98	1.600	0.125	0.42	n.s.
Non-financial performance	DT outcome expectations	3.17	3.44	-1.466	0.161	0.43	n.s.
Quality improvement	DT outcome expectations	3.92	3.76	1.492	0.148	0.35	n.s.
Process efficiency	DT outcome expectations	3.83	3.63	1.452	0.158	0.33	n.s.
Decision-making	DT outcome expectations	3.08	3.39	-1.233	0.236	0.41	n.s.
Support for accessing funding	EDIH service usefulness	3.58	3.86	-1.198	0.254	0.59	n.s.
All other items (20)	-	-	-	-	-	-	all n.s.

Note. Welch t-test (unequal variances assumed). * p<0.05; . p<0.10 (borderline); n.s. p>0.10. d = Cohen's d effect size: 0.2 small, 0.5 medium, 0.8 large. Group A (n=12) limits statistical power; non-significant results do not imply equivalence between groups.

DT outcome expectations and anticipated EDIH service usefulness. Pearson correlations between DT outcome expectations and anticipated EDIH service usefulness are significant for 29 of 40 possible pairs, with all four EDIH services producing between five and ten significant associations with DT outcome expectation items (Table 4). The three strongest associations are safety and security aspirations with digital skills development (r=0.532, p<0.001), non-financial performance aspirations with test before investing (r=0.479, p<0.001), and digital integration aspirations with test before investing (r=0.438, p<0.001). Test before investing and digital skills development attract the broadest coherence, each producing ten and nine significant associations with DT outcome expectation items respectively.

Table 4. DT outcome expectations × EDIH service usefulness - Pearson r heat map

	Digital skills development	Test before investing	Support for accessing funding	Identification of suitable technology suppliers
Safety & security	**0.532*****	0.370**	0.296*	0.247*
Non-financial performance	**0.425*****	**0.479*****	0.325**	0.271*
Digital integration	**0.403*****	**0.438*****	0.340**	0.265*
Decision-making	**0.437*****	**0.424*****	0.365**	0.265*
Innovation	0.322**	0.387***	**0.413*****	0.330**
Financial performance	0.395***	0.379**	0.186	0.198
Process efficiency	0.374**	0.376**	0.167	0.206
Quality improvement	0.245*	0.340**	0.149	0.096
Value chain collaboration	0.299*	0.251*	0.218	0.227
Stakeholder relations	0.222	0.281*	0.029	0.233

Note. Pearson r (n=71). Rows sorted by maximum r. *** p<0.001; ** p<0.01; * p<0.05; blank = n.s.

4. Discussions

This study addresses two intersecting needs: the absence of technology-intensity-differentiated evidence on digital transformation needs, barriers/challenges, expectations, and service demand within regional manufacturing SME populations; and the practical requirement of FIT EDIH for granular, empirically grounded intelligence to design and prioritize its services.

Technology intensity differentiates DT profiles - but not the most critical barrier

The Eurostat technology-intensity classification reproduces several theoretically expected gradients, confirming its diagnostic value for DT profiling – a contribution to a literature that has predominantly treated manufacturing SMEs as a homogeneous analytical category (Mittal et al., 2018). Group A firms operate from a substantially more advanced digital baseline (41.7% on cloud or integrated platforms vs. 11.9% of Group B), record higher DT approach scores (M=5.67 vs. 4.37), and concentrate their challenges in domains consistent with Industry 4.0 systemic integration: supply chain complexity (41.7% vs. 15.3%), technical skill depth (66.7% vs. 40.7%), and compliance-integrated DT

(Legal/GDPR: 25.0% vs. 3.4%). At the industry level, R&D expenditure intensity serves as an aggregate proxy for the prior technological knowledge base that, per absorptive capacity theory (Cohen & Levinthal, 1990), shapes a firm's capacity to recognize, assimilate, and apply new digital technologies - and by extension, the starting point from which DT adoption must proceed. Group B firms face a more foundational modernization challenge: obsolete technology constrains production digitalization for 62.7% of firms (vs. 41.7% of Group A), recruitment cost is the primary HR barrier for 45.8% (vs. 16.7%), and financial risk around technology investment is cited by 49.2% (vs. 33.3%) - a profile consistent with the barriers documented in the SME Industry 4.0 literature (Da Rocha Moro et al., 2025; Ghobakhloo & Iranmanesh, 2021).

The most consequential finding, however, is where technology intensity does not differentiate. Planning and monitoring/control and identifying suitable technologies for modernization – each cited by approximately two-thirds of the full sample (Total: 64.8% for both items; Group A: 50.0% and 58.3%; Group B: 67.8% and 66.1%) – are the two highest-cited challenges in the entire dataset. Their co-occurrence and cross-group convergence establish a sector-agnostic pre-adoption bottleneck regardless of industry type: firms simultaneously lack the operational management capacity and the technology scanning capability to initiate structured DT – a pattern consistent with the prior knowledge constraint that absorptive capacity theory identifies as foundational to technology adoption (Cohen & Levinthal, 1990). For FIT EDIH, pre-investment testing and identification of suitable technology suppliers directly address this bottleneck and are warranted as universal first-contact offerings across both industry groups.

DT approach heterogeneity within Group B exceeds what technology intensity captures

Group B constitutes 83.1% of the sample (and is FIT EDIH’s primary service population). Its DT approach distribution reveals four coexisting sub-populations: low awareness (10.2%), passive recognition (10.2%), intent-to-act (35.6%), and urgency-frozen (22.0%) - with 78.0% yet to initiate DT.

The urgency paradox – identified in the descriptive pattern and confirmed statistically by one-way ANOVA – demonstrates that these sub-populations are not points on a linear adoption progression but distinct motivational states with different intervention requirements. SMEs that recognize DT as urgently needed but have not yet initiated action ($n=14$) record the lowest Technology Ambition Index of any urgency-motivated or active sub-population ($M=2.29$ vs. $M=2.71$ for firms already engaging ad hoc and $M=3.15$ for those executing a comprehensive plan), while simultaneously recording the highest EDIH Demand Index in the sample ($M=3.75$). The ANOVA result is robust ($F(5,65)=3.803$, $p=0.004$, $\eta^2=0.226$), and the positive association between DT approach stage and technology ambition (Pearson $r=+0.350$, $p=0.003$) confirms the broader positive trend while the non-monotonic pattern among urgency-motivated but not yet acting firms reveals the limits of a linear progression assumption. Consistent with the attention-based view of the firm (Ocasio, 1997), urgency may redirect organizational attention toward the problem of DT without generating the technology scanning capacity required to act on it. For FIT EDIH, this cohort requires structured technology road-mapping and pre-investment demonstration as first interventions, not awareness-raising. Group A's profile raises a distinct implication. Two-thirds are already active – equally split between ad hoc engagement (33.3%) and comprehensive planning (33.3%) – yet ad hoc engagement, by definition, lacks the strategic coherence that sustained DT requires. In an Industry 5.0 context, where resilience and human-centered integration require deliberate technology orchestration rather than opportunistic tool adoption (European Commission, 2021), converting reactive digital activity into structured roadmaps constitutes a specific and tractable EDIH intervention for this group – one focused on integration and strategic coherence rather than technology identification, which Group B requires.

Technology co-demand clusters define differentiated EDIH assessment tracks

Group B's significantly higher rating for robots and automation (Group A: M=2.25 vs. Group B: M=2.93; p=0.044, d=0.63) – the only technology relevance inter-group difference formally confirmed – is consistent with the prevalence of manual production processes in lower-technology-intensity industries, where automation – a foundational Industry 4.0 technology (Liao et al., 2017) – emerges as the most proximate digitalization priority. Group A's descriptively higher rating for IT infrastructure (Group A: M=3.33 vs. Group B: M=2.98; p=0.230) points toward investment in the digital backbone underpinning more sophisticated applications. These differences suggest that the technology entry point for EDIH conversations should differ structurally by group.

The Spearman correlation analysis identifies three technology co-demand clusters, with all intra-cluster pairs significant at p<0.001: a physical-digital integration cluster (IoT, CAD/CAM, Digital Twin; strongest pair: IoT x Digital Twin, r=0.81), an advanced digital backbone cluster (Cloud, Cybersecurity, AI, Big data; strongest pair: Cloud x Cybersecurity, r=0.80), and a customer-facing digital cluster (Website x Social media, r=0.75). Four cross-cluster pairs also exceed r=0.70, notably IoT x Cybersecurity (r=0.74) and IoT x AI (r=0.73), indicating ecosystem interdependencies spanning cluster boundaries – consistent, by analogy, with platform complementarity logic (Gawer & Cusumano, 2014). For FIT EDIH, cluster-structured assessments are likely to generate more actionable and complete technology roadmaps than single-technology consultations, by surfacing co-demanded technologies that single-item approaches would miss.

Service demand is universal and aspiration-coherent, with one confirmed group difference

Both groups converge on quality improvement (Group A: M=3.92; Group B: M=3.76) and process efficiency (Group A: M=3.83; Group B: M=3.63) as their top two expected DT outcomes. The divergence on innovation – ranked eighth for Group A (M=3.08) but third for Group B (M=3.61), the largest DT outcome gap at 0.53 points – indicates that Group B additionally frames DT as a competitive repositioning lever, consistent with catch-up dynamics in lagging regional economies where structural distance from the EU digital frontier is greater (Tödtling & Trippl, 2005). Group B rates eight of ten outcome dimensions higher than Group A, suggesting a DT rationale that extends beyond operational consolidation (though whether this reflects strategic ambition, greater performance gaps, or both cannot be determined from cross-sectional data alone). The convergence on quality and efficiency provides a shared communication register for EDIH outreach across both groups; the innovation divergence warrants differentiated framing for Group B even when delivering the same service.

All four EDIH services receive anticipated usefulness scores above the scale midpoint, and Pearson correlations between DT approach stage and each service item are all non-significant (all $p>0.25$). This null finding challenges threshold-based service access logic and supports a parallel-track architecture from first contact. The one inter-group difference formally confirmed – identification of suitable technology suppliers (Group B: $M=3.61$ vs. Group A: $M=3.08$; $p=0.023$, $d=0.91$) – directly mirrors Group B's dominant challenge: two-thirds cite identifying suitable technologies as a primary barrier, and they rate the usefulness of this service at a statistically distinguishable level. Digital skills development approaches but does not reach significance ($p=0.081$, $d=0.66$), consistent with Group B's weaker internal digital competency base. Finally, 29 of 40 DT outcome expectation x EDIH service usefulness pairs are significant, with the strongest links connecting safety and security aspirations with digital skills development ($r=0.532$, $p<0.001$) and non-financial performance aspirations with test before investing ($r=0.479$, $p<0.001$). SMEs with richer DT outcome expectations rate all four EDIH services as more useful – a pattern that supports structured outcome-expectation assessment as a targeting tool for FIT EDIH's service prioritization.

Limitations

Several limitations constrain the scope of the study. The sample is confined to manufacturing SMEs in a single Romanian region, and respondent self-selection via FIT EDIH's digital channel may favor more digitally aware SMEs than the broader regional manufacturing population, limiting generalization beyond the surveyed SMEs. The extended data collection window introduces potential temporal variation that the cross-sectional analytical approach cannot control for, and cross-sectional design precludes causal inference. Group A's small size ($n=12$) limits statistical power for group-level comparisons; most inter-group descriptive differences should be interpreted as indicative rather than confirmatory. Replication across other regional and national contexts, with larger and more balanced samples, is required to assess the generalizability of the technology-intensity differentiation patterns reported here.

5. Conclusions

Effective digital transformation support for manufacturing SMEs demands evidence-based differentiation – by industry technology intensity, by DT approach stage, and by the specific barriers and technology priorities that define each firm's starting point. This study provides empirical grounding for that differentiation in the context of FIT EDIH and the Centru Region of Romania.

Three actionable conclusions emerge. First, industry technology intensity differentiates DT profiles in practically meaningful ways – digital baseline, challenge structure, technology priorities, and department targets all differ systematically between high and medium-high technology industries (Group A, $n=12$) and medium-low and low technology industries (Group B, $n=59$) – confirming that industry-level stratification is a necessary first input to EDIH needs assessment. Yet the two highest-cited challenges in the entire dataset (each selected by approximately two-thirds of SMEs regardless of industry group) converge on planning and monitoring/control and identifying suitable technologies for modernization, establishing a sector-agnostic pre-adoption bottleneck that justifies universal first-contact EDIH intervention.

Second, within Group B (83.1% of the sample and FIT EDIH's primary service population), DT approach stage operates as an independent dimension that industry classification alone cannot capture. The urgency paradox is the most practically significant finding: SMEs at an earlier DT approach stage – recognizing DT as urgently needed but not yet acting – record the highest anticipated EDIH service demand in the sample (EDIH Demand Index: M=3.75) yet the lowest technology ambition (Technology Ambition Index: M=2.29), lower than firms already acting ad hoc (M=2.71) and those executing a comprehensive plan (M=3.15). Structured road mapping and pre-investment demonstration (not awareness-raising) are the warranted first interventions, but they cannot be identified as such without prior diagnostic needs assessment.

Third, the uniform distribution of anticipated EDIH service demand across all DT approach stages confirms that needs are present throughout the spectrum. Needs assessment is not a gatekeeping mechanism – it is a calibration tool determining the depth and configuration of support from first contact, not whether support is offered at all.

Taken together, these findings make the empirical case for a dual-dimension EDIH intake protocol – assessing industry technology intensity and DT approach stage as independent, complementary dimensions – as the foundation for service design that is differentiated where the evidence demands it and universally accessible where it does not.

The study is limited by its single-region, cross-sectional design, the small size of Group A (n=12), and potential self-selection bias through the FIT EDIH access channel; replication across other EDIH contexts with larger, more balanced samples is required to assess generalizability.

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