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Strengthening Competitiveness of Korean Testing, Inspection, and Certification Institutions for Global Market Expansion

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Abstract: (1) Background/Purpose: The global Testing, Inspection, and Certification (TIC) market is expanding at a compound annual growth rate of approximately 3.3–5.0%, driven by tightening international regulations, the rise of renewable energy and healthcare industries, and accelerating digital transformation. Korean TIC institutions, however, remain disproportionately concentrated in the domestic market, constrained by structural deficiencies in skilled human resources, testing equipment, and international networks, while facing intensifying competition from global TIC leaders such as SGS, TÜV SÜD, and Bureau Veritas operating within Korea. (2) Methodology: This study employs a mixed-method approach. Quantitative analysis uses One-Way ANOVA (Welch's) and Games-Howell post-hoc tests applied to the 2023 Korea Testing and Certification Industry Association (KOTICA) national survey data (n = 7,889 institutions), segmented into eight revenue-size groups, to identify statistically significant differences in competitiveness perceptions and equipment holdings. Qualitative analysis benchmarks the training programs of the Korea Testing and Research Institute (KTR) Academy against the SGS Academy, and applies a SWOT framework to the Korean TIC industry. (3) Findings: Statistically significant differences were confirmed across all eight revenue groups for four competitiveness dimensions (capability/scope, expert staff, investment scale, external reputation; all $p < .0001$). Equipment holdings differ significantly by revenue group ($p < .0001$), with institutions generating under 100 million KRW holding an average of 5 equipment types compared to 278 for the 20–30 billion KRW group. KTR Academy offers 30 programs, primarily domestic-standards-focused, compared to SGS Academy's 85 programs spanning international standards, digital technologies, and online delivery. SWOT analysis reveals that strong manufacturing demand and government support constitute key strengths, while outdated infrastructure, skills shortages, and limited international networks are principal weaknesses. (4) Originality/Value: This study provides the first systematic empirical analysis of the Korean TIC industry's competitiveness gap using large-sample ANOVA, and derives evidence-based strategic recommendations covering human resource development, equipment modernization, and diversified business and marketing strategies.

Keywords: testing, inspection, and certification (TIC); Korean TIC industry; global competitiveness; ANOVA; human resource development; digital transformation; SWOT analysis; SGS; accreditation

1. Introduction

1.1. Research Background and Necessity

The Testing, Inspection, and Certification (TIC) industry has become increasingly central to modern industrial structures. As technology innovation accelerates and globalization deepens, the need to verify the quality, safety, and regulatory compliance of products and services is intensifying. The global TIC market has been expanding at an annual average growth rate of 3.3–5.0% (Markets and Markets, 2023), driven by growth in manufacturing, healthcare, renewable energy, and digital technologies. In 2022, the global TIC market reached approximately USD 218 billion, and is projected to reach USD 265 billion by 2028.

Korean TIC institutions, however, have not fully captured this global growth opportunity. A significant majority of domestic TIC institutions continue to operate within the saturated domestic market, competing primarily on price, which hinders innovation and growth. Structural challenges include: (i) a shortage of highly qualified professionals and the absence of internationally aligned training programs; (ii) outdated testing equipment that limits the precision and scope of testing services; (iii) slow adoption of digital transformation technologies such as AI, IoT, and blockchain; and (iv) limited international network presence compared to leading global TIC entities.

In contrast, global TIC leaders such as TÜV SÜD (Germany), Bureau Veritas (France), and UL (United States) have leveraged advanced technology, comprehensive training programs, and extensive international networks to achieve dominant market positions. These firms are simultaneously expanding into the Korean domestic market, further

intensifying competitive pressure on domestic institutions. The combined revenues of the world's top ten TIC institutions in 2022 exceeded KRW 57.3 trillion (approximately USD 44.2 billion), compared with the combined revenues of Korea's seven major TIC institutions of approximately KRW 843 billion—roughly 1.5% of that total.

This study departs from the premise that Korean TIC institutions' global competitiveness requires structural enhancement in three interconnected areas: human capital, testing infrastructure, and strategic business orientation. Using the 2023 KOTICA national survey as its empirical foundation, complemented by international benchmarking and SWOT analysis, the study aims to diagnose the industry's structural weaknesses and propose actionable strategies.

1.2. Research Objectives

This study pursues three specific objectives:

1. To examine whether central government and industry association support policies and investments translate into measurable competitiveness improvements for Korean TIC institutions, and to identify the primary structural barriers to global market entry.
2. To quantitatively assess the relationship between institutional revenue scale and key competitiveness factors—expert human resources, equipment holdings, investment scale, and external reputation—using ANOVA-based statistical analysis of the 2023 KOTICA industry survey.
3. To benchmark Korean TIC institutions' training programs against international best practices (SGS Academy), and to propose integrated strategic recommendations for human resource development, equipment modernization, and business/marketing strategy diversification.

1.3. Research Scope and Methodology

This study utilizes the 2023 KOTICA TIC Industry Survey, conducted from July 17 to September 8, 2023, covering 7,889 institutions across the Korean TIC service market. The survey data include institutional workforce composition, equipment holdings, competitiveness perceptions, and revenue structure. Survey respondents were classified into eight revenue-size groups (G1: <100 million KRW to G8: ≥30 billion KRW).

Quantitative analysis was conducted using Jamovi (v2.5) statistical software with One-Way ANOVA (supplemented by Welch's ANOVA where the homogeneity of variance assumption was violated, as confirmed by Levene's test) and Games-Howell post-hoc tests to identify statistically significant inter-group differences. Qualitative analysis examined the training program portfolios of KTR Academy (domestic) and SGS Academy (international) as of November 2024, and applied a SWOT framework to systematically evaluate the Korean TIC industry's internal strengths and weaknesses and external opportunities and threats.

2. Environmental Analysis

2.1. Overview of the TIC Industry

The TIC industry is a high-value-added service sector that verifies the quality, safety, and regulatory compliance of products, services, and processes. It operates through three complementary and mutually reinforcing core activities:

- Testing: the scientific and objective measurement of a product's or service's performance, quality, and safety in a laboratory environment using standardized procedures.
- Inspection: confirmation that products, equipment, systems, or services comply with specified requirements and standards, typically performed in manufacturing or field environments. Inspection encompasses both quantitative measurement and qualitative assessment.
- Certification: the formal attestation, by an independent third-party body, that a product, service, or system meets defined standards or regulations. Certification provides legal force and international recognition.

These three activities form a coherent ecosystem: testing generates technical data; inspection uses that data to verify requirement compliance; certification formally validates and communicates compliance to markets and regulators. The TIC industry thus constitutes an essential intermediary between producers, regulators, and consumers in both domestic and international trade contexts.

The TIC industry is organized along two service delivery models. The third-party service market involves independent accredited organizations providing objective, internationally recognized testing, inspection, and certification services—critical for companies seeking access to global markets. The in-house market involves large manufacturers conducting testing and certification internally, primarily in technology-intensive sectors such as automotive, electronics, and semiconductors, to accelerate development timelines while maintaining confidentiality. The two models are

complementary: many firms use in-house testing during development and engage third-party certification for final market approval.

Figure 1. Interrelationships within the TIC industry ecosystem.

2.2. Domestic TIC Market

By 2022, the total Korean TIC market was estimated at approximately KRW 154.7 trillion, with a compound annual growth rate (CAGR) of 2.5%. The third-party service market accounted for KRW 87.2 trillion (CAGR 7.5%), while the in-house market accounted for KRW 67.5 trillion (declining CAGR of -3.0%), reflecting the structural shift toward outsourced, accredited testing services.

Table 1. Domestic TIC market size trend. Unit: 100M KRW. Source: KOTICA (2023).

Market Segment	2020 (100M KRW)	2021 (100M KRW)	2022 (100M KRW)	CAGR (%)
Total Domestic Market	147,149	145,623	154,713	2.5
Service Market	75,440	81,071	87,218	7.5
In-House Market	71,709	64,551	67,513	-3.0

The 2023 KOTICA survey reveals a highly fragmented and small-scale industry structure: 61.9% of institutions employ fewer than 10 persons, 88.6% generate revenues below KRW 5 billion (approximately USD 3.8 million), and 88.8% of institutions are non-accredited. For-profit corporations constitute 64.1% of institutions by organizational type. The combined revenues of Korea's seven major TIC institutions (approximately KRW 843 billion) represent roughly 11% of SGS Group's annual revenue of KRW 9.0 trillion—a stark illustration of the global scale gap.

Table 2. Composition of Korean TIC service market institutions. Source: KOTICA (2023).

Category	Sub-category	Estimated No. of Institutions	Share (%)	Notes
Total	—	7,889	100.0	
Organization Type	State / Local Gov.	57	0.7	
	Public Institution	158	2.0	
	Non-profit Corporation	1,382	17.5	
	For-profit Corporation	5,059	64.1	
	Sole Proprietor	1,234	15.6	
Accreditation	Accredited	882	11.2	
	Non-accredited	7,007	88.8	
Employees	< 10 persons	4,884	61.9	
	10–19 persons	1,487	18.8	
	20–49 persons	883	11.2	
	50–99 persons	313	4.0	
	100–299 persons	188	2.4	
	≥ 300 persons	134	1.7	
Revenue	< 100M KRW	262	3.3	
	100M–500M KRW	1,412	17.9	
	500M–1B KRW	2,034	25.8	
	1B–5B KRW	3,285	41.6	
	5B–10B KRW	282	3.6	
	10B–20B KRW	298	3.8	

Category	Sub-category	Estimated No. of Institutions	Share (%)	Notes
	20B–30B KRW	110	1.4	
	≥ 30B KRW	205	2.6	

Global TIC leaders including SGS, TÜV SÜD, and Bureau Veritas have substantially expanded their domestic Korean operations, intensifying competitive pressure and further limiting the growth opportunities available to smaller domestic institutions. Meanwhile, the industry's revenue structure reveals an over-reliance on low-margin statutory testing and government-mandated inspection, with limited penetration of high-value-added services such as consulting, training, and sustainability certification.

Table 3. Korean TIC service market workforce by education level (summary). Source: KOTICA (2023).

Category	Institutions	Doctoral	Master's	Bachelor's	Associate	High School or Below	Total (persons)
Total	7,889	8,523	20,367	68,694	18,498	5,204	121,286
Accredited	882	2,224	6,238	17,603	3,599	1,770	31,434
Non-accredited	7,007	6,300	14,130	51,091	14,898	3,434	89,852

Table 4. Korean TIC service market revenue by service type. Unit: M KRW. Source: KOTICA (2023).

Category	Testing (M KRW)	Inspection (M KRW)	Certification (M KRW)	Total (M KRW)
Total	3,471,184	3,554,429	611,629	7,637,242
Accredited	2,553,382	332,237	349,056	3,234,675
Non-accredited	917,802	3,222,192	262,572	4,402,566

2.3. Global TIC Market

The global TIC market reached USD 218.1 billion in 2022 and is projected to grow at a CAGR of 3.3% to USD 265 billion by 2028 (Markets and Markets, 2023). Third-party service markets are growing faster (CAGR 3.7%) than in-house markets (CAGR 2.9%), with the third-party segment's share of total market expanding from 47.3% in 2021 to a projected 48.7% by 2028.

Figure 2. Global TIC market size trend. Source: Market US (2024).

Table 5. Global TIC market size trend by sourcing type. Unit: USD billion. Source: Markets and Markets (2023).

Segment	2021	2022	2023	2024	2025	2026	2027	2028	CAGR (%)
Total (USD B)	210.8	218.1	224.0	231.0	238.9	247.1	256.0	265.0	3.3
Third-party Service	99.8	103.7	106.9	110.7	114.9	119.3	124.1	129.0	3.7
In-House	111.0	114.4	117.1	120.3	123.9	127.8	131.9	136.0	2.9
Service share (%)	47.3%	47.5%	47.7%	47.9%	48.1%	48.3%	48.5%	48.7%	—

Table 6. Global TIC market size trend by service type. Unit: USD billion. Source: Markets and Markets (2023).

Segment	2021	2022	2023	2024	2025	2026	2027	2028	CAGR (%)
Total (USD B)	210.8	218.0	223.9	231.0	238.8	247.1	256.0	265.0	3.3
Testing	118.2	122.3	125.7	129.8	134.2	139.0	144.1	149.3	3.4
Inspection	38.3	39.5	40.4	41.6	42.8	44.1	45.5	46.9	2.9
Certification	35.0	36.5	37.9	39.5	41.2	43.0	45.0	47.1	4.3
Others	19.3	19.7	19.9	20.2	20.6	20.9	21.4	21.8	1.8

Certification is the fastest-growing service category (CAGR 4.3%), driven by expanding ESG compliance requirements, ISO standard adoption across industries, and regulatory strengthening in healthcare and food safety sectors. Testing remains the largest category (2022: USD 122.3 billion), with sustained demand from electronics, automotive, and pharmaceutical sectors.

Leading global TIC entities—SGS (Switzerland, 1878), Bureau Veritas (France, 1828), DEKRA (Germany, 1925), Intertek (UK, 1885), and TÜV SÜD (Germany, 1866)—have achieved global leadership through a combination of broad geographic presence, comprehensive service portfolios extending to consulting and training, advanced technology adoption, and systematic workforce development. European-based institutions (France's AFNOR, Germany's TÜV SÜD, Switzerland's SGS) dominate the international service market, while North American associations (ASTM, ASQ) provide specialized certification tied to industry practice, and Australia's NATA invests substantially in government-led workforce development. These leaders are also actively pursuing the Asian market—a high-growth opportunity—through localized training programs and marketing investment.

3. Competitiveness Analysis of Korean TIC Institutions

3.1. Statistical Analysis of 2023 KOTICA Survey Data

3.1.1. Revenue Distribution and Service Market Revenue Profile

The 2022 service market revenue of the Korean TIC industry totaled KRW 7,637.2 billion, with inspection (KRW 3,554.4 billion, 46.5%) and testing (KRW 3,471.2 billion, 45.5%) accounting for the vast majority of revenues, and certification contributing only KRW 611.6 billion (8.0%). This revenue composition reflects a structural emphasis on volume-driven, price-competitive testing and inspection over higher-margin certification and advisory services.

Table 7. Korean TIC service market revenue by revenue group. Unit: M KRW. Source: KOTICA (2023).

Revenue Group	No. of Institutions	Testing (M KRW)	Inspection (M KRW)	Certification (M KRW)	Total (M KRW)
Total	7,889	3,471,184	3,554,429	611,629	7,637,242
G1: <100M	262	485	1,436	0	1,921
G2: 100M–500M	1,412	31,829	178,763	22,345	232,937
G3: 500M–1B	2,034	191,285	502,855	36,913	731,053
G4: 1B–5B	3,285	843,704	1,722,618	213,468	2,779,790
G5: 5B–10B	282	362,293	284,723	53,862	700,878
G6: 10B–20B	298	296,229	415,362	25,810	737,401
G7: 20B–30B	110	125,820	180,185	39,925	345,930
G8: ≥30B	205	1,619,539	268,488	219,308	2,107,335

3.1.2. Competitiveness Perception Relative to Global Leaders

Respondents evaluated their institution's competitiveness relative to top global TIC entities on a 5-point scale across four dimensions. The overall mean scores for investment scale (2.54) and expert staff (2.68) fell below the midpoint of 3.00, indicating that Korean TIC institutions self-assess as significantly below global leaders on these dimensions. External reputation and trust (3.06) was the only dimension rated above 3.00 overall.

The revenue-group disaggregation reveals a clear monotonic gradient: institutions in lower revenue groups consistently rated themselves significantly less competitive across all four dimensions compared with larger institutions. The largest gaps were recorded between the smallest and middle revenue groups (G1 vs. G5 for capability/scope; G1 vs. G7 for expert staff), confirming that structural resource constraints are not uniformly distributed but are concentrated in smaller institutions.

Table 8. Competitiveness perception relative to global leaders, by revenue group. Scale: 1–5. Source: KOTICA (2023).

Revenue Group	No. of Inst.	Capability & Scope	Expert Staff	Investment Scale	External Reputation
Total	7,889	2.74	2.68	2.54	3.06

Revenue Group	No. of Inst.	Capability & Scope	Expert Staff	Investment Scale	External Reputation
G1: <100M KRW	262	2.24	2.31	2.24	2.40
G2: 100M–500M	1,412	2.41	2.37	2.27	2.70
G3: 500M–1B	2,034	2.65	2.53	2.35	2.95
G4: 1B–5B	3,285	2.90	2.83	2.69	3.29
G5: 5B–10B	282	3.15	3.09	2.90	3.28
G6: 10B–20B	298	3.09	3.05	2.99	3.10
G7: 20B–30B	110	3.18	3.40	3.03	3.35
G8: ≥30B	205	2.85	2.90	2.85	3.21

3.1.3. Testing Equipment Holdings

The aggregate equipment holdings of 7,889 Korean TIC institutions totaled 230,388 equipment types, with an average of 30 types per institution. Equipment valued at or above KRW 100 million (high-cost) averaged only 2 types per institution. At the revenue group level, the contrast is dramatic: G1 institutions (<100M KRW) held an average of 5 total equipment types (1 high-cost), compared to 278 total types (15 high-cost) for G7 institutions (20B–30B KRW).

Table 9. Testing equipment holdings by revenue group. Source: KOTICA (2023).

Revenue Group	No. of Inst.	Total Equipment Types			Per-Institution Average			
		All	≥100M KRW	<100M KRW	All	≥100M KRW	<100M KRW	
Total	7,889	230,388	17,126	213,261	30	2	28	—
G1: <100M	262	1,195	126	1,069	5	1	4	—
G2: 100M–500M	1,412	16,374	920	15,454	12	1	11	—
G3: 500M–1B	2,034	32,204	1,400	30,804	16	1	15	—
G4: 1B–5B	3,285	79,343	5,688	73,655	25	2	23	—
G5: 5B–10B	282	17,258	2,121	15,137	63	8	55	—
G6: 10B–20B	298	17,807	2,529	15,278	62	9	53	—
G7: 20B–30B	110	27,680	1,535	26,145	278	15	263	—
G8: ≥30B	205	38,526	2,807	35,719	208	15	193	—

3.2. One-Way ANOVA Analysis

3.2.1. Competitiveness Factors by Revenue Group

To test whether there are statistically significant differences in competitiveness factor perceptions across the eight revenue groups, One-Way ANOVA analyses were conducted for each of the four competitiveness dimensions (capability/scope, expert staff, investment scale, external reputation). Given violation of the homogeneity of variance assumption (Levene's test, Table 11), Welch's ANOVA results are interpreted as the primary analysis.

Table 10. One-Way ANOVA results for competitiveness factors by revenue group. Source: Author's analysis using Jamovi v2.5.

Dependent Variable	F-statistic	df1	df2	p-value
Capability & Scope	5,673	7	860	< .0001
Expert Staff	6,094	7	863	< .0001
Investment Scale	5,500	7	860	< .0001
External Reputation / Trust	6,304	7	863	< .0001

Table 11. Homogeneity of variances test (Levene's) for competitiveness factors.

Variable	F	df1	df2	p-value
Capability & Scope	5.05	7	7,880	< .0001
Expert Staff	2.31	7	7,880	0.0235
Investment Scale	2.18	7	7,880	0.0328
External Reputation / Trust	3.44	7	7,880	0.0011

All four competitiveness dimensions showed statistically significant inter-group differences ($p < .0001$). Games-Howell post-hoc tests confirmed that most pairwise group differences were statistically significant. For capability and scope, the largest mean difference was between G1 (<100M KRW) and G5 (5B–10B KRW): -0.905 ($p < .001$). For expert staff, the largest difference was between G1 and G7 (20B–30B KRW): -1.103 ($p < .001$), suggesting that skilled human resources constitute the single most differentiating competitiveness factor across revenue groups.

Figure 3. Games-Howell Post-Hoc Test – Capability and Scope.

Figure 4. Games-Howell Post-Hoc Test – Expert Staff.

Figure 5. Games-Howell Post-Hoc Test – Investment Scale.

Figure 6. Games-Howell Post-Hoc Test – External Reputation and Trust.

3.2.2. Equipment Holdings by Revenue Group

A One-Way ANOVA was also conducted to assess differences in total equipment holdings across the eight revenue groups.

Table 12. One-Way ANOVA results for equipment holdings by revenue group.

Variable	Method	F-statistic	df1	df2	p-value
No. of Equipment Types	Welch's ANOVA	487,456	7	826	< .0001
	Fisher's ANOVA	571,563	7	8,180	< .0001

Table 13. Homogeneity of variances test (Levene's) for equipment holdings.

Variable	F	df1	df2	p-value
No. of Equipment Types	1,983	7	8,180	< .0001

Levene's test confirmed violation of homogeneity of variance ($F(7, 8180) = 1,983$, $p < .0001$), supporting the use of Welch's ANOVA. Welch's ANOVA confirmed statistically significant inter-group differences in equipment holdings ($p < .0001$). Games-Howell post-hoc tests revealed that all pairwise group differences were statistically significant.

Figure 7. Games-Howell Post-Hoc Test – Number of Equipment Types.

Key pairwise differences: G1 vs. G7 mean difference: -27.3 equipment types; G6 vs. G7 mean difference: -21.8 types; G1 vs. G8 mean difference: -20.34 types. These results confirm that equipment holdings are a primary structural differentiator between small and large Korean TIC institutions, and that the resource gap is statistically robust.

3.2.3. Summary of Statistical Analysis

The statistical analyses confirm three principal findings for the Korean TIC industry:

4. Expert staff and investment scale are the competitiveness dimensions where the largest performance gaps exist between revenue groups, with the smallest institutions significantly underperforming on both dimensions relative to larger counterparts.
5. Equipment holdings are strongly and significantly correlated with revenue size, confirming that testing infrastructure is both a driver and an indicator of institutional competitiveness.
6. The competitive gap between small-to-medium institutions and large institutions is both substantial and statistically robust, indicating systemic structural constraints that are unlikely to self-correct without deliberate policy and strategic intervention.

3.3. Education Program Benchmarking

3.3.1. KTR Academy (Domestic)

The Korea Testing and Research Institute (KTR) Academy offers 30 training programs as of 2024, delivered exclusively in an offline format. Programs are classified as: Testing (19 programs, 63.3%), Inspection (5 programs, 16.7%), and Certification (6 programs, 20.0%). The curriculum focuses primarily on domestic Korean standards (KS, KOLAS requirements) and legally mandated qualification programs.

Table 14. KTR Academy curriculum overview (2024). Source: KTR Academy official course schedule.

No.	Category	Course Title
1	Testing	Carbon Neutrality MRV & Life Cycle Assessment: Theory and Regulatory Trends
2		KS P ISO 15189 Laboratory Management Practice
3		KS Q ISO/IEC 17043 Proficiency Testing Management Practice
4		ISO/IEC 17043:2023 Transition Briefing (Accredited PT Organizations)
5		ISO 15189:2022 Transition Briefing (Accredited Medical Testing Labs)
6		KS Q ISO/IEC 17020 Inspection Body Management Practice
7		Measurement Uncertainty Estimation
8		KS A ISO 17034 Reference Material Producer Management Practice
9		KS Q ISO/IEC 17025 Testing Laboratory Management Practice
10		Quality Control Criteria Operations
11–16		Quality Control Criteria Advanced Courses (6 modules)
17		Medical Device Testing: Extractables, Sterility & Cytotoxicity
18		Sanitary Products Hygiene Education
19		Product Carbon Footprint Calculation Methods
20	Inspection	Infectious Disease Diagnostics – Reference Material Production
21		Infectious Disease Diagnostics – Proficiency Testing Operations
22		Infectious Disease Lab Management (National Standard Labs)
23		Infectious Disease Lab Management (Public Health Research Institutes)
24		Reusable Battery Safety Inspection Procedures
25	Certification	KOLAS Staff Continuing Education
26		Quality Control Criteria Internal Auditor
27		Internal Auditor Training
28		Medical Device Regulatory Affairs (RA) Specialist (Online)
29		KS P ISO 15189 Assessor Course
30		Assessor Continuing Education (Medical Testing)

3.3.2. SGS Academy (International)

SGS Academy operates 85 training programs as of 2024, delivered through both online and offline channels. Programs are distributed across: Testing (30 programs, 35.3%), Inspection (8 programs, 9.4%), Certification (16 programs, 18.8%), and Career Development eLearning (31 programs, 36.5%). The curriculum spans ISO management systems, food safety (FDA, FSSC 22000), medical devices (MDR, MDSAP, ISO 13485), ESG and sustainability reporting, LCA, and advanced cybersecurity certification courses.

Table 15. SGS Academy curriculum overview (2024). Source: SGS Academy official course schedule.

No.	Category	Course Title
1–3	Testing	ISO 9001/14001/45001 Requirements & Practical Application

No.	Category	Course Title
4		ISO/IEC 27001:2022 Revised System Transition
5–6		ESG Practice & Sustainability Report Writing and Verification
7–9		LCA (Life Cycle Assessment): Fundamentals to Advanced Application
10–11		FMEA [AIAG-VDA] & VDA 6.3 Process Audit
12–15		Food Safety Culture / FDA Response / FSSC 22000 v6 Transition
16–17		Food Microbiology Testing Methods (with lab practice)
18–19		US Market Export: FDA Labeling & FTC Advertising Regulations
20–22		MDSAP / ISO 13485 Medical Device QMS Requirements
23–30		EU MDR (Regulation 2017/745): Technical Documentation, GSPR, Clinical Evaluation
31–38	Inspection	SQF Quality Systems / QMS Software Validation / EO Sterilization Validation / IEC 62366 Usability
39–54	Certification	ISO 9001/14001/45001/22716/27001/13485 Lead Auditor & Implementer; IATF 16949; FSSC 22000; FDA PCQI; EU MDR Compliance Officer
55–85	Career Dev. (eLearning)	ISO 22301/31000/37001/9001/27001/45001/50001/13485/14001 Foundation, Lead Auditor & Lead Implementer; GDPR DPO; CMMC; Cybersecurity; Medical Device QMS

3.3.3. Comparative Analysis and Implications

KTR Academy's strength lies in its domestic regulatory specificity and hands-on operational training, directly applicable to Korean practitioners. However, its program scope is narrow, almost exclusively focused on domestic standards and statutory compliance, with limited online delivery options that restrict accessibility.

SGS Academy's advantages include: breadth across international standards (ISO, FDA, EU MDR), emerging fields (ESG, LCA, cybersecurity), and global market access requirements; flexible online delivery enabling worldwide learner participation; and a dedicated career development track that supports long-term professional advancement. Its limitation is relatively lower specificity for domestic Korean regulations, which may require supplementation for Korea-specific compliance contexts.

The critical gap is not merely quantitative (30 vs. 85 programs) but qualitative: SGS Academy's curriculum maps to emerging global sectors (sustainable certification, digital security, advanced medical devices) and prepares professionals for international market entry, whereas KTR Academy primarily serves domestic compliance needs. For Korean TIC institutions seeking global competitiveness, this curriculum gap translates directly into a human capital gap.

3.4. SWOT Analysis of the Korean TIC Industry

3.4.1. Strengths

The Korean TIC industry benefits from a strong, stable demand base anchored in Korea's manufacturing-intensive economy. The diversity of sectors requiring TIC services—electronics, automotive, medical devices, construction, energy—provides broad and relatively recession-resistant demand. Public institutions and government-mandated certification requirements generate a guaranteed revenue floor. Recent investments in digital transformation and advanced testing capabilities have begun to enhance the reliability and value of TIC services in high-technology sectors. Government policy support (Ministry of Trade, Industry and Energy; Korea Agency for Technology and Standards) provides institutional backing for industry development.

3.4.2. Weaknesses

The industry's principal weaknesses are: (i) inadequate advanced testing equipment, particularly in smaller institutions, limiting precision and scope; (ii) a shortage of internationally qualified personnel capable of performing and certifying to global standards; (iii) limited and domestically focused training programs that do not prepare professionals for international market expectations; (iv) high operating costs relative to service fees, compressing margins particularly in the inspection-dominant revenue mix; and (v) underdeveloped international networks and limited foreign market presence.

3.4.3. Opportunities

The expanding global demand for specialized TIC services in high-growth sectors—renewable energy certification, advanced healthcare device approval, green technology compliance, and ESG reporting verification—presents significant

new market opportunities. Digital transformation technologies (AI, IoT, big data analytics, blockchain) offer the potential to substantially enhance service efficiency, real-time monitoring capability, and digital certification delivery. The Korean government's stated commitment to expanding TIC industry support (including facilitating global market entry) provides a policy tailwind. The ASEAN and Southeast Asian TIC markets remain relatively less served by global TIC leaders, representing a geographic expansion opportunity for Korean institutions with relevant regional expertise.

3.4.4. Threats

The most significant threats are the continued expansion of global TIC leaders (SGS, TÜV SÜD, Bureau Veritas) into the Korean domestic market, leveraging superior technology, capital, and international recognition; the progressive tightening of international regulatory requirements, which raises the compliance threshold for TIC services and disadvantages institutions with limited technical capabilities; economic uncertainty and export slowdown, which can reduce demand for TIC services tied to manufactured goods exports; and the widening technology gap as global leaders accelerate AI and IoT integration into TIC processes, further distancing their capabilities from those of domestic Korean institutions.

3.4.5. Summary

The SWOT analysis confirms a structural asymmetry: the Korean TIC industry's strengths are primarily demand-side (stable domestic industrial demand, government support), while its weaknesses are primarily supply-side (equipment, skills, technology, international networks). The industry's most significant opportunities—high-growth international sectors and digital transformation—require precisely the supply-side capabilities in which it is currently deficient. Closing this gap is therefore the central strategic priority for the industry's global competitiveness enhancement.

4. Strategic Recommendations

Based on the quantitative competitiveness analysis, education program benchmarking, and SWOT analysis, this study proposes three integrated strategies to strengthen the global competitiveness of Korean TIC institutions.

4.1. Human Resource Development Strategy

Expert human resources were identified as the single most differentiating competitiveness factor, with the largest statistical gap between revenue groups and the strongest association with global competitiveness perceptions. A comprehensive human resource development strategy is therefore foundational to all other competitiveness improvements.

7. Develop internationally aligned training programs. Korean TIC institutions should establish structured training curricula mapped to global standards such as ISO, IEC, and sector-specific frameworks (EU MDR, FDA, FSSC 22000). Programs should cover emerging high-growth domains including ESG/carbon neutrality, advanced medical device regulation, digital security, and LCA. The SGS Academy's modular, multi-tier structure (Testing, Inspection, Certification, Career Development) provides a relevant benchmark. Industry associations (KOTICA) and government bodies should co-fund the development of nationally standardized, internationally competitive certification programs.
8. Strengthen university-industry collaboration. Partnerships between TIC institutions and universities should be formalized to create specialized TIC-related academic programs, curriculum contributions, and structured industry internship pathways. Joint research projects can simultaneously develop technological capabilities and generate a next-generation talent pipeline.
9. Expand digital and online training delivery. Replicating SGS Academy's online delivery model—currently absent from KTR Academy's curriculum—would substantially expand the accessible learner population, reduce geographic barriers, and support the cost-effective scaling of training programs. Tiered learning pathways (introductory, intermediate, advanced) with modular progression structures should be adopted to accommodate practitioners at all career stages.

4.2. Testing Equipment Modernization Strategy

The strong and statistically significant correlation between equipment holdings and institutional revenue (and, by extension, competitiveness) confirms that testing infrastructure is a critical strategic asset. An equipment modernization strategy should encompass three priority areas:

10. Prioritize advanced technology adoption. AI-enabled automated testing systems and IoT-integrated real-time monitoring equipment should be prioritized for acquisition, particularly in high-growth testing domains such as renewable energy system certification, medical device performance testing, and autonomous vehicle safety

verification. Digital data management systems that provide real-time equipment utilization monitoring, automated calibration scheduling, and predictive maintenance can significantly improve asset efficiency.

11. Establish equipment-sharing networks. Public-private shared resource networks, analogous to shared research infrastructure in academia, can enable smaller institutions to access high-value equipment they cannot independently finance. Government co-investment through R&D support mechanisms can lower the financial threshold for equipment modernization in small-to-medium TIC institutions.
12. Apply outcome-oriented investment prioritization. Investment decisions should be guided by correlations between equipment capability and market opportunity. High-value equipment acquisitions should be concentrated in high-growth sectors with strong global demand (e.g., green certification, digital technology certification), and directed toward institutions demonstrating the organizational capacity to leverage the investment for international market entry. A 2007 industry study found that advanced equipment adoption improved testing precision by 34% and enhanced testing capability ratios by 32% (Kim, 2007), demonstrating the operational multiplier effect of equipment investment.

4.3. Business and Marketing Strategy

The structural and human resource improvements proposed above require a complementary strategic orientation toward the global market. Three business and marketing strategy dimensions are proposed:

13. Market diversification and new sector entry. Korean TIC institutions should leverage their manufacturing-sector expertise as a launchpad for entry into high-growth adjacent sectors: renewable energy system certification, advanced healthcare device testing, and autonomous vehicle safety validation. Portfolio diversification reduces dependence on price-competitive domestic testing and inspection revenues, and positions institutions to capture the growing global demand for specialized high-value TIC services.
14. Customer-centric differentiated service development. The intensifying presence of global TIC leaders in Korea demands that domestic institutions develop genuinely differentiated service propositions. Digital certification platforms that accelerate service delivery, provide real-time testing result transparency, and integrate with clients' quality management systems can offer a practical competitive advantage over slower-moving global competitors in the Korean domestic context. Long-term client relationship management programs should be developed to build the trust capital that underpins client retention.
15. International network expansion and standards participation. Active engagement in international standardization forums (ISO Technical Committees, IEC Working Groups) elevates Korea's visibility and influence in global TIC standard-setting, generating credibility that supports market entry. Strategic partnerships with leading global TIC entities—involving knowledge exchange, mutual recognition agreements, and joint service offerings—can accelerate Korean institutions' acquisition of international network access and market credibility.

5. Conclusions and Implications

5.1. Summary and Conclusions

This study analyzed the global competitiveness status of Korean TIC institutions using the 2023 KOTICA national industry survey, comparative education program benchmarking, and SWOT analysis. The findings converge on three central conclusions.

First, structural resource gaps—in expert human resources, testing equipment, and international networks—are the primary determinants of Korean TIC institutions' global competitiveness gap, and these gaps are systematically and significantly correlated with institutional revenue scale. The statistical evidence confirms that smaller institutions are not simply less resourced by degree; they are structurally disconnected from the global competitiveness requirements of the industry.

Second, the Korean TIC industry's training infrastructure is significantly underdeveloped relative to global leaders. KTR Academy's 30 domestically-focused programs compare unfavorably with SGS Academy's 85 internationally-mapped programs, with the qualitative gap—the absence of internationally relevant technical content and online delivery—being more consequential than the numerical difference.

Third, a coherent set of three integrated strategies—human resource development aligned with international standards, systematic equipment modernization with shared-access mechanisms, and market diversification combined with international network expansion—provides a practical and evidence-based roadmap for addressing the industry's structural deficiencies and repositioning Korean TIC institutions as credible global competitors.

This study acknowledges several limitations. The survey data is primarily domestic, limiting the ability to fully

capture the perspective of global TIC stakeholders. Qualitative data from industry practitioners and international experts would enrich the strategic analysis. The proposed strategies tend toward medium-term interventions; longer-term structural transformation pathways require additional analysis. The integration of digital transformation into actual TIC operational processes—beyond strategic recommendation—warrants more detailed implementation guidance in future work.

5.2. Implications

For policymakers, the findings underscore the need to redesign TIC industry support programs so that benefits reach primary producers of testing capability—specifically the small-to-medium institutions that constitute 88.6% of the industry—rather than concentrating support in large institutions that already possess competitive resources. Shared equipment infrastructure programs, internationally aligned training subsidies, and mutual recognition facilitation would address the most acute structural gaps.

For institutional managers, the data provide clear empirical benchmarks: institutions that invest in expert staff and equipment at levels commensurate with their revenue tier consistently outperform those that do not, and the gap compounds over time. International network engagement is not a luxury for large institutions; it is an accelerator of the competitiveness improvements that smaller institutions most urgently require.

For industry associations (KOTICA), the study identifies a mandate to develop and operate a nationally standardized, internationally relevant training certification program that provides Korean TIC professionals with credentials recognized in global markets—closing the structural gap that SGS Academy's model exposes. Such a program, developed in partnership with government and leading domestic institutions, would represent a strategic infrastructure investment in the industry's collective human capital.

Appendix A

A.1. Major Global TIC Institutions

Table A1. Major global TIC institutions: overview. Source: Corporate annual reports; KEB Hana Bank exchange rates.

Rank	Institution (Country)	Founded	Revenue (2022 basis)	Employees
1	Eurofins Scientific (Luxembourg)	1987	KRW 9.13T (EUR 6.71B)	61,379
2	SGS Group (Switzerland)	1878	KRW 9.00T (CHF 6.64B)	97,797
3	Bureau Veritas (France)	1828	KRW 7.68T (EUR 5.65B)	80,194
4	DEKRA SE (Germany)	1925	KRW 5.16T (EUR 3.80B)	48,646
5	Intertek Group (UK)	1885	KRW 5.09T (GBP 3.19B)	43,597
6	TÜV SÜD (Germany)	1866	KRW 3.89T (EUR 2.86B)	26,595
7	DNV GL (Norway)	1864	KRW 3.37T (NOK 25.03B)	12,708
8	TÜV Rheinland (Germany)	1872	KRW 3.09T (EUR 2.27B)	20,870
9	APPLUS+ (Spain)	1996	KRW 2.79T (EUR 2.05B)	26,414
10	TÜV NORD (Germany)	1869	KRW 1.97T (EUR 1.45B)	12,238
11	ALS Limited (Australia)	1863	KRW 1.89T (AUD 2.11B)	18,148
12	Lloyd's Register (UK)	1760	KRW 1.59T (EUR 998M) [2021]	7,117
13	Mistras Group (USA)	1978	KRW 889B (USD 687M)	5,400

Note 1: Revenue converted to KRW using annual average exchange rates (KEB Hana Bank).
Note 2: Total revenues of top 10 institutions: KRW 57.3 trillion (approx. USD 44.2 billion).
Note 3: Lloyd's Register: 2021 data used; 2022 annual report not published at time of analysis.

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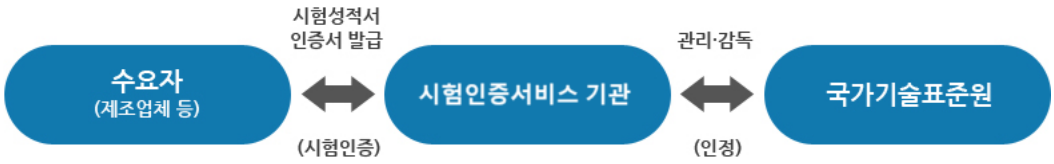
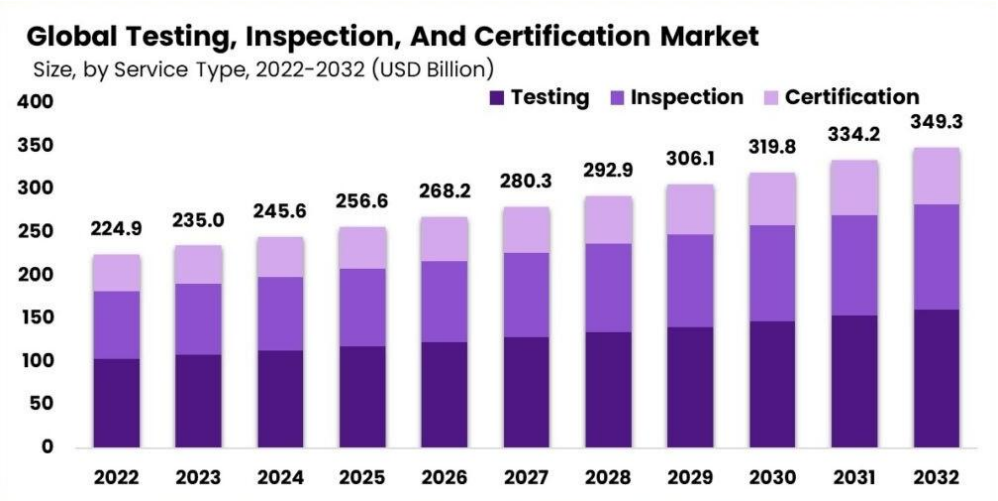
<그림 1> 시험인증산업의 상호관계



<그림 2> 국외 시험인증시장의 산업규모 추이



※ 출처 : Global Testing, Inspection and Certification Market By Service Type (Testing, Inspection, and Certification), By Sourcing Type (In-House Sourcing, and Outsourced Sourcing), By Application, By Region and Companies - Industry Segment Outlook, Market Assessment, Competition Scenario, Trends, and Forecast 2023-2032

<그림 3> Games-Howell Post-Hoc Test – 능력 및 범위

Games-Howell Post-Hoc Test – 능력 및 범위

		1	2	3	4	5	6	7	8
1	Mean difference	—	−0.180 ***	−0.416 ***	−0.670 ***	−0.905 ***	−0.8715 ***	−0.9286 ***	−0.6236 ***
	p-value	—	< .0001	< .0001	< .0001	< .0001	< .0001	< .0001	< .0001
2	Mean difference		—	−0.236 ***	−0.489 ***	−0.725 ***	−0.6913 ***	−0.7484 ***	−0.4435 ***
	p-value		—	< .0001	< .0001	< .0001	< .0001	< .0001	< .0001
3	Mean difference			—	−0.253 ***	−0.489 ***	−0.4553 ***	−0.5124 ***	−0.2074 ***
	p-value			—	< .0001	< .0001	< .0001	< .0001	< .0001
4	Mean difference				—	−0.235 ***	−0.2019 ***	−0.2590 ***	0.0459 ***
	p-value				—	< .0001	< .0001	< .0001	< .0001
5	Mean difference					—	0.0334 **	−0.0236	0.2813 ***
	p-value					—	0.0034	0.4889	< .0001
6	Mean difference						—	−0.0571 ***	0.2479 ***
	p-value						—	< .0001	< .0001
7	Mean difference							—	0.3049 ***
	p-value							—	< .0001
8	Mean difference								—
	p-value								—

Note. * p < .05, ** p < .01, *** p < .001

<그림 4> Games-Howell Post-Hoc Test – 전문인력

Games-Howell Post-Hoc Test – 전문인력

		1	2	3	4	5	6	7	8
1	Mean difference	—	−0.0678 ***	−0.220 ***	−0.524 ***	−0.787 ***	−0.7529 ***	−1.103 ***	−0.5745 ***
	p-value	—	< .0001	< .0001	< .0001	< .0001	< .0001	< .0001	< .0001
2	Mean difference		—	−0.153 ***	−0.457 ***	−0.719 ***	−0.6851 ***	−1.035 ***	−0.5067 ***
	p-value		—	< .0001	< .0001	< .0001	< .0001	< .0001	< .0001
3	Mean difference			—	−0.304 ***	−0.566 ***	−0.5325 ***	−0.882 ***	−0.3540 ***
	p-value			—	< .0001	< .0001	< .0001	< .0001	< .0001
4	Mean difference				—	−0.262 ***	−0.2286 ***	−0.578 ***	−0.0502 ***
	p-value				—	< .0001	< .0001	< .0001	< .0001
5	Mean difference					—	0.0339 **	−0.316 ***	0.2123 ***
	p-value					—	0.0013	< .0001	< .0001
6	Mean difference						—	−0.350 ***	0.1784 ***
	p-value						—	< .0001	< .0001
7	Mean difference							—	0.5281 ***
	p-value							—	< .0001
8	Mean difference								—
	p-value								—

Note. * p < .05, ** p < .01, *** p < .001

<그림 5> Games-Howell Post-Hoc Test – 투자규모

Games-Howell Post-Hoc Test – 투자규모

		1	2	3	4	5	6	7	8
1	Mean difference	—	−0.0422 ***	−0.1168 ***	−0.456 ***	−0.668 ***	−0.7510 ***	−0.8064 ***	−0.6176 ***
	p-value	—	< .0001	< .0001	< .0001	< .0001	< .0001	< .0001	< .0001
2	Mean difference		—	−0.0746 ***	−0.414 ***	−0.626 ***	−0.7088 ***	−0.7642 ***	−0.5754 ***
	p-value		—	< .0001	< .0001	< .0001	< .0001	< .0001	< .0001
3	Mean difference			—	−0.340 ***	−0.551 ***	−0.6342 ***	−0.6897 ***	−0.5009 ***
	p-value			—	< .0001	< .0001	< .0001	< .0001	< .0001
4	Mean difference				—	−0.212 ***	−0.2946 ***	−0.3500 ***	−0.1613 ***
	p-value				—	< .0001	< .0001	< .0001	< .0001
5	Mean difference					—	−0.0828 ***	−0.1382 ***	0.0506 ***
	p-value					—	< .0001	< .0001	< .0001
6	Mean difference						—	−0.0554 ***	0.1333 ***
	p-value						—	< .0001	< .0001
7	Mean difference							—	0.1888 ***
	p-value							—	< .0001
8	Mean difference								—
	p-value								—

Note. * p < .05, ** p < .01, *** p < .001

<그림 6> Games-Howell Post-Hoc Test – 대외적 평판 신뢰도

Games-Howell Post-Hoc Test – 대외적 평판 신뢰도

		1	2	3	4	5	6	7	8
1	Mean difference	—	−0.304 ***	−0.553 ***	−0.886 ***	−0.87594 ***	−0.694 ***	−0.9535 ***	−0.7969 ***
	p-value	—	< .0001	< .0001	< .0001	< .0001	< .0001	< .0001	< .0001
2	Mean difference		—	−0.249 ***	−0.581 ***	−0.57157 ***	−0.389 ***	−0.6491 ***	−0.4925 ***
	p-value		—	< .0001	< .0001	< .0001	< .0001	< .0001	< .0001
3	Mean difference			—	−0.332 ***	−0.32287 ***	−0.141 ***	−0.4004 ***	−0.2438 ***
	p-value			—	< .0001	< .0001	< .0001	< .0001	< .0001
4	Mean difference				—	0.00963	0.192 ***	−0.0679 ***	0.0887 ***
	p-value				—	0.8033	< .0001	< .0001	< .0001
5	Mean difference					—	0.182 ***	−0.0775 ***	0.0791 ***
	p-value					—	< .0001	< .0001	< .0001
6	Mean difference						—	−0.2598 ***	−0.1031 ***
	p-value						—	< .0001	< .0001
7	Mean difference							—	0.1566 ***
	p-value							—	< .0001
8	Mean difference								—
	p-value								—

Note. * p < .05, ** p < .01, *** p < .001

<그림 7> Games-Howell Post-Hoc Test – 장비 종 수

Games-Howell Post-Hoc Test – 장비 종 수

		1	2	3	4	5	6	7	8
1	Mean difference	—	−7.04 ***	−11.27 ***	−17.57 ***	−56.6 ***	−55.19 ***	−273 ***	−203.4 ***
	p-value	—	< .0001	< .0001	< .0001	< .0001	< .0001	< .0001	< .0001
2	Mean difference		—	−4.24 ***	−10.54 ***	−49.6 ***	−48.16 ***	−266 ***	−196.4 ***
	p-value		—	< .0001	< .0001	< .0001	< .0001	< .0001	< .0001
3	Mean difference			—	−6.30 ***	−45.4 ***	−43.92 ***	−262 ***	−192.2 ***
	p-value			—	< .0001	< .0001	< .0001	< .0001	< .0001
4	Mean difference				—	−39.1 ***	−37.62 ***	−256 ***	−185.9 ***
	p-value				—	< .0001	< .0001	< .0001	< .0001
5	Mean difference					—	1.44 ***	−217 ***	−146.8 ***
	p-value					—	< .0001	< .0001	< .0001
6	Mean difference						—	−218 ***	−148.2 ***
	p-value						—	< .0001	< .0001
7	Mean difference							—	70.0 ***
	p-value							—	< .0001
8	Mean difference								—
	p-value								—

Note. * p < .05, ** p < .01, *** p < .001