sme-transformation-TOE-fit

TOE Framework : T x E ?

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Beyond Linear TOE: How Technology--Environment Congruence Shapes Digital Transformation Training Effectiveness in Korean SMEs

This site is the open research notebook for the TOE-Fit study. It documents the research problem, theoretical framework, methodology, and analytical procedure. It is a process record, not a results repository --- see Products for the disclosure policy on findings.

Project Details

Item	Value
Owner	Chungil (Chad) Chae --- Wenzhou-Kean University
Co-authors	Dong-Yeol Jeong, Tae Hee Na --- Korea University of Technology and Education
Type	Research (quantitative, mixed-method)
Status	Revision pending --- Draft v1 complete, internal peer review returned Major Revision
Created	2026-04-11
Last site update	2026-08-21

Research Problem

The Technology--Organization--Environment (TOE) framework is conventionally applied as a linear additive model: Technology, Organization, and Environment each contribute independently to an adoption or performance outcome. This study asks whether that specification is adequate for explaining digital transformation (DT) training effectiveness in manufacturing SMEs --- and whether a nonlinear, congruence-based reading of TOE explains what the linear model cannot.

The proposed reinterpretation borrows from Person--Environment (P-E) Fit theory: what matters is not the level of Technology or the level of Environment taken separately, but the fit between them. Where a firm's DT awareness (T) and its smart-system infrastructure (E) are misaligned in either direction, training is expected to convert poorly into capability.

Research Questions

RQ	Question
RQ1	Does a linear additive TOE model predict DT training effectiveness?
RQ2	Does a Technology × Environment interaction provide incremental validity over linear main effects?
RQ3	What is the shape of the T×E response surface, and where does it reach its optimum?
RQ4	How does organizational size moderate the T×E relationship?

PICO

Element	Specification
P	Korean manufacturing SMEs (1--300 employees) participating in K-Hitech DT training, n=244
I	T×E congruence --- simultaneously high DT awareness and smart-system infrastructure, modelled as an RSM second-order interaction
C	Linear additive TOE path model with T, O, E as independent predictors
O	Change in DT competency from pre- to post-training

How this site is organized

- Research Logs --- chronological record of the study, the analysis pipeline, and draft versions

- Research Note --- working ideas, open questions, and the procedures actually followed
- Theoretical Framework --- the four theories combined and the hypotheses derived from them
- Methodology and Method --- research design, model specifications, data collection, and sample
- Literature Review --- search strategy, research gap, and the verified reference base
- Products --- manuscript status, publication plan, and disclosure policy

Research Logs

Research Log

Reverse-chronological record of project events. Entries state what happened and where the artefact lives.

2026-08-21

- Full project review conducted. Knowledge base recompiled incrementally; this site populated from template stubs for the first time.
- Review finding: the project has been dormant since 2026-05-20. None of the four CRITICAL peer-review items has been started.

2026-08-20

- Project work-log folder introduced (`docs/13_  /`) under the cross-project logging convention.

2026-05-20

- Data collection method document updated. This is the last substantive content change in the project to date.

2026-05-04

- Internal structured peer review of Draft v1 completed. Five-document package produced: manuscript summary, theoretical-background mapping with citation verification, mixed-methods evaluation framework, full reviewer report, author self-critique.

- Recommendation: Major Revision. Four CRITICAL, six MAJOR, ten MINOR concerns. None fatal; together they prevent the headline claim from being sustained at its current strength.
- Companion document drafted on the dependent-variable problem, setting out five resolution paths.

2026-05-03

- Draft v1 (English) assembled --- five chapters, 16,759 words.

2026-04-30

- Integrated conceptual framework v1.0 produced through the ScholarRAG synthesis pipeline.
- Manuscript chapters and cover letters to two target journals finalized.

2026-04-14

- Supplementary methodological documents produced: RSM time-precedence redesign, lagged panel redesign, TOE causal inference, cross-dimension interaction.

2026-04-11

- Analysis declared complete. PICO and WOS search strategy finalized. Knowledge base compiled for the first time.

2026-03-31

- Phase 3 (response surface analysis) complete. Final synthesis report drafted.

2022–2025

- K-Hitech DT training panel data collected across four annual waves.

Meeting Log

No formal co-author meeting minutes have been recorded in the project repository to date. Coordination with co-authors (Dong-Yeol Jeong, Tae Hee Na) has taken place outside the documented record.

Standing item for the next meeting. The internal peer review of 2026-05-04 returned a Major Revision recommendation whose first item changes the study's dependent variable. That decision is not the lead author's alone to make, because it determines whether the manuscript can go to the primary target journal at all. The meeting should settle:

1. Whether K-Hitech administrative records (attendance, module completion, certification) can be obtained through the co-authors' institutional channels.
2. If not, whether the multi-year subsample is an acceptable basis for an objective outcome measure.
3. A revised target submission window, replacing the lapsed 2026-05-30 completion date.

Analysis Version Log

The empirical pipeline ran 36 analytical models across three phases, organized as 22 separate R projects (T0--T22). All analyses were run on R 4.4.0 (Apple Silicon) with `set.seed(20260301)`.

Phase 1 — Exploratory (T0–T9, 13 models)

Descriptive statistics, exploratory factor analysis, hierarchical regression, latent profile analysis, fuzzy-set QCA, longitudinal comparison, structural topic modelling, multiple correspondence analysis, importance--performance analysis, panel random-effects regression, propensity score matching, latent transition analysis.

Phase 2 — Causal and structural (T10–T21, 12 models)

Staggered difference-in-differences, hierarchical regression, mediation, sequential mediation, size moderation with Johnson--Neyman intervals, 2×2 ANOVA, moderated mediation, TOE path SEM, ordinal logistic regression, four-class latent profile analysis, fsQCA combined with DID, cross-lagged panel model.

Phase 3 — Nonlinear response surface (T22, 11 models)

Bivariate response surface models (combo1--combo5) and multivariate response surface models (A1, A2, B1, B2, C1, C2) under dual TOE and Training-Transfer framings.

Toolchain

Component	Version
R	4.4.0 (Apple Silicon)
rsm	0.10.6
RSA	0.10.6
QCA	3.23
boot	1.3-30
lavaan	---
Seed	20260301

Inference uses HC3 robust standard errors (Breusch--Pagan $p<.001$ in 8 of 11 response surface models) and 5,000-sample bootstrap confidence intervals.

> ⚠ Reproducibility note
>
> All Draft v1 estimates were produced under the toolchain above. The pending revision requires re-running the response surface pipeline against a different dependent variable. The toolchain must be pinned or re-verified before that run, otherwise differences caused by the DV change cannot be separated from differences caused by environment drift.

Draft Version Log

v1 — 2026-05-03

Item	Value
Length	16,759 words
Structure	5 chapters: Introduction, Literature Review, Method, Findings, Discussion & Conclusion
Accompanying	Cover letters to two target journals
Status	Complete, unrevised
Review outcome	Major Revision (2026-05-04)

Chapter files were last modified 2026-04-30 and have not been touched since. No v2 exists.

Planned v2 — not started

v2 is blocked on the dependent-variable decision (see Questions and Answers). Because that decision changes what is being measured, every results table, figure, and the Findings and Discussion chapters must be regenerated rather than edited. The two cover letters must also be rewritten: both lean on the measurement-gap argument, which is precisely the claim the revision destabilizes.

Research Note

Ideas and Thoughts

Working notes on what the analysis suggested, recorded as interpretation rather than as established result.

The organizing idea

TOE is normally read as three additive levers: improve Technology, improve Organization, improve Environment, and outcomes improve. If that reading is correct, a linear model should recover it. When a linear model recovers nothing, there are two possible conclusions --- the framework does not apply here, or the framework applies but the functional form is wrong. This study pursues the second.

The candidate functional form comes from P-E Fit theory, where the outcome depends on the correspondence between two dimensions rather than on their levels. Transposed to TOE, this makes T×E congruence the operative mechanism and turns the analysis into a response surface problem rather than a regression-coefficient problem.

Five cross-cutting patterns

Recurring across the 36 models:

1. Awareness--performance disconnect. Awareness alone does not track outcomes; its effect appears to be conditional on infrastructure.
2. Resource paradox. More resources do not monotonically improve outcomes; the relationship with firm size reverses beyond a point.
3. Linear null, nonlinear recovery. The same data that yield nothing under an additive specification yield structure under a second-order one.
4. Dose--response separation. Training appears to build awareness and infrastructure, yet the self-reported competency measure does not register the change proportionally.

5. Equifinality. Configurational analysis recovers more than one sufficient route to high training effectiveness, which an average-effects model cannot represent.

Where this could go wrong

The uncomfortable observation, recorded here because it drove the peer review: the study's own argument is that a single self-report item under-captures training effects --- and the single self-report item is what every nonlinear estimate is built on. If that instrument is unreliable enough to justify the argument, it is unreliable enough to undermine the estimates that make the argument. This is not a limitation to be noted in a final section; it is a design problem that has to be resolved before the claims can stand.

Possible spin-off

The time-precedence work produced six alternative designs, one of which --- modelling how the optimum point on the response surface moves over time rather than treating it as fixed --- is a methodological contribution in its own right and does not depend on this study's substantive claims.

Questions and Answers

Open questions carried by the project, in priority order. These are unresolved; answers are recorded when they arrive.

Q1. Does the central finding survive an objective outcome measure?

Status: unanswered --- this is the blocking question.

The headline results rest on a single self-report item that is also the object of the study's own measurement critique. Three outcomes are possible: the objective and self-report measures converge, giving the strongest available evidence; the objective measure is stronger, supporting the measurement-gap argument; or the objective measure returns nothing, in which case the finding is a common-method artefact and the paper must be reconstructed. Resolution paths were drafted on 2026-05-04; none has been executed.

Q2. Can the panel-dependent methods be re-estimated on the true panel?

Status: unanswered.

Of 219 firms, 171 appear in only one wave. Two of the five triangulating methods assume genuine panel structure and therefore need to be restricted to the subset of firms observed in more than one year. Whether that subset retains sufficient power is not yet tested. Year fixed effects do not substitute for firm fixed effects on single-wave cohorts.

Q3. What survives multiple-comparison correction?

Status: partially answered.

With eight hypotheses evaluated across 36 models, family-wise error is a real risk. Under a corrected threshold the claim becomes narrower and must be restated as such. The fix is re-tabulation and an explicit confirmatory/exploratory split, not re-analysis --- which is why it is sequenced last despite being straightforward.

Q4. Does the interaction survive a proper common-method-variance diagnostic?

Status: unanswered.

The draft cites a single-factor test as its CMV diagnostic. The methodological standard explicitly recommends against relying on that test alone. A latent method factor approach is required, and CMV belongs in Methods rather than Limitations.

Q5. Is the contribution a theoretical extension or a methodological one?

Status: unresolved framing question.

The draft claims an organizational-level extension of a person-level theory in one section while defending the work as a methodological extension elsewhere. These cannot both stand. Resolving it means engaging the organizational-level alternatives --- complementarity theory, dynamic capabilities, resource-based reasoning --- rather than asserting novelty.

Q6. How many theories should the discussion actually integrate?

Status: answered --- fewer.

The draft's discussion invokes sixteen frameworks. The review's judgement, accepted here, is that four or five carry the argument and the rest should be citations rather than integrations.

Procedures

The procedure actually followed, in sequence.

1. Research setup

Research problem, PICO specification, and research questions defined. Target population fixed as manufacturing SMEs enrolled in the K-Hitech DT training programme.

2. Literature search

Six Web of Science search blocks constructed around four intersecting domains, with intersection queries used to isolate the focal set. Screening follows PRISMA. See Searching and Inclusion & Exclusion.

3. Synthesis

Retrieved literature processed through ScholarRAG, a staged review-automation pipeline, in systematic-review mode. Output: the integrated conceptual framework v1.0.

4. Data preparation

Raw responses screened for missingness; the missingness mechanism tested before deletion. Constructs assembled and reliability assessed. See Data.

5. Sequential model estimation

Three nested specifications estimated in order --- linear main effects, first-order interactions, then second-order curvature --- so that each addition can be tested incrementally rather than asserted. See Method.

6. Response surface analysis

Surface statistics computed under the Edwards (2002) protocol; the stationary point located and bootstrapped for confidence intervals.

7. Configurational analysis

Fuzzy-set QCA run on the upper quartile of the outcome, with theoretically anchored calibration and a sensitivity re-run at a stricter consistency cutoff.

8. Triangulation

Five methods applied to the same substantive question so that agreement or disagreement between them is informative rather than assumed.

9. Drafting

Five-chapter manuscript assembled, with cover letters to the two highest-ranked target journals.

10. Internal peer review

Structured review conducted against the draft, producing a five-document package and a Major Revision recommendation.

11. Revision — pending

Not started. The revision sequence is fixed by dependency: the dependent-variable decision comes first because it determines every downstream estimate; the panel restriction and the common-method diagnostic follow; multiple-comparison correction is last because it is re-tabulation rather than re-analysis.

Theoritical Framework

Related Theories

Core frameworks

Theory	Source	Role in this study
Technology--Organization--Environment	Tornatzky & Fleischer (1990)	The foundational frame, reinterpreted here in nonlinear form rather than replaced
Person--Environment Fit	Edwards (1994); Edwards & Cable (2009)	Supplies the congruence logic and the polynomial operationalization
Sociotechnical Systems	Trist & Bamforth (1951)	Grounds the claim that technical and social subsystems must be jointly optimized
Configurational Equifinality	Ragin (2008)	Justifies treating multiple routes to the same outcome as substantive rather than noise

Supporting extensions

Theory	Source	Role
Liability of Smallness	Aldrich & Auster (1986)	Explains attenuation at the small-firm end of the size distribution
Optimal Distinctiveness	Brewer (1991)	Motivates an interior optimum rather than a monotonic size effect
AMO framework	Appelbaum et al. (2000)	Decomposes training effectiveness into ability, motivation, and opportunity

Theory	Source	Role
Absorptive Capacity	Cohen & Levinthal (1990)	Prior-knowledge constraint on assimilating new technology
Organizational Inertia	Hannan & Freeman (1984)	Structural resistance at the larger-firm end
Training Transfer	Baldwin & Ford (1988)	Alternative framing of the outcome as transfer rather than adoption
Dynamic Capabilities	Teece, Pisano & Shuen (1997)	Organizational-level alternative to be engaged, not assumed away

Methodological canon

Contribution	Source
Second-order response surface	Box & Wilson (1951)
Response surface analysis for congruence	Edwards & Parry (1993); Edwards (2002)
RSA reporting standards	Shanock et al. (2010)
Common-method variance standards	Podsakoff, MacKenzie, Lee & Podsakoff (2003)
Unmeasured latent method factor	Williams, Hartman & Cavazotte (2010)
fsQCA standards	Schneider & Wagemann (2012); Greckhamer et al. (2018)
Digital transformation definition	Vial (2019)

Relationship Between Theories

The four core frameworks are not stacked as parallel justifications. Each answers a different question, and the answers chain.

TOE supplies the dimensions, not the functional form

TOE identifies what matters --- technological, organizational, and environmental context --- but it does not specify how those contexts combine. The conventional additive reading is a modelling convention that the framework itself does not require. This leaves room to keep TOE's dimensions while replacing its functional form, which is what this study does.

P-E Fit supplies the functional form

P-E Fit theory holds that outcomes depend on correspondence between two dimensions, and that misfit in either direction is costly. It also arrives with an established estimation protocol: polynomial regression with surface statistics, rather than difference scores. Applying that protocol to the T and E dimensions of TOE converts a vague claim about ``alignment'' into a testable surface geometry with named coefficients and directional predictions.

Sociotechnical Systems explains why fit should matter here

P-E Fit explains how to model congruence but not why congruence should govern this particular outcome. Sociotechnical theory does: technical and social subsystems must be jointly optimized, and optimizing one alone degrades the whole. Awareness without infrastructure, and infrastructure without awareness, are the two failure modes that this predicts --- which is exactly the incongruence penalty the surface analysis is built to detect.

Configurational Equifinality explains what a surface cannot show

A response surface describes one continuous function with a single optimum. It cannot represent the possibility that structurally different firms reach high effectiveness by different routes. Configurational analysis can. The two are therefore complementary rather than competing: the surface characterizes the average geometry, the configurational analysis characterizes the discrete routes through it.

The chain, stated compactly

TOE fixes the dimensions → Sociotechnical Systems argues that those dimensions must be jointly optimized → P-E Fit provides the estimator for joint optimization → Configurational Equifinality recovers the multiple routes that a single estimated surface averages over.

Where the framing is still contested

Transposing P-E Fit from the individual to the firm--environment level is a real move, not a notational one, and the draft has not yet settled whether it claims that as a theoretical extension or as a methodological application. Organizational-level theories of complementarity and dynamic capabilities make overlapping predictions and must be engaged rather than bypassed. This is an open item --- see Questions and Answers.

Theoritical Framework

Structure

The framework retains TOE's three dimensions but replaces the additive combination rule with a congruence rule on the Technology--Environment pair, with Organization entering as a moderator whose effect is expected to be non-monotonic.

- T --- digital transformation awareness within the firm
- E --- smart-system infrastructure available to the firm
- O --- organizational size
- Outcome --- change in DT competency from pre- to post-training

Hypothesis

H	Statement
H1	A linear additive TOE specification fails to predict DT training effectiveness.
H2	A Technology × Environment interaction adds explanatory power beyond linear main effects.
H3	The T×E response surface exhibits a ridge along the congruence line and an asymmetric penalty for incongruence.
H4	Organizational size moderates training effectiveness in an inverted-U pattern, with an interior optimum.
H4a	At the small-firm end, effectiveness is attenuated by resource constraints (liability of smallness).
H4b	At the large-firm end, effectiveness is attenuated by a ceiling effect.
H5	Training causally increases infrastructure and awareness.
H6	A single self-report outcome measure captures substantially less of the training effect than an objective outcome measure.
H7	More than one configuration of conditions is sufficient for high training effectiveness (equifinality).

H	Statement
H8	A compensation path exists in which strong infrastructure substitutes for weak awareness.

Surface predictions

Under the Edwards (2002) parameterization, the P-E Fit reading of TOE makes directional predictions about the surface statistics rather than about individual regression coefficients:

Statistic	Meaning	Prediction
a1	Slope along the congruence line	Not the primary claim; may be near zero
a2	Curvature along the congruence line	Non-zero, indicating an optimum exists rather than a monotonic gain
a3	Asymmetry between the two directions of misfit	Non-zero if one failure mode is worse than the other
a4	Curvature along the incongruence line	Negative --- the signature prediction. Misfit in either direction imposes a penalty

a4 is the hypothesis that distinguishes this framework from a conventional interaction model. An interaction term alone shows that T and E are non-additive; a negative a4 shows that the non-additivity takes the specific form P-E Fit predicts.

> **Estimation status**
>
> All hypotheses were evaluated against Draft v1 and are being re-evaluated under the pending revision, which changes the outcome measure. Estimates are therefore not reproduced here --- see Products.

Methodology and Method

Methodology

Stance

The study is quantitative and explanatory, organized around a single methodological commitment: a null result under one functional form is not evidence of absence, it is evidence about that functional form. The design is therefore comparative across specifications rather than confirmatory within one.

Design

Repeated cross-section over four annual waves, drawn from a government DT training programme. The data are administrative in origin rather than researcher-solicited, which strengthens coverage and weakens control over instrumentation --- a trade-off that shapes the study's central open problem.

Analytical strategy

Three nested specifications estimated in sequence, so that each addition is tested rather than assumed:

```
Step 1 (M_main):  Y = b0 + b1*T + b2*E + b3*O + b4*EDU + year_dummies + e
Step 2 (M_m7):    + b5*(T x E) + b6*(T x O) + b7*(E x O)
Step 3 (M_rsm):   + b8*T^2 + b9*E^2 + b10*O^2          <- main model
```

Incremental F-tests between steps establish whether each layer of complexity earns its place. The second-order step is required not because it maximizes fit but because surface interpretation is undefined without full curvature terms.

Triangulation

Five methods are applied to the same substantive question so that convergence or divergence between them is itself evidence:

Method	Approach	What it identifies
Paired comparison	pre versus post	within-respondent change
Propensity score matching	matched comparison	selection into training
Staggered difference-in-differences	pre-post by cohort	within-firm change
Cross-lagged panel model	t1 to t2 cross-lag	temporal ordering
Response surface analysis	second-order surface	functional form

> **!** Known design limitation under revision
>
> Two of these five methods assume genuine panel structure, and most firms appear in only one wave. The pending revision restricts those two methods to the subset of firms observed in multiple years. Year fixed effects do not substitute for firm fixed effects on single-wave cohorts.

Inference

Heteroskedasticity-consistent (HC3) standard errors throughout; bootstrap confidence intervals for derived quantities that have no closed-form standard error, including the location of the surface stationary point.

Causal claims

The response surface analysis is cross-sectional and supports associational claims only. Six alternative designs that would establish time precedence have been drafted --- lagged, difference-based, cross-lagged, time-varying, growth-curve, and dynamic-optimum specifications. The first of these is the intended addition to

the robustness section; the last is a potential methodological paper in its own right.

Method

Response surface analysis

Surface statistics are computed from the second-order regression coefficients under the Edwards (2002) parameterization:

```
a1 = b1 + b2          slope along the congruence line X = Y
a2 = b3 + b4 + b5     curvature along the congruence line
a3 = b1 - b2          slope along the incongruence line X = -Y
a4 = b3 - b4 + b5     curvature along the incongruence line
```

Interpretation rules applied:

Condition	Reading
a1 > 0, significant	Outcome rises monotonically as T and E rise together
a2 < 0	An optimum exists along the congruence line --- a concave ridge
a3 different from 0	The two directions of misfit are not equivalent
a4 < 0	Incongruence imposes a curvature penalty --- the P-E Fit signature

Stationary point and its uncertainty

The stationary point of the fitted surface is a derived quantity with no closed-form standard error, so it is bootstrapped:

```r
boot_sp <- boot(
  data,
  statistic = function(d, i) {
    fit <- rsm(Y ~ SO(T, E), data = d[i, ])
    canonical(fit)$xs
  },
  R = 1000
)
boot.ci(boot_sp, type = "perc")
```

Reporting the stationary point without an interval would overstate its precision; the interval is what determines whether the located optimum is interpretable at all.

Configurational analysis

Parameter	Setting
Outcome	Upper quartile of the outcome measure
Conditions	T, E, organizational size, training exposure
Calibration	Theoretical anchors at the scale endpoints and midpoint
Frequency threshold	2
Consistency cutoff	0.80, with a 0.85 strict sensitivity re-run
Bootstrap	5,000 samples

Calibration anchors are theoretical rather than sample-derived, and anchor sensitivity is reported rather than assumed away --- configurational results are known to move under anchor perturbation, and a solution that survives only at one calibration is not a finding.

Robustness

- HC3 standard errors on all surface models

- Bootstrap intervals on derived quantities
- Subgroup estimation across size bands
- Multi-threshold sensitivity on configurational cutoffs
- Model comparison by information criterion alongside explained variance

Revisions in progress

The four items identified by internal review are being addressed in dependency order: the outcome measure first, then the panel restriction, then the common-method diagnostic, then multiple-comparison correction. The last is re-tabulation rather than re-analysis, which is why it is sequenced last despite being the least effortful.

Data Collection Strategy

Source programme

Data come from the K-Hitech digital transformation training platform, operated jointly by the Korea Institute for Advancement of Technology and the Ministry of Trade, Industry and Energy. The programme targets manufacturing SMEs of 1--300 employees and provides both DT training and smart-factory infrastructure support.

Why this source

Three properties make it suitable, and one makes it problematic.

Suitable: it covers four consecutive years, giving temporal spread that a one-shot survey cannot; participation is administratively recorded rather than self-selected into a research study; and the population is exactly the one the research question concerns.

Problematic: the instrument was designed for programme administration, not for this study. The outcome item was not built to support the measurement claims the analysis places on it. This is the source of the study's principal open problem.

Respondents

One to two senior respondents per firm --- chief executive, chief information officer, or chief technology officer. Senior respondents give informed answers about firm-level infrastructure and strategy, at the cost of a single perspective per firm and no independent corroboration.

Structure

Repeated cross-section rather than a designed panel. Firms enter as they enrol; some return in later waves, most do not. The resulting structure supports pooled analysis directly and within-firm analysis only on the returning subset.

Planned augmentation

The pending revision requires an outcome measure that does not depend on the same respondent as the predictors. Two routes are under consideration: matching participants to administrative programme records --- attendance, module completion, certification --- or constructing a change measure from the infrastructure variable on the subset of firms observed in more than one wave. Whether the first route is available depends on institutional data access that has not yet been tested; the second requires no external permission but applies to a smaller sample.

Data

Sample

Item	Value
Raw responses	282
Dropped for missing data	38
Analytic sample	244
Distinct firms	219
Firms appearing in more than one wave	48 (approximately 22%)
Observations from multi-wave firms	111
Firms appearing once	171
Waves	2022--2025
Firm size range	1--300 employees

Missingness was tested before deletion rather than after; the test was consistent with data missing completely at random, which is what licenses listwise deletion here.

Composition

Wave	N
2022	32
2023	71
2024	73
2025	68

Sector composition in the first wave: manufacturing 56%, IT 22%, services 22%.

Geographic distribution: Capital area 38%, Yeongnam 31%, Chungcheong 18%, Honam 13%.

Measures

Construct	Operationalization
Technology (T)	Digital transformation awareness, self-reported
Environment (E)	Smart-system infrastructure score
Organization (O)	Firm size, log-transformed
Training exposure	Programme participation intensity
Outcome	Post-minus-pre DT competency, single five-point self-report item

Test--retest reliability on the multi-wave subset: T r=.78, E r=.82.

> **!** Measurement problem under revision
>
> The outcome is a single self-report item answered by the same respondent who supplies the T and E predictors. The study's own argument is that single self-report items under-capture training effects --- which means the instrument that motivates the argument is also the instrument the estimates depend on. Resolving this is the first item of the pending revision, and it changes the dependent variable rather than merely adding a robustness check.

Structural caveat

The distinction between 219 firms and 244 observations matters for method selection. Methods that require within-firm variation are identified only on the 48 firms observed more than once. Applying them to the pooled sample and relying on year fixed effects does not recover firm-level identification.

Literature Review

Searching and Inclusion & Exclusion

Search architecture

Six Web of Science blocks covering four intersecting domains, plus two intersection queries that isolate the focal set. Blocks are constructed to be individually interpretable --- each answers ``what exists on this topic'' --- while the intersections answer ``what exists at the gap''.

Block	Focus	Expected yield
A	TOE × digital transformation × SME	~250
B	TOE × nonlinear or interaction effects	~80
C	P-E Fit × technology or organization	~150
D	RSM × congruence × management or IS	~100
E	DT training effectiveness × SME	~300
F	TOE × fit or alignment	~50

Intersection queries

Query	Purpose	Expected yield
A AND B	TOE + DT + nonlinear --- the focal set	~20--40
(A OR F) AND C	TOE + fit precedents	~15--30

Combined raw yield before deduplication: approximately 880--1,300 records. The small size of the intersection sets is itself the evidence for the gap --- if A AND B returned hundreds of records, the study's premise would not hold.

Inclusion criteria

- Indexed in SSCI or SCIE
- Web of Science category: Management, Information Science, or Business
- Document type: Article or Review
- Published 2010--2026, with foundational works from 2000--2009 admitted where they are canonical for a construct

Exclusion criteria

- Conference abstracts, editorials, book reviews, and other non-peer-reviewed material
- Studies outside the management, IS, and business domains
- Studies with no empirical or theoretical bearing on technology adoption, congruence, or training effectiveness

Screening

Screening follows PRISMA: identification, deduplication, title and abstract screening, full-text assessment, and inclusion, with counts and exclusion reasons recorded at each stage.

Synthesis pipeline

Retrieved records are processed through ScholarRAG, a staged review-automation pipeline operating in systematic-review mode with a target corpus of 50--300 papers after screening. The pipeline supports extraction and synthesis; inclusion decisions and interpretation remain manual.

PRISMA

Stage-by-stage counts are reported in the manuscript. They are not reproduced here because the corpus is subject to the same revision cycle as the analysis.

Reference List

The working bibliography is maintained in BibTeX alongside the manuscript and rendered in References. References organized by their role in the model are listed in Model and Key References.

Status

Category	State
Verified standard citations	12 confirmed against source during the 2026-05-04 review
Required additions identified by review	Common-method variance standards, RSA reporting standards, panel and DID inference standards, moderation inference, digital transformation definition
Recently dated sources	Require identifier verification and in-press labelling before submission

Verification policy

Every citation must be verified against the source record before it appears in the manuscript. A plausible-looking reference that has not been checked is treated as absent, not as provisional. Recently published sources are labelled in press until an identifier resolves.

Research Problem

The problem

Digital transformation training for small and medium manufacturers is a substantial public investment, and the TOE framework is the standard lens for explaining why some firms convert such investment into capability and others do not. Applied conventionally --- as three independent additive predictors --- TOE has produced an extensive body of adoption research. It has produced much less that explains training effectiveness, and where the additive specification returns nothing, the usual inference is that the context variables do not matter here.

That inference confuses the framework with the model. TOE names three dimensions; it does not require them to combine additively. If the true relationship is one of correspondence between dimensions rather than accumulation across them, an additive model is correctly specified to find nothing, and finding nothing tells us about the estimator rather than the phenomenon.

The gap

The literature contains each necessary component separately:

- TOE applied to digital transformation in SMEs
- P–E Fit congruence theory with an established polynomial operationalization
- Response surface methodology as an accepted tool in management and information systems research
- Studies of DT training effectiveness in manufacturing firms

What it does not contain is their intersection. No prior study combines the TOE framework, a P–E Fit congruence operationalization, and second-order response surface analysis to explain DT training effectiveness in manufacturing SMEs. The gap is specific and structural rather than a matter of insufficient coverage.

The claim under test

That Technology–Environment congruence, not Technology or Environment level, is the operative mechanism — and that a framework which appears inapplicable under linear specification becomes informative under a congruence specification.

What would falsify it

A response surface that shows no curvature penalty for misfit would leave the linear null standing as a substantive result rather than a specification artefact. Equally, if the finding holds only for a self-report outcome and disappears under an objective one, the result is a common-method artefact rather than evidence for congruence. The second of these is an open question in this study rather than a hypothetical — see Questions and Answers.

Model and Key References

Key references organized by the role they play in the model rather than by topic.

Framework foundation

Reference	Contribution
Tornatzky & Fleischer (1990)	Original TOE formulation
Oliveira & Martins (2011)	Systematic review of TOE applications
Baker (2012)	TOE update and critical assessment

Congruence logic and its estimation

Reference	Contribution
Edwards (1994), OBHDP 58	Polynomial regression as the alternative to difference scores
Edwards & Parry (1993), AMJ	Response surface analysis canon
Edwards (2002), Organizational Research Methods 5(4)	The congruence protocol followed here
Edwards & Cable (2009), JAP 94(3)	P-E Fit operationalized through RSA
Kristof-Brown et al. (2005)	P-E Fit meta-analysis
Shanock et al. (2010), JBP	RSA reporting standards
Box & Wilson (1951)	Second-order response surface foundations

Why joint optimization

Reference	Contribution
Trist & Bamforth (1951), Human Relations	Sociotechnical systems
Cohen & Levinthal (1990)	Absorptive capacity
Appelbaum et al. (2000)	AMO framework

Size effects

Reference	Contribution
Aldrich & Auster (1986)	Liability of smallness
Hannan & Freeman (1984)	Organizational inertia
Brewer (1991), PSPB	Optimal distinctiveness

Configurational analysis

Reference	Contribution
Ragin (2008)	fsQCA canon
Schneider & Wagemann (2012)	Standards of good practice
Greckhamer et al. (2018)	Coverage and consistency benchmarks

Measurement and inference standards

Reference	Contribution
Podsakoff, MacKenzie, Lee & Podsakoff (2003), JAP 88, 879--903	Common-method variance standards
Williams, Hartman & Cavazotte (2010), ORM	Unmeasured latent method factor
Spector (2006)	Critique of CMV folklore
Hayes (2015; 2017)	Moderation inference
Wooldridge (2010)	Panel estimation standards
Bertrand, Duflo & Mullainathan (2004)	Inference in difference-in-differences

Domain definitions

Reference	Contribution
Vial (2019), JSIS 28(2)	Digital transformation definition
Westerman et al. (2011)	Digital maturity
Baldwin & Ford (1988)	Training transfer

Citation verification

The 2026-05-04 internal review verified twelve of the standard citations directly and identified further references required by methodological standards but absent from Draft v1 --- principally the CMV, RSA-reporting, and panel-inference entries above. Several recently dated sources still require identifier verification and appropriate in-press labelling before submission.

Quotes and Paraphrases

Extracted passages and paraphrases are held in the project's literature workspace rather than published here, because the collection is a working artefact that mixes verbatim source text with drafting notes.

Conventions used in the working file

- Verbatim text is marked as a quotation with page or section locator and is never edited, including where the source contains errors.
- Paraphrases are recorded separately from quotations and carry the same locator, so that the distinction survives into drafting.
- Interpretive commentary is kept in a third register, so that a reader of the file can always tell what the source said from what the author concluded.

The purpose of the separation is narrow and practical: once a passage has been through a draft cycle, it becomes difficult to reconstruct whether a sentence was the source's or the author's. Keeping the registers apart at capture time is the only reliable point at which that distinction is cheap to maintain.

Products

Manuscript

Item	Status
Draft v1	Complete --- five chapters, 16,759 words, 2026-05-03
Internal peer review	Complete --- 2026-05-04, Major Revision
Revision v2	Not started
Submission	Not submitted

The internal review raised four critical, six major, and ten minor concerns. None is fatal, but together they prevent the central claim from being sustained at its current strength. The first critical item changes the study's dependent variable, so the remaining items cannot be settled ahead of it.

Publication plan

The project is structured as a multi-paper programme, of which the TOE-Fit non-linear extension is the lead paper and the only one currently drafted. Target journals are ranked by fit with TOE framework extensions, digital transformation context, and mixed quantitative methods, with policy-oriented outlets as a secondary tier. Journals with strict measurement and panel standards are out of reach until the outcome-measure problem is resolved --- which is a reason to resolve it rather than a reason to aim lower.

Cover letters to the two highest-ranked targets were written against Draft v1 and will require rewriting, because both lean on the measurement-gap argument that the revision destabilizes.

Disclosure policy for findings

> **!** Important
>
> Numerical results are deliberately not published on this site.
> The manuscript is unpublished and under revision, and the first item of that revision replaces the dependent variable on which every estimate rests. Publishing coefficients now would put numbers into circulation that are expected to change, in a form that invites citation. They will be released with the published paper.
> What is published here is the study's design, theoretical framework, methodology, and analytical procedure --- the parts that are stable and that make the eventual results interpretable.

Data and code

Analysis code is organized as 22 R projects covering the full pipeline. Analytical outputs --- tables and figures --- are versioned alongside the manuscript. Neither is publicly released, as the underlying data derive from a government programme and are subject to its terms.

References