CAN PUBLISHED DIGITAL TRANSFORMATION CASES TEST A CONFIGURATIONAL THEORY? A THREE-VALUED TESTABILITY DIAGNOSIS OF PLUS–D

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Abstract

Can published case studies test configurational explanations of digital transformation and resilience? We diagnose the testability of PLUS–D using eleven European goods-producing SME and mid-sized cases recoded from three published studies. Nine cases report transformation progression under chronic disturbance; only two report resilience under an acute shock. Present, absent and unreported conditions are evaluated with strong-Kleene logic, separating realized at-risk instances from corpus-uninstantiated and missingness-blocked claims. Only P5 has a realized instance, but that firm comes from a result-referentially selected source study; its rejecting-stance/stalled-progression correspondence is therefore an illustration, not validation. Three propositions are corpus-uninstantiated and four are blocked by missing evidence. All three cross-theory linkages remain untested. The contribution is an information-systems-oriented testability diagnosis for reusing published digital-transformation cases: it identifies what the record can adjudicate, how reporting endogeneity limits inference and what primary data a valid test requires.

Keywords: digital transformation; information systems; secondary case analysis; configurational theory; three-valued logic; testability; SMEs

JEL Classification: L26; O33; M15; L60

1. Introduction

After Russia's invasion of Ukraine, 68% of EU firms faced energy-bill increases of 25% or more, manufacturing most exposed at 74% [1, p. 12]. Digital technology is not scarce: 70% of EU firms — 77% in manufacturing — already use an advanced technology [1, p. 30]. SMEs differ from large firms in depth, not access: 33% implement several simultaneously, against 50% [1, p. 30].

Shallow adoption plus shock exposure concentrated on manufacturing poses a question linear adoption models cannot answer. Published evidence documents family manufacturers whose transformation stalled under owners rejecting digitalization on identity grounds [2] alongside a five-employee firm that built a digital sales channel within weeks of losing its market [3]: effort and outcomes are not proportional.

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Building on paradox theory [4], threat–rigidity theory [5] and dynamic capabilities [6], PLUS–D proposes configurational explanations over Paradoxical leadership (P), Learning and sensing capabilities (L), Unabsorbed slack (U), Shock exposure (S) and Digitalization (D, presence-anchored), joined to decision architecture and the pivotal rights-holder's stance. This study does not claim to validate that framework. Instead, it asks whether published digital-transformation cases can place its propositions at empirical risk. Nine of the eleven cases describe transformation progression under chronic industry disturbance; only two describe crisis resilience under an acute shock, so the two outcomes are not pooled as one construct:

RQ: To what extent can published digital-transformation case evidence adjudicate PLUS–D's configurational propositions, and which measurement, sampling or logical constraints prevent a valid test?

Two pre-stated strata, a NACE-anchored sector rule and a codebook govern the recoding of eleven firm-level cases. A formal apparatus (Section 4) — strong-Kleene semantics, severity σ and its completable ceiling, codability κ and property-space coverage — determines case-wise evidentiary status and diagnoses what the record can decide; corpus-level thresholds and sampling eligibility are declared separately. PLUS–D is the object of this information-systems-oriented testability diagnosis, not a framework claimed as verified.

An earlier conference paper [7] introduced the three lenses, the linkage concept, the condition set, Figure 1 and conceptual P1–P5. New here are the RQ, corpus, three-valued apparatus, all recoding, diagnostics, results and discussion. The evaluation is exploratory rather than pre-registered: P1, P3 and P4 were repaired after their original clauses proved ill-formed in the measurement language; P5b and Rule D-t are revision-stage amendments; P6 is corpus-derived. These timings are carried into the proposition and method sections rather than represented as an ex-ante confirmatory test.

2. Theoretical background

2.1. Three lenses and their specification gaps

Paradox theory treats organizations as sites of persistent tensions to be engaged, not resolved, through acceptance and iterating resolution — notably temporal or structural separation [4]; paradoxical leader behaviours link to adaptive outcomes [8], though both–and feasibility is contested [9]. Separation, however, presupposes deployable resources, sensing routines and decision latitude the theory leaves unspecified.

Threat–rigidity theory predicts the opposite pathology: threat produces stress, restricted information processing and constricted control, so organizations revert to well-learned routines precisely when novelty is required [5]. Threat-versus-opportunity appraisal moderates this [10], [11]; unspecified are its preconditions — the scanning, resources and decision rights under which an opportunity appraisal survives a shock.

Dynamic capabilities theory supplies the reconfiguration vocabulary — sensing, seizing, transforming [6]. Sensing and learning capabilities recur as SME transformation triggers [12], while the controlling family's disposition governs whether they are exercised [2]; underspecified is the configuration under which sensed opportunities are seized, since sensing without deployable resources or owner sponsorship yields awareness without action [13].

2.2. The conversion problem in information systems research

Information systems research frames the dependent variable as conversion: IT creates value as digital options requiring complementary capabilities [14]; returns follow depth and integration rather than adoption [15]; business-model experimentation mediates the payoff [16]. Resilience is a capability process [17] resting on antecedent endowments, notably unabsorbed slack [18], [19]; SME evidence links it to digitalization only indirectly, through resource availability [20], and finds configurations rather than single levers [21]. Adoption is not conversion quantitatively either: across 245 North American SMEs the depth and scope of crisis-time digitalisation relate to resilience in inverted-U form [22] — an external-validity contrast, not a European replication. Missing is a testable account of combinations, supplied by configurational logic [23]: equifinality [24] and causal asymmetry — failure configurations are not Boolean complements of success ones [25] — are invisible to linear models.

3. The PLUS–D framework

3.1. Integration mechanism

The lenses fail in complementary ways; PLUS–D's contribution is three cross-theory linkages no lens supplies alone.

1. **Paradox × slack (the material-precondition linkage).** Both–and framing becomes practice only when deployable resources fund the separation it requires.

2. **Threat–rigidity × paradox and prior crisis experience (appraisal survival).** Opportunity appraisal moderates rigidity [10]; PLUS–D proposes that an earlier crisis, when explicitly invoked in the response repertoire, supplies an experiential basis for interpreting a new shock, while paradoxical framing keeps alternative responses available.

3. **Capabilities × decision architecture (sponsorship).** Sensing converts into seizing only when decision-rights holders carry the learning agenda: in owner-dominated firms this sharpens Teece's [6] entrepreneurial-management argument into an observable ex-ante condition and specializes the family-firm ability–willingness conjunction [26], [27].

3.2. Conditions

- **P — Paradoxical leadership orientation:** both–and framing of competing demands, enacted through temporal or structural separation [4], [8].
- **L — Learning and sensing capabilities:** scanning, experimentation and absorption of external knowledge [6], [12].

- **U — Unabsorbed slack:** a pre-existing stock of uncommitted resources — financial headroom, spare capacity, managerial attention [18], [19]; in-crisis deployability events are recorded separately.
- **S — Shock exposure:** *chronic*, sustained discontinuous pressure (disruption of a mature industry); *acute*, a discrete exogenous shock (a pandemic lockdown).
- **D — Digitalization:** depth and integration beyond isolated tools [15], time-indexed as D_t0 and read before the disturbance (Section 5.2).
- **DA — Decision architecture and stance:** the allocation of decision rights (central, decentralized, balanced), plus Stance, recording the pivotal rights-holder's disposition toward the digital agenda (rejecting ≺ passive ≺ sponsoring), read from ex-ante indicators (personal digital use, sponsorship of the first digital project, digital hiring), so stance is never inferred from success. Socioemotional wealth puts family principals at both ends [28]: not ownership but the observable stance is the condition. Stance re-operationalizes the willingness construct of the corpus's principal source [2]; since De Massis et al. [26] formalize ability and willingness as jointly sufficient for family-oriented particularistic behavior, the DA × Stance conjunction is that claim re-expressed set-theoretically for the digital agenda, resource discretion becoming decision rights and family-centred goals an observable technology-domain stance [27].
- **PCE — Prior crisis experience:** documented survival of an earlier crisis, invoked in the response repertoire.

Outcome. Regime-specific: transformation progression (advanced / partial / stalled) under chronic disturbance [17]; crisis resilience (high / partial / low) under acute shock. Grades compare only within regime.

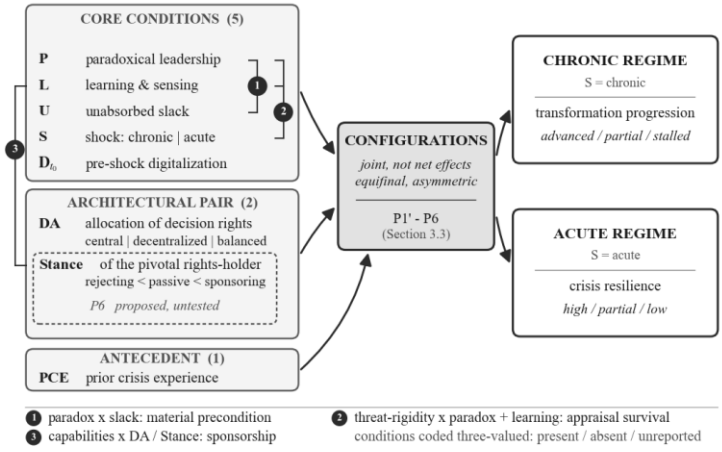


Figure 1. The PLUS–D framework: eight elements — five core conditions (P, L, U, S, D), the decision-architecture–stance pair and prior crisis experience — whose configurations, not net effects, produce regime-specific outcomes; the stance element carries P6, annotated as proposed and untested.

3.3. Propositions in set-theoretic form

Each proposition is a sufficiency claim whose antecedent is a conjunction of literals evaluated three-valued (Section 4.1). Shock regime is a literal of the antecedent, not an external scope parameter, so an unreported regime evaluates to u rather than silently excluding the case, and the confirming-instance threshold is counted within regime; the same device splits the former P4′ into P4a and P4b. The success/failure asymmetry is deliberate [25].

- **P1′ — Slack-enabled paradox pathway.** P ∧ U ∧ D_t0 ∧ (S = chronic) ⊆ O_advanced; the binary t_0 anchor replaces P1's ordinal digitalization clause, a replacement rather than a weakening.
- **P2 — Capability-driven adaptation pathway.** L ∧ D_t0 ∧ (DA = decentralized) ∧ (S = acute) ⊆ O_high, even without unabsorbed slack.
- **P3′ — Experience-enabled adaptive vigilance pathway.** PCE ∧ P ∧ ¬D_t0 ∧ (S = acute) ⊆ O_high, prior crisis experience and paradoxical framing converting threat arousal into vigilant scanning.
- **P4a — High-investment trap, chronic regime.** D_t0 ∧ (DA = central) ∧ ¬U ∧ ¬P ∧ (S = chronic) ⊆ O_stalled.
- **P4b — High-investment trap, acute regime.** D_t0 ∧ (DA = central) ∧ ¬U ∧ ¬P ∧ (S = acute) ⊆ O_low. Resource strain plus information-processing constriction converts investment into rigidity [5], [16]; the proceedings version's regime-indexed consequent [7] becomes this pair.
- **P5 — Identity lock-in.** (Stance = rejecting) ∧ (DA = central) ∧ ¬L ∧ (S = chronic) ⊆ O_stalled.
- **P5b — Distributed rights.** (Stance = rejecting) ∧ (DA ≠ central) ∧ (S = chronic) ⊆ ¬O_stalled: that stance is not decisive where rights are distributed.
- **P6 — Sponsorship pathway (proposal).** (Stance = sponsoring) ∧ L ∧ D_t0 ∧ (DA = central) ∧ (S = chronic) ⊆ O_advanced: its former scope condition, owner-led rights, folded in as DA = central and L carried because the proposal instantiates the capabilities × decision-architecture linkage (Section 3.1). Derived in Section 6.3, proposed for primary testing.

Seven stated propositions and one proposal result: P5b a declared amendment, P4a/P4b the folding-induced split of P4′ (Section 4.2).

4. Formal apparatus

4.1. Three-valued coding and strong-Kleene semantics

Coding is an assignment v: C × $\mathcal{C}$ → {1, 0, u} over the conditions of Section 3.2 and the case set $\mathcal{C}$: present (1) on explicit evidence, absent (0) only on explicit negation or directly contradictory evidence, undetermined (u) on silence or ambiguity. Literals take the forms c, ¬c, (X = x) and (X ≠ x), and every literal over a u-cell evaluates to u.

Antecedents are conjunctions of literals evaluated in strong-Kleene logic K_3 [29, §64, pp. 332–340] (Table 1, panel A): $[\![\text{Ant}(P_j)]\!](i) = 1$ if every literal is 1, 0 if any literal is 0, u otherwise. K_3's third value is read as *unknown* — unreported — not as Kleene's *undefined*: the distinction is not terminological, since the unknown reading motivates the strong tables and the undefined reading the weak ones [29]. Under the information order of Section 4.2 the strong tables are the greatest monotone extension of the classical tables, so the choice is forced rather than licensed. Two features matter: 0 dominates u, so one absent condition settles an otherwise unreadable case; and excluded middle fails, $[\![c \vee \neg c]\!](i) = u$ wherever $v(c, i) = u$, so silence-is-not-absence follows from the semantics.

Table 1. Strong-Kleene semantics and the antecedent–outcome verdict grid

A. Conjunction $[\![x \wedge y]\!]$	y = 1	y = u	y = 0
x = 1	1	u	0
x = u	u	u	0
x = 0	0	0	0
B. Negation $[\![\neg x]\!]$	x = 1 → 0	x = u → u	x = 0 → 1
C. Verdict grid $[\![\text{Ant}]\!](i)$	O(i) = O_pred	O(i) ≠ O_pred	Contribution
1	**1** — confirming instance, i ∈ I(P_j)	**0** — contradicting instance, i ∈ F(P_j)	σ increases by 1
u	**1** (u ∨ 1) — true without risk	**u** — undetermined	none; corpus-wide → Undetermined (type III)
0	**1** — vacuously true	**1** — vacuously true	none; corpus-wide → antecedent uninstantiated (type II)

Note. Panels A and B give the strong-Kleene truth tables for the connectives used in antecedent evaluation [29, §64, esp. pp. 332–335]; panel C gives the case-wise K_3 value of $[\![\neg Ant \vee O]\!](i)$ in bold, collapsed onto whether the observed outcome is the predicted one. Four of the six cells make the implication true; only the $[\![Ant]\!] = 1$ row puts it at risk, so σ counts that row alone (truth without risk is not support). Source: derived.

4.2. Deriving the verdict rules; the fifth category

A proposition $\text{Ant}(P_j) \subseteq O_pred$ asserts sufficiency; case-wise it is the material implication $[\![\neg \text{Ant} \vee O]\!](i)$, and since outcomes are fully coded the informative object is the 3 × 2 grid of antecedent value against outcome match (Table 1, panel C). Nothing turns on this definition rather than Łukasiewicz's primitive →, which differs in one cell only, both arguments undetermined: outcomes being coded in eleven of eleven cases, that cell is never instantiated and the two agree at all eighty-eight proposition–case pairs.

The K_3 grid determines only case-wise evidentiary status: confirming, contradicting, undetermined or vacuously true. It does not derive numerical

thresholds or sampling eligibility for corpus-level verdicts. Let C = I \ F denote confirming instances. We therefore apply a separately declared, mutually exclusive external decision rule in this order: **Refuted** if |F| ≥ 2; **Revision indicated** if |F| = 1; **Supported** if |F| = 0, |C| ≥ 2 and the cases are eligible for support-side inference; **Provisionally supported** if |F| = 0, |C| = 1 and support-side eligibility holds; **Illustrative pattern only** if |F| = 0 and |C| ≥ 1 but result-referential sampling precludes support-side inference; **Undetermined** if σ = 0 and at least one antecedent evaluates to u; and **antecedent uninstantiated** if every antecedent evaluates to 0. The two-instance threshold and support-side eligibility rule are external decisions, not consequences of K_3.

The grid also exposes a category the proceedings rules did not name [7]: σ = 0 arises either because some antecedent is undetermined, or because every one evaluates to 0, no *case* being undetermined — individual cells may be, where a coded literal already forces the conjunction to 0. The second is vacuously true on this case set: **antecedent uninstantiated** (type II). This corpus-level label does not claim that the logical formula is globally unsatisfiable.

Three verdict-rule amendments are declared, not passed off as mechanical rule application [30]. First, the component-contradiction clause is narrowed to necessity-in-path claims: under equifinality a case matching every literal but one, yet carrying the predicted outcome, exhibits a second sufficient path and cannot contradict a sufficiency claim [24]. Only P5b asserts a within-path necessity — centralized rights necessary for a rejecting stance to stall the firm — so the clause is specified but not exercised, σ(P5b) = 0. Second, the refutation-side rules are made mutually exclusive by distinguishing one contradicting instance from two or more. Third, P5b is itself a revision-era split of the proceedings version's converse clause. Rule D-t (Section 5.2) is a measurement amendment and is counted separately.

Monotonicity: refutations persist, support-side patterns do not. Order the truth values by information, u ⊏ 0 and u ⊏ 1, extended pointwise: v ⊑ v′ means v′ fills some undetermined cells of v. The strong-Kleene connectives are monotone in ⊑, so ⟦Ant⟧*v(i)* ⊑ ⟦*Ant*⟧{v′}(i) and, outcomes being fully coded, I_v ⊆ I_{v′}, F_v ⊆ F_{v′} and σ_v ≤ σ_{v′}. Thus F only grows; a refutation-side verdict persists, whereas a support-side pattern is defeasible. Type II is terminal under completion because 0 is already maximal, while type III is non-terminal. Numerical verdict thresholds and sampling eligibility remain external rules. P5 currently has σ = 1 and σ_max = 2; completing Steel's Stance as rejecting would add a matching instance but would not remove the sampling limitation.

4.3. Severity σ, codability κ, property-space coverage

Let I(P_j) = {i ∈ 𝒞 : ⟦Ant⟧(i) = 1} and F(P_j) = {i ∈ I(P_j) : O(i) ≠ O_pred}. **Realized test severity** is σ(P_j) = |I(P_j)|, the number of cases that

put the proposition at risk; it counts at-risk cases, not independent evidence chains. Because $[\![\text{Ant}]\!](i) = 1$ only if every literal evaluates to 1, $I(P_j) \subseteq E(\ell) := \{i \in \mathcal{C} : [\![\ell]\!](i) = 1\}$ for every literal ℓ, so $\sigma(P_j) \leq \min_\{\ell \in \text{Ant}(P_j)\} |E(\ell)|$ — a bound read from the antecedent columns alone, computable before any outcome is coded and needing no dominance relation. Marginals do not deliver σ: P5b's two substantive literals have two positive instances each but disjoint extensions, so the bound is 2 while $\sigma(P5b) = 0$.

Measurement dividend. The completable ceiling of severity is $\sigma_max(P_j) = |\{i \in \mathcal{C} :$ no literal of $\text{Ant}(P_j)$ evaluates to 0 at $i\}|$ — the cases at 1 or u, each at-risk under some completion and no other case ever. The difference $\sigma_max - \sigma$ is the **measurement dividend**: severity obtainable from these eleven cases by reporting alone. Table 5 gives $\sigma_max = (8, 0, 2, 7, 0, 2, 0, 5)$ against $\sigma = (0, 0, 0, 0, 0, 1, 0, 0)$ — up to 23 further at-risk instances in the sum of proposition-specific ceilings. Those gains are not jointly attainable because P1′ and P4a require opposite values of P and U at shared cases; the best single completion raises total σ from 1 to 17. $\sigma_max = 0$ is the arithmetic content of type II.

Extensional collapse. Since $I(\text{Ant}) = \bigcap_\{\ell \in \text{Ant}\} E(\ell)$, a literal ℓ' is *extensionally redundant* whenever $E(\ell) \subseteq E(\ell')$: deleting ℓ' leaves I, F and σ unchanged. Here E(Stance = rejecting) = {Textiles} is contained in both E(¬L) and E(DA = central), so the full P5 antecedent cannot be distinguished from weaker antecedents retaining rejecting Stance. The guarantee covers I, F and σ only; σ_max and untestability type need not be invariant. Like σ and κ, the extensions ignore outcomes, so collapse is a pre-coding diagnostic.

Six literals here have empty extension, in three structurally distinct kinds. U, ¬U, PCE and D_t0 are empty through reporting and leave their cases at u; DA = decentralized is empty on a fully coded condition, so it forces 0 rather than u, which makes P2 uninstantiated on this corpus; and ¬P is a distinct structural blocker, P being coded present at three cases and negated at none (3/0/8), so absent paradox cognition is unobserved rather than unreported (Section 6.4). Every missingness-blocked proposition contains at least one such literal (P1′: U, D_t0; P3′: PCE; P4a: D_t0, ¬U, ¬P; P6: D_t0), so its bound is attained by a single column.

σ differs from the antecedent-set case counts inside consistency denominators [31], [32] in role, not arithmetic: computed before outcomes are read and used as a design instrument rather than a parameter of fit. The novelty claimed is narrow — multi-value QCA multiplies a condition's *levels* [33], whereas the third value here is a *truth* value for unreported cells. The truth tables determine case-wise evidentiary status; the corpus-level thresholds remain declared decision rules. We know of no prior treatment of missingness in set-theoretic secondary coding that combines these elements; the claim is open to correction.

Codability κ(c) is the realized share of non-u cells for condition c — an ex post property of this corpus, not of the genre (Table 4); U and PCE stand at 0.000. The **property space** Ω is the product of the conditions' level sets, $|\Omega| = 2^4 \times 2 \times 3 \times 3 \times 2 = 576$. A point is instantiated only if a case is coded on every condition, and *none here is: the rate is 0/576 = 0.0%* — a corollary of κ(U) = κ(PCE) = 0, not an independent finding. On the fully coded conditions (L, DA, S), |Ω_coded| = 12 and five configurations are observed: coverage 5/12 = 41.7% (Section 6.2). Parameters of fit are deferred, but not for incomputability: consistency clears the pre-registered thresholds there (5/6 = 0.833 w.r.t. O_advanced, 2/2 = 1.000 w.r.t. O_stalled), but five of the eight conditions are dropped, so any consistent point is confounded with the unmeasured ones [31], [34].

4.4. Pre-coding testability screening

Severity is forecastable before coding from two rates: ρ_report(c), the probability that a case study of this genre reports condition c at all, and ρ_pos(c), the probability that a reported value is the positive one the literal requires; then $E[\sigma(P_j)] \approx |\mathcal{C}| \cdot \Pi_c \rho_report(c) \cdot \rho_pos(c)$. Case studies of SME digitalization report capabilities, governance and technology stock routinely, slack stocks and prior-crisis histories only incidentally, so ρ_report(U) ≈ ρ_report(PCE) ≈ 0. It is operatively a zero-factor screen: one condition with ρ_report ≈ 0 drives the product to ≈ 0, so every proposition carrying U or PCE had E[σ] ≈ 0 before any case was read. Both rates are calibrated on the same three-study genre sample they screen, so the pre-coding claim is illustrated, not validated; validation requires a held-out sample of the genre. The division of labour with κ is exact: κ is ex post and corpus-specific, ρ_report ex ante and genre-level.

The product form assumes independent reporting, which the corpus does not provide. Rates calibrated and applied on these same three studies illustrate the arithmetic rather than validate the screen; the assumption-free severity bound remains the operative diagnostic.

The apparatus separates three kinds of untestability. **Type I, ill-formed:** the antecedent is not expressible in the measurement language (an ordinal predicate over a binary condition, say); the repair is restatement at no data cost, applied to **P1** and **P3** — restated as P1′ and P3′ — and to **P4**'s consequent, regime-indexed as P4′ and then split into P4a and P4b (Section 3.3). P6 is a new proposal and P5b a declared amendment, neither a type-I repair. **Type II, antecedent uninstantiated:** the claim is well formed, but every case-level antecedent evaluates to 0; only new cases help. **Type III, missingness-blocked:** satisfiability is undecided because required cells are u; only measurement helps. The apparatus is bounded to conjunctive antecedents over crisp or ordinal conditions with regime-scoped graded outcomes, not necessity claims, disjunctive antecedents or fuzzy membership.

5. Corpus and coding

5.1. Population, strata, sector rule, and screening

The corpus combines criterion screening with explicitly disclosed theoretical sampling, in the lineage of case-survey and meta-synthetic reuse of published case evidence [35], [36] — a conceptual synthesis, not a systematic review. In particular, the three [2] cases were retained as a result-referential contrast — two stalled willingness-suppressing cases and one enabling case — and cannot provide confirmatory support-side evidence for P5.

Two strata were stated before screening. **Stratum 1 — EU-definition SMEs:** goods producers (NACE A–C) under 250 employees, headcounts marginally above the cap entering flagged, with no verdict resting on them. **Stratum 2 — family-controlled mid-sized manufacturers:** majority family-owned, family-managed goods producers of 250–1,000 employees concentrating decision rights in the family; the ceiling is an authorial scope decision and these cases are scope-flagged.

The sector rule is NACE-anchored and outcome-independent in content — a firm qualifies if it produces physical goods — but its cost is recorded: excluding services removes the corpus's only candidate acute-shock failure, the restaurant in [3]. The disturbance criterion requires a documented chronic or acute exogenous disturbance; the geopolitical shock motivating the programme has no firm-level case evidence meeting it [37], so the test draws on two documented European regimes — chronic digital disruption of mature manufacturing and the acute COVID-19 shock.

Six criteria were applied at study and case screening: (C1) stratum membership; (C2) goods-producing, NACE A–C; (C3) digitalization described; (C4) disturbance documented; (C5) a case-level resilience-relevant outcome; (C6) three conditions codable. Two study exclusions cut against convenience — [13], the closest CEE context, and [38]; [39] fell on the same criteria and enters as narrative context only. Within [2], however, three of fourteen firms were retained through result-referential theoretical sampling. The remaining eleven were not recoded for PLUS–D; their source-reported characteristics are listed for transparency, but no complete-case criterion failure or duplicate configuration is inferred.

Eleven cases result: six Italian SMEs [12], three Northern-Italian family manufacturers [2] and two DACH producers under COVID-19 [3].

Table 2. Source-study screening against criteria C1–C6

Study, design and context	Judgment
[12] — 6 Italian manufacturing family SMEs; chronic digital disruption of mature "Made in Italy" industries; fieldwork 2019	**Include — 6 cases** (Stratum 1; chronic regime)
[2] — 14 Northern-Italian manufacturing family firms; chronic Industry 4.0 pressure; 54 interviews	**Include — 3 cases for theoretical illustration:** Textiles and Steel as stalled willingness-suppressing cases, and Food produce as an enabling contrast. Selection was result-referential. The other eleven firms were not recoded for PLUS–D; no complete-case exclusion classification is claimed
[3] — 5 DACH/Liechtenstein SMEs; acute COVID-19 shock; temporary business model innovation	**Include — 2 cases**: spirits manufacturer (NACE C), organic agri-food producer (NACE A). Three service firms excluded by the NACE rule, among them the study's least successful case (restaurant, NACE I) — the documented cost of the sector rule
[13]; [38]	**Exclude** — C5, C6: group-level evidence; coping outcomes not assessed
[37] — 40 interviews, managers of large and mid-sized Ukrainian firms across 13 mostly non-goods-producing sectors; acute wartime shock; thematic analysis	**Exclude** — C1–C2, C5–C6: firms outside both strata; findings thematic, no per-case conditions. Closest available evidence on the motivating geopolitical shock
[39]; [40]; six survey and review studies of SME digitalization	**Exclude** — C4–C6: engagement levels or thematic aggregates, no case narratives. Named in the deposited screening log

Note. C1–C6 as defined in the text. The audit package distinguishes criterion screening from the result-referential theoretical sampling of the three [2] cases and lists the eleven non-recoded firms without assigning unobserved PLUS–D classifications. Source: authors' screening and sampling record.

5.2. Codebook, coding rules, and coder

Coding followed a purpose-built codebook (Table 3 summarizes the contested conditions; the full rules are supplied in the supplementary package). The coding unit is the whole case, published narratives supporting no finer slicing; the three-valued convention of Section 4.1 binds throughout, so silence read as absence is barred by the semantics. Two rules bind the coder against convenient inference (Table 3): P is paradox *cognition*, U a *pre-existing stock*. Outcomes are calibrated per regime so failure-side evidence registers; D is binary, conflating channel-side with production-side digitalization.

Time indexing. D is read at t_0 — before the disturbance and before the source's transformation narrative begins — and the outcome at t_1, so the two are independent by construction and "the advanced cases are the digitalized ones" cannot hold by definition; where no onset is datable, t_0 is the last narrative point before that programme. **Rule D-t** requires integration across at least two of {digital sales channel, CRM/customer data, analytics}, or Industry 4.0 process technology; a stand-alone sales channel does not meet the presence anchor. The rule was adopted during revision and applied to all three cases reporting pre-

disturbance evidence. Fratelli Carli's channel was recoded to D_t0 = 0, leaving no positive D_t0 instance; a single-indicator sensitivity would instead put Carli at 1 and P6 at $\sigma \geq 1$.

All 69 non-missing cells carry a quote or comparative-table anchor with a source locator. Recoding was performed by a single human coder, also an author of the framework under test; no independent human second coder was involved. For a non-exhaustive robustness check, a fresh AI assistant received the codebook and source excerpts with assigned codes withheld and generated source-grounded codes for 18 selected cells. The codes matched 16 of 18 assignments ([2] 6 of 8; [3] 10 of 10). P5 outcomes and shock-regime cells were not included, and [2] D_end was descriptive rather than proposition-bearing. The two mismatches concerned Steel Stance and D_end. The stricter Steel Stance = u reading was adopted in the final matrix; this AI-assisted check is neither human intercoder assessment nor intra-coder re-derivation. Further safeguards are the quote-anchored audit trail and explicit decision rules, including amendments disclosed in Sections 4.2 and 5.2. Shock exposure is coded per study for nine cases; at the [2] cases it rests on that study's Industry-4.0 framing (p. 2301, p. 2306) — the corpus's weakest anchor, now located, still a standing-condition statement rather than a discrete shock.

Table 3. Codebook anchors for the four contested conditions

Condition	Presence anchor (quoted example)	Absence anchor (quoted example)
P — paradoxical leadership orientation	both–and framing enacted through separation: "reach a balance between the old and the new" [12]; a distinct unit or communication line for the new activity alongside the old	explicit either/or framing of competing demands. A negative attitude toward digital technology codes to Stance, not to P = 0
L — learning and sensing	systematic scanning; pilots before rollout; absorption of external knowledge; new functions created for digitally related work	long-tenured managers who "just do the same thing… set up a practice and that's how they look at it" [2]; decisions from owner experience only
U — unabsorbed slack (pre-existing stock)	documented pre-existing reserves, patient capital, or spare capacity available before the disturbance	explicit statement of no financial headroom or inability to fund a response. In-crisis freed capacity and external grants → deployability-event memo, not U = 1
Stance — stance of the pivotal rights-holder	*sponsoring:* "The family pushed the digitalization project… This is the priority of the new generation" [2]; "The family started the digitalization process! I wanted the first e-commerce" [12]	*rejecting:* an explicit refusal of the digital agenda attributed to the rights-holder, e.g. "You can have all the data you want, but do you need this data?" [2]. Identity foreclosure or association withdrawal without a technology-domain refusal is coded missing, not rejecting

Note. Stance is ordinal (rejecting ≺ passive ≺ sponsoring) and coded only where the act is attributed to the pivotal rights-holder at case level; study-level attributions are recorded as disclosed alternatives. The mechanical conditions (PCE, S, D, DA, Outcome) are specified in the supplementary codebook. Source: authors' codebook; quotations from the source studies as cited.

6. Results

6.1. Coding matrix, frequencies, and codability

Table 4 reports the coding matrix.

Table 4. Coding matrix and condition codability (11 cases; 1 = present, 0 = absent, . = missing)

Case (study)	Stratum, size	P	L	U	Stance	S	D_t0	D_end	DA	Outcome
Chronic regime — outcome: transformation progression										
Fratelli Carli (M)	1 (150)	1	1	.	spon	chr	0	1	central	advanced
De Matteis (M)	1 (270*)	.	1	.	spon	chr	.	1	central	advanced
Freddy (M)	1 (130)	.	1	.	spon	chr	.	1	central	advanced
Essequadro (M)	1 (36)	.	1	.	spon	chr	.	1	central	advanced
B.Home (M)	1 (57)	.	1	.	spon	chr	.	0	central	partial
SOVET (M)	1 (30)	.	1	.	.	chr	.	1	central	advanced
Food produce (Ap)	1 (112)	.	1	.	spon	chr	.	1	balanced	partial
Steel (Ap)	2 (837)	.	0	.	.	chr	.	0	central	stalled
Textiles (Ap)	1 (103)	.	0	.	rej	chr	.	0	central	stalled
Acute regime — outcome: crisis resilience										
Case A (C)	1 (>200†)	1	1	.	.	acu	0	0	balanced	high (non-digital)
Case E (C)	1 (5)	1	1	.	spon	acu	0	1	central	high (digital)
κ (codability)	—	**0.273**	**1.000**	**0.000**	**0.727**	**1.000**	**0.273**	**1.000**	**1.000**	**1.000**

*Note. Studies: M = [12]; Ap = [2] (cases labelled by sector: their Case D = Textiles, Case H = Steel, Case C = Food produce); C = [3]. Stance ∈ {rejecting ≺ passive ≺ sponsoring}; spon = sponsoring, rej = rejecting. * De Matteis (270 employees) marginally exceeds the 250-employee cap; † Case A is reported only as ">200 employees": both flagged marginal. PCE is missing in 11 of 11 cases and omitted as a column; U is never observed. Stance is missing at SOVET, Steel and Case A; Steel's identity and association-withdrawal passages do not explicitly reject digitalization. Deployability events (memo fields, not U): Case A — capacity freed by demand contraction; Case E — in-crisis investment in cooling and a farm store. κ = share of non-missing cells. Outcome grades are [DERIVED], not grades printed in the sources. Source: authors' recoding.*

Marginals: P 3/0/8; L 9/2/0; Stance 7/1/3 sponsoring/rejecting/missing; D_t0 0/3/8; DA 9 central, 2 balanced. L is fully coded and prevalent, while the resource-and-cognition conditions are sparse: P is never explicitly negated, U is never observed and D_t0 = 1 has no instance. Outcome levels align with the source studies, so between-study patterns may reflect their sampling logics. No case instantiates the complete property space (0/576); every verdict concerns a projection.

6.2. Configuration inventory and property-space coverage

The full partial-configuration inventory is supplied in the supplementary package. On the fully coded projection (L, DA, S), the 11 cases occupy five of 12 possible points (41.7%); seven points are logical remainders. Three descriptive rows collapse to (L = 1, DA = central, S = chronic), illustrating why the partial inventory cannot support minimization.

Two observations follow. First, in the chronic regime every advanced case combines L with D_end and both stalled cases lack both, but the pattern carries no evidential weight: of the 18 cross-pairs differing on D_end, 17 are concordant, 0 discordant, 1 a tie, so γ(D_end, ordered chronic outcome) = 1.000 — definitional overlap. Second, among the eight Stance-coded cases the single rejecting firm stalled, while sponsoring outcomes disperse (chronic: advanced 4, partial 2; acute: high 1). This descriptive pattern cannot test causal asymmetry [25].

6.3. Proposition verdicts and realized severity

Table 5. Proposition verdicts, realized severity σ, completable ceiling σ_max and untestability type

Proposition (folded antecedent)	σ	σ_max	Type	Verdict
P1′ P ∧ U ∧ D_t0 ∧ (S = chr) ⊆ O_advanced	0	8	III	Undetermined by missingness (u = 8, 0 = 3); blockers: U unmeasured; no case combines P = 1 with pre-disturbance digitalization
P2 L ∧ D_t0 ∧ (DA = decentralized) ∧ (S = acu) ⊆ O_high	0	0	II	Antecedent uninstantiated; DA fully coded, decentralized rights realized nowhere
P3′ PCE ∧ P ∧ ¬D_t0 ∧ (S = acu) ⊆ O_high	0	2	III	Undetermined by missingness (u = 2, 0 = 9); blocker: PCE (κ = 0.000)
P4a D_t0 ∧ (DA = central) ∧ ¬U ∧ ¬P ∧ (S = chr) ⊆ O_stalled	0	7	III	Undetermined by missingness (u = 7, 0 = 4); blockers: U, ¬P; D_t0 = 1 has zero instances
P4b D_t0 ∧ (DA = central) ∧ ¬U ∧ ¬P ∧ (S = acu) ⊆ O_low	0	0	II	Antecedent uninstantiated: both acute cases carry D_t0 = 0 and P = 1
P5 (Stance = rejecting) ∧ (DA = central) ∧ ¬L ∧ (S = chr) ⊆ O_stalled	**1**	2	Sampling-limited	**One-case illustration** consistent with P5; ineligible for support-side inference because the case comes from result-referential theoretical sampling. Steel-rejecting alternative: σ = 2
P5b (Stance = rejecting) ∧ (DA ≠ central) ∧ (S = chr) ⊆ ¬O_stalled	0	0	II	Antecedent uninstantiated: the two substantive extensions are disjoint
P6 (Stance = sponsoring) ∧ L ∧ D_t0 ∧ (DA = central) ∧ (S = chr) ⊆ O_advanced	0	5	III	Undetermined by missingness (u = 5, 0 = 6); blocker: D_t0 has no positive instance

Note. $\sigma = |\{i \in \mathcal{C} : [\![Ant]\!](i) = 1\}|$ and $\sigma_max = |\{i \in \mathcal{C} : \text{no literal evaluates to 0 at } i\}|$. The measurement dividend is 23 in the proposition-specific sum. The three type-II propositions are vacuously true on this corpus. P2 and P4b remain type II under the Rule D-t sensitivity. Under the adopted coding I(P5) = {Textiles}, F(P5) = ∅ and Steel's antecedent is u; coding Steel Stance as rejecting would raise σ(P5) to 2 without changing its sampling ineligibility. Outcome grades are [DERIVED]. Source: authors' computation from Table 4.

Table 5 reports the verdicts; every σ = 0 follows from the antecedent columns of Table 4, before any outcome is coded. Three propositions are antecedent-uninstantiated and four are missingness-blocked. P5 alone has a realized at-risk case (σ = 1), but it is an illustration rather than a support verdict because it came from result-referential theoretical sampling.

P5 is the only proposition with a realized at-risk case. Textiles instantiates the adopted antecedent and is stalled, yielding σ = 1 and F = ∅. Its owner dismisses digitalization on its merits — "you can have all the data you want, but do you need this data?" (Table 3) [2]. This is evidence consistent with P5, but not confirmatory support: the case was retained through result-referential theoretical sampling, and Stance, ¬L and outcome come from a dependent source narrative.

Steel-Stance adjudication. The final matrix adopts the fresh-assistant reading of Steel's Stance as missing because the cited identity and association-withdrawal passages do not explicitly reject digitalization. If the earlier rejecting code were retained, I(P5) would become {Steel, Textiles} and σ(P5) would rise from 1 to 2. Steel D_end = missing would not affect any proposition-level σ because D_end is not a P5 literal. Either reading remains sampling-limited and ineligible for a support-side verdict.

Three dependencies are disclosed rather than smoothed. First, [2] grades cases through the willingness construct that also grounds Stance, so outcomes were re-derived from digitalization-progress evidence; source-level dependence remains. Second, P5 depends on assigning chronic Industry-4.0 pressure to Textiles from a study-level anchor; withdrawing that assignment makes σ(P5) = 0. Third, E(Stance = rejecting) = {Textiles} is contained in E(¬L) and E(DA = central), so the full configuration is observationally equivalent here to weaker antecedents retaining rejecting Stance.

P2, P4b and P5b are antecedent-uninstantiated (Table 5); P5b only under the adopted coding, its status resting on the Food-produce Stance cell — the corpus's only chronic case with DA ≠ central, coded sponsoring here — so were that cell missing P5b would be missingness-blocked, a sensitivity disclosed in the supplementary package. Case E — capability core, centralized family leadership, outcome high — is not a counterexample to P2, which is silent on cases outside its antecedent; its existence is consistent with, but no single case tests, equifinality [24]. It motivates P6, proposed rather than tested: among chronic owner-led sponsoring cases with end-of-case digitalization, four of four advanced — $\tilde{\sigma}$(P6 | D_end) = 4, F = ∅, against σ(P6) = 0 — an association constitutively confounded with the digitalization–outcome overlap, so P6 enters the follow-up untested.

P1′, P3′, P4a and P6 are undetermined by missingness (blockers in Table 5). Because the sources record deployability events rather than stocks, primary testing should measure resources as both pre-existing stock and deployability at

the decision moment. The acute cases do not report whether prior crisis experience was invoked, so P3′ requires direct measurement of that condition. P4a meets a success/stall bias: threat–rigidity [5] and business-model evidence [16] keep it alive, but the sector rule removed the nearest failure candidate ([3]'s restaurant).

The three cross-theory linkages of Section 3.1 map one for one onto propositions, each ending in a blocker: paradox × slack onto P1′, blocked by U; appraisal survival onto P3′, blocked by PCE; sponsorship onto P6, blocked by D_t0 — the framework's integrative content is exactly the untested part.

6.4. Report-conditional measurement endogeneity

The missingness pattern is itself a finding. P is codable in 3 of 7 success cases and 0 of 4 non-success, so reporting is outcome-dependent for a condition that enters two propositions. Stance is codable in 1 of 2 stalled cases and 7 of 9 non-stalled cases; the stricter Steel adjudication therefore removes the earlier appearance that Stance was especially visible at failures. Because P is codable only where a source narrates success, $F = \emptyset$ holds under current reporting for any P-containing antecedent, so the corpus cannot presently refute P1′ or P3′. This report-conditional measurement endogeneity reinforces the decision not to assign a support-side verdict. The $\kappa(c \mid O)$ are supplied in the supplementary package.

7. Discussion

7.1. Contributions

The central result is a diagnosis of evidential capacity rather than a validation of PLUS–D. Nine cases concern transformation progression under chronic disturbance, whereas only two concern resilience under an acute shock. Pooling these outcomes as one construct would overstate both construct consistency and empirical coverage. P5's single realized instance comes from a result-referential theoretical sample; it is therefore an illustration, not confirmation. The evidence cannot distinguish the full P5 configuration from weaker explanations retaining rejecting stance.

For information-systems research, the analysis shifts attention from whether digital technologies are present to whether published evidence permits claims about their organizational conversion [14], [41]. Digital-transformation cases report technologies, achievements and managerial narratives, but often omit the temporally ordered organizational conditions required to test configurational explanations. The resulting missingness is not random: success narratives make some leadership conditions visible, while failure-oriented accounts make resistance visible. The three-valued apparatus makes that limitation auditable by distinguishing absence from non-reporting, identifying uninstantiated antecedents and estimating how much additional severity measurement could provide [36]. Its contribution is not that K_3 verifies PLUS–

D, but that it prevents descriptive case correspondences from being presented as confirmation.

The diagnosis also bounds the substantive theories. The acute cases come from a study of successful adapters, so acute rigidity cannot appear here [5]. In the selected [2] contrast, rights-holder stance and learning capability co-vary, so neither can be established as the discriminator [28]. The sensing-to-seizing hinge in owner-led firms [6] remains unresolved, and decision architecture is near-invariant — 9 central of 11, none decentralized. All three cross-theory linkages map onto blocked propositions; the integrative content of PLUS–D remains proposed for primary testing.

7.2. Boundary conditions, limitations, and the follow-up design

The claims are analytical and corpus-specific, not statistical [31]. Nine of eleven cases are Italian, none from Central or Eastern Europe; two sit at or above the EU SME size threshold, a third may. The acute subset has no outcome variance and predates the 2022 geopolitical shock. Outcomes were derived by the recoder, one human coder also authored the framework, the non-exhaustive robustness check was AI-assisted, and no case instantiates the complete property space. The results therefore describe the testability of these reports, not the prevalence or causal effectiveness of PLUS–D configurations.

A valid follow-up should separate transformation progression from resilience, measure conditions before outcomes, sample successful and unsuccessful transformations, include non-central decision architectures and collect independent evidence for stance, learning, slack, prior crisis experience and pre-disturbance digitalization. It should pre-register consistency ≥ 0.80, PRI ≥ 0.70 and frequency ≥ 2 [30]. Proposition-specific completion ceilings imply up to 23 further at-risk instances from fuller reporting, but jointly compatible completion raises total σ by at most 16, from 1 to 17. P5 requires new, prospectively selected cases. In Textiles, rejecting owner stance co-occurred with absent learning capability, centralized rights and stalled progression; the evidence does not identify stance as the binding constraint.

8. Conclusion

This study used PLUS–D to diagnose whether published digital-transformation cases can test a configurational explanation. The answer is largely negative but methodologically informative. Nine of the eleven cases concern transformation progression and only two concern resilience. Three propositions have antecedents uninstantiated in this corpus, four are missingness-blocked and all three cross-theory linkages remain untested. P5 has one realized instance from a result-referential theoretical sample; its rejecting-stance/stalled-progression correspondence is an illustration rather than validation. Thus no proposition receives a support-side verdict.

The contribution is a three-valued testability diagnosis for secondary information-systems and digital-transformation case research. By distinguishing absence from non-reporting and evaluating antecedents before outcomes, the approach identifies what a corpus can adjudicate without converting missing evidence into apparent support. Reliability remains limited: no independent human second coder was involved; a non-exhaustive AI-assisted source-grounded check matched 16 of 18 selected assignments and changed the final Steel Stance adjudication, but does not substitute for human intercoder assessment. PLUS–D should remain a framework proposed for primary testing.

Declarations

The recoding was performed by one of the authors, also an author of the framework under test (Section 5.2). No independent human second coder was involved. An anonymized supplementary package containing the quote-anchored coding ledger, codebook, sampling record, outcome derivations, sensitivity logs and the non-exhaustive AI-assisted 18-cell robustness worksheet will be supplied to the editor and reviewers during submission. Public deposit may follow acceptance. Competing interests: none declared.

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