

E-Logistics Effectiveness in Bangladesh's RMG Sector: A Combined NCA–fsQCA Study

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Abstract

Digital logistics can improve visibility, coordination, reliability, and customer interaction, yet technological sophistication alone does not guarantee that firms realize these benefits. This study identifies conditions that are necessary and alternative configurations that are sufficient for high perceived e-logistics effectiveness in Bangladesh's ready-made garment (RMG) sector. A cross-sectional survey used random respondent selection, 70 professionals were invited and 60 usable questionnaires were returned (85.7%). Necessary Condition Analysis (NCA) and fuzzy set Qualitative Comparative Analysis (fsQCA) were combined. The study specific four-item benefit composite shows strong empirical coherence (Cronbach's $\alpha = 0.936$; McDonald's $\omega = 0.937$). CE-FDH NCA with 10,000 permutations identifies top management awareness as the only condition with both a practically meaningful and statistically supported necessity effect ($d = 0.433$, $p < 0.001$). Using frequency ≥ 2 , consistency ≥ 0.80 , and standard PRI ≥ 0.65 , the observed-data complex fsQCA solution identifies two pathways: MGT*~TECH*~INTL*EXT and MGT*SIZE*INTL*EXT, with solution consistency 0.963 and coverage 0.595. A separate low outcome analysis yields different configurations, supporting causal asymmetry. Robustness checks show that management awareness is the most stable cross specification element, while exact pathway structure is sensitive to some coding and case-exclusion choices. The study contributes a transparent, bounded configurational explanation of e-logistics benefit realization in Bangladesh RMG.

1. Introduction

Digital logistics has become central to contemporary supply-chain management because firms increasingly depend on timely, accurate, and integrated information across procurement, production, inventory, transportation, and customer facing activities. These capabilities are especially important in export-oriented manufacturing, where logistics performance depends on coordination across organizational and national boundaries. In Bangladesh's ready-made garment (RMG) sector, manufacturers operate within buyer-driven supply networks in which visibility, reliability, responsiveness, and information exchange directly affect operational coordination. Yet investment in digital systems does not automatically translate into organizational value; the same technology can produce different outcomes depending on how it is understood, implemented, and embedded in the organization.

This problem creates a clear research need. Bangladesh focused studies have established the importance of information technology, managerial capability, and supply-chain practices in the apparel and RMG context, but the dominant empirical approach remains symmetric and net-effect oriented (Alam, 2023; Uddin et al., 2023). Such designs are well suited to estimating average relationships, but they do not determine whether a particular condition is indispensable for high e-logistics effectiveness or whether several different combinations can produce the same favorable outcome. International studies increasingly demonstrate that digital transformation and supply-chain outcomes may arise through multiple configurations rather than a single universally superior technological path (Zhang et al., 2021; N'Dri & Su, 2024; Shang et al., 2024; Li et al., 2025).

Accordingly, this study addresses three connected problems: limited configurational evidence on e-logistics benefit realization in Bangladesh's RMG industry; insufficient separation of necessity from sufficiency in the existing empirical logic; and limited combined use of Necessary Condition Analysis (NCA) and fuzzy-set Qualitative Comparative Analysis (fsQCA) in this context. The study therefore asks not which isolated factor has the largest average effect, but which conditions constrain high perceived effectiveness and which alternative combinations are sufficient for that outcome.

The research objective is to identify the necessary conditions and alternative sufficient configurations of digital system sophistication, top-management awareness, organizational scale, international market orientation, and external adoption pressure associated with high perceived e-logistics effectiveness in Bangladesh's RMG industry. The corresponding research question is: Which technological, organizational, and environmental conditions are necessary, and which alternative combinations of these conditions are sufficient, for high perceived e-logistics effectiveness in Bangladesh's RMG industry?

The study contributes in four ways. It provides Bangladesh RMG evidence focused on benefit realization rather than technology adoption alone; it uses a configurational logic that accommodates Pathway convergence and asymmetry; it combines NCA and fsQCA so that necessity and sufficiency are evaluated separately; and it translates the resulting patterns into bounded managerial implications for digital logistics alignment. Because the data are cross-sectional and respondent level, the findings are interpreted as necessity constraints and set theoretic associations rather than temporal causal effects or firm level population estimates.

2. Literature Review

2.1 Digital Logistics and Benefit Realization

Digital technologies reshape the way supply chains capture, exchange, and act on information. Reviews of digital supply chains associate these technologies with improved visibility, coordination, responsiveness, integration, and data enabled decision-making (Kache & Seuring, 2017; Büyüközkan & Göçer, 2018; Ben-Daya et al., 2019; Farajpour et al., 2023). Supply Chain 4.0 research similarly emphasizes that digital resources generate value through their interaction with processes, managerial capabilities, and organizational arrangements rather than through technology acquisition alone (Frederico et al., 2020; Garay-Rondero et al., 2020; Govindan et al., 2022).

The distinction between technology adoption and benefit realization is therefore fundamental to e-logistics. Enterprise systems, cloud platforms, tracking applications, and digitally enabled coordination can be present without producing proportional gains in profitability, customer interaction, security, reliability, or visibility. Digital-transformation research describes value creation as an organizational process involving capability development, routines, leadership, skills, and process alignment (Vial, 2019; Verhoef et al., 2021; Machado et al., 2021). Evidence from manufacturing and supply chain contexts

likewise shows that benefits depend on organizational readiness and the fit between technological capabilities and operational requirements, while digitalization can also introduce new risks and dependencies that require managerial attention (Ghadge et al., 2020; Kessler et al., 2022; Rad et al., 2022; Qader et al., 2022; Sharma et al., 2022). Together, this literature indicates that e-logistics effectiveness should be studied as an organizationally embedded outcome rather than a direct function of technological sophistication.

2.2 Bangladesh RMG, TOE Conditions, and Digitalization

Bangladesh's RMG industry provides a demanding setting for digital-logistics coordination because firms operate in globally connected production networks with tight buyer requirements, supplier dependencies, documentation needs, and delivery commitments. Within this context, Alam (2023) used the Technology-Organization-Environment (TOE) framework to examine ICT adoption among apparel-sector executives, while Uddin et al. (2023) linked supply-chain practices and organizational capabilities to competitive advantage among export-oriented RMG manufacturers. These studies confirm that technological and organizational factors matter in the sector, but their symmetric SEM designs estimate average relationships rather than set-theoretic necessity or alternative sufficient combinations.

The TOE perspective remains useful because it organizes digitalization conditions without assuming that each dimension operates independently. Technological conditions describe the sophistication and characteristics of the systems available to the organization, organizational conditions capture internal managerial and structural capacity; and environmental conditions represent market exposure and external pressure. Prior digital-transformation and supply-chain research consistently highlights leadership, organizational readiness, external pressure, and technological resources as interdependent influences on implementation and performance (García-Ortega et al., 2021; Weerabahu & Samaranyake, 2023; N'Dri & Su, 2024). This makes TOE an appropriate organizing framework for a configurational study of RMG e-logistics effectiveness.

2.3 Configurational Research and the Remaining Gap

Configurational research provides a direct way to examine causal complexity that is difficult to represent through average net effects. fsQCA evaluates whether different combinations of conditions are consistently sufficient for an outcome and explicitly accommodates conjunction, Pathway convergence, and causal asymmetry (Pappas & Woodside, 2021; Greckhamer et al., 2018). Recent applications show that cloud service adoption, digital transformation, and competitive performance can emerge through different TOE or capability combinations (Zhang et al., 2021; N'Dri & Su, 2024; Shang et al., 2024; Li et al., 2025).

NCA addresses a different question: whether a condition places a ceiling on the attainable level of an outcome and is therefore necessary but not sufficient (Dul, 2016; Dul et al., 2020; Dul et al., 2023). Combining NCA with fsQCA is useful because a condition can be necessary without being sufficient, while a condition that appears in a sufficient recipe need not be individually necessary. The remaining gap is thus not simply a lack of another digitalization study. What is missing is respondent level evidence

from Bangladesh's RMG sector that separates practical necessity from configurational sufficiency when explaining perceived e-logistics effectiveness. The present study addresses that gap through a combined NCA–fsQCA design grounded in TOE.

3. Conceptual Framework

The conceptual framework translates TOE into five conditions associated with high perceived e-logistics effectiveness. The technological context is the sophistication of the digital system (TECH). Manager readiness and resource capacity are reflected in the organizational context captured by top-management awareness (MGT) and organizational scale (SIZE). The environmental context is captured by international market orientation (INTL) and external adoption pressure (EXT) which reflect exposure to cross-border coordination requirements and pressure from buyers, customers, suppliers or competition. BENEFIT is the perceived e-logistics effectiveness in terms of profitability improvement, customer interaction, security and reliability.

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4. Methodology

4.1 Research Design and Analytical Strategy

The study uses a quantitative, cross-sectional, exploratory configurational design. The unit of analysis is the individual RMG professional's report about the organizational context in which e-logistics is used. NCA and fsQCA answer distinct parts of the objective: NCA evaluates whether a minimum level of a condition is required to attain high effectiveness, while fsQCA evaluates whether multiple combinations are sufficient. A condition may constrain the outcome without being sufficient, and a condition may appear in a sufficient configuration without being individually necessary (Dul, 2016; Dul et al., 2023; Pappas & Woodside, 2021).

4.2 Research Context, Sampling, and Data

The empirical setting is Bangladesh's RMG industry. The survey was administered through Google Forms between 9 May and 15 June 2026 to RMG professionals working in factories located in Chattogram, Gazipur, Narayanganj, and Savar. The sampling frame comprised eligible professionals identified within participating factories. Eligibility required employment in supply chain/operations, management,

information technology, commercial operations, accounts/finance, human resources, or a related function, together with sufficient familiarity with the organization's logistics or digital system practices. Eligible individuals were assigned unique numbers and selected using a computer-generated random-number procedure. Seventy selected professionals were invited; 60 usable questionnaires were returned, yielding an 85.7% usable-response rate. The analytical sample contains only these 60 usable respondent-level records; no frequency-reconstructed cases were added to compensate for nonresponse or unusable returns.

Random selection occurred at the respondent level, not at an independently verified firm level. Firm identifiers were not retained in a form that permits clustering checks or a count of unique firms. Consequently, probability based respondent selection does not establish independence among organizations, and the study does not claim that the 60 observations represent 60 distinct firms. Inference is therefore restricted to the respondent level sample and should not be interpreted as a population estimate for all Bangladesh RMG firms.

Table 1 summarizes the respondent and organizational profile. Supply chain and operations personnel form the largest functional group. The sample is concentrated in larger organizations, and half of respondent's report working for international RMG companies. External buyer/customer/supplier requests constitute the most frequently reported adoption driver, which is directly relevant to the environmental-pressure condition.

Table 1
Respondent and organizational profile

Characteristic	Category	n	%
Department	Supply chain and operations	21	35.0
Department	Other/unspecified	10	16.7
Department	Management	9	15.0
Department	Information technology	8	13.3
Department	Human-resource development	6	10.0
Department	Accounts and finance	5	8.3
Department	Commercial	1	1.7
Organization type	International RMG company	30	50.0
Organization type	Both local and international	16	26.7
Organization type	Local RMG company	14	23.3
Employee size	301+	42	70.0
Employee size	201–300	13	21.7
Employee size	100–200	3	5.0
Employee size	50–100	2	3.3
Primary adoption driver	Customer/supplier/buyer request	32	53.3
Primary adoption driver	Business-process change	10	16.7
Primary adoption driver	Internal staff request	9	15.0
Primary adoption driver	Competition	6	10.0
Primary adoption driver	Other	3	5.0

Source: authors' analysis.

4.3 Measurement, Composite Coherence, and Technology Coding

Perceived e-logistics effectiveness (BENEFIT) is the mean of four study specific five-point items covering profitability improvement, customer interaction improvement, security and reliability, and customer visibility. The items were developed for this study rather than adopted from a previously validated scale. Accordingly, BENEFIT is treated as an exploratory benefit composite/index, not as a fully validated reflective latent construct. This distinction is important: the purpose of the composite is to summarize

complementary perceived benefit domains for configurational analysis, while empirical coherence checks are used to determine whether averaging the four items is defensible.

The four items show strong empirical coherence. Cronbach's α is 0.936 and McDonald's ω from a one-factor model is 0.937, avoiding reliance on alpha alone (McNeish, 2018). Corrected item–total correlations range from 0.785 to 0.905. Sampling adequacy is acceptable (KMO = 0.844), Bartlett's test of sphericity is significant, $\chi^2(6) = 208.56$, $p < 0.001$, and a one-factor maximum-likelihood solution yields standardized loadings from 0.797 to 0.948. These results support the empirical coherence of the composite in this sample while not converting the study-specific items into a universally validated scale. Table 2 reports the item-level descriptive.

Table 2
Measurement descriptives and exploratory composite evidence

Measure	Role	Mean	SD	Median	Response distribution (1/2/3/4/5)
Profitability improvement	Outcome item	4.050	1.111	4.0	2 / 5 / 8 / 18 / 27
Customer interaction improvement	Outcome item	4.133	1.127	4.0	3 / 4 / 4 / 20 / 29
Security and reliability	Outcome item	4.067	1.133	4.0	1 / 9 / 3 / 19 / 28
Customer visibility	Outcome item	4.017	1.242	4.0	3 / 8 / 3 / 17 / 29
Top-management awareness	Condition	4.033	1.089	4.0	3 / 3 / 7 / 23 / 24
BENEFIT composite	Outcome	4.067	1.058	4.375	Range 1.25–5.00

Source: authors' analysis. BENEFIT: $\alpha = 0.936$; $\omega = 0.937$; corrected item–total $r = 0.785$ – 0.905 ; KMO = 0.844; Bartlett $\chi^2(6) = 208.56$, $p < 0.001$; one-factor loadings = 0.797–0.948.

TECH is derived from the open-ended reported IT-system field. Coding is deliberately conservative and reproducible. The final coding sheet contains each of the 27 unique literal system descriptions once, together with its frequency, category, fuzzy membership, alternative broad code, and written rationale; the coding sheet itself does not contain the outcome variable. This structure minimizes case by case discretion and makes every classification auditable from the analytical workbook. Generic or vague descriptions are coded low; named/local/specialized systems and major vendor names without explicit product/version evidence are coded moderate; and explicit advanced enterprise/cloud ERP platforms, multiple major platforms, or advanced automation are coded high. In particular, stand-alone 'Oracle' or 'SAP' labels are not assumed to prove advanced enterprise integration. The broad TECH robustness specification deliberately reclassifies these major vendors only responses upward to test the most consequential boundary decision.

A retained second independent human coding record is not available, so Cohen's kappa is not reported or reconstructed. Instead, coding credibility is addressed through an exhaustive documented dictionary, conservative decision rules, separation of the coding sheet from the outcome, and a substantively broader recoding sensitivity. This approach provides reproducibility and exposes classification uncertainty rather than masking it.

Table 3
Digital-system sophistication coding rubric and final frequencies

TECH category	Decision rule/examples	Fuzzy membership	n	%
Low / basic-vague	Spreadsheet, generic communication/inventory, unclear/basic descriptions	0.05	7	11.7
Moderate / named-specialized	Local/specialized ERP or named vendor without explicit advanced product/version evidence	0.40	38	63.3
High / explicit advanced	D365, Oracle ERP/NetSuite, SAP S/4HANA, multiple major platforms, RPA/PLC	0.95	15	25.0

Source: authors' analysis. The complete 27-response coding dictionary and rationales are retained in the analytical workbook.

4.4 Fuzzy-Set Calibration

Calibration was theory and category anchored, rather than selected to maximize solution fit (Greckhamer et al., 2018; Pappas & Woodside, 2021). BENEFIT uses full non membership at 2.50 because an average at or below this point reflects predominantly non-positive benefit perceptions, the crossover at 3.75 marks the transition between mixed positive evaluations and a generally positive benefit profile, and 4.75 represents clear membership because responses are then almost uniformly at the upper end of the five-point scale. 4.00 is an alternative outcome crossover that tests whether results are contingent on the more permissive 3.75 boundary.

Thus, the substantive meaning of each ordered category is condition memberships, not equal numeric spacing. For MGT, scores 1 and 2 indicate clear non-membership of high management awareness; score 3 is neutral, and therefore placed slightly outside the set (0.45); scores 4 and 5 indicate clear strong membership (0.75/0.95). A named system, with no indication of advanced integration, is deliberately put just outside the set of advanced enterprise systems for TECH (0.40) while explicit advanced platforms are assigned 0.95. SIZE is a measure of being a large organization: 50–100 and 100–200 employees are clearly/more out (0.05/0.25), 201–300 more in than out (0.65) and 301 + clearly in (0.95). INTL codes local firms as clearly out (0.05), firms serving both local and international markets as strongly but not fully in (0.80) and international firms as clearly in (0.95). EXT is crisp because the recorded primary adoption trigger either provides explicit evidence of buyer, customer, supplier or competitive pressure (1)

or does not (0). These selections maintain the semantic ordering of questionnaire categories, and are fully reported in Table 4.

The ± 0.001 adjustment is a transparent tie-breaking rule only, which does not materially change membership magnitudes or ordering. In the main 3.75 calibration, cases having direct membership of exactly 0.500 are raw BENEFIT = 3.75 and are set to 0.499 because the independently defined high-benefit descriptive criterion is raw ≥ 4.00 . With the alternative 4.00 calibration, raw BENEFIT = 4.00 cases at exactly 0.500 are bumped up to 0.501 since they satisfy that pre-specified high benefit criterion. This does not eliminate cases at maximum ambiguity, but retains the direction of the tie break anchored to the same substantive high-benefit rule. Robustness to the alternative outcome crossover is reported in Table 10.

Table 4
Calibration anchors and substantive set-membership rules

Set	Raw operationalization	Main membership rule	Rationale/sensitivity
BENEFIT	Four-item mean	2.50 / 3.75 / 4.75	Alternative crossover = 4.00
MGT	Raw 1 / 2 / 3 / 4 / 5	0.05 / 0.20 / 0.45 / 0.75 / 0.95	Neutral positioned just outside high-awareness set
TECH	Basic / named-specialized / explicit advanced	0.05 / 0.40 / 0.95	Broad major-vendor recoding tested
SIZE	50–100 / 100–200 / 201–300 / 301+	0.05 / 0.25 / 0.65 / 0.95	Membership in large-organization set
INTL	Local / both / international	0.05 / 0.80 / 0.95	Mixed scope strongly but not fully international
EXT	External request/competition vs. other	1.00 / 0.00	Three ambiguous “Other” cases recoded in sensitivity

Source: authors’ analysis.

4.5 Necessary Condition Analysis

NCA is applied to the raw condition and outcome scales to test whether a minimum level of a condition constrains the attainable level of perceived e-logistics effectiveness. Because the predictors are binary or ordinal with relatively few levels, the Ceiling Envelopment Free Disposal Hull (CE-FDH) technique is used as the primary ceiling method. CE-FDH is suitable for categorical or limited-level data, while effect size d expresses the ceiling-zone area as a proportion of the empirical scope (Dul, 2016; Dul et al., 2023).

$$d = \frac{\text{Ceiling} - \text{zone area}}{\text{Empirical scope area}}$$

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Statistical significance is evaluated with an approximate permutation test using 10,000 permutations (Dul et al., 2020). Following NCA guidance, $d < 0.10$ is treated as small, $0.10 \leq d < 0.30$ as medium, $0.30 \leq d < 0.50$ as large, and $d \geq 0.50$ as very large. A condition is interpreted as substantively necessary only when its effect is practically meaningful ($d \geq 0.10$) and statistically supported ($p < 0.05$) (Dul, 2016; Dul et al., 2023). Bottleneck levels are reported in raw units to show the minimum observed condition level compatible with selected levels of the outcome.

4.6 fsQCA Analytical Procedure

fsQCA proceeds through set-theoretic necessity analysis, truth-table construction, and Boolean minimization. Necessity consistency assesses whether outcome membership is contained within condition membership; sufficiency consistency assesses whether membership in a configuration is contained within the outcome (Pappas & Woodside, 2021).

$$Consistency_{Nec}(X \rightarrow Y) = \frac{\sum \min(X_i, Y_i)}{\sum Y_i}$$

2

.....

$$Consistency_{Suff}(X \rightarrow Y) = \frac{\sum \min(X_i, Y_i)}{\sum X_i}$$

3

.....

PRI consistency is calculated using the standard proportional-reduction-in-inconsistency formulation, which discounts the portion of a configuration simultaneously contained in both the outcome and its negation (Greckhamer et al., 2018; Pappas & Woodside, 2021).

$$PRI = \frac{[\sum \min(X_i, Y_i) - \sum \min(X_i, Y_i, 1 - Y_i)]}{[\sum X_i - \sum \min(X_i, Y_i, 1 - Y_i)]}$$

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Five conditions yield 32 logically possible crisp configurations. Fourteen configurations are observed in the sample. The main frequency threshold is set to two cases rather than one because it excludes singleton-driven rows while retaining 56 of 60 respondents (93.3%) in truth-table rows meeting the frequency criterion. This balances the small sample against the risk of treating one case configurations as stable sufficient evidence (Greckhamer et al., 2018). The main sufficiency threshold is consistency ≥ 0.80 and PRI ≥ 0.65 ; frequency = 1, consistency = 0.85, and PRI = 0.70 are tested separately.

The complex solution, which relies only on empirically observed positive truth-table rows, is treated as the primary substantive result because limited diversity is material in a 60-case, five-condition design. Intermediate and parsimonious solutions are nevertheless reported for transparency. Directional expectations for the intermediate solution favor the presence of MGT, SIZE, and EXT; TECH and INTL are left unconstrained because theory and prior evidence do not justify a universal direction. Parsimonious simplification is interpreted cautiously because it uses all permissible logical remainders and can therefore be more assumption dependent than the observed-data complex solution.

4.7 Robustness and Asymmetry Tests

Robustness checks change one analytical decision at a time where possible: frequency threshold (2 versus 1), consistency threshold (0.80 versus 0.85), PRI threshold (0.65 versus 0.70), outcome crossover (3.75 versus 4.00), technology classification, external-pressure coding, and case inclusion. Three later repeated-profile observations are excluded for $N = 57$; 17 straight line response profiles are excluded for $N = 43$; both restrictions yield $N = 42$. Straight-line cases are retained in the main analysis because identical ratings can represent genuine perceptions, but their exclusion tests sensitivity. A separate truth table for BENEFIT uses the same main frequency, consistency, and PRI thresholds to assess causal asymmetry.

5. Results and Discussion

5.1 Descriptive Findings and Measurement Coherence

The ~BENEFIT composite is positively distributed but retains meaningful variation: mean = 4.067, SD = 1.058, median = 4.375, and range = 1.25–5.00. Using 4.00 only as a descriptive crisp threshold, 44 respondents (73.3%) fall in the high-benefit group and 16 (26.7%) below it. This descriptive threshold is not the main fuzzy set crossover. The item level means in Table 2 are similar, and the reliability checks reported in Section 2.3 support aggregation for this exploratory composite while preserving the distinction between empirical coherence and full-scale validation.

5.2 NCA Results and Bottlenecks

Table 5 reports CE-FDH NCA results. MGT has a large necessity effect ($d = 0.433$) and the permutation test is significant ($p < 0.001$). SIZE has a medium effect size ($d = 0.133$) but does not reach $p < 0.05$ ($p = 0.079$), so it is not treated as statistically supported necessity. TECH and EXT are statistically non-random but their effects are small ($d = 0.067$), below the practical 0.10 benchmark. INTL has $d = 0.000$. Under the joint practical and statistical criterion, MGT is the only condition supported as substantively necessary for high perceived e-logistics effectiveness.

Table 5
CE-FDH Necessary Condition Analysis

Condition	Ceiling zone	Scope	Effect size d	Permutation p	Magnitude	Supported as necessary
MGT	6.500	15.000	0.433	< 0.001	Large	Yes
TECH	0.500	7.500	0.067	0.012	Small	No
SIZE	1.500	11.250	0.133	0.079	Medium	No
INTL	0.000	7.500	0.000	1.000	None	No
EXT	0.250	3.750	0.067	0.002	Small	No

Source: authors' analysis; 10,000 permutations. Practical threshold $d \geq 0.10$ and $p < 0.05$.

Table 6 expands the NCA result into raw unit bottlenecks. The substantive signal is concentrated in MGT: reaching BENEFIT = 4.0 is compatible only with MGT ≥ 3 , and reaching 4.5–5.0 requires MGT ≥ 4 . Other variables show finite empirical minima at the uppermost outcome levels, but because their overall NCA effects fail the joint practical and statistical rule, those values are reported descriptively and are not interpreted as robust necessity claims.

Table 6
CE-FDH bottleneck levels in original raw units

Target BENEFIT	Minimum MGT	Minimum TECH	Minimum SIZE	Minimum INTL	Minimum EXT
3.00	3	1	1	1	0
4.00	3	1	1	1	0
4.50	4	1	2	1	0
4.75	4	2	3	1	0
5.00	4	2	3	1	1

Source: authors' analysis. Codes: TECH 1–3; SIZE 1–4; INTL 1–3; EXT 0/1. Non-MGT bottlenecks are descriptive because those conditions do not satisfy the joint necessity criterion.

5.3 fsQCA Necessity Analysis

The fsQCA necessity check provides a complementary membership-based assessment (Table 7). MGT reaches necessity consistency of 0.924 with coverage of 0.880 and is the only condition above the conventional 0.90 benchmark. SIZE is comparatively high at 0.865 but remains below the necessity threshold. TECH, INTL, EXT, and all negated conditions are lower. The agreement between NCA and

fsQCA therefore supports MGT as the principal individual necessity signal while showing that no other single condition is indispensable.

Table 7
fsQCA necessity consistency and coverage

Condition	Necessity consistency	Coverage
MGT	0.924	0.880
~MGT	0.199	0.519
TECH	0.574	0.806
~TECH	0.548	0.760
SIZE	0.865	0.736
~SIZE	0.207	0.802
INTL	0.722	0.720
~INTL	0.345	0.803
EXT	0.749	0.825
~EXT	0.251	0.478

Source: authors' analysis.

5.4 Truth-Table Analysis

Fourteen of the 32 logically possible configurations are observed. Ten observed configurations contain at least two cases and together account for 56 of the 60 respondents (93.3%). Applying the main thresholds of frequency ≥ 2 , consistency ≥ 0.80 , and standard PRI ≥ 0.65 leaves four positive truth-table rows (Table 8). The configuration code follows *MGT – TECH – SIZE – INTL – EXT*, where 1 indicates presence and 0 absence.

Table 8
Positive truth-table rows meeting the main inclusion thresholds

Configuration	Frequency	Consistency	PRI	Raw coverage
10101	6	0.987	0.982	0.170
10111	19	0.987	0.983	0.295
11111	7	0.977	0.972	0.315
10001	3	0.928	0.858	0.102

Source: authors' analysis.

5.5 Sufficient Configurations

Boolean minimization of the four positive observed rows produces two complex pathways. Pathway 1 combines high management awareness, absence of explicitly advanced technology, limited international orientation, and external pressure; organizational scale is unrestricted. Pathway 2 combines high management awareness, large organizational scale, international orientation, and external pressure; technology is unrestricted. The complex solution has consistency 0.963 and coverage 0.595 (Table 9). Because this solution rests only on observed positive rows, it is the primary substantive result.

$$BENEFIT \leftarrow (MGT * \sim TECH * \sim INTL * EXT) + (MGT * SIZE * INTL * EXT) \\ \dots\dots\dots (5)$$

Table 9
Complex, intermediate, and parsimonious high-outcome solutions

Solution	Configuration	Consistency	Raw coverage	Unique coverage	Interpretation
Complex P1	MGT * ~TECH * ~INTL * EXT	0.961	0.199	0.112	Observed-data route
Complex P2	MGT * SIZE * INTL * EXT	0.965	0.483	0.397	Observed-data route
Complex overall	P1 + P2	0.963	0.595	—	Primary substantive solution
Intermediate I1	MGT * SIZE * EXT	0.971	0.628	—	Uses theory-consistent remainders
Intermediate I2	MGT * ~TECH * ~INTL * EXT	0.961	0.199	—	Same as complex P1
Intermediate overall	I1 + I2	0.963	0.657	—	Reported for transparency
Parsimonious	EXT	0.825	0.749	—	Remainder-intensive logical simplification

Source: authors' analysis.

The two complex pathways share MGT and EXT, but their remaining ingredients differ. P1 shows that an explicitly advanced technology platform is not a universal prerequisite: high perceived benefits can occur with non-advanced technology when management awareness is high, international exposure is limited, and external pressure is present. P2 represents a scale-and-internationalization route in which management awareness, large organizational size, international orientation, and external pressure combine while technology is unrestricted. This is evidence of Pathway convergence, not evidence that low technology is intrinsically superior.

The intermediate and parsimonious solutions are intentionally interpreted more cautiously. Under directional expectations favoring MGT, SIZE, and EXT while leaving TECH and INTL unconstrained, the intermediate solution includes MGT*SIZE*EXT and the P1 route. The unrestricted parsimonious solution reduces to EXT alone. Because this simplification depends heavily on logical remainders, it is not used to claim that EXT is a standalone substantive explanation. Instead, the observed data complex solution anchors interpretation, while NCA independently establishes MGT as the only robust individual necessity condition. This separation avoids conflating logical parsimony, configurational recurrence, and individual necessity.

5.6 Low-Outcome Analysis and Causal Asymmetry

A separate truth table for ~BENEFIT using the same main thresholds identifies a different complex solution: ~MGT*SIZE*INTL*~EXT + ~ MGT*~TECH*SIZE*~EXT. The two low-outcome pathways have consistency 0.901 and 0.903, respectively; the combined solution has consistency 0.871 and coverage 0.416. The low-outcome solution is therefore not the simple inverse of either high outcome pathway. This empirical difference supports causal asymmetry: conditions associated with high effectiveness cannot be mechanically reversed to infer low effectiveness (Pappas & Woodside, 2021).

5.7 Robustness Analysis

Table 10 summarizes robustness checks using the standard PRI calculation. The main two-path complex solution survives higher consistency (0.85), higher PRI (0.70), an alternative outcome crossover of 4.00, the N = 57 repeated profile exclusion, and alternative coding of ambiguous EXT cases. Lowering the frequency threshold to one introduces four pathways, including singleton-dependent routes, and reduces solution consistency; this supports the more conservative two case main threshold. Broad TECH coding changes the solution to three paths, indicating genuine technology classification sensitivity. Excluding all straight-line response profiles also changes the exact complex structure, although MGT remains present in every highoutcome term. These results justify treating MGT as the most stable substantive element and the precise peripheral pathway structure as context- and coding-sensitive rather than invariant.

Table 10
Robustness and sensitivity of the high-outcome complex solution

Specification	N	Thresholds	Resulting complex solution	Solution consistency	Solution coverage
Main	60	Freq 2; 0.80 / 0.65	P1 + P2	0.963	0.595
Frequency threshold = 1	60	Freq 1; 0.80 / 0.65	Four-path singleton-inclusive solution	0.930	0.578
Consistency threshold = 0.85	60	Freq 2; 0.85 / 0.65	P1 + P2	0.963	0.595
PRI threshold = 0.70	60	Freq 2; 0.80 / 0.70	P1 + P2	0.963	0.595
Outcome crossover = 4.00	60	Freq 2; 0.80 / 0.65	P1 + P2	0.928	0.606
Broad TECH coding	60	Freq 2; 0.80 / 0.65	Three-path solution; P2 retained	0.942	0.694
Alternative EXT coding	60	Freq 2; 0.80 / 0.65	P1 + P2	0.940	0.622
Repeated-profile exclusion	57	Freq 2; 0.80 / 0.65	P1 + P2	0.960	0.585
Straight-line exclusion	43	Freq 2; 0.80 / 0.65	Three-path solution	0.925	0.614
Combined exclusions	42	Freq 2; 0.80 / 0.65	MGT*SIZE*INTL + P1	0.878	0.715

Source: authors' analysis.

5.8 Theoretical Contribution

The combined NCA–fsQCA results refine the theoretical argument in three ways. First, they separate individual necessity from configurational sufficiency. MGT is the only condition supported as individually necessary by both CE-FDH NCA and fsQCA necessity analysis, while the complex fsQCA solution shows that MGT operates within more than one sufficient route. Second, the complex solution demonstrates equifinality: one pathway combines MGT with ~TECH, ~INTL, and EXT, while another combines MGT with SIZE, INTL, and EXT. Third, the technology result challenges a technology deterministic account without claiming that lower sophistication is preferable. Recent configurational studies likewise show that digitalization and TOE dimensions contribute through context-dependent combinations rather than as universal stand-alone determinants (N'Dri & Su, 2024; Shang et al., 2024; Li et al., 2025).

The Bangladesh contribution is more specific than a generic emerging-market claim. Prior Bangladesh apparel/RMG studies identify significant technology, management, and capability relationships using

symmetric SEM approaches (Alam, 2023; Uddin et al., 2023). The present evidence complements rather than contradicts those studies: a variable can matter on average yet still be substitutable in some configurations, or necessary without being sufficient. The combined NCA–fsQCA design therefore adds causal logic information that a single net effect coefficient cannot provide.

5.9 Managerial Implications

For RMG managers, the most defensible practical implication comes from the NCA result rather than from treating any fsQCA recipe as a universal prescription. At the upper observed outcome levels, high perceived effectiveness is constrained when management awareness is low: Table 6 shows that $BENEFIT \geq 4.5$ is observed only when MGT is at least 4 ('agree') on the original five-point scale. Management understanding of logistics objectives, process redesign, user capability, and implementation governance should therefore accompany digital-system investment (García-Ortega et al., 2021; Machado et al., 2021).

The complex fsQCA solution then adds segmentation. P1 suggests that firms with less explicit advanced platform evidence can still report high benefits when management awareness and external pressure are present in a lower-internationalization context. P2 describes a large, internationally oriented route in which management awareness and external pressure combine with organizational scale. Because broad TECH coding and straight-line exclusions alter some pathways, managers should use these recipes diagnostically rather than deterministically. The robust message is alignment: digital technology should be evaluated together with managerial readiness, organizational context, and externally driven coordination requirements.

5.10 Limitations and Future Research

Several limitations define the boundary of inference. First, 70 professionals were invited and 60 usable questionnaires were analyzed, but random selection was respondent-level and firm identifiers were not retained in a form that establishes the number of unique firms or within firm independence. Second, the study is cross sectional and cannot establish temporal causality. Third, BENEFIT is a study specific four item exploratory composite rather than a previously validated scale or independently audited operational outcome, strong alpha, omega, item total correlations, and one factor coherence support aggregation in this sample but do not constitute universal construct validation. Fourth, conditions and outcome are reported by the same respondents, so common-method inflation remains possible. Fifth, response distributions are concentrated toward the high end of the Likert scale, creating potential ceiling effects. Sixth, TECH is coded from free-text descriptions; the exhaustive dictionary and sensitivity analysis improve reproducibility, but no retained independent second coder record permits a kappa estimate. Finally, 17 straight-line profiles and three later repeated profile records are retained in the main analysis and tested through exclusions; changes under the stricter case exclusion specifications show that exact peripheral pathways should be replicated. Future research should use larger firm-level samples, preserve firm identifiers, use multi respondent and objective performance data, independently replicate technology coding, and employ longitudinal designs.

6. Conclusion

This study identifies both necessary conditions and alternative sufficient configurations associated with high perceived e-logistics effectiveness among Bangladesh RMG professionals. CE-FDH NCA shows that top management awareness is the only condition with both a practically meaningful and statistically supported necessity effect. Using the standard PRI formulation and a conservative frequency threshold of two cases, the observed-data complex fsQCA solution identifies two routes: MGT*~TECH*~INTL*EXT and MGT*SIZE*INTL*EXT, with solution consistency 0.963 and coverage 0.595. A separate low-outcome solution is structurally different, supporting causal asymmetry. Robustness tests show that the exact peripheral structure is sensitive to some technology coding and case-exclusion decisions, but management awareness remains the most stable cross-method signal. The evidence therefore does not support a universal technology sophistication requirement; digital benefits are better understood as context-dependent configurations anchored by managerial readiness. For practice, firms should align technology decisions with management understanding and their organizational and external coordination context. For research, the results provide a transparent exploratory baseline for larger firm level, longitudinal, independently coded, and objective-performance studies.

Declarations

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Clinical Trial Registration

Not applicable. This study does not involve clinical trials.

Ethics approval and consent to participate

Not Applicable. The respondents were given freedom to participate in the survey. There is not any identical information collected as well.

Consent to Participate

Not applicable.

Consent to Publish

Not applicable.

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Conflict of Interest

The authors declare no conflict of interest related to the research, analysis, or material presented in this manuscript.

Data is available here: <https://drive.google.com/file/d/1bnGaNXoUjoJPHc9M9iVpUGgiM7kdhUje/view?usp=sharing>

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Figures

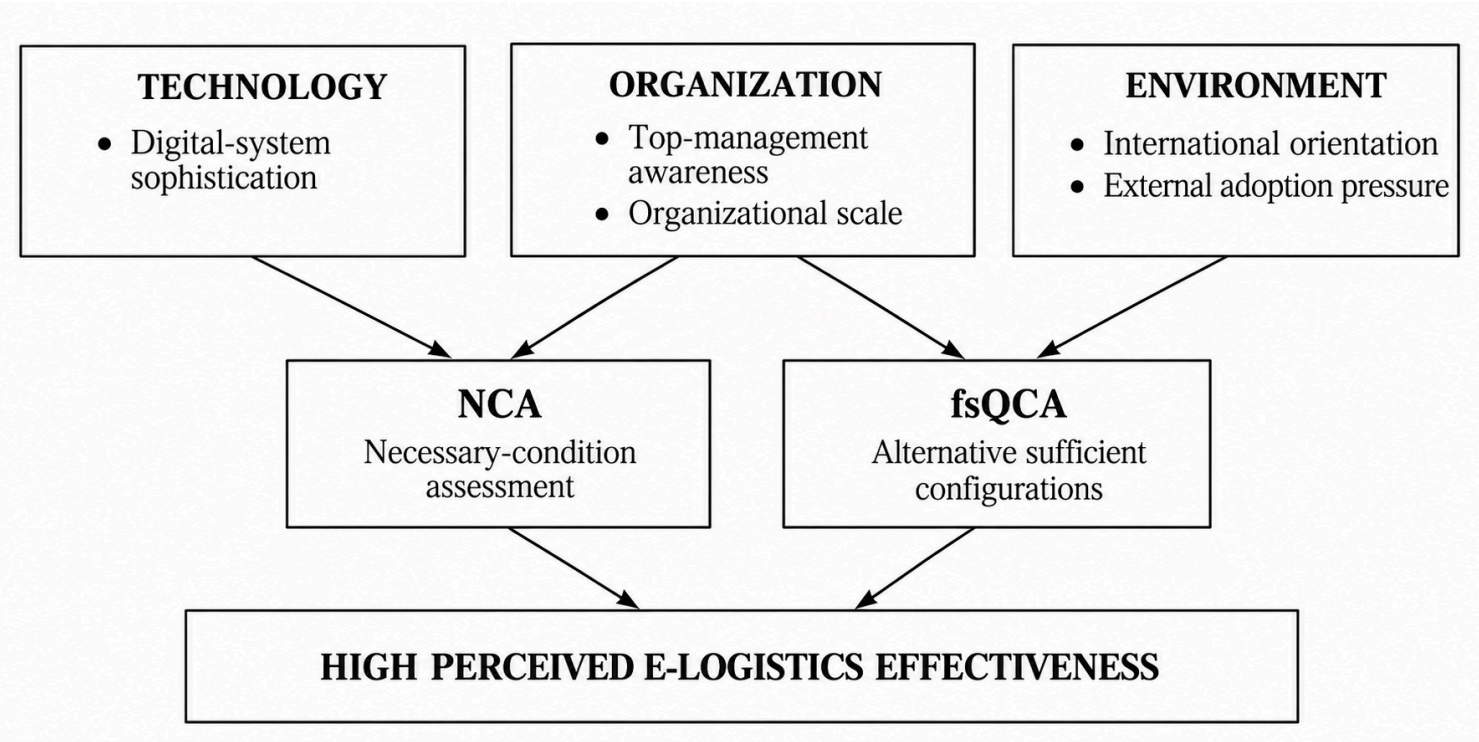


Figure 1

TOE-informed conceptual framework and combined NCA–fsQCA analytical logic. Source: authors’ conceptualization

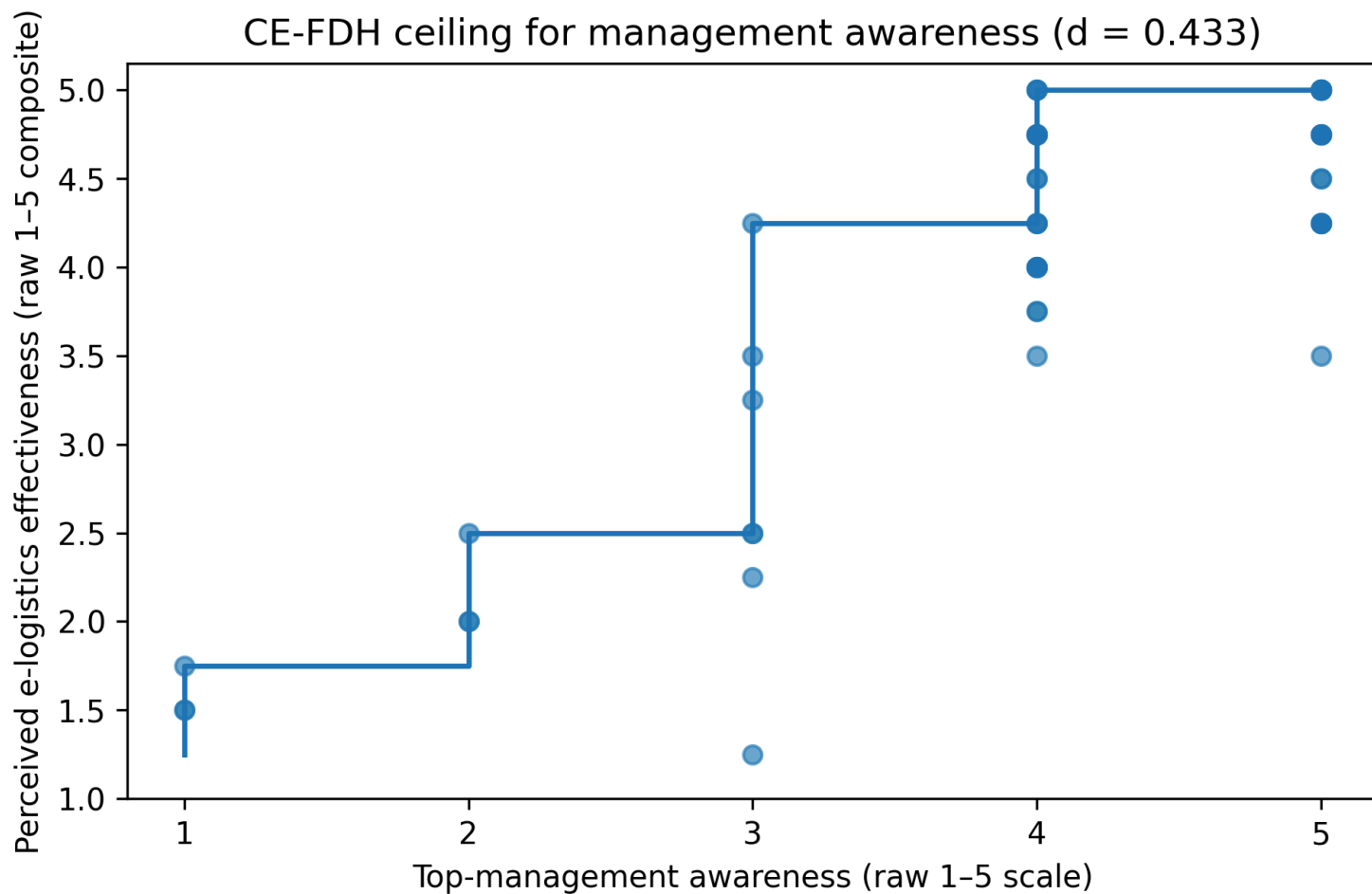


Figure 2

CE-FDH ceiling for top-management awareness and perceived e-logistics effectiveness. Source: authors' analysis.

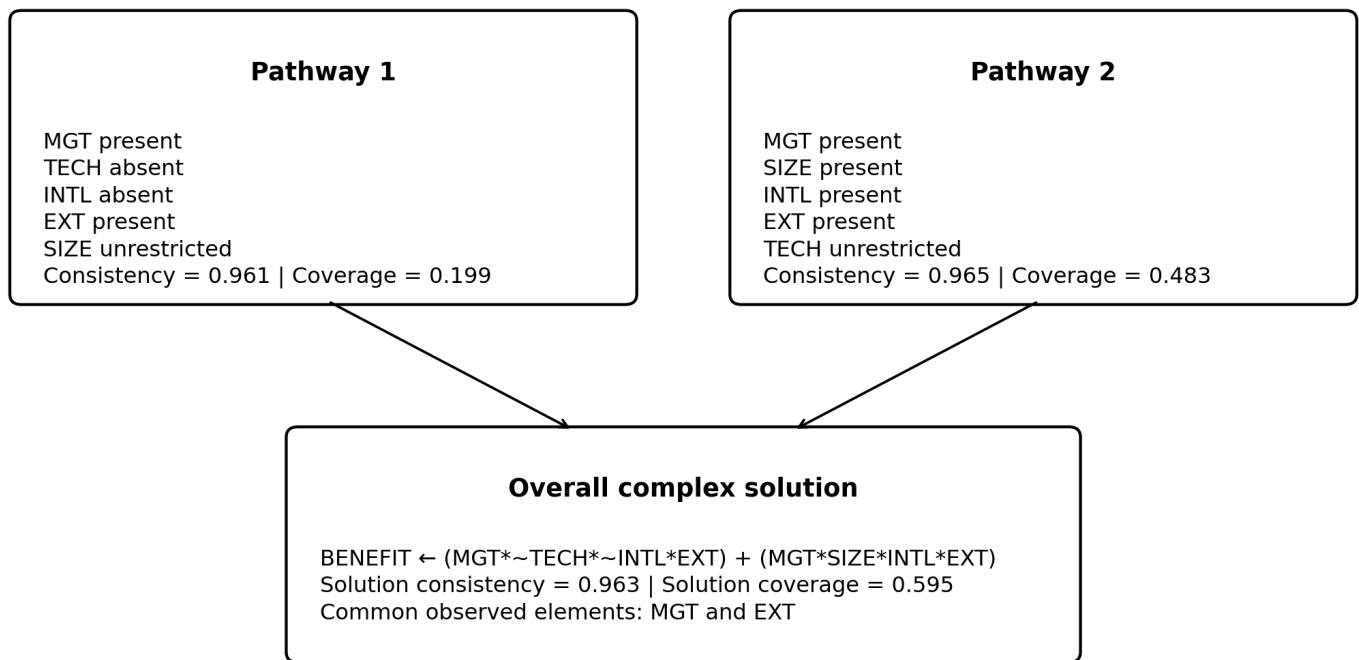


Figure 3

Main observed-data complex pathways to high perceived e-logistics effectiveness. Source: authors' analysis.