

## The Factor Analysis of Digital Transformation Leadership for Private University Administrators in Hainan Province

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### Abstract

This mixed-methods study aimed to: (1) identify the indicators of digital transformation leadership (DTL) among administrators in private universities in Hainan Province, China; (2) analyse and synthesise its key factors; (3) develop a DTL model for administrators in these universities; and (4) verify its empirical fit. The study combined documentary research, qualitative interviews with nine administrators (purposive sampling), a survey of 108 administrators drawn via Yamane's formula from a population of 155, and a focus-group validation with ten experts. Instruments comprised a structured interview protocol and a 48-item 5-point Likert questionnaire with content validity verified by experts (IOC) and reliability confirmed by Cronbach's alpha. Analyses included descriptive statistics, content analysis, Exploratory Factor Analysis (EFA; principal axis factoring, varimax rotation), second-order Confirmatory Factor Analysis (CFA), and composite reliability.

Results aligned with the four objectives. (1) Forty-eight preliminary indicators were identified and refined through EFA item purification. (2) EFA (KMO=0.800; Bartlett's  $\chi^2(1128)=3200.937$ ,  $p < .001$ ) extracted five factors explaining 52.75% of variance after rotation: Digital Use & Data Governance; Digital Competence & Change Leadership; Internal Digital Environment & Support; Digital Vision & Strategy; and External Collaboration & Digital Governance Network. (3) These five dimensions were integrated into a structural DTL model. (4) Second order CFA showed acceptable fit; standardized loadings ranged from 0.390 to 0.787 (all  $p < .001$ ), with Internal Digital Environment & Support ( $\beta=0.787$ ) contributing most strongly. Composite reliabilities of first-order factors ranged 0.849–0.919; expert evaluation confirmed theoretical soundness and practical applicability. The study contributes a context-specific DTL

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model with implications for leadership development and educational digitalization policy.

**Keywords:** Digital Transformation Leadership; Private Universities; Hainan Province; Factor Analysis; Higher Education Administration

## Introduction

Rapid advances in artificial intelligence, big data, cloud computing, and 5G have reshaped organizational management and, in higher education, elevated digital transformation from a peripheral initiative to a strategic imperative for governance, instructional quality, and institutional competitiveness (Kane, et al., 2015; Westerman, et al., 2014). University administrators' leadership has emerged as the decisive factor in whether such transformation succeeds (Akbari & Pratomo, 2022; Jiang, et al., 2023). In China, national policy notably the Overall Layout Plan for the Construction of Digital China foregrounds digital governance and educational digitalisation (Wu, 2023), and Hainan Province has likewise prioritised educational digitalisation, presuming that university leaders can translate digital strategy into institutional practice. That presumption has rarely been tested empirically in private universities.

Empirically, many universities especially private ones struggle with fragmented digital platforms, limited data integration, constrained investment, and a shortage of administrators trained in digital governance (Cai & Hu, 2024; Xie & Wang, 2023; Zhu, et al., 2024). Existing digital-leadership frameworks derive largely from Western corporate or public-university contexts and do not necessarily map onto Chinese private higher education, and few studies have integrated digital competence, change management, strategy, and external collaboration into one empirically verified structural model. (Cai & Hu, 2024; Onan, 2024)

The present study addresses this gap by answering three questions: (1) What indicators compose DTL among administrators in private universities in Hainan Province? (2) What underlying factors emerge when those indicators are analyzed and synthesized? (3) How well does the resulting structural model fit empirical data and withstand expert evaluation? The study thereby contributes both theoretical refinement and practical guidance for leadership development and educational-digitalization policy.

## Research Objectives

1. To identify the indicators of digital transformation leadership among administrators in private universities in Hainan Province.
2. To analyse and synthesise the key factors of digital transformation leadership among administrators in private universities in Hainan Province.
3. To develop a digital transformation leadership model for administrators in private universities in Hainan Province.
4. To verify the empirical fit of the digital transformation leadership model for administrators in private universities in Hainan Province.

## Research Methodology

This research employed a mixed-methods design integrating documentary research, qualitative research, quantitative research, and expert validation, because DTL is conceptually complex and context-dependent: qualitative inquiry captured practitioners' perspectives, quantitative analysis tested the factor structure, and expert validation assessed practical applicability.

### 1. Documentary and qualitative phase.

A systematic review of academic articles, policy documents, and research reports produced a preliminary pool of indicators. Structured interviews with nine administrators selected via purposive sampling from nine private universities in Hainan Province explored leadership practices, digital governance, and transformation strategies; data were analyzed through content analysis to refine the indicator pool.

### 2. Quantitative phase.

The target population comprised 155 administrators from nine private universities. A sample of 108 was determined by Yamane's formula and drawn through proportional allocation and simple random sampling. The instrument was a 48-item 5-point Likert questionnaire; content validity was verified via IOC by experts and reliability confirmed through Cronbach's alpha. Analyses included descriptive statistics, EFA (principal axis factoring, varimax rotation), second-order CFA, and composite reliability estimation.

### 3. Expert validation.

A focus group of ten experts in educational administration and digital transformation reviewed the conceptual framework, factor structure, and applicability

of the model; their comments were used to refine it for conceptual clarity, structural coherence, and practical relevance.

## Results

**1. Objective 1; Indicator Identification.** Of 155 administrators across nine private universities, 108 valid questionnaires were collected (69.68%). Respondents were diverse in gender, age, education, and experience (Table 1), providing a reliable basis for factor analysis. Forty-eight preliminary indicators derived from documentary review and interviews were subsequently refined through EFA item purification.

| Personal status           | Number of people | Percentage    |
|---------------------------|------------------|---------------|
| <b>1. Gender</b>          |                  |               |
| Male                      | 69               | 63.89         |
| Female                    | 39               | 36.11         |
| <b>Total</b>              | <b>108</b>       | <b>100.00</b> |
| <b>2. Age</b>             |                  |               |
| Under 40 years old        | 26               | 24.07         |
| 41–50 years old           | 67               | 62.04         |
| 51 years old and above    | 15               | 13.89         |
| <b>Total</b>              | <b>108</b>       | <b>100.00</b> |
| <b>3. Work Experience</b> |                  |               |
| 6–10 years                | 26               | 24.07         |
| 11–15 years               | 16               | 14.81         |
| 16–20 years               | 51               | 47.22         |
| More than 21 years        | 15               | 13.90         |
| <b>Total</b>              | <b>108</b>       | <b>100.00</b> |
| <b>4. Education Level</b> |                  |               |
| Bachelor's degree         | 36               | 33.33         |
| Master's degree           | 60               | 55.56         |
| Doctoral degree           | 12               | 11.11         |
| <b>Total</b>              | <b>108</b>       | <b>100.00</b> |

Table 1 Sample Characteristics

**2. Objective 2; Factor Analysis and Synthesis.** EFA prerequisites were satisfied (KMO=0.800; Bartlett's  $\chi^2(1128)=3200.937$ ,  $p < .001$ ; Table 2). Items X2–X6, X21, X39, X42, and X44 were removed during item purification; the final 39-item scale

produced a five-factor solution explaining 52.748% of the total variance after rotation (Table 3). The scree plot (Figure 1) corroborated the five-factor structure.

| Indicator                               | Value    |
|-----------------------------------------|----------|
| Kaiser–Meyer–Olkin (KMO)                | 0.800    |
| Bartlett’s test of sphericity: $\chi^2$ | 3200.937 |
| df                                      | 1128     |
| p-value                                 | < .001   |

Table 2 KMO and Bartlett’s Test of Sphericity

| Factor | Initial Eigenvalue | % of Variance | Cumulative % | Rotation Sums of Squared Loadings | % of Variance | Cumulative % |
|--------|--------------------|---------------|--------------|-----------------------------------|---------------|--------------|
| 1      | 10.984             | 22.883        | 22.883       | 5.572                             | 11.609        | 11.609       |
| 2      | 5.321              | 11.086        | 33.969       | 5.442                             | 11.338        | 22.947       |
| 3      | 4.758              | 9.912         | 43.882       | 5.346                             | 11.138        | 34.086       |
| 4      | 3.500              | 7.291         | 51.173       | 5.041                             | 10.501        | 44.587       |
| 5      | 2.835              | 5.906         | 57.079       | 3.918                             | 8.162         | 52.748       |

Table 3 Eigenvalues and Variance Explained by the Extracted Factors

Five factors with eigenvalues greater than 1 explained 57.08% of the total variance before rotation and 52.75% after rotation, adequately representing the underlying dimensions of DTL among administrators in private universities.

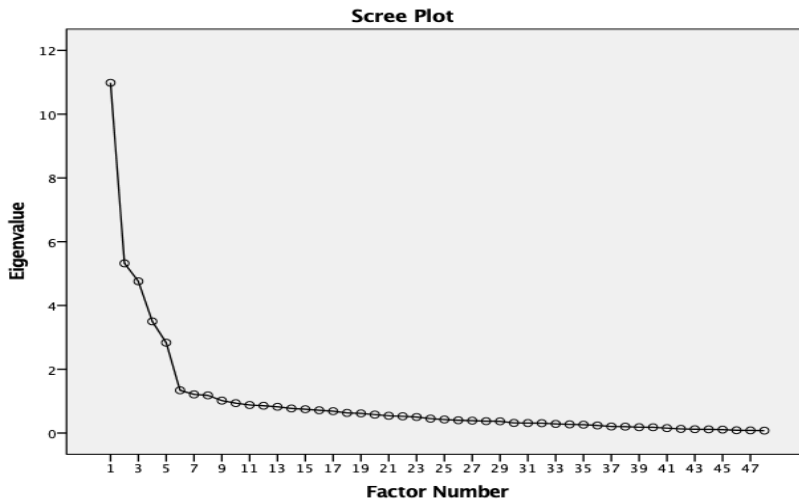


Figure 1 Scree Plot

| Factor        | Number of Items | Loading Range |
|---------------|-----------------|---------------|
| Factor 1 (F1) | 9               | 0.700 – 0.795 |
| Factor 2 (F2) | 9               | 0.656 – 0.791 |
| Factor 3 (F3) | 10              | 0.612 – 0.761 |
| Factor 4 (F4) | 10              | 0.551 – 0.737 |
| Factor 5 (F5) | 7               | 0.630 – 0.766 |

*Extraction Method: Principal Axis Factoring. Rotation Method: Varimax with Kaiser Normalization.*

Table 4 Summary of Factor Loadings

All retained items loaded above 0.50 (range 0.551–0.795), confirming strong association with their latent factors. Based on indicator content, the dimensions were labelled: F1 Digital Use & Data Governance; F2 Digital Competence & Change Leadership; F3 Internal Digital Environment & Support; F4 Digital Vision & Strategy; F5 External Collaboration & Digital Governance Network.

**3. Objective 3 — Model Development.** Based on the EFA and qualitative findings, a DTL model was developed conceptualizing the construct as a multidimensional higher-order structure composed of five interrelated first-order dimensions (Figure 2).

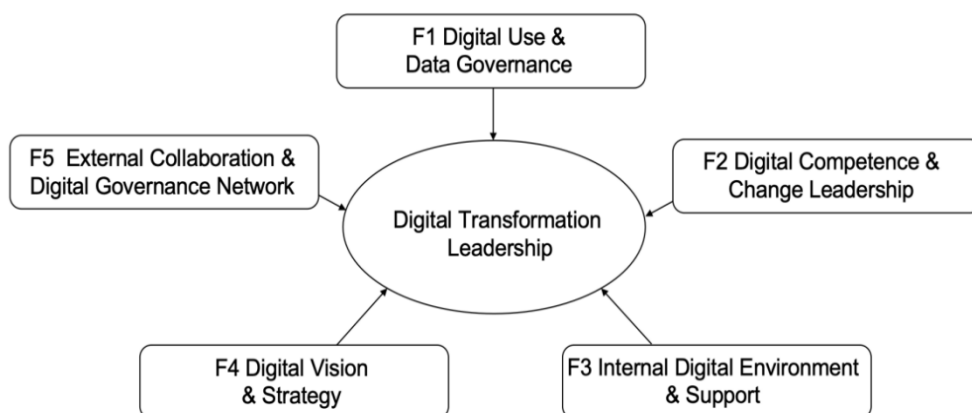


Figure 2 Conceptual Structure of Digital Transformation Leadership

**4. Objective 4 — Empirical Verification of the Model.** Second-order CFA produced fit indices that met recommended thresholds, confirming the measurement model's validity for representing DTL (Figure 3).

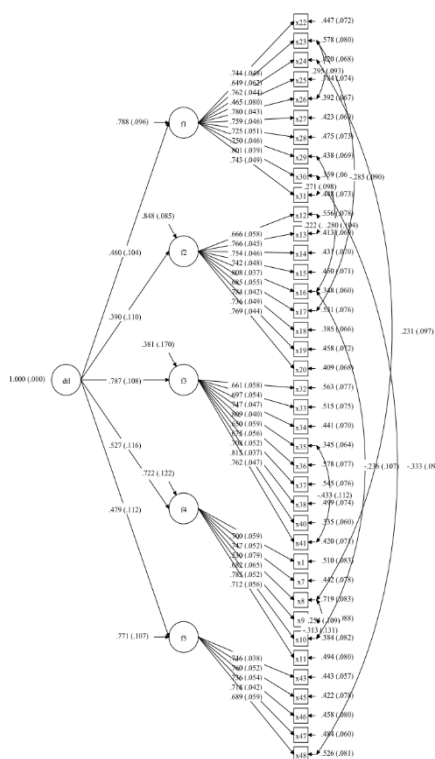


Figure 3 Second-Order CFA Model of Digital Transformation Leadership

Standardized path coefficients from the higher-order construct ranged from 0.390 to 0.787, all significant ( $p < .001$ ): Internal Digital Environment & Support ( $\beta=0.787$ ), Digital Vision & Strategy ( $\beta=0.527$ ), External Collaboration & Digital Governance Network ( $\beta=0.479$ ), Digital Use & Data Governance ( $\beta=0.460$ ), and Digital Competence & Change Leadership ( $\beta=0.390$ ).

| Second-Order Factor                     | First-Order Factor | Standardised Loading ( $\beta$ ) | S.E.  | Est./S.E. | p-value |
|-----------------------------------------|--------------------|----------------------------------|-------|-----------|---------|
| DTL (Digital Transformation Leadership) | F1                 | 0.460                            | 0.104 | 4.426     | < .001  |
|                                         | F2                 | 0.390                            | 0.110 | 3.563     | < .001  |
|                                         | F3                 | 0.787                            | 0.108 | 7.293     | < .001  |
|                                         | F4                 | 0.527                            | 0.116 | 4.562     | < .001  |
|                                         | F5                 | 0.479                            | 0.112 | 4.267     | < .001  |

Table 5 Standardised Factor Loadings of the Second-Order CFA Model

| Construct | Number of Items | Composite Reliability (CR) | Interpretation         |
|-----------|-----------------|----------------------------|------------------------|
| F1        | 10              | 0.911                      | Excellent reliability  |
| F2        | 9               | 0.919                      | Excellent reliability  |
| F3        | 9               | 0.913                      | Excellent reliability  |
| F4        | 6               | 0.872                      | Good reliability       |
| F5        | 5               | 0.849                      | Good reliability       |
| DTL       | 5               | 0.666                      | Acceptable reliability |

Table 6 Reliability Coefficients of the Digital Transformation Leadership Model

Composite reliabilities of first-order factors ranged 0.849–0.919 (good to excellent); the second-order DTL construct's CR was 0.666, acceptable for exploratory higher-order models (Hair, et al., 2019). The measurement model therefore demonstrates satisfactory reliability and construct validity.

## Discussion

### 1. Sample diversity and the emergence of a five-factor structure.

The sample's diversity in gender, age, education, and experience 62% aged 41–50 and 55.6% holding a master's degree supports external validity and echoes Yukl (2013) and Bush (2011) on the role of background and experience in shaping leadership. EFA produced a coherent five-factor structure explaining 52.75% of variance after rotation. The reason such a structure emerged, rather than a single general factor, is that digital transformation in higher education is simultaneously technological, organizational, strategic and relational: administrators must adopt technology, develop personal competence, cultivate an enabling environment, articulate a vision, and engage external partners. This coheres with Kane, et al. (2015) and Westerman, et al. (2014). Two caveats apply: the sample is bounded to private universities in a single province, and the 52.75% explained variance, while adequate, leaves indicator-level residual variance open to future refinement.

**2. The structural model and its empirical fit.** Second-order CFA confirmed DTL as a higher-order construct composed of five interrelated dimensions, with all loadings significant and first-order CRs of 0.849–0.919. A higher-order specification is appropriate because digital transformation requires coordinated management of technology, strategy, internal support, and external collaboration an integrative quality that a set of independent factors would not capture (Bass & Riggio, 2006; Northouse, 2018). That the second-order CR is 0.666 acceptable rather than excellent is itself informative: the five dimensions are meaningfully but not redundantly related, indicating distinct capabilities rather than proxies for one latent trait.

**3. Why Internal Digital Environment & Support (F3) contributes most strongly.** F3's loading ( $\beta=0.787$ ) was substantially higher than the others and reflects the specific conditions of Hainan private universities. First, contextual constraint: administrators repeatedly described fragmented platforms, limited data integration, and constrained investment (Cai & Hu, 2024; Xie & Wang, 2023), making the internal environment infrastructure, information systems, data governance, technical support, and a digital-use culture the binding constraint on all other leadership actions. A compelling vision (F4) or strong collaboration network (F5) cannot produce results if the internal environment cannot absorb them. Second, institutional-support logic: private universities lack the subsidies and slack of public institutions, so supportive environments are decisive for enabling digital behavior. Third, cognitive salience:

administrators experience internal support as the everyday medium of digital change and weight it accordingly when judging leadership effectiveness. This converges with Westerman, et al. (2014) on organizational alignment and with Zhu, et al. (2024) on institutional support as the strongest predictor of digital-transformation outcomes in Chinese universities.

**4. Why Digital Competence & Change Leadership (F2) is lowest, and critical evaluation.** F2 ( $\beta=0.390$ ) remained significant but contributed least, for three reasons. First, a developmental lag: administrators in Chinese private universities still rely on traditional approaches and lack systematic training in digital competence and change-leadership techniques (Jiang, et al., 2023; Xie & Wang, 2023), which compresses variation across respondents and attenuates covariance with the higher-order construct. Second, a substitution effect with F3: where internal support is strong, outcomes usually attributed to individual competence are produced by the system rather than the leader. Third, measurement: behavioral change leadership items are susceptible to social desirability, further attenuating discrimination. The low loading does not mean digital competence is unimportant; it signals that it is underdeveloped and under-leveraged, making it a high-return target for leadership development (Akbari & Pratomo, 2022). Four limitations of the model should be acknowledged: (i) it is correlational and does not establish causal pathways; (ii) its empirical basis is geographically bounded to private universities in Hainan Province; (iii) the second-order CR (0.666) suggests alternative bi-factor or correlated-factors specifications could be compared in future work; and (iv) data are cross-sectional and self-reported, so triangulation with organizational outcome data is warranted. Despite these limitations, the convergence of EFA, CFA, reliability analysis, and expert validation provides a defensible basis for treating the five dimensional structure as a credible, context-appropriate account of DTL.

## New Knowledge

This study's original contribution extends along three distinct axes rather than restating prior work. (1) A context-specific construct: existing digital-leadership frameworks derive from corporate organizations (Kane, et al., 2015; Westerman, et al., 2014) or Western public universities; this study is the first to develop and empirically verify a DTL model calibrated to private universities in Hainan Province institutions characterized by fragmented digital platforms, constrained investment,

and administrator-led initiative. (2) An integrated five-dimensional structure: prior research has examined digital vision, competence, data governance, institutional support, and external collaboration as separate or loosely coupled themes; the present study integrates them into a single second-order structure in which all five dimensions are empirically distinguishable yet meaningfully related, showing administrators perceive DTL as a multidimensional capability rather than a single trait. (3) A diagnostic insight about the binding constraint: Internal Digital Environment & Support is the dimension most strongly linked to DTL, while Digital Competence & Change Leadership contributes least reframing digital transformation in resource-constrained private universities around building institutional scaffolding (infrastructure, data governance, support systems) rather than exhorting individual administrators.

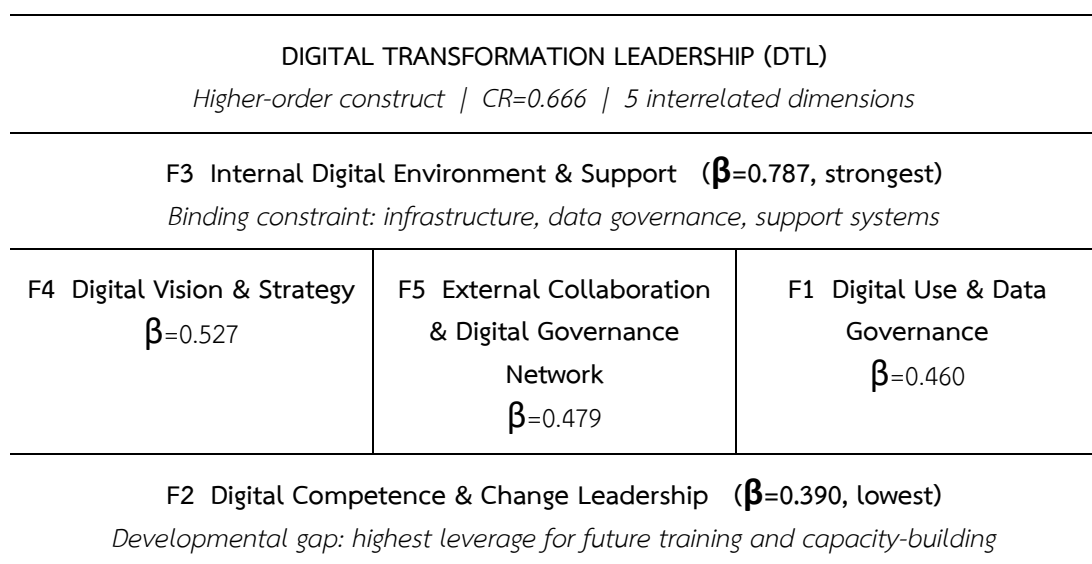


Figure 4 Contribution Structure of the Digital Transformation Leadership Model

Figure 4 summarises the contribution: the novel claim is not merely a five-dimensional structure, but that in private universities in Hainan Province the internal digital environment is the binding constraint on DTL, while individual digital competence is its most under developed component extending existing theory with a context-specific, empirically anchored model and providing a concrete agenda for leadership development and institutional investment.

## Conclusion and Suggestion

This study developed and empirically verified a structural DTL model for administrators in private universities in Hainan Province, conceptualizing DTL as a higher-order construct composed of five interrelated dimensions: Digital Use & Data Governance, Digital Competence & Change Leadership, Internal Digital Environment & Support, Digital Vision & Strategy, and External Collaboration & Digital Governance Network. EFA, CFA, and expert validation jointly support the model's validity, reliability, and applicability.

### 1. Policy Recommendations.

1.1 The Ministry of Education and relevant agencies should formulate clear digital transformation policies for private higher-education institutions and provide strategic guidance and targeted funding for digital-leadership development, with particular attention to the internal digital environment the strongest contributor in this study.

1.2 Agencies overseeing higher education should promote systematic digital capacity-building and professional training for leaders, since digital competence and change leadership is the least developed dimension and thus has the highest marginal return on investment.

1.3 Educational authorities should encourage structured collaboration between private universities, technology organizations, and industry partners to strengthen external digital governance networks.

### 2. Future Research.

2.1 Replicate the model in other Chinese provinces and in public universities to test generalizability.

2.2 Employ longitudinal or intervention designs to examine causal relationships between the internal digital environment and institutional digital-transformation outcomes.

2.3 Triangulate administrator self-reports with organizational performance data to strengthen external validity.

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