International Journal of Industrial and Manufacturing Systems Engineering
2026, Vol. 11, No. 1, pp. 16–23
https://doi.org/10.11648/j.ijimse.20261101.12

Research Article

Determinants of Industry 4.0 in Polytechnic College in Addis Ababa

Ahmed Gashaw Yimam[1, *], Biadgelign Ademe[2]

[1]TVET Leadership and Management, Federal Democratic Republic of Ethiopia Technical and Vocational Training Institute (FTVTI), Addis Ababa, Ethiopia

[2]Curriculum Design and Development, Federal Democratic Republic of Ethiopia Technical and Vocational Training Institute (FTVTI), Addis Ababa, Ethiopia

Abstract

This research explores the main drivers of Industry 4.0 (I4.0) adoption inside government-owned polytechnic institutions in Addis Ababa, Ethiopia, focusing on the interplay between technology infrastructure, human capital, and governance. This study's main goal is to examine how these institutional factors affect colleges' capacity to match their vocational training output to the changing digital needs of the regional manufacturing industry. Even with governmental initiatives like "Digital Ethiopia 2030," there is still a big disconnect between industry demands and institutional preparedness, leading to a "vocational paradox" that impedes economic growth. The study uses the Dynamic Capabilities Theory (DCT) as a theoretical framework to address this, quantitative survey data from 184 practitioners. In order to ascertain how organizations manage swift technological disruption, the technique places a strong emphasis on an objective examination of organizational capacities, particularly sensing, seizing, and changing. The results show that although Industry 4.0 is well known, institutions are severely limited by a "technological maturity gap," which is typified by acute shortages of specialized hardware, such as IoT and 3D printing equipment. Institutional factors account for 54.3% of the variation in curriculum-industry alignment, according to regression analysis. In particular, Governance Frameworks was shown to be the main systemic lever (β =.438), followed by Digital Leadership (β =.192) and Technological Infrastructure (β =.268). As a result, the study comes to the conclusion that a structural change toward decentralized governance and updated infrastructure is necessary for a successful digital transformation; leadership vision alone is not enough. Adopting scalable "virtual surrogates" to get around physical hardware constraints and directing faculty growth toward required annual industry attachments and specialized 4IR certifications are among the recommendations. In order to evaluate the efficacy of policies and investigate the impact of foreign direct investment on polytechnic institutions' sensing capacities, future studies should follow these factors longitudinally.

Keywords

Industry 4.0, Dynamic Capabilities Theory, TVET, Digital Leadership, Digital Readiness, Institutional Agility

*Correspondence: Ahmed Gashaw Yimam (ahmedgashaw2001@gmail.com)

Received: 16 June 2026; **Accepted:** 1 July 2026; **Published:** 22 July 2026

Copyright: © The Author(s), 2026. Published by Science Publishing Group. This is an **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

1. Introduction

The needs for workforce preparation in Technical and Vocational Education and Training (TVET) systems have fundamentally changed as a result of the Fourth Industrial Revolution (Industry 4.0) [18]. The global labor market is changing at a rate never seen before due to the integration of cyber-physical systems, artificial intelligence (AI), and da-ta-driven management [16, 25]. In order to achieve economic progress, rising economies such as Ethiopia must match their vocational training with these global technical norms [1, 24]. In particular, the "Digital Ethiopia 2030" plan places a strong emphasis on creating a workforce that is fluent in technology; yet, Addis Ababa's polytechnic institutions today confront a chronic government-technical divide that jeopardizes this national goal [3, 4, 20]. Institutions must move toward a "Gold Standard" of management, characterized by AI-integrated pedagogy and a dedication to lifelong learning, in order to stay competitive [12]. In this perspective, digitalization is a socio-economic need for achieving Sustainable Development Goal (SDG) 8, which relates to decent work and economic growth, rather than only a technological improvement [24].

Even though there is a clear need for contemporary technological skills, Addis Abeba's polytechnic colleges face a "vocational paradox," where recent systemic overhauls have led to enrollment plummeting by 50% [27]. Institutions are frequently limited by antiquated infrastructure and legacy management approaches, even while national policy encourages digital transformation [2, 3, 8]. According to recent research, the main obstacles to institutional adaptability are staff "technophobia" and a lack of committed professional development [13, 17]. Additionally, there is a structural mismatch between the particular needs of the regional manufacturing industry and vocational programs [15, 19]. Colleges are still unable to take use of the potential presented by 4IR if these obstacles are not addressed, especially the requirement for resilient governance and strong digital leadership [5, 16, 28].

This study, which is based on the Dynamic Capabilities Theory (DCT), investigates the factors that influence Industry 4.0 adoption in order to overcome these institutional shortcomings [22]. Because it looks at the organizational practices sensing, seizing, and transforming by which organizations create new resource configurations to be competitive, DCT offers a suitable framework [11, 22]. Using this paradigm, this study investigates how institutional capacity affects schools' capability to align their training programs with industry demands [12, 28].

This study's main goal is to investigate the institutional elements that determine Industry 4.0 preparedness at Addis Ababa's government-owned polytechnic colleges and assess how these factors affect the alignment of vocational output with industry demand. In particular, the following research questions are the focus of this study:

1) What is the current state of digital readiness in Addis Ababa’s polytechnic colleges regarding technological infrastructure and staff competency [4]?
2) To what extent does Digital Leadership influence the adoption of 4IR technologies within these institutions [10, 16]?
3) To what extent do Digital Leadership, Technological Infrastructure, and Governance frameworks collectively predict the alignment of TVET curricula with industrial demand?

The focus of this study is Addis Ababa's government-funded polytechnic institutions, which were chosen because of the area's large concentration of developing industrial parks. The study offers policymakers a useful road map to close the technical maturity gap and guarantee that vocational output satisfies modern industry standards by concentrating on internal institutional deterrents rather than more general macroeconomic variables [4].

2. Materials and Methods

This section offers thorough information on the methodological framework, guaranteeing the study's reproducibility and strong analytical basis.

2.1. Research Paradigm

The paradigm used in this work is post-positivist [6]. This method is predicated on the idea that empirical observation may be used to objectively evaluate and quantify the institutional factors influencing Industry 4.0 adoption. This paradigm makes it easier to examine theoretical links, particularly those derived from the Dynamic Capabilities Theory (DCT), using organized numerical analysis by concentrating on observable events and statistical data.

2.2. Research Approach and Design

A cross-sectional design serves as the foundation for the study's quantitative research methodology. To determine and quantify the determinants of digital transformation and curriculum-industry alignment, quantitative data is gathered using structured instruments. In order to model institutional determinants using inferential statistics, a cross-sectional design is used to give a statistically representative picture of polytechnic colleges at a specific moment in time.

2.3. Research Setting

The government-owned polytechnic colleges in Addis Ababa, which act as the main institutional pipeline for the city's industrial workforce, are included in the research setting. In order to match vocational output with the "Digital Ethiopia 2030" goal, these institutions are now subject to national

Technical and Vocational Education and Training (TVET) reforms. The chosen universities offer a cross-sectional perspective on institutional capacity and "technological maturity" throughout the industry by representing three crucial industrial clusters: ICT, automotive, and manufacturing.

2.4. Population and Sampling

Target Population: The population consists of N=340 employees from Addis Ababa's government-owned polytechnic colleges, including teachers, department heads, and college deans [7, 21].

Sample Size: 184 people were included in the sample. Yamane's Formula was used to determine this [26]:

$n = \frac{N}{1+Ne^2}$ where N is the population size and e is the margin of error (0.05), ensuring the results are statistically representative at a 95% confidence level [21].

Sampling Technique: Stratified random sampling is used in this investigation. To guarantee that each professional echelon was fairly represented, the population was split into three separate strata: instructors, department heads, and deans. Simple random sampling was used to choose individuals within each stratum in order to reduce selection bias and improve the findings' generalizability.

2.5. Data Collection Instruments

Data were collected using two primary instruments:

1. Structured Questionnaire: A 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree) designed to measure four latent variables: Institutional Leadership, Technological Infrastructure, Human Capital, and Governance.

2.6. Validity and Reliability

Validity: Content validity was established through expert review by academic supervisors to ensure the survey items directly mapped to the research objectives and the theoretical framework of DCT.

Reliability: The internal consistency of the survey scales was verified using Cronbach's Alpha (alpha). For the qualitative component, data triangulation comparing survey results with interview findings was utilized to ensure the consistency and dependability of the results.

2.7. Data Analysis Methods

Quantitative Analysis: All statistical calculations were performed using SPSS (v28) [9]. While readiness levels were summarized using descriptive statistics (mean, frequency, and standard deviation), the predictive efficacy of digital leadership and infrastructure on institutional I4.0 adoption was examined using inferential statistics, particularly Multiple Linear Regression.

3. Results

3.1. Participant Profile and Demographic Distribution

Table 1. *Demographic characteristics of respondents (N=184).*

Variable	Category	Frequency	Percent (%)
Sex	Female	68	37.0
	Male	116	63.0
Age	20-30	58	31.5
	31-40	114	62.0
	41-50	8	4.3
	Above 50	4	2.2

Total N=184; 100%.

Table 1 provides an overview of the research participants' demographics. The workforce is mostly in the mid-career stage, as shown by the concentration of respondents in the 31-40 age range (62.0%), followed by the 20-30 age bracket (31.5%), with a total sample size of N=184. The gender breakdown in Table 1 shows that there were more male respondents (63.0%) than female respondents (37.0%). All things considered, the profile shown in Table 1 indicates that the study represents the viewpoints of a seasoned professional cohort that is in a good position to assess the challenges of curricular alignment and digital transformation inside their organizations.

3.2. Participant Academic Qualification and CoC Status

Table 2. *Academic qualifications and CoC status of respondents.*

Educational Background	Competent (n=158)	Not Yet Competent (n=26)	Total (N=184)
MSc/MA Degree	48 (30.4%)	4 (15.4%)	52 (28.3%)
BSc/BA Degree	94 (59.5%)	18 (69.2%)	112 (60.9%)

Educational Background	Competent (n=158)	Not Yet Competent (n=26)	Total (N=184)
Diploma/Level IV/V	16 (10.1%)	4 (15.4%)	20 (10.9%)

CoC: Certificate of Competency.

Table 2 indicates that 85.9% of participants are classified as "Competent." There is a "certification gap" where 69.2% of the "Not Yet Competent" category has a BSc/BA, despite the fact that 89.2% have an undergraduate degree or above. This suggests a discrepancy between academic theory and practical certification.

3.3. Analysis for RQ1: Current State of Digital Readiness

Table 3. *Descriptive statistics for digital readiness indicators (N=184).*

Digital Readiness Item	N	Mean	Std. Deviation	Skewness
12. Dependable high-speed internet availability	184	2.74	1.22	0.15
13. Access to 4IR hardware (IoT, VR/AR, 3D printers)	184	2.80	1.20	-0.07
14. Technical know-how to instruct 4IR concepts	184	2.80	0.98	0.05
15. Regular organizational training on 4IR tech	184	2.66	1.18	0.28

Note: All items measured on a 5-point Likert scale.

Digital preparedness is often shown to have a "technological maturity gap." The data demonstrates that present institutional capability is inadequate for 4IR integration, with mean scores falling below the neutral threshold of 3.0. The biggest obstacle is professional development (M = 2.66), which supports [4] conclusions on the systemic character of these resource limitations.

3.4. Analysis for RQ2: Influence of Digital Leadership

Table 4. *Descriptive statistics for leadership and adoption scores (N=184).*

Variable	Mean	Std. Deviation	N
Leadership Score	2.97	0.96	184
Adoption Score	2.58	0.95	184

The mean score for Digital Leadership (M = 2.97, SD = 0.96) is higher than the mean score for Industry 4.0 technology adoption (M = 2.58, SD = 0.95), according to the data in Table 4. The standard deviations for both variables are comparatively close, as the table illustrates, suggesting that respondents' opinions on technological integration and leadership quality are consistently divided. These results point to a significant gap between the perception of leadership and the use of technology; in particular, the lower mean score for the Adoption Score shows that, although digital leadership is seen at a moderate level, Industry 4.0 technology adoption and practical application within these institutions are still at a lower, foundational stage. In the end, this alignment gap offers a solid mathematical foundation for the claim that, despite its existence, institutional leadership has not yet successfully sparked a high rate of technology adoption.

Table 5. *Correlation between digital leadership and Industry 4.0 adoption.*

Variable	Leadership Score	Adoption Score
Leadership Score	1	.488**
Adoption Score	.488**	1

*Note: *Correlation is significant at the 0.01 level (2-tailed).

Table 5's correlation analysis shows a moderate-to-strong positive link that is statistically significant (r =.488, p <.01). This supports the "sensing" and "seizing" dynamic skills proposed by Teece (2007) and offers empirical evidence that leadership behaviors vision, strategic prioritization, and resource

advocacy are the main forces behind institutional 4IR adoption.

3.5. Analysis for RQ3: Determinants of Curriculum-Industry Alignment

Table 6. Pearson correlation matrix of institutional determinants and alignment.

Variable	Alignment_Score	Leadership	Infrastructure	Governance
Alignment_Score	1.000	.561**	.574**	.641**

*Note: *Correlation is significant at the 0.01 level (1-tailed).

The Pearson correlation matrix, which looks at the link between the degree of Curriculum-Industry Alignment and institutional variables including Leadership, Infrastructure, and Governance, is shown in Table 6. All three factors continue to have a positive and statistically significant link with alignment (all $p < 0.01$), according to the analysis in Table 6. In particular, Table 6 shows that Governance has the highest positive association ($r = .641$) with the Alignment Score [11], followed by Infrastructure ($r = .574$) and Leadership ($r = .561$). These findings, which are summed up in Table 6, show that although all three institutional elements are important, governance structures have the greatest impact on guaranteeing that vocational curriculum continue to be successfully in line with industry demands. As a result, the correlation matrix demonstrates that improving institutional governance is a crucial precondition for closing the gap between business and academia at polytechnic institutions.

Table 7. Model summary and ANOVA for institutional determinants.

Model	R Square	Adjusted R Square	F-value	Sig.
1	.543	.535	71.149	.000

The model summary and ANOVA findings for the influence of institutional factors on Curriculum-Industry Alignment are shown in Table 7. The institutional determinants Leadership, Infrastructure, and Governance collectively explain 54.3% of the variance in the Alignment Score, according to the model's R-square value of .543. The model's stability is confirmed by the corrected R-square of .535, indicating that these variables are reliable indicators of curriculum-industry integration. Additionally, as shown in Table 7, the F-value of 71.149 ($p < .001$) is statistically significant, indicating that the identified institutional determinants significantly affect the degree of alignment and that the regression model is a very reliable match for the data.

Table 8. Coefficients of institutional determinants on curriculum alignment.

Variable	Unstandardized B	Std. Error	B (β)	t-value	Sig.
(Constant)	.212	.173	-	1.227	.222
Leadership_Score	.183	.064	.192	2.870	.005
Infrastructure_Score	.223	.055	.268	4.071	.000
Governance_Score	.425	.056	.438	7.558	.000

Note: Dependent Variable: Alignment_Score.

The regression analysis determines the precise contributions of each institutional factor on curricular alignment, as seen in Table 8. According to the findings, governance has the most beneficial impact on the dependent variable and is the most significant predictor of alignment ($\beta = .438$, $p < .001$).

While Digital Leadership continues to have a statistically significant, albeit lesser, influence (β =.192, p =.005), Infrastructure also shows up as a major determinant (β =.268, p <.001). Collectively, these institutional variables explain for 54.3% of the variance in curriculum alignment, as revealed by the regression model. These results highlight the importance of digital leadership and infrastructure, but the main way polytechnic institutions can guarantee successful alignment with business demands is by establishing strong governance structures.

4. Discussion

The results show that a "technological maturity gap" limits institutional preparedness for Industry 4.0. Institutional factors account for 54.3% of the variance in curriculum-industry alignment, according to the Multiple Linear Regression study (R^2 =.543, p <.001).

The main predictor was found to be governance frameworks (β =.438, p <.001), indicating that policy flexibility is a more important factor in alignment than leadership alone. This is consistent with [28] assertion that institutional responsiveness depends on decentralized governance. Although 4IR adoption [16] is significantly accelerated by digital leadership (r =.488, p <.01), the data indicates that leadership vision faces systemic constraints in the absence of the "seizing" capacity offered by strong infrastructure and flexible governance [23]. These findings support the Dynamic Capabilities Theory (DCT) in the Ethiopian TVET setting, where inflexible regulatory frameworks and legacy infrastructure impede the shift from "sensing" to "transforming" [14].

5. Conclusions

The implementation of Industry 4.0 in Addis Ababa's polytechnic institutions is really a structural rather than a simply technological barrier, according to the study's findings. Empirical research shows that Governance Frameworks serve as the primary systemic lever for curriculum-industry convergence, while Digital Leadership serves as the catalyst for innovation.

According to the report, there is a severe technical maturity gap that is marked by inadequate hardware and little professional advancement. Decentralized governance and the use of "virtual surrogates" for training to avoid large capital costs should be given top priority by policymakers in order to address this. To further isolate the influence of government on institutional agility, future research should do comparison analysis between private and government-owned institutions and conduct longitudinal studies to monitor the implementation of the "Digital Ethiopia 2030" agenda.

Abbreviations

4IR	Fourth Industrial Revolution
AI	Artificial Intelligence
CoC	Certificate of Competency
DCT	Dynamic Capabilities Theory
BoLS	Bureau of Labor and Skills
IoT	Internet of Things
SDG	Sustainable Development Goal
TVET	Technical and Vocational Education and Training

Acknowledgments

The Addis Ababa Tegbareid Polytechnic Colleges management and faculty are acknowledged by the authors for their cooperation throughout the data gathering procedure. We also thank the Addis Ababa City Administration BoLS for their technological support in making institutional records more accessible.

Author Contributions

Ahmed Gashaw Yimam: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing

Biadgelign Ademe: Supervision, Validation, Writing – review & editing

Data Availability Statement

The data supporting the outcome of this research work has been reported in this manuscript.

Conflicts of Interest

The author declares no financial, personal, or professional conflicts of interest that could have influenced the research findings or data interpretation.

References

[1] African Center for Economic Transformation (ACET). (2026). *Building TVET systems for economic transformation in Ethiopia*. https://acetforafrica.org/research-and-analysis/reports-studies/multi-country-studies/building-tvet-systems-for-economic-transformation-in-ethiopia/

[2] Association for the Development of Education in Africa (ADEA). (2020). *Labor market information systems and vocational training synchronization*.

[3] Bekele, A. (2025a). Awareness and readiness towards Industry 4.0: Ethiopian higher technical and vocational education and training instructors. *International Journal of Vocational Education and Training Research, 11*(1), 45-62. https://www.researchgate.net/publication/405157900

[4] Bekele, A. (2025b). Digital readiness and the technological maturity gap in Ethiopian TVET institutions. *Journal of Vocational Education and Training in Africa, 12*(1), 45-62.

[5] Brown, R. (2025). Resilient leadership in the age of technological disruption. Academic Press.

[6] Bryman, A. (2016). *Social research methods*. Oxford University Press.

[7] Creswell, J. W., & Plano Clark, V. L. (2018). *Designing and conducting mixed methods research*. Sage Publications.

[8] Federal TVET Institute (FTVTI). (2020). *National TVET strategy and policy framework*. Ministry of Science and Higher Education. https://mahe.kstvet.ac.ke/sites/default/files/2022-01/Ethiopia%20National%20TVET%20Strategy%202020.pdf

[9] Field, A. (2018). Discovering statistics using IBM SPSS statistics. Sage Publications.

[10] Gaikwad, S., Deshmukh, R., & Kulkarni, S. (2026). Implementation of Industry 4.0 technologies in technical and vocational education in Maharashtra. *Asian Journal of Computer and Technology, 8*(1), 12-28. https://www.asianssr.org/index.php/ajct/article/download/1445/1053

[11] Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2019). *Multivariate data analysis* (8th ed.). Cengage Learning.

[12] Harrison, L. (2026). The new gold standard: Virtual surrogates in polytechnic management. *International Journal of Educational Technology, 19*(2), 112-128.

[13] Ibrahim, S. (2024). Human capital and the shift to data-driven pedagogy in vocational training. *African Journal of Technical Education, 8*(3), 201-215.

[14] Molla, T. (2024). Internal institutional determinants of digital transformation in TVET. *Ethiopian Journal of Educational Research, 15*(2), 89-104.

[15] Motsepe, H., Sethu, M. J., Sikhosana, S., & Dladlama, B. (2026). Aligning technical and vocational education and training curricula with labour market demands: An assessment of contemporary relevance. *International Journal of Applied Research in Business and Management, 7*(2), 88-105.

[16] Mubarak, A., & Petraite, M. (2025). Digital leadership for Industry 4.0: Agility and innovation. *Journal of Digital Management, 12*(3), 201-218.

[17] Novak, J. (2025). The speed of industrial software evolution and its impact on TVET staff development. *Global Journal of Engineering Education, 22*(1), 34-48.

[18] OECD. (2022). The future of vocational education and training. OECD Publishing.

[19] Roberts, K. (2025a). Agile curriculum development: Bridging the industry-academia gap. Springer Publishing.

[20] Roberts, L. (2025b). *TVET implementation plan (2025-2030): Strategic alignment for a skilled workforce*. Ministry of Technical Education. https://objectstorage.ap-dcc-gazipur-1.oraclecloud15.com/n/axvjbnqprylg/b/V2Ministry/o/office-techedu/2024/12/f2c1e9e0a0114d4d95c7f45766019a37.pdf

[21] Saunders, M., Lewis, P., & Thornhill, A. (2019). *Research methods for business students*. Pearson.

[22] Teece, D. J. (2007). Explicating dynamic capabilities: The nature and microfoundations of (sustainable) enterprise performance. *Strategic Management Journal, 28*(13), 1319-1350.

[23] Thompson, P. (2025). Infrastructure shortages and digital connectivity in developing economies. *International Journal of Digital Development, 14*(2), 22-39.

[24] UNDP. (2025). Sustainable development goal 8: Progress and challenges in technical education. United Nations Development Programme.

[25] World Bank. (2025). Global trends in technical and vocational education and training. World Bank Publications.

[26] Yamane, T. (1967). *Statistics: An introductory analysis*. Harper and Row.

[27] Zekarias, E. (2026, February 22). Ethiopia's TVET enrollment plummets by 50% amid systemic overhaul. *Capital Newspaper*. https://capitalethiopia.com/2026/02/22/ethiopias-tvet-enrollment-plummets-by-50-amid-systemic-overhaul/

[28] Zidana, M. (2025). Decentralized governance models for agile TVET institutions. *Journal of Educational Policy and Management, 9*(3), 150-167.

Biography

Ahmed Gashaw Yimam is a PhD candidate at the Federal Technical and Vocational Training Institute and an instructor at Kelela Polytechnic College. Adama Science and Technology University awarded him a BSc in Software Engineering in 2013, while Federal Technical and Vocational Training Institute awarded him an MSc in Information Technology in 2022. His research focuses on the modernization of vocational education in emerging countries, digital transformation, and Dynamic Capabilities Theory. Ahmed looks at how industry connections, institutional flexibility, and governance might close the technical maturity gap. His goal is to strengthen polytechnic colleges as centres of technical innovation and skilled labour development. He is dedicated to evidence-based policy change.

Research Field

Ahmed Gashaw Yimam: Artificial Intelligence Development in Education, Agile Leadership in Vocational Institutions, Value Chain Training and Development, Technical and Vocational Education and Training Transformation, Digital Leadership in Educational Institutions, Small and Medium Enterprises Development, and Machine Learning Applications in Training

Biadgelign Ademe: Pedagogical Innovation, Strategic Educational

Leadership, Vocational Training Systems, Quality Assurance in Education, Institutional Governance, Green TVET, and Green Skills