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A Reference Enterprise Architecture for TVET Digitalization: Readiness Assessment for Developing Countries

Dr. Abhijit Gupta [1], Dr. Shreedhar Marasini [2]

Young Minds Creation, Research and Development Department,
[1]abhi@youngminds.com.np, [2]shree@youngminds.com.np

***Abstract*— Technical and Vocational Education and Training (TVET) institutions in developing countries are under increasing pressure to use digital technologies for teaching, administration, assessment, student services, and industry linkage. However, purchasing computers, installing software, or providing internet access does not by itself create digital transformation. Transformation requires changes in business processes, organizational capability, data management, applications, technology, security, and interoperability. This paper examines whether TVET institutions in developing countries are ready for such transformation and proposes a Reference Enterprise Architecture (REA) to support readiness assessment and digital transformation planning. The proposed architecture contains six connected domains: Business, Data, Application, Technology, Security, and Integration Architecture. The framework builds on enterprise architecture principles, developing-country e-readiness research, ICT-in-education literature, and evidence from Nepal. Nepal is used as a contextual case because its government had already established Government Enterprise Architecture (GEA), e-government policies, and digital development strategies. However, its 2018 EGDI of 0.4748 also indicates continuing infrastructure and human-capital constraints. The paper argues that TVET readiness should be assessed as an institutional capability rather than as simple technology availability. The proposed REA provides a practical reference for governments and TVET agencies to identify gaps, prioritize investment, improve interoperability, and establish a phased path toward digital transformation.**

***Keywords*— TVET, digital transformation, enterprise architecture, e-readiness, developing countries, Nepal, ICT governance.**

I. INTRODUCTION

Digital technology is increasingly changing how Technical and Vocational Education and Training (TVET) institutions deliver teaching, manage administration, assess learners, maintain records, and connect graduates with employers. However, digital transformation is broader than the introduction of computers, internet services, or individual software applications. It requires changes in institutional processes, organizational capability, data management, applications, infrastructure, security, and interoperability. The World Bank emphasizes that digital technologies produce sustainable benefits only when supported by appropriate institutions, skills, infrastructure, and governance [1].

Previous e-readiness studies in Nepal similarly show that readiness depends on multiple and interconnected factors. Gupta, Marasini, and Shakya identified software, hardware, networks, ICT policies, security, and human resources as important dimensions of e-government readiness [2]. Marasini and Shakya further highlighted the importance of human resources and infrastructure [3] [4], while Gupta and Shakya emphasized information-system security, auditing, and governance [5] [6] [7]. These findings are relevant to TVET institutions, but they do not provide a sector-specific architecture that connects these capabilities into a single transformation model.

This study therefore examines whether TVET institutions in developing countries are sufficiently prepared for digital transformation and proposes a Reference Enterprise Architecture (REA) to assess and improve that readiness. The architecture covers six dimensions: Business, Data, Application, Technology, Security, and Integration Architecture. Nepal is used as a contextual case because its government had established enterprise architecture and digital-development policies. The study aims to provide a practical framework for assessing institutional readiness, identifying architectural gaps, prioritizing investments, and supporting sustainable TVET digital transformation.

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II. Literature Review

Digital transformation differs from simple digitalization. Digitalization normally involves converting existing information or processes into digital form, while transformation involves changing how an organization operates and creates value. This distinction is important in education because technology can reproduce inefficient processes if organizational structures and business rules remain unchanged.

A. E-Readiness and Institutional Capability

E-readiness research provides a useful starting point. Gupta, Marasini, and Shakya [2] assessed Nepalese ministries through six domains: software and information systems, ICT hardware, network systems, ICT plans and policies, ICT security, and human resources. Their work demonstrates that readiness is multidimensional rather than dependent on one technology.

Marasini and Shakya [3] examined human-resource readiness and emphasized skills, qualifications, training, competency, computer literacy, willingness, and preparedness. Their infrastructure study [4] similarly showed that ICT infrastructure is a fundamental requirement for effective electronic services. These findings are highly relevant to TVET because instructors, administrators, technical staff, and institutional leaders are central to digital adoption.

Gupta and Shakya's information-system audit studies [6], [8] emphasize security, reliability, control, and systematic assessment. Their cloud-security study [7] further highlights the risks associated with data control, privacy, and dependence on external technology providers. These concerns become more important as TVET institutions move from isolated applications toward shared platforms.

B. Enterprise Architecture

EA provides a broader organizational perspective. TOGAF defines Business Architecture in terms of strategy, governance, organization, and processes; Data Architecture in terms of data assets and management; Application Architecture in terms of application blueprints; and Technology Architecture in terms of the technology infrastructure required to support applications [9].

Public-sector EA is particularly relevant to developing countries because government institutions frequently operate multiple systems developed at different times. Research on public-sector EA has identified duplication, incompatibility, lack of uniformity, and integration problems as important barriers to effective service delivery [10]. EA therefore provides a mechanism for moving from isolated projects toward a coordinated institutional architecture.

C. ICT and Education

UNESCO's ICT Competency Framework for Teachers emphasizes that ICT integration requires teacher competencies, professional development, institutional leadership, and supportive policy environments [11]. This supports the argument that TVET transformation cannot be achieved through infrastructure investment alone.

Digital skills are also increasingly important for learners. UNESCO's work on digital literacy recognizes digital skills as part of preparation for employment and participation in a digital society [12]. Developing-country education systems therefore need both institutional digital capability and learner-facing digital capability.

D. Developing-Country Context

The World Bank's *World Development Report 2016* found that digital benefits are unevenly distributed and that infrastructure must be supported by human capital, institutional capacity, and appropriate governance [1]. This provides a strong theoretical basis for treating TVET digital transformation as a socio-technical problem.

Nepal illustrates this challenge. The 2018 UN E-Government Survey placed Nepal at rank 117 with an EGDI of 0.4748. Its Online Service Index was relatively stronger at 0.6875, while its Telecommunication Infrastructure Index was only 0.2413 and Human Capital Index 0.4957 [13]. This combination suggests that online government capability can develop faster than the underlying infrastructure and human capacity required for broad institutional transformation.

Nepal's Digital Nepal Framework, published in 2019, identified digital foundation and education among its eight priority sectors and proposed 80 digital initiatives [14]. The framework therefore provides a national policy context, but a sector-specific EA is required to translate national ambitions into TVET institutional capabilities.

III. Methodology/ Conceptual Framework

This study uses a conceptual and comparative research design. It combines a review of literature with analysis of Nepal's policy and institutional context. The literature was selected from peer-reviewed research, international

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development organizations, government documents, enterprise architecture standards, and ICT-in-education frameworks. Priority was given to sources addressing e-readiness, enterprise architecture, ICT infrastructure, human resources, cybersecurity, digital education, and TVET.

The framework is synthesized rather than statistically validated. It extends existing e-readiness work by connecting readiness dimensions to architectural domains.

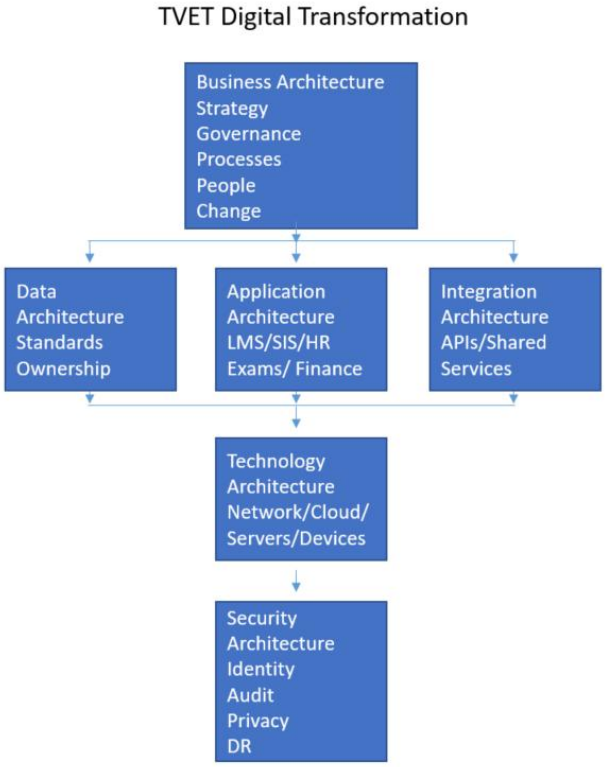

Fig 1. Reference Enterprise Architecture for TVET Digital Transformation

The proposed model contains six domains:

1) **Business Architecture** – strategy, governance, organizational structure, processes, roles, services, and change management.
2) **Data Architecture** – data ownership, standards, master data, data quality, privacy, records, and information lifecycle.
3) **Application Architecture** – institutional applications, learning systems, student systems, examination systems, HR systems, finance, and analytics.
4) **Technology Architecture** – networks, computing, storage, cloud or data-center infrastructure, devices, connectivity, and availability.
5) **Security Architecture** – identity, access control, cybersecurity, backup, disaster recovery, audit, privacy, and risk management.
6) **Integration Architecture** – APIs, interoperability standards, shared services, registries, data exchange, and external-sector connectivity.

Security is treated as an enterprise-wide architectural concern rather than an isolated technical component. Integration is similarly treated as a core architectural capability because institutional transformation requires systems to exchange information.

The model can be operationalized through a five-level readiness scale:

Level 1 – Initial: manual and fragmented processes; limited ICT capability.
Level 2 – Developing: basic digital systems exist but remain isolated.
Level 3 – Defined: processes, standards, responsibilities, and core applications are documented.
Level 4 – Integrated: major applications, data, and services are interoperable.
Level 5 – Transformative: digital capabilities continuously improve services, decisions, teaching, and institutional performance.

A readiness score may be calculated as:

$$R = \frac{\sum_{i=1}^{6} w_i D_i}{\sum_{i=1}^{6} w_i}$$

Where:

- R = *Overall readiness score*
- D_i = *Readiness score for dimension i*
- w_i = *Weight assigned to dimension i*
- $i=1,\ldots,6$ = *Six readiness dimensions*

Equal weights may be used during initial assessment; expert-derived weights can be introduced after empirical validation.

IV. Analysis and Discussion

The proposed framework indicates that TVET readiness should not be measured by the number of computers,

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internet connections, or software packages installed. A digitally equipped institution may still remain at a low maturity level if its data are duplicated, applications cannot exchange information, security controls are weak, or staff cannot use the systems effectively.

The Nepal case illustrates this issue. Nepal's 2018 EGDI score of 0.4748 placed it in the medium group, with a substantial difference between Online Service Index and Telecommunication Infrastructure Index [13]. This indicates that visible online services do not necessarily imply equivalent institutional readiness.

The findings of Gupta, Marasini, and Shakya reinforce this interpretation. Human resources, infrastructure, software, security, planning, and networks must operate together [2] [3] [4]. Information-system auditing adds another layer by requiring institutions to verify whether systems remain secure, reliable, controlled, and aligned with organizational objectives [6] [8].

For TVET, the implication is direct: readiness must be assessed across the complete enterprise. A school may have an LMS but no student master database; it may have an examination application but no integration with student registration; or it may have internet connectivity but no backup and disaster-recovery capability. Such institutions are digitized in parts but are not digitally transformed.

V. Case Studies and Examples

A. Nepal's Government Architecture

Nepal provides an important developing-country example because it established a Government Enterprise Architecture. The Nepal GEA proposed architecture across business, data, application, technology, security, and integration domains [15]. The same principles emphasized interoperability, common standards, data control, security, privacy, and service-oriented architecture.

This provides a strong foundation for a TVET reference architecture. Instead of designing every institution's information systems independently, a sector architecture can define common data, application, technology, security, and integration standards.

B. Education Institutions

The Center for Education and Human Resource Development (CEHRD) was established in 2018 through the integration of central education agencies. Its establishment demonstrates the government's movement toward institutional coordination in education [16]. Although CEHRD is not a TVET institution, the model demonstrates why education information systems require coordination across organizational units.

C. CTEVT and TVET Institutions

The Council for Technical Education and Vocational Training (CTEVT) is Nepal's national apex body for TVET. Its functions include policy formulation, quality control, competency-based curricula, occupational skill standards, testing, research, and training-needs assessment [17]. These functions naturally produce shared information requirements across institutions.

Evidence available also shows movement toward ICT-enabled TVET. In November–December 2019, CTEVT officials, instructors, and representatives of technical schools participated in training on ICT-based e-learning development [18]. This suggests an emerging human-capacity foundation, but training alone does not establish enterprise-wide readiness.

The 2019 employer-engagement initiative involving nine CTEVT schools also illustrates the need for information exchange between institutions and industry [19]. A mature TVET architecture should therefore support student, graduate, employer, skills, curriculum, and labour-market information flows.

D. Institutional Comparison

TABLE I.
Illustrative TVET Digital-Readiness Assessment

Institution/Level	Business	Data	Applications	Technology	Security	Integration	Main Readiness Issue
Central TVET authority	Medium	Medium	Medium	Medium	Medium	Low–Medium	Sector coordination
Large TVET institution	Medium–High	Medium	Medium–High	Medium	Medium	Low	Application silos

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Small TVET school	Low–Medium	Low	Low–Medium	Low–Medium	Low	Low	Resources and skills
Developing-country TVET system	Variable	Low–Medium	Variable	Low–Medium	Low–Medium	Low	Fragmentation
Target state	High	High	High	High	High	High	Continuous improvement

The table is a conceptual assessment, not a statistical measurement of individual institutions. Its purpose is to demonstrate how the REA can identify different types of institutional gaps.

VI. Policy Recommendations

A. Establish a sector-level TVET enterprise architecture

National TVET authorities should define a common reference architecture before large-scale procurement. The architecture should establish common principles for business processes, data, applications, technology, security, and interoperability.

B. Create a common TVET data model

A national TVET data model should define core entities such as institution, student, instructor, course, curriculum, qualification, assessment, certificate, employer, graduate, and occupation. Data ownership and access responsibilities should also be defined.

C. Prioritize interoperability

New systems should provide documented APIs and use open standards wherever practical. Institutions should avoid creating separate databases for information that must be shared nationally.

D. Strengthen digital literacy and ICT training

UNESCO's ICT Competency Framework emphasizes structured teacher development and institutional leadership in ICT integration [11]. TVET instructors and administrators therefore require continuous training in digital pedagogy, information management, cybersecurity, and digital administration.

E. Improve infrastructure

Investment should focus not only on computers but also on reliable connectivity, power, servers or cloud infrastructure, backup, disaster recovery, secure networks, and technical support. The World Bank's findings show that digital infrastructure must be combined with human and institutional capacity to generate sustainable benefits [1].

F. Introduce security and audit by design

Security controls should be incorporated into architecture, procurement, development, and operation. Regular information-system audits should verify access control, data protection, backup, logging, vulnerability management, and continuity.

G. Use phased implementation

Institutions should first establish governance and data standards, then modernize core applications, followed by integration and advanced analytics. This reduces the risk of investing in disconnected systems.

VII. Conclusion

Digital transformation in TVET is an organizational transformation supported by technology, not a technology procurement exercise. This paper has examined the readiness question through enterprise architecture and proposed a Reference Enterprise Architecture containing Business, Data, Application, Technology, Security, and Integration Architecture.

The framework extends earlier e-readiness research in Nepal. Gupta, Marasini, and Shakya demonstrated that ICT readiness depends on several interacting domains, including infrastructure, software, security, policies, networks, and human resources [2]. Their subsequent studies on information-system audit and security [6] [8] [7]together with Marasini and Shakya's work on human resources and infrastructure [3] [4], provide important foundations for the proposed model. Research on government software development and project success [20] [21] further indicates that technology projects require organizational alignment and sustainable implementation.

The Nepal context demonstrates both progress and limitations. The country had established government enterprise architecture, digital-government policies, and the Digital Nepal Framework by 2019. Yet its 2018 EGDI remained 0.4748, with relatively weaker infrastructure and human-capital components [13]. This supports the argument

that policy and application development do not automatically produce institutional digital maturity.

The main contribution of this paper is therefore a sector-oriented EA model that can be used as both a reference architecture and readiness-assessment instrument. It enables TVET authorities to move from fragmented ICT projects toward coordinated digital transformation.

The framework has limitations. It is conceptual and has not been statistically validated through a large TVET survey. The institutional comparison is illustrative rather than a measured national assessment. Future research should test the six domains across public and private TVET institutions, develop empirically derived weights, validate the five-level maturity model, and examine whether higher architectural maturity produces measurable improvements in educational quality, administrative efficiency, employment outcomes, and industry engagement.

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