

IEEE Standard for Digital Transformation Architecture and Framework

IEEE Industrial Electronics Society

Developed by the
Industrial Electronics Society Standards Committee

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STANDARDS

IEEE Standard for Digital Transformation Architecture and Framework

Developed by the

Industrial Electronics Society Standards Committee
of the
IEEE Industrial Electronics Society

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IEEE SA Standards Board

Abstract: An architecture and framework for digital transformation are provided by this standard. The need for a comprehensive plan for effective digital transformation that addresses the people element, the process element, and the digital technologies is identified by this standard. Each of these three elements are covered in more detail. Leadership and workforce management issues associated with organizational change management are addressed by the people element. The impact on business processes is discussed in the process clause. In addition, the application of business process changes in different types of business operations are addressed. A brief overview of the technologies most commonly associated with digital transformation is provided in the technology clause. The impact these technologies can have within a business is reviewed. Finally, organizational sustainability and its close interconnection with digital transformation is presented.

Keywords: agile, artificial intelligence, augmented reality, big data, blockchain, digital transformation, digital twin, IEEE 2023™, Internet of Things, machine learning, sustainability, virtual reality

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Participants

At the time this standard was completed, the Digital Transformation Working Group had the following membership:

Lee Stogner, Chair
Raymond Sheen, Vice Chair
Ralf (Xin) Ma, Secretary
Yu Yuan, Editor-in-Chief
Raymond Sheen, Chair of Subgroup 1
Keith Plemmons, Chair of Subgroup 2
Denny (Qiqi) Wang, Chair of Subgroup 3

<i>Organization Represented</i>	<i>Name of Representative</i>
OxSenses Corporation.....	Yu Yuan
National Security Agency.....	Raymond Sheen
Travelsky Technology Limited (Accounting Centre of China Aviation)	Yuan Yongjun

The Working Group gratefully acknowledges the contributions of the following participants. Without their assistance and dedication, this standard would not have been completed.

Andy Burns	Tim Jansen	Joana Olszewska
Wenting Chang	Haobo Lai	Qianshang Qu
Daniel Chen	Daozhuang Lin	Manuel Vexler
Hui Ding	Giuseppe Mascarella	Kefei Wang
Bob Frankston	Joel Myers	Cathy Wang
Jim Frazer	Taurus Ning	Wang Yao
Darwin Hochstedler	Douglas Novotny	Qiongfang Zhang
Ning Hu		Frankie Zhang

The following members of the entity Standards Association balloting group voted on this standard. Balloters may have voted for approval, disapproval, or abstention.

OxSenses Corporation	Hisense Electronic	Intel Corporation
Beijing Tsingzhi Shuyuan	Technology (Shenzhen)	Lenovo Group Limited
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Tyler L. Jaynes
Thomas Koshy
Howard Li
Xiaohui Liu
Kevin W. Lu
Hiroshi Mano

Daleep C. Mohla
Annette D. Reilly
Robby Robson
Daniel Sabin
F. Keith Waters
Sha Wei
Luyang (Eric) Zhang

Introduction

This introduction is not part of IEEE Std 2023-2025, IEEE Standard for Digital Transformation Architecture and Framework.

Digital transformation has become a major movement in business and industry as companies transition from an Industry 3.0 technology base to an Industry 4.0 technology base. This standard can be used by organizations to establish strategies and plans for their transition. The standard is not a technical standard in the sense that it does not provide specifications for digitalization technologies. That type of information is found in other IEEE standards that are referenced in this document. The goal for this standard is to provide background and guidance so that organizations can create a strategy to make the technical and organizational transformations necessary to be successful within the digitalized Industry 4.0 environment.

The standard provides a framework for transition that has three elements, or *pathways*: people, process, and technology. Each of those pathways is then addressed in detail within one clause of the standard. Finally, the standard discusses principles for maintaining and sustaining the digital transformation.

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IEEE Standard for Digital Transformation Architecture and Framework

1. Overview

1.1 Scope

This standard provides an architecture and framework for digital transformation development, usage, implementation, and interfaces for applications. The architecture and framework address scalability, systems and interfaces, security, and privacy challenges for digital transformation applications.

1.2 Purpose

The purpose of this project is to develop definitions and a protocol for digital transformation implementations for applications.

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall* equals *is required to*).^{6,7}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

⁶ The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

⁷ The use of *will* is deprecated and cannot be used when stating mandatory requirements; *will* is only used in statements of fact.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

There are no normative references in this standard.

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.⁸

digital transformation (DX): The integration of three developing trends and capabilities. First is the adoption of advanced digital technologies such as Internet of Things (IoT); artificial intelligence (AI); big data; digital twin; virtual reality (VR), augmented reality (AR), mixed reality (MR), and extended reality (XR); blockchain; and so forth. Second is the reformulation of business platforms and processes to operate in a lean, resilient, and real-time collaborative manner with customers and supplier networks. Third is the shift in workforce engagement to operate using virtual and boundaryless teams. The result is to significantly improve operations or disruptively enable new business models.

Digital Transformation 1.0: The foundational phase of digital transformation, driven by the integration of mature and widely adopted technologies such as cloud computing, big data, mobile internet, and the Internet of Things (IoT). It focuses on enhancing operational efficiency through the digitization of processes, enabling data-driven decision-making, and fostering initial connectivity across systems, platforms, and stakeholders. This phase lays the groundwork for improved productivity and incremental business model innovations without fundamentally disrupting existing structures.

Digital Transformation 2.0: Represents the advanced, synergistic evolution of digital transformation, propelled by the collaborative development and integration of cutting-edge technologies including artificial intelligence (AI), metaverse, and decentralization. Building on the foundations of Digital Transformation 1.0, it emphasizes intelligent autonomous systems, immersive virtual experiences, and distributed trust mechanisms to enable radical reconfiguration of business ecosystems, real-time adaptive operations, and boundaryless collaboration. The result is profound operational enhancements and the emergence of disruptive, decentralized business models that redefine value creation and stakeholder interactions.

benchmarking: A process that involves an assessment of current product or process features and characteristics and an assessment of key competitive or best-in-class product or process features and characteristics. These two assessments are compared to determine where improvement opportunities exist with the current products or processes.

charrette: An intensive, multidisciplinary workshop with the aim of developing a design or vision for a project or planning activity. A charrette may also be understood as a collaborative session in which a group of key stakeholders and external subject matter experts (SMEs) draft a conceptual plan for a business or digital transformation (DX) initiative. (Adapted from U.S. Environmental Protection Agency)

NOTE—See U.S. Environmental Protection Agency.⁹

⁸*IEEE Standards Dictionary Online* is available at: <http://dictionary.ieee.org>. An IEEE account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

⁹ Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

digital platform: Usually composed of cloud computing resource services and the industrial ecosystem. The platform creates a digital environment in which business transactions can be completed with very little friction.

human-machine interface (HMI): A communication tool that allows human operators to engage and interact with machines. Devices can range from a control panel with buttons and lights to a high-definition touch screen. A software application can also be considered as part of this interface.

Industry 4.0: This refers to the fourth industrial revolution. Its companies are manufacturing organizations that rely on intelligent networked systems to manage and monitor operations. Manufacturing operations are designed and managed as a fully integrated system rather than functional areas of expertise or manufacturing capacity and technology.

value stream mapping (VSM) methodology: A lean-management method for analyzing the current state and designing a future state of a process that takes a product or service from inception through delivery to the customer. The focus is on identifying waste and delays that do not add value.

3.2 Acronyms and abbreviations

AI	artificial intelligence
AR	augmented reality
BIM	building information management
CAD/CAM	computer-aided design/computer-aided manufacturing
CCB	change control board
CDM	chief digital manager
CDO	chief digital officer
CoBot	collaborative robot
DX	digital transformation
DXO	digital transformation office
EEF	enterprise environmental factor
ER	extended reality
FMEA	failure mode and effects analysis
IoT	Internet of Things
IT	information technology
KDD	knowledge discovery in database
MR	mixed reality
OPA	organizational process asset
OT	operational technology
PVR	persistent virtual reality
SaaS	software as a service
SWOT	strengths, weaknesses, opportunities, and threats
VR	virtual reality

4. Digital transformation framework

4.1 General

Transformation implies change. Managing the implementation of that change is a critical component of digital transformation (DX). This clause establishes the baseline framework for an organization to plan and implement DX. It provides guidance on directing and managing an organization through the transformation process of becoming a digital enterprise.

The organizational change elements of this standard provide a framework that outlines key aspects of managing organizational change. There are many techniques and approaches to the management of change. The best-known practices for a given organization are often dependent upon the enterprise environmental factors including cultural environment, organizational maturity, organizational structure, and organizational leadership. Application of best-known practices in each stage or phase of organizational change contributes significantly to success in transformation into a data-driven organization.

Some organizations may be considered to be operating within a data-driven environment. These may be connected electronically, utilizing technology where applicable, and to some extent networked from a data management and control perspective. These organizations may be performing well but are still challenged in one or more operational areas. The purpose of this standard is to provide an actionable framework for any organization to successfully transform digitally.

A digitally transformed organization shall have characteristics that include the following:

- Universal access to real-time data
- Technology that enables smarter-faster decision-making
- Data analytics and metrics
- Fully networked technology systems
- Written and fully implemented technology plans
- Appropriate use of process sensors to provide operational data
- Full depth application of technology to include energy management

A digitally transformed organization is different from an Industry 4.0 organization in the following ways:

- Industry 4.0 is another term for the fourth industrial revolution in manufacturing.
- Industry 4.0 is related to the application of digital technology. These technologies include various aspects of automation, data exchange, cloud computing, robotics, big data, artificial intelligence (AI), Internet of Things (IoT), and other technologies.
- Industry 4.0 is the application of digital technologies to achieve industrial objectives. These practices may also be associated with intelligent manufacturing practices and human-machine interface (HMI) or technologies that connect a person to a machine, system, or device.
- DX is not manufacturing or industry specific. The framework presented in this standard is intended to be adaptable to any enterprise or organizational entity.
- DX is a process that applies to people, processes, and technology. Implemented strategically, it can enhance an enterprise's capabilities by making operations more transparent, accountable, and conducive to innovation and improvement.
- DX enables manufacturing companies to apply advanced technologies to move operations from mass production to more personalized, customer-focused, and adaptive operations.

This standard is not intended to provide an exhaustive list of best-known practices. But if properly applied, it is intended to enable a data-driven organization to make smarter-faster decisions. By its nature, DX is transformative and involves multiple business and production processes, along with integrated projects and courses of action. In some cases, an organization's entire value chain may be impacted. The scope of transformation, the amount of investment, and the magnitude of operational change illustrate the role of executive leadership as the change agent. This type of leader shall have a comprehensive understanding of the organization, the ability to make tough and technical decisions, the desire to act in the overall interest of the organization, and the authority to set objectives and deliver desired objectives.

DX requires an understanding of current and future endpoints, along with pathways for reaching desired objectives. This journey can take a broad spectrum of paths, but one thing is clear. The transformation will be an iterative process that starts with vision and goal setting and iterates toward an organizational model, processes, and practices focused on delivering a digital agenda based on adaptive or agile practices within a digitally enabled culture.

4.2 Initial assessment

A DX assessment phase (Assess) instantiates an intentional change process. The activities associated with the Assess phase establish the DX at the applicable organizational level and can be performed separately from the phased project management approach delineated in 4.4. This separation of the Assess phase enables decision-makers to prepare the organization for DX. Preparatory actions may be organized in terms of people, processes, and technology.

The activities of the Assess phase culminate with an Assess Gate Review and a Charter document. The Assess Gate Review serves as a go/no-go decision point supported with applicable documentation and referenced inputs. The Charter becomes the primary input and reference document for subsequent phases. The Charter serves to communicate the objectives, business impact, goals, scope, timeline, and key team members, along with defined internal and external stakeholders. Because of the possible time gap between the Assess and subsequent DX phases, it may be necessary to periodically review the Charter with applicable organizational domains. Stakeholders within each organizational domain may be expected to identify courses of action and value streams within each domain.

In the Assess phase, current operations for the organizational elements under consideration for DX are profiled. This profile is the result of a material, data, or information flow or some derivative of a value stream mapping (VSM) methodology. This initial profile provides the basis for internal and external benchmarking of organizational changes as the DX progresses. Also, the profile may also be used to confirm the value proposition at any or all organizational levels.

As early as possible, the leadership team is established. This team shall engage in an initial stakeholder assessment of organizational leaders and their level of interest and authority regarding the DX. A variety of tools and techniques may be used to assess stakeholders, including a matrix analyzing “interest and authority.” The matrix may be used to determine appropriate levels of communication and desired involvement. It may be noted that leaders with a significant amount of interest and authority normally form the core team and steering committee for the transformation.

Also, a stakeholder engagement assessment matrix can be used to indicate the level of engagement the project team has assessed each stakeholder in terms of helping to assure DX success (see Table 1). Identifying and monitoring the gap between current (C) and desired (D) levels is important. This allows the DX leadership team to focus coaching and communication efforts to effectively close the gap and thereby increase success. A typical scale for assessing engagement is Unaware, Resistant, Neutral, Supportive, and Leading.

Table 1—Example stakeholder engagement matrix

Stakeholder	Unaware	Resistant	Neutral	Supportive	Leading
Stakeholder 1	—	—	—	C, D	—
Stakeholder 2	C	—	—	D	—
Stakeholder 3	—	C	—	D	—

As a key organizational process asset, the stakeholder analysis shall be revisited on an established cadence as the DX progresses. The purpose of the tracking is to monitor the evolution of stakeholders during the DX. For example, this analysis can be used to plan and provision change management, design, training, team organization, and continuous improvement. Each of these activities could occur as the DX project progresses and would involve a changing cadre of stakeholders.

As an output of this analysis, a Stakeholder Register would be developed as a formal project document. This document would list individuals, groups, or organizations that may be or consider themselves to be impacted by the DX activities or outcomes. This register may be updated and monitored during each review cycle.

The approved business strategy is a business document used to create the Charter. This document connects the decisions made to justify the expenditure of resources with the expected outcomes of the DX. Typically, the business case is supported by a benefit-cost analysis, along with established organizational boundaries.

The DX sponsor approves the Charter to formally authorize the existence of the initiative and to provide the key people with the authority to apply organizational resources to DX-related activities. The activities that lead up to signing and publishing the Charter are organizationally dependent. The Assess Gate Review announces the creation of the Charter, including identifying key team members, levels of decision authority, vision, and mission of the DX.

4.3 Three pathways for transformation

4.3.1 General

Beginning with the end in mind, the desired end state of the transformation shall be established and recognized. Otherwise, there is a significant risk that the effort will be lost. This subclause guides the establishment of the desired end state. The graphic below shows three main pathways aligned to the objective of DX.

4.3.2 People pathway

As noted in [Figure 1](#), the People pathway encompasses the courses of action related to the knowledge, skills, abilities, and organizational changes required to transform the organization. This transformation along the People pathway can be described as the development of an ecosystem that promotes a data-driven organization. This organization has the expertise, practices, and governance to analyze, derive insights, and promote data-driven decision-making.

The goals associated with the People pathway include the ability to generate, access, and aggregate data sources, while expanding their analytical capabilities. In some cases, third-party service providers may be sourced to augment an organization's capabilities. Also, suppliers and other entities may be added to the ecosystem. From a pathway perspective, traditional relationships may be reconfigured to leverage the other Pathways.

Whatever the situation, the objectives include the use of data for competitive and strategic advantage. This advantage can be observed as modified behavior of stakeholders, enhanced product offerings, and a focus on new product development. The modified behavior of stakeholders may include data-driven decision-making, data proliferation, along with faster cycles of action. The enhanced products may involve embedded data collection systems. These systems enable personalized user experiences to turn data into knowledge and new products.

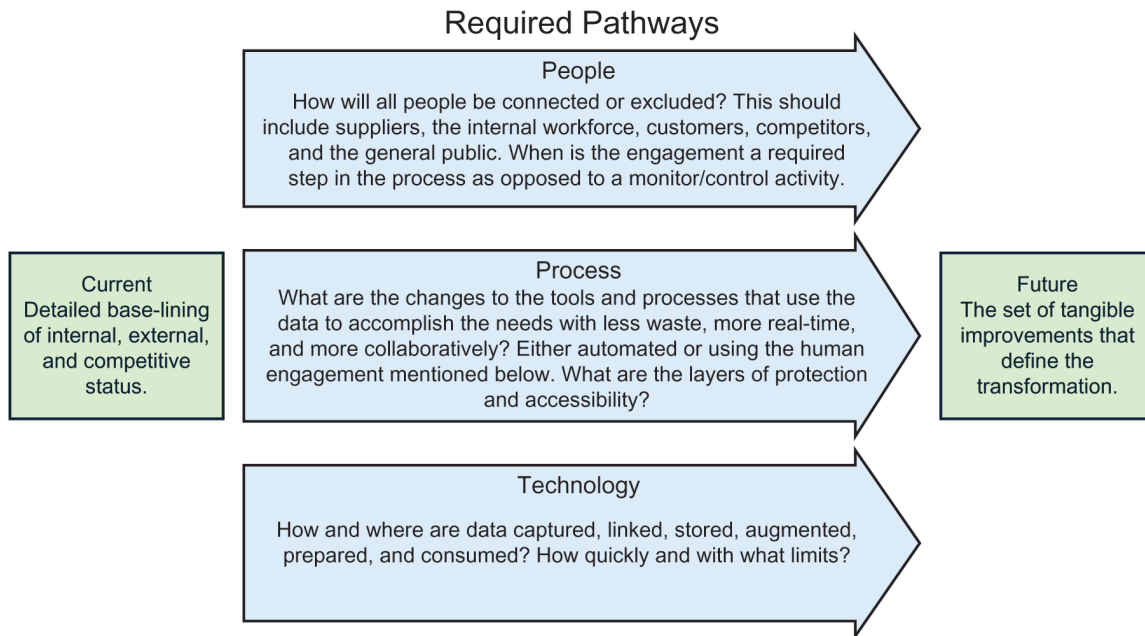


Figure 1—Three pathways for digital transformation

4.3.3 Process pathway

As noted in Figure 1, the Process pathway encompasses the courses of action related to the tools and processes that use the data to accomplish the needs or objectives of the organization.

The work methods of the organization before the DX began and those methods that will continue beyond the DX are the main focus of the Process pathway. These methods are distinct from those tools and techniques applied during the transformation that specifically result in improved data-driven work methods. This distinction is important to maintain as the DX progresses because of the allocation and accountability of dedicated resources.

There are many tools that may be used in the transformation process. Treating the transformation as a project or portfolio of projects is illustrated in Figure 1. These tools may include value stream mapping, benchmarking, process maps, and other analytic or decision-making applications. The application of these tools improves the work methods, focused on using data to deliver products, services, or results with less waste, more real-time decision-making, and more stakeholder collaboration.

4.3.4 Technology pathway

As noted in Figure 1, the Technology pathway encompasses the courses of action related to the following:

- Aggregating data from users, customers, sensors, machines, devices, and so forth.
- Storing, modeling, processing, and securing this data.
- Generate timely control signals, visualization, and alarms.
- Analytics, including predictions, machine learning, deep learning, and artificial intelligence..
- Personalization of large amounts of disparate data to individual users.
- Advancing the digital technology capabilities includes the collection of operational metrics and process data in real time. The derivative result is the ability to interactively and dynamically alter the performance of a system or subsystem. Also, by aggregating and possibly anonymizing data, new intelligence may be securely delivered to individual users.