The Industry Digital Transformation Framework

Rev 31

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1 INTRODUCTION

The Industry Digital Transformation Framework builds on the IIC Digital Transformation (DX) in Industry[1] whitepaper. It outlines key concerns and viewpoints for developing and implementing DX initiatives across industries. It also discusses the drivers for Industry DX and the connected digital technologies that enable this transformation.

This framework is intended for executive and technical leaders who are interested in defining and executing a bold DX vision and strategy at both tactical and strategic levels. It provides clear guidance on how to approach DX, focusing on core processes and the innovation processes needed to overcome typical challenges and barriers in Information Technology (IT) / Operational Technology (OT) environments across industries[2]. It also covers considerations for DX at the enterprise level. The framework concludes with several examples of industry DX initiatives, providing practical insights and lessons learned to inspire and inform the efforts of business executives and technical leaders.

2 INDUSTRY DIGITAL TRANSFORMATION

Digital Transformation is a Caterpillar to Butterfly Journey. It is the innovative and principled application of connected digital technologies, coupled with organizational and process restructuring, to better compete, disrupt the market, avoid being disrupted, and ultimately create new value for the organization and its stakeholders across the ecosystem.

Although DX is not new, it remains a hot topic, where enabling technologies[3] play a growing role in the organizations' ability to create value and deliver new value to the market. In section 4, we discuss two types of DX initiatives in industry, their drivers and the issues and considerations involved in their implementation:

- Tactical initiatives that focus on a core process within the organization, and
- Strategic initiatives that encompass the entire enterprise, its business model, core processes, and organization as a whole.

2.1 DIGITIZE, DIGITALIZE, TRANSFORM

As illustrated in figure 2-1, the DX journey consists of three main stages: digitization, digitalization and the actual digital transformation. While these terms are interconnected and may overlap in certain scenarios, organizations sometimes use them interchangeably. However, they have distinct and fundamental differences.

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1 IIC Digital Transformation in Industry whitepaper - *https://www.iiconsortium.org/pdf/Digital_Transformation_in_Industry_Whitepaper_2020-07-23.pdf*

2 Example: manufacturing, healthcare, transportation, power distribution, oil and gas, and more.

3 Example: IoT (Internet of Things), digital twins, AI, additive manufacturing, and more.

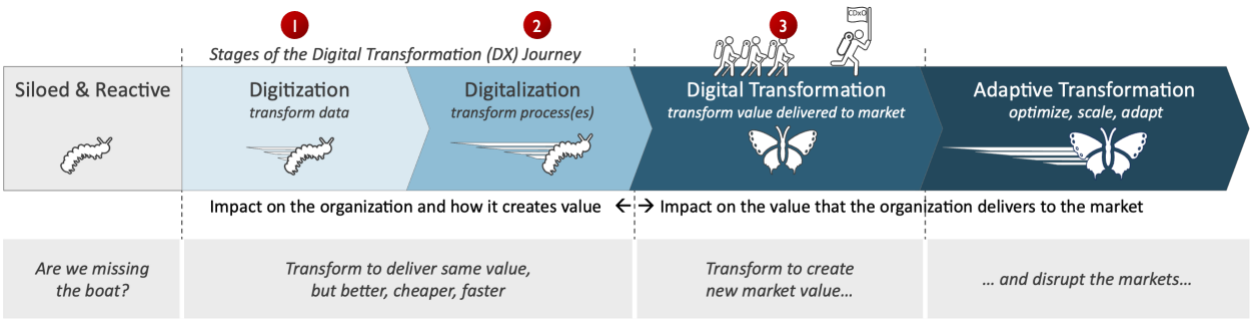

Figure 2-1: The digital transformation journey. (Source: IIC.)

Digitization ❶*:* This stage focuses on converting analog data associated with core processes into digital form and integrating it into processes. Eliminating reliance on analog data addresses a major source of inefficiencies in white-collar and blue-collar work environments.

Digitalization ❷*:* In this stage, the focus shifts to incorporating digital data into core processes, optimizing these processes, and on harmonizing and integrating them. This applies to both internal and cross-ecosystem processes. Key benefits include streamlined operations, data-driven decision making, and cost reduction.

Note: With digitization and digitalization, the organization will continue to deliver the same value to its market constituents, but it will do so more efficiently and more cost-effectively. Some of these benefits may be passed on to customers through lower prices and more reliable product availability.

Digital Transformation ❸*:* This stage leverages the work done during the previous stages and focuses on transforming the value delivered to customers and other stakeholders in the ecosystem. These external outcomes may include new business models and new types of product offerings, for example product-as-a-service. The goal is to innovate, become customer-centric, leapfrog the competition, enter new markets, and potentially create blue ocean markets.

The DX journey continues beyond this point, where the focus shifts to optimizing and scaling of the transformed business in order to realize the strategic goals of DX, for example:

- Grow new revenue streams,
- Accelerate profits,
- Leverage blue ocean markets,
- Adapt and pivot as necessary,
- Future-proof the organization.

The DX journey is enabled through the implementation of emerging and emergent digital technologies. See Section 5 for details.

2.2 DIGITAL ENTERPRISES

During the DX journey, the enterprise's DNA evolves, leading to the emergence of the digital enterprise. This transition accelerates when the organization has achieved significant digitization and digitalization levels, organizational and cultural changes focused on innovation and seamless optimization and integration of physical and digital spaces. The Digital Enterprise concept corresponds to stage [E] (see Section 4 and Figure 4-1).

Becoming a digital enterprise is a well-charted and highly rewarding endeavor that results in a more valuable and agile organization. It enhances the ability of the organization to pivot and scale, disrupt business and markets, and integrate new technologies more effectively and efficiently. Digital Enterprises are much better prepared to leverage disruptive technologies, to pivot, transform and future proof themselves. This is critical for enterprises with major IoT and digital twin systems. Becoming a digital enterprise is key to achieving true market-facing DX, maximizing value and competitive advantage. Digital Enterprises are central to digital engineering and digital threads.

3 TRANSFORMING PROCESSES

DX initiatives may be tactical, focusing on specific areas in the business and its operation, or strategic focusing on the whole enterprise, its business models, structures, and processes. Refer to Section 4 for details.

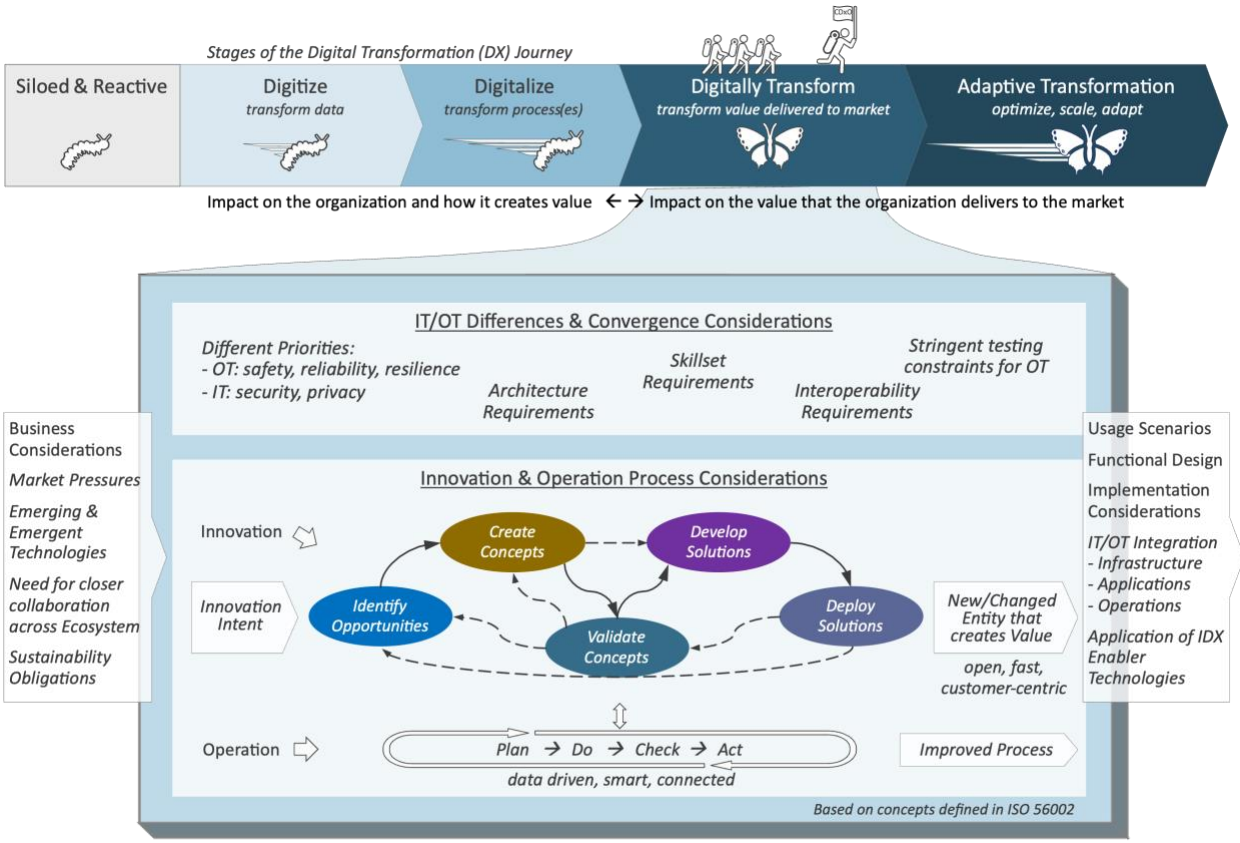

Figure 3-1: Digital transformation and innovation management. (Source: IIC.)

This section discusses the transformation of the innovation and operational processes required to execute either type of initiative. We base these discussions on the ISO 56002[4] standard which provides a framework for establishing, implementing, maintaining, and improving an innovation management system in any organization. The standard covers various aspects of innovation management, such as strategy, culture, processes, and results.

3.1 BUSINESS CONSIDERATIONS

Over the past decade, the pace of innovation has accelerated due to growing market pressures and rapid technological advances. Key drivers include:

- Automating repetitive tasks with digital tools to reduce human errors and allocate resources to more strategic initiatives,
- Streamlining processes, eliminating bottlenecks and downtimes, and enhancing field collaboration with digital technologies,
- Using analytics tools for instant insights and real-time decision making,
- Using IoT and digital twins for equipment monitoring and preventive maintenance,
- Creating a customer perspective by leveraging customer data to provide personalized products and services,
- Tracking and managing inventory to minimize overstock,
- Enhancing supply chain visibility through improved collaboration.

DX fosters innovation and creates unique value beyond incremental changes such as efficiency gains. It redefines value propositions through customer-centric strategies, connecting with customers in real-time via IoT. This fosters cross-divisional collaboration, partnerships, and ecosystem integration. Innovatively applying emerging and emergent technologies creates solutions that enable organizations to compete more effectively in price and quality while adapting to fast-changing market dynamics.

Integrating these solutions with IT systems extends the network effect and benefits across industries. Market shifts and sustainability requirements drive organizations to collaborate, reducing uncertainties fueling further innovation.

3.2 IT/OT DIFFERENCES & CONVERGENCE CONSIDERATIONS

Organizations undergoing DX aim to deliver innovative products and services by integrating IT and OT. This integration requires an innovation process from idea to launch that meets the complex needs of the combined IT and OT environments.

Integrating IT and OT environments within the context of DX initiatives presents significant challenges due to the inherent digital/physical divide. This divide creates complexities across business, technology, operations, organization, culture, priorities, standards, best practices, governance, risk, and compliance. For instance, safety, reliability, and resilience are vital in OT but less prioritized in IT.

[4] ISO 56002 Standard - *https://www.iso.org/standard/68221.html*

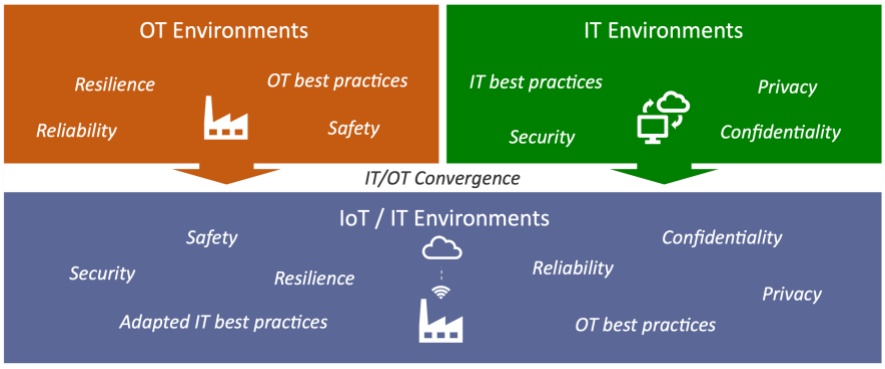

Figure 3-2: IT/OT convergence. (Source: IIC.)

Successful DX requires overcoming these challenges with an innovative and holistic approach that bridges IT-OT gaps. This approach should also account for differing goals, standards, priorities, and best practices of IT and OT. These challenges become particularly critical in environments where OT-based systems depend on IT infrastructure for their own operation and innovation. Moreover, when combined with IT-based business systems, these OT systems are crucial for delivering new market value. The table below outlines some of the major differences between IT and OT:

Considerations	OT Domain	IT Domain
High priorities	Safety, reliability, resilience	Security, privacy
Dominant architecture	Physical interactions-centric	Software centric
Testing requirements	Stringent (safety priorities and low malleability of hardware design)	Open
Performance requirements	Low latency, high reliability and resilience, cloud and edge architecture	High throughput, significant cloud component
Skill set focus	Hardware knowledge	Software knowledge
Standards	Interfaces between generic designs	Interoperability
Lifespan of assets	Longer, industrial assets are built to operate for years	Shorter, due to rapid technological advances
Asset characteristics	Purpose-built with specialized software, proprietary protocols	Off-the-shelf, replaceable, generally run on common operating systems
Focus of technology	Manage physical operations and machinery	Manage processing of data and information
Environment	Industrial settings, direct interface with machinery and processes	General computing environment, data-centric tasks
Upgrade cycles	Infrequent, requires significant downtime	Frequent, often remote and seamless
Risk tolerance	Low, due to safety-critical operations	Higher, with a focus on data recovery and security measures

Considerations	OT Domain	IT Domain
Real-time interaction	Essential for continuous process control	Not essential, batch or delayed processing is often acceptable
Data formats	Industry-specific, often proprietary	Standardized, interoperable formats
Power requirements	Consistent and high availability power sources	Standard power sources, flexibility in deployment
System integration	Vertical integration within specific industries	Horizontal integration across diverse systems and applications
Failure impact	Catastrophic, affecting human safety or environmental harm	Significant, primarily affecting operational continuity or data loss

Table 3-1: IT/OT convergence considerations. (Source: IIC.)

These differences impact various aspects of the operations and innovation, such as development, performance, architecture, interoperability, testing, and process design. Organizations that rely on OT technology must adopt new processes suitable for environments where IT and OT coexist or converge. For details, refer to the IIC Trustworthiness Framework Foundation publication[5].

3.3 INNOVATION PROCESS CONSIDERATIONS

The DX framework of the Boston Consulting Group (BCG) encompasses the notion of "digitize the core", which includes digitizing operation and product and service innovation[6]. This section discusses this subject in the context of changes in operation and innovation processes. DX involves more than just upgrading technology; it focuses on creating new value through innovation. As such, innovation is at the heart of DX, driving the generation and delivery of novel solutions that meet the needs and expectations of customers and stakeholders.

Important: Without innovation, DX projects would be mere IT projects, lacking the strategic vision and differentiation essential for achieving competitive advantage and sustainable growth.

To innovate effectively, DX initiatives need a systematic innovation management approach. One such approach is the ISO 56002 standard for innovation management, which outlines stages including defining innovation intent, identifying opportunities, creating concepts, validating concepts, developing solutions, and deploying solutions. Each stage should have clear objectives, criteria, methods, and tools to ensure the quality and feasibility of outcomes. DX initiatives require the right innovation process that suits the project's context, goals, and challenges.

Some innovation processes may be hindered by the organization's own management systems:

- May not foster a culture of innovation suitable for the project,

[5] IIC Trustworthiness Framework Foundation - *https://production.iiconsortium.org/pdf/Trustworthiness_Framework_Foundations.pdf*

[6] BCG: Jens Riedl, et al., "Why Road Freight Needs to Go Digital – Fast" - *https://www.bcg.com/publications/2018/why-road-freight-needs-go-digital-fast*

- May not allocate sufficient resources for the processes, and
- May be too rigid, linear, or risk-averse, leading to suboptimal or ineffective solutions.

DX projects should adopt an innovation process that fosters a culture of innovation and enables the creation of new values.

Note: Industry DX is a strategic digital imperative for asset intensive industries, such as manufacturing, energy, and transportation. Innovation in these industries is challenging due to their perfectionist culture rooted in OT, involving physical engineering and automation. Their rigorous "innovation process" requires evidence at each stage, while failure is not tolerated due to their serious consequences for safety, quality, and reliability.

3.3.1 Fast Innovation Process

To succeed in today's DX era, industries must embrace innovative mindsets that integrate IT and OT for greater flexibility, agility, and experimentation. A fast-fail approach is crucial, emphasizing quick feedback from testing virtual and physical prototypes, and learning from failures to refine solutions. This approach mitigates the risks of Industry DX innovation projects, by avoiding costly errors in the later stages. Industries must recognize how DX reshapes innovation processes and aligns them with their specific context, goals, and challenges.

Testing in innovation processes is critical for verifying and enhancing solution designs. Yet unlike software-intensive organizations, hardware-intensive organizations undergoing DX often face challenges due to costly and time-consuming physical prototypes. Hardware-intensive organizations tend to have a perfectionist culture that requires flawless evidence at each stage of the innovation process, slowing down progress and increasing the failure risk. To overcome this challenge, organizations should leverage technologies, such as IoT, 3D printing, CAD/CAE, XR, AI, and digital twins, enabling cost-effective and faster testing with real and virtual prototypes. These technologies also enable visualization and validation of designs against technology and market requirements, by involving stakeholders such as engineers and customers. This approach drives collaboration, feedback, collaboration, and iteration in the innovation process, leading to a fast innovation process with better quality and feasibility.

Moreover, these technologies can be applied throughout the innovation process, from idea generation to deployment, creating and sharing concepts and solutions faster and checking for mistakes. This transition to a fast-test-and-fail approach reduces the risk of DX innovation projects, countering the perfectionist culture of firms.

Examples of fast innovation processes include GE and Bosch, which have adopted tools and frameworks such as FastWorks (GE) and MVP[7]-as-a-Service (Bosch) based on lean start up and design thinking principles, effectively utilizing prototypes (e.g. MVPs).

[7] Minimum Viable Product.

3.3.2 Open Innovation Process

OT-intensive firms often adopt a closed innovation process with compartmentalized resources and expertise, limiting external collaboration due to organizational siloes and hierarchical structures. In addition, these firms face intense pressure to prioritize safety, reliability, and resilience in their operation, further reducing opportunities for external interaction. Industry DX requires innovation processes that leverage external partners and sources. Developing internet-enabled products and services requires frequent open collaboration among stakeholders (e.g. divisions, partners) to harness diverse and novel perspectives effectively.

Example: Developing a smart forklift requires an open innovation, multiple party process. The warehouse company sets the requirements for functions, features, performance, safety, and cost. The pallet company creates compatible pallets. The software company develops user interfaces and software for sensors and algorithms. The data analytics company analyzes geospatial, loading, and maintenance data. The IoT company connects the forklift to the Internet and other devices. The vision company adds cameras and image processing for object detection and tracking. The logistics company integrates the forklift into inventory and routing systems. The communication company provides network services. This open innovation process leverages diverse perspectives and expertise to create a better solution.

Inviting participants from different domains and disciplines leverages diverse perspectives, creative thinking and unique expertise, leading to a more innovative and effective solution. This open process fosters an inclusive and collaborative ecosystem of suppliers who actively contribute to the innovation outcome, enhancing the company's overall value proposition and competitive advantage. Incorporating diverse inputs from new participants avoids potential pitfalls, reduces the risks of failure, and ensures high-quality innovation that is sustainable, has long-term viability, and is well-aligned with market demands.

3.3.3 Customer-Centric Innovation Process

The customer-centric innovation process strategically considers customer needs and expectations throughout the product or service lifecycle, from inception and development to deployment, ongoing usage and decommissioning. The needs of customers drive product and service design, requiring suppliers to cultivate and develop empathy as a vital skill to understand these needs. However, the chronic lack of continuous and meaningful connectivity between customers and suppliers limits the potential to support customers in extracting optimal value across the product and service lifespan.

Incorporating internet connectivity and related technologies into products and services enables suppliers to not only enhance existing offerings, but also to create new ones, grounded on a deeper insight into customer needs and usage outcomes. This customer centricity transcends conventional empathy and involves an obsessive dedication to customer satisfaction at every phase and touchpoint of the product and service lifecycle.

Customer-centric innovation goes beyond adding Internet connectivity to products. It requires a fundamental shift in the mindset and culture of the organization, from product-oriented to

customer-oriented. Organizations must understand customer problems, preferences, and expectations, and involve them in the design and development process, to co-create and co-innovate, and deliver additional value through positive and memorable experiences, building trust and loyalty, by exceeding expectations.

In the next sub-sections, we discuss two innovation processes: GE Fastworks (described briefly) and Bosch MVP-as-a-Service.

3.3.4 EXAMPLE 1: GE FASTWORKS

This product innovation process is fast, open, and customer-centric (Lim et al. 2021). It emphasizes customer centricity, empathy, fast iteration of MVPs, and the discovery of customer wants through open collaboration. The process reduces risks in meeting customer needs. The process begins with a deep understanding of customer needs, approached with empathy to ensure a comprehensive grasp of the problem context. This is followed by creating a potential solution and systematically verifying critical assumptions—essentially, the leaps of faith regarding the potential solution design. MVPs are then meticulously developed to test the most high-priority assumptions in a real-world setting, enabling the generation of "learning metrics" derived from direct customer feedback and interactions.

The following diagram illustrates the "GE FastWorks" based innovation process[8]:

Figure 3-3: GE Fastworks. (Source: IIC.)

Using this rapid feedback and the resulting learning metrics as a foundation, a critical decision-making process determines whether to "pivot" or "persevere" with the current strategy:

- Persevere: Continue iterative cycles of developing, refining, and optimizing the current product concept to align with customer needs.
- Pivot: Identify and acknowledge flaws or misalignment in the current concept and adapt by changing direction through additional iterative cycles of innovation and redesign.

[8] IIC: Lim CH, Kai; Kordel, Kim Isabel; Seo, Gwihyeon; McCann, Jeff. BizOps for Digital Transformation in Industries White Paper. 2021.p 11. Figure 6 Process of building MVPs.

3.3.5 EXAMPLE 2: BOSCH MVP-AS-A-SERVICE

Bosch's MVP-as-a-Service framework highlights the importance of changing innovation process management in DX initiatives. Initially, Bosch assumed that assigning qualified professionals to lead the DX initiatives would suffice. However, early projects faced challenges due to divergent IT and OT cultures, priorities, and requirements (Howard 2018). As a result, Bosch developed the "MVP-as-a-service" framework to foster a fast innovation process (allowing fast fail) with open and transparent collaboration (IT and OT stakeholders). The framework emphasizes intensive interaction with customers during early development stages, enhancing customer-centricity.

The framework approaches new solution development by considering user, business, and technology aspects from the start. Assumptions are made transparent and validated, and the solution is iteratively tested with the customer. For details, refer to Lim et al. 2021.

The following diagram illustrates the "MVP as a service" based innovation process[9].

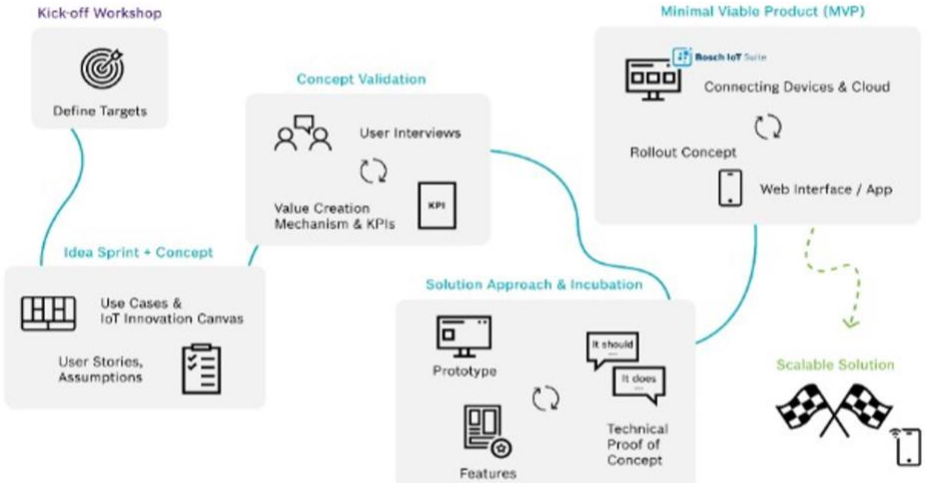

Figure 3-4: Process of building MVPs. (Source: IIC.)

3.4 OPERATION PROCESS CONSIDERATIONS

Changes to the innovation process should proceed in parallel with changes to the operation process, covering three areas:

Digitalized Process: The digitalized operation process is data driven.

Smart Process: Human decisions are augmented by DX-enabling technologies such as AI, digital twins, IoT, Extended Reality, and many more. AI-enabled Edge devices can also make smart decisions. This optimizes and reduces business process complexity and minimizes errors in communication or decision-making (Interview with Pieter Schalkwyk, 11/08/2023).

[9] IIC: Lim CH, Kai; Kordel, Kim Isabel; Seo, Gwihyeon; McCann, Jeff. BizOps for Digital Transformation in Industries White Paper. 2021.p 12. Figure 7 Process of building MVPs. *https://www.iiconsortium.org/pdf/BizOps-for-Digital-Transformation-in-Industries-Whitepaper.pdf*

Connected Process: Extends beyond silos of production lines, sites, and firms, enabled by trusted data sharing infrastructure, such as dataspace. This facilitates data exchange across different groups and organizations, fostering operational efficiency, and maximizing performance.

This digital, smart, and connected operation process becomes the new operation process that creates value for the organization and consistently leads to improved overall outcomes. The new innovation processes (Section 3.3) and the new operation process (Section 3.4) enable firms undergoing DX to achieve better and more sustainable outcomes. The interactive influence of innovation and operation processes fosters a synergistic effect, further improving outcomes, operational efficiency, and long-term competitive advantage.

3.5 IMPLEMENTATION CONSIDERATIONS

Implementing process changes require modifications to the organization's cultural guidelines and systematic changes to management systems. This involves a top-down approach that creates frameworks for changes to innovation and operation processes, mandated by executive leadership, and a bottom-up approach that provides behavioral guidelines to encourage employees to voluntarily change their behaviors and support new processes.

Example: "GE FastWorks" (see Section 3.3.4) exemplifies an effective top-down approach, enabling fast, open and customer centric innovation processes. GE's "GE belief" establishes a bottom-up guideline designed to instill cultural change and ensure decision-making aligns with innovation processes. Similarly, Bosch's "MVP-as-a-service" framework (see Section 3.3.5) and "Bosch Value" reflect comparable strategies for balancing top-down and bottoms-up approaches.

Reliance on the top-down approach alone is insufficient to achieve desired transformational outcomes. Leadership must proactively remove management systems barriers that impede the innovation process. This requires an active engagement by a flexible, agile and responsive executive team. Rigby, D., et al. (2020) discusses the importance of having the CEO as the agile initiative owner. Agile leadership should focus on problem solving to drive innovation, address systematic changes of management systems, and replace tedious report reviews with collaborative problem-solving sessions.

Bosch adopted this executive leadership approach during its own DX, transforming board meetings into interactive sessions where "participants stand, use plan walls and constantly ask what are the next steps in our journey." (Howard 2018).

4 DIGITAL TRANSFORMATION INITIATIVES

DX initiatives can be tactical in nature, focusing on specific areas in the business and its operation, for example line-of-business, process, production line, department, product offering, and more. Conversely, initiatives may be strategic, focusing on the entire enterprise by redefining business models, structures, and processes. While tactical and strategic DX initiatives share similarities, they have distinct differences. Refer to Figure Figure 4-1 below.

[A] Digitization (tactical): This stage focuses on transforming the data produced and consumed by a core process into digital form.

[B] Digitalization (tactical): This stage focuses on leveraging digital technologies of a core process and its digitized data to streamline that process, optimize it and integrate it with other digital processes. This work may also involve process re-engineering.

[C] Digital Transformation (tactical): This stage focuses on the transformation of customer-facing outcomes (business, services, etc.) and the value that the transformed core process delivers to the market and its stakeholders.

[D] Digitization (strategic): This stage focuses on digitizing data produced and consumed by the major core processes in the enterprise (as opposed to a specific process in [A]).

[E] Digitalization (strategic): This stage focuses on the digitalization of the major core processes as described for [B]. At this stage, the volume of data produced and consumed by the enterprise will sharply increase. Also, the enterprise will become a digital enterprise.

[F] Digital Transformation (strategic): This stage focuses on the long-term goal of transforming the outcomes and value that the enterprise delivers to the market and its constituents.

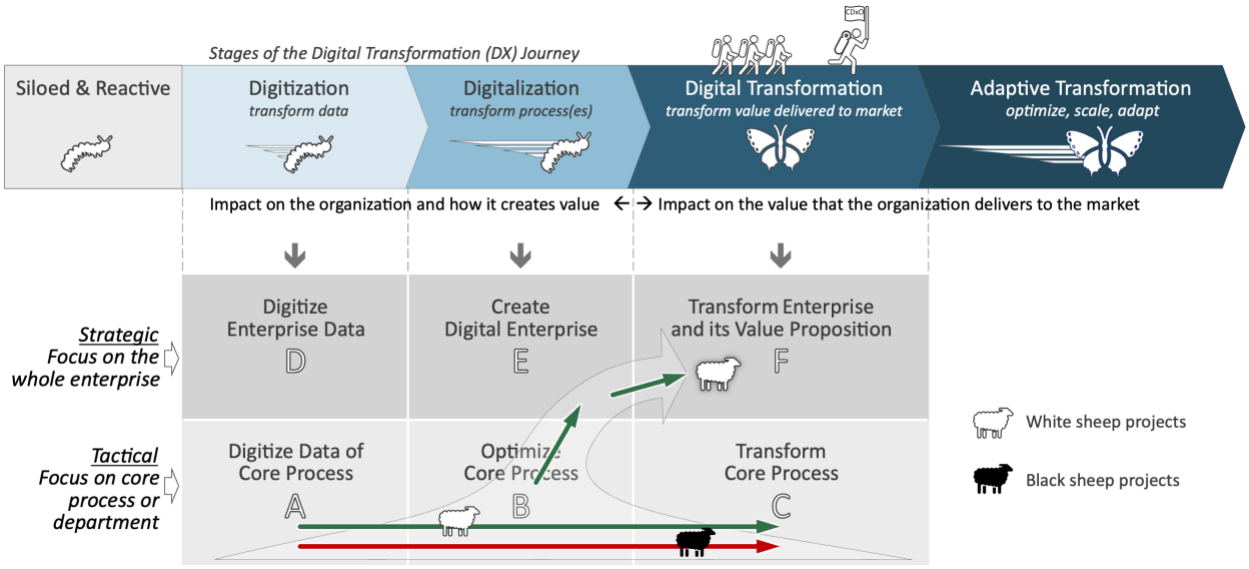

Figure 4-1: Digital transformation, Strategic vs Tactical (Source: IIC.)

Tactical and strategic (enterprise) DX initiatives often advance in parallel, raising concerns about their relationships, interdependence and required coordination. Enterprise DX initiatives require a deeper reflection about a wider range of considerations than tactical DX initiatives require.

4.1 Strategic DX Initiatives

For large organizations, the scale and complexity of challenges may necessitate a comprehensive and adaptive strategy that reshapes the whole enterprise, including its business models, structures, and processes. Given the dynamic and often unpredictable nature of market

conditions, a robust DX strategy must be malleable, incremental, and continuously learning and evolving, enabling organizations to navigate uncertainties effectively:

- Transition offering from being based on Capital Expenditure (CAPEX) to a product-as-a-service based on Operational Expenses (OPEX), or hybrid, to secure steady, long-term revenue, and align with shifting customer preferences,
- Foster a culture of innovation, transformation and continuous learning by embedding digital DNA across the enterprise, supporting efforts at all levels,
- Deliver seamless customer experience across physical and digital touch points,
- Leverage artificial intelligence (AI) and analytics tools to uncover deep insights into customer needs and new growth opportunities.

4.1.1 DX VIEWPOINTS

We provide an overview of the considerations, critical factors, strategic approach, organizational changes, and implementation roadmap that should be taken into account within such a methodology. In order to describe strategic DX initiatives in a structured way, this framework uses architectural viewpoints, based on the IIC Industrial Internet Reference Architecture[10], which is inspired by the ISO/IEC/IEEE 42010:2011[11] standard. Stakeholders, whether internal individuals and teams, or external organizations, play a key role in these viewpoints.

Business Viewpoints

This viewpoint addresses stakeholder goals to align DX initiatives with their enterprise vision, business strategy, values, and outcomes:

Internal & External Drivers: Identify business forces driving transformation such as increased competition, threats from digital native entrants, supply chain pressures, and cost optimization needs. Evaluate if technology solutions alone can address these challenges.

Scope of Transformation: Define target business models, new value-delivery methods, internal processes optimizations to maximize Return on Investment (ROI). Set clear success criteria (targets, timeline) with Key Performance Indicators (KPIs).

Business Strategy: Define a digital-driven strategy with well-defined objectives, clear investment levels and measurable ROI targets. Ensure alignment with internal and external drivers, while establishing the necessary organizational maturity to execute and sustain strategy.

Legal & Regulatory Drivers: Evaluate how legal and regulatory requirements across jurisdictions influence the business transformation strategy.

Innovation Strategy: Discover untapped markets or innovative opportunities aligned with the initiative. Establish innovative business models, processes, and value propositions to secure a competitive edge.

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[10] IIC: Industrial Internet Reference Architecture - *https://www.iiconsortium.org/wp-content/uploads/sites/2/2022/11/IIRA-v1.10.pdf*

[11] ISO/IEC/IEEE 42010:211 standard - *https://www.iso.org/standard/50508.html*

Executive Sponsorship: Designate a C-level executive sponsor to define the vision and mandate, ensure engagement, empower a team to execute the DX strategy, and measure its progress.

Enterprise DX Program: Treat the Enterprise DX initiative as a structured program and not a project. Develop a mission, define phases, assign an empowered executive to lead its execution, and establish clear reporting guidelines.

Risk Management: Mitigate risks related to business, technical, finance, change management and organizational maturity.

Usage Viewpoints

This viewpoint focuses on stakeholder concerns about priorities, team coordination, and improving customer experience and adapting them to evolving needs:

Stakeholders: Map internal and external ecosystem stakeholders, along with their viewpoints, concerns, and maturity levels.

End-user Feedback: Incorporate a virtuous cycle where end-user feedback on products and services drives continuous improvement and innovation, ensuring alignment with evolving needs and fostering sustained engagement.

Think Big, Start Small: Begin with tactical projects targeting specific processes. Validate their proof-of-value, learn and scale.

Collaborate, Coordinate: Define collaboration protocols across internal teams, existing DX teams, and external ecosystem partners.

Adaptive Systems: Develop innovative customer-centric solutions with adaptability to evolving technologies and user needs. Leverage customer feedback for continuous improvements.

Data Viewpoints

This viewpoint emphasizes data's strategic value, governance and lifecycle in the enterprise:

Data Analytics: Use advanced AI and analytics tools to gain deeper and actionable insights.

Data Governance: Implement value-based data lifecycle management using methods that address the transactions, operations, business needs, and compliance tracks of the data lifecycle.

Data Value: Develop a framework for understanding and evaluating the value of enterprise data assets: tangible/intangible, present/future. Emphasize the critical role of data in the Digital Enterprise and its ability to create value.[12]

[12] Unlocking the Full Potential of Enterprise Data: Managing Valuable Data Assets Through Their Lifecycles - *https://www.objectmanagementgroup.org/wp-content/uploads/sites/8/2025/02/JOI_20250204_3_Unlocking_the_Full_Potential_of_Enterprise_Data_Standalone.pdf*

Functional Viewpoints

This viewpoint examines enabling technologies, IT/OT convergence, and organization and talent realignment:

Enabling Technologies: Assess emerging and emergent technologies critical to DX (example AI, IoT, digital twins, XR), focusing on those that can redefine capabilities. Evaluate the maturity levels of these technologies, and the organization's readiness to adopt them.

Challenges of the IT/OT Divide: Align OT priorities (safety, reliability, resilience) with IT priorities (security, privacy) and explore opportunities for their integration. Foster a culture and implement best practices to bridge the IT/OT divide effectively.

Organizational Realignment: Implement a talent development program and leverage external expertise to meet DX demands.

Security Viewpoints

This viewpoint addresses stakeholder concerns regarding security challenges[13] arising from DX initiatives, particularly digitization and digitalization efforts involving physical assets and their associated data:

Trustworthiness in DX: Prioritize reliability, safety, privacy, and operational efficiency in projects leveraging digital twins, AI, and IoT technologies.

Brownfield Deployments: Strengthen resilience and security by retrofitting legacy systems and addressing inherent vulnerabilities.

Greenfield Designs: Embed security from the initial design phase, focusing on robust data protection, secure communication, and system resilience.

Key Security Measures: Implement strong endpoint protection, cryptographic safeguards for data and communication, and stringent identity management protocols.

IT/OT Integration: Bridge security considerations across IT/OT systems for seamless protection.

Compliance: Maintain adherence to evolving regulatory standards and requirements.

Securing Supply Chains: Safeguard end-to-end supply chains by monitoring vulnerabilities, ensuring third-party compliance, protecting data exchanges, and preventing cyber threats that affect integrity and reliability.[14]

Continuous Efforts: Conduct ongoing security monitoring, risk assessments, and lifecycle management to proactively address threats and ensure system integrity.

[13] IIC Industry Internet Security Framework 2.0 - *https://www.iiconsortium.org/iisf/*

[14] MITRE: System of Trust Framework - *https://sot.mitre.org/framework/system_of_trust.html*

Implementation Viewpoints

This viewpoint addresses the roadmap, execution, and tactical alignment of DX initiatives:

Transformation Timeline: Define start points, execution timelines, and key milestones.

Enterprise OT systems: Align OT systems with expected DX-driven changes to maximize value.

Tactical Project Alignment: Integrate tactical DX initiatives into the Enterprise DX strategy. Identify beneficial projects (*white sheep*) and address challenges of less-aligned projects (*black sheep*) with mitigation strategies. Refer to Section 4.1.2 for details.

Rapid Prototyping: Foster a culture of rapid prototyping and experimentation to test innovative ideas and embrace "fail fast" principles.

Continuous Monitoring: Implement frameworks to track progress and re-align execution.

4.1.2 WHITE SHEEP VS BLACK SHEEP INITIATIVES

Managing tactical DX initiatives can be challenging, particularly when some are misaligned with the DX strategy, its objectives, budget, or resources. Some initiatives may even predate the enterprise strategy itself. As shown in Figure 4-1, aligned and misaligned tactical DX initiatives are represented as *white sheep* and *black sheep*. Initiatives deemed *white sheep* align well with the DX strategy, contributing positively to its goals. In contrast, *black sheep* initiatives are misaligned—even conflict—with strategic DX objectives, priorities, budget constraints, or resource allocations, thereby risking the success of the overall transformation. The enterprise should adopt a structured approach for dealing with these DX initiatives:

Comprehensive Assessment: Evaluate tactical DX initiatives for alignment with DX strategy, focusing on strategic objectives, value contribution, and resource impact.

Prioritization and Guidelines: Create clear evaluation guidelines to support objective decision-making. Prioritize *white sheep* projects that promise high value and resource efficiency. Assess *black sheep* projects individually for their relevance and impact on enterprise goals.

Strategic Adjustments: Realign tactical DX projects to align with enterprise goals. Assess Adjust *black sheep* projects and in the extreme case consider discontinuing them. Use lessons learned from *black sheep* projects to enhance future planning and improve alignment processes.

Business Executives and technical leaders should foster a unified transformation framework by aligning tactical and strategic initiatives through proactive collaboration and frequent priority reassessments. Addressing *black sheep* challenges while strengthening *white sheep* initiatives ensures a cohesive and impactful DX strategy.

4.1.3 ENTERPRISE DX PROGRAM

Enterprise DX requires a structured program, not just isolated technology-driven projects. The program requires long-term thinking, innovative strategies, and careful analysis, often encompassing multiple projects under a unified mission.

Structure and Mission

The Enterprise DX program requires a clear mission statement, a permanent structure, and leadership and governance frameworks. It must align with strategic goals through a multi-project roadmap while balancing the top-down strategic vision with practical and bottom-up realities, including market conditions, resources availability, and technology and organizational maturity. The program should integrate with other enterprise initiatives, for example carbon emissions reduction and reporting. Refer to Section 4.4.3.

Program Requirements	Details
Transform DX vision into strategy and roadmap	Clear, pragmatic, and actionable roadmap
Align organization's digital maturity level with the transformation objectives	Maturity level of technologies under consideration
Identify innovation opportunities and potential	Without innovation, DX projects lack strategic vision and differentiation
Adopt a lean start approach to navigate uncharted areas	For example, design, business, and competition feasibility
Lead cross-functional teams through the DX journey	Internal stakeholders, tactical DX project teams, external ecosystem stakeholders
Drive execution while maintaining balance between strategic goals and tactical realities	Middle-out: Alignment between top-down vision and bottom-up DX projects and their realities
Develop a change management plan	Address cultural and organizational adjustments
Identify budget requirements	Also oversee ROI objectives
Categorize tactical DX projects (*white sheep*) according to their transformational potential	Including adjacent/marginal advances they contribute to DX strategy
Identify *black sheep* projects	Develop mitigation strategies for them
Define metrics for measuring program's progress and success	It is important to have a clear definition of success.
Implement governance, communication and risk mitigation strategies	This is a key responsibility of the leader of the DX initiative.
Continuously adapt strategies based on emerging challenges and opportunities	Foster agility and resilience to efficiently respond to market dynamics and technological advancements.

Table 4-1: Enterprise DX program scope. (Source: IGnPower.)

Executive Sponsor

Strong executive sponsorship is essential for the continued success of the Enterprise DX initiative. The C-level executive sponsor must define the overall vision, identify the strategic issues (business) facing the organization and outline the scope and timeframe of the transformational outcomes needed to address them.

Internal responsibility: Mandate (business objectives, timeframes, ROI targets, etc.) and empower the DX Program team to execute on the enterprise DX initiative. Resolve political issues within the organization. Preventing DX fatigue and maintaining sponsor engagement is crucial to the success of the enterprise DX initiative.

External responsibility: Provide public commitment to the DX initiative and its goals, with significant impact on corporate image and stock valuation.

Enterprise DX Program Team

The program team responsible for the execution of the DX initiative must include internal stakeholders, such as business leaders, operations managers, IT, OT, security, sustainability, leaders of ongoing tactical DX project teams, and external ecosystem stakeholders. Ideally, the leader of the program team should be an executive-level professional mandated and empowered by the executive sponsor to implement and execute the enterprise DX strategy.

This individual should possess a broad range of skills and experience, including:

- Understanding of market DX drivers,
- Deep knowledge of enterprise DX concepts and methodologies,
- Awareness of business model and technical innovation processes, including the disruptive potential of emerging and emergent digital technologies, especially AI,
- Recognizing the impacts of transformation on the ecosystem,
- Navigating the IT/OT convergence challenges,
- Understanding of digital enterprise dynamics and the value of enterprise data assets,
- Developing a DX roadmap in alignment with enterprise DX organizational goals,
- Awareness of sustainability and ethical objectives,
- Maintaining north-south communication across the DX initiative layers, including engaging in executive-level communication to maintain sponsor involvement, and providing guidance to tactical DX teams to align them with the enterprise DX vision.

In larger organizations, an internal candidate is often preferred as a leader due to their familiarity with the organization's structure, dynamics, culture, history and internal politics. If such expertise is unavailable, organizations should consider engaging an external advisor as a sherpa and servant leader. This advisor may assist in specific tasks (e.g. developing a DX roadmap) or offer broader advisory services over extended periods.

4.2 TACTICAL DX INITIATIVES

Most DX initiatives are not strategic in nature. They are more tactical in nature, focusing on specific, narrowly scoped areas within an organization. These initiatives address immediate operational challenges, improve efficiency, and deliver measurable value across domains such as production lines, processes, departments, or product offerings. They are particularly effective for tackling pressing issues and driving improvements on a smaller, more manageable scale. Tactical DX initiatives follow similar frameworks as strategic DX initiatives:

- Digitization: Converting process data into digital formats,
- Digitalization: Digitizing and optimizing a specific process, and integrating it with other workflows to streamline operations,
- Digital Transformation: Enhancing process-level outcomes to deliver to greater value to stakeholders through innovations in services, products, and operations.

Tactical DX initiatives often serve as testing grounds for digital technologies, offering valuable insights and lessons before scaling to strategic transformation. Their narrow scope enables rapid execution and focused investments. Coordination with broader strategic DX initiatives ensures cohesive progress, positioning them as catalysts for adopting digital and AI-driven innovation across the organization. Tactical DX initiatives foster innovation on a smaller scale while aligning with enterprise goals, serving as key components of a balanced and effective DX strategy. Refer to Section 4.1.2 on *white sheep* vs *black sheep* initiatives.

Sections 4.1 and 4.2 have described different types of DX initiatives and outlined the essential preparation steps for executing them. These sections have also emphasized the importance of adopting innovative and comprehensive approaches to align enterprise objectives with overarching long-term business strategies, while optimizing resource allocation to achieve the transformational impact of tactical initiatives.

4.3 Enabling Role of Technology

DX is driven by emerging and emergent, digital and connected technologies like digital twins, AI, IoT, edge devices, distributed ledger, extended reality (XR), hyperconnectivity (e.g., 5G, 6G), unmanned aerial vehicles (UAVs), and robotics. Some of these technologies target specific applications, while others have broad use cases. They enable innovation across domains, improve service delivery, open new revenue streams, and enhance customer satisfaction.

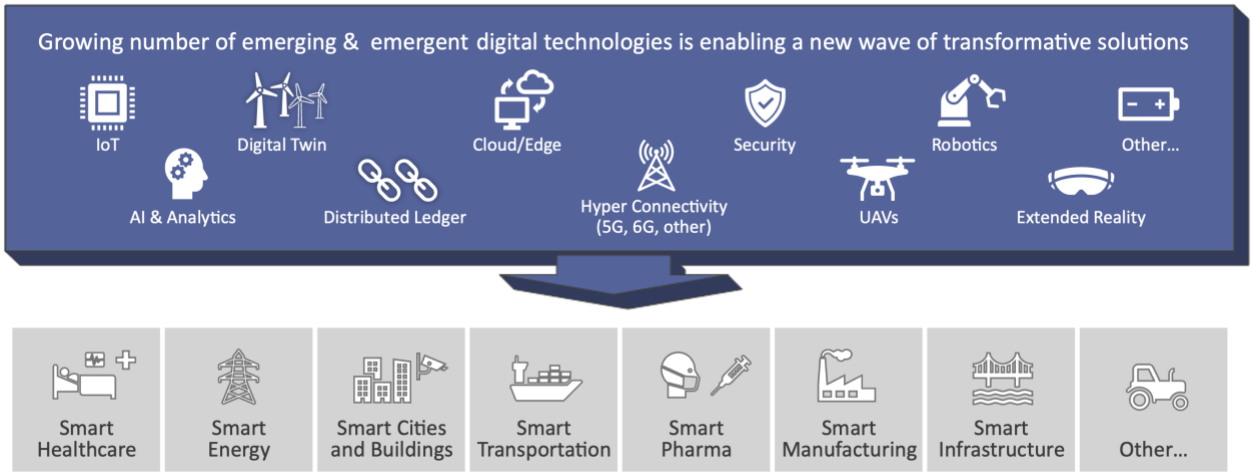

Figure 4-2: Emerging & emergent digital technologies are enabling transformative solutions.

This section discusses the role of three key technologies as well as that of the concept of Digital Engineering. A detailed description of these technologies and their capabilities is beyond the scope of this framework.

4.3.1 DIGITAL TWINS

The Digital Twin Consortium (DTC) defines[15] the digital twin as *an integrated data-driven virtual representation of real-world entities and processes, with synchronized interaction at a specified frequency and fidelity. Digital twins are motivated by outcomes, driven by use cases, powered by integration, built on data, enhanced by physics, guided by domain knowledge, and implemented in dependable and trustworthy IT/OT/ET systems.*

As stated in the DTC Platform Stack Architectural Framework[16], two concepts in the above definition inform an architecture:

- Entities and processes: the approach needs to be applicable to building digital twins of both physical systems and logical processes and often needs to accommodate both.
- Synchronization: there needs to be a mechanism for enabling and controlling this key qualifying element.

The definition is further elaborated with three points. Digital twin systems transform business by accelerating holistic understanding, optimal decision-making and effective action. They use real-time and historical data to represent the past and present and simulate predicted futures. Finally, digital twins are motivated by outcomes, tailored to use cases, powered by integration, built on data, guided by domain knowledge and implemented in IT/OT systems.

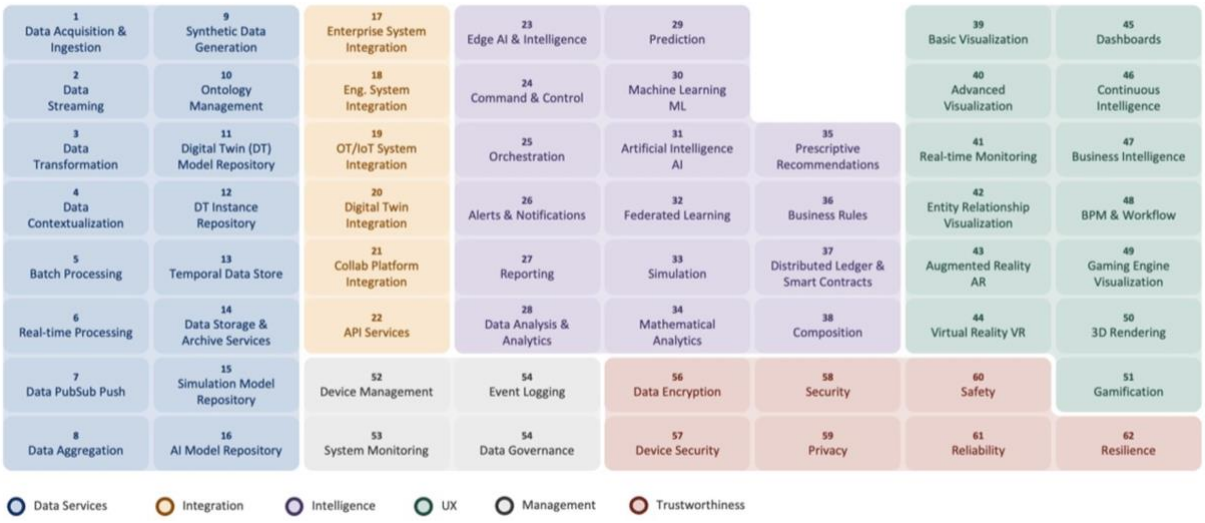

Figure 4-3: Digital Twin Capabilities Periodic Table. (Source: Digital Twin Consortium.)

The DTC Digital Twin Capabilities Periodic Table[17] (CPT) guides organizations in designing, developing, deploying, and operating digital twins based on capability requirements. It uses a periodic table approach, that clusters capabilities around six high level categories: data services, integration, intelligence, user experience, management and trustworthiness.

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15 DTC definition of digital twins - *https://www.digitaltwinconsortium.org/glossary/glossary/#digital-twin*

16 DTC Platform Stack Architectural Framework - *https://www.digitaltwinconsortium.org/wp-content/uploads/sites/3/2023/07/Platform-Stack-Architectural-Framework.pdf*

17 DTC Digital Twin Capabilities Periodic Table - *https://www.digitaltwinconsortium.org/initiatives/capabilities-periodic-table/*

CPT supports executive strategic planning and funding deliberations, as well as shopfloor discussions when gathering requirements for digital twin-based applications. It provides visual guidance for collaboration, brainstorming, and making capability requirements explicit. Critically, CPT is key for defining how digital twin capabilities enable DX.

Digital twin systems transform business by accelerating and automating holistic understanding, continuous improvement, decision-making, and interventions through effective action. Digital twins enable DX through the following capabilities:

- *Virtual Modeling:* Using models and simulations they replicate real-world assets, enabling testing and optimization in virtual environments before physical implementation,
- *Bidirectional Data Flow:* Real-time data exchange between physical assets and digital twins ensures accuracy and provides live representation of physical systems,
- *Scenario Simulation:* They simulate "what-if" scenarios to predict outcomes of different strategies, enabling risk-free experimentation and data-driven decisions,
- *Behavior Prediction:* Pattern analysis and behavior forecast of assets over time supports predictive maintenance, resource optimization, and performance improvement, and
- *Integration with IoT and AI:* Digital twins often leverage IoT for real-time data and AI for advanced analytics to provide deeper insights, smarter operations, and personalized customer experiences, all essential elements of DX.

4.3.2 ARTIFICIAL INTELLIGENCE

AI is a foundational enabler of DX, excelling at analyzing large datasets to generate actionable insights, automate complex tasks and drive innovation and optimization at a large scale. Generative AI accelerates DX by automating the creation of innovative prototype designs, content, and real-world scenario simulations, shortening product development cycles and enhancing customer experiences. Autonomous AI agents[18, 19] amplify this impact by dynamically managing intricate actions and tasks such as supply chain optimization and predictive maintenance. AI capabilities span a range of technologies:

- *Machine Learning Models* learn from historical and real-time data to identify trends and improve predictions,
- *Natural Language Processing* powers human-like chatbots and sentiment analysis by understanding human-like language,
- *Computer Vision* processes visual data, detects defects, and tracks inventory,
- *Predictive Analytics* forecasts outcomes for better planning and resource utilization,
- *Generative AI* fosters innovation, reduces complexity of repetitive operational tasks, and
- *Agentic AI* adapts dynamically to changing conditions and drives business agility and operational efficiency.

[18] Forbes: AI Agents are Accelerating Digital Transformation - *https://www.forbes.com/sites/timothypapandreou/2024/10/11/ai-agents-are-accelerating-digital-transformation-are-you-ready/*

[19] Forbes: AI Agents in 2025 - *https://www.forbes.com/councils/forbestechcouncil/2025/03/07/ai-agents-in-2025-transforming-business-redefining-leadership-and-accelerating-digital-transformation/*

By embedding AI across processes, businesses can achieve significant transformative benefits[20]. Its ability to analyze data and extract actionable insights enables organizations to transition to data-driven decision-making, real-time monitoring, and innovative and personalized customer interaction at scale. AI empowers businesses to deliver tailored recommendations, drastically redefining dynamic engagement and customer value.

4.3.3 INTERNET OF THINGS (IOT)

Another critical enabler of DX is IoT technology which connects physical assets to digital networks via sensors, devices, and systems that share real-time data. IoT connectivity across ecosystems enables advanced real-time monitoring, asset control and management. This drives efficiency, resource optimization, and solutions like intelligent automation, predictive maintenance, and product-as-a-service models.

Combined with AI and analytics, IoT enables data-driven decision-making through actionable insights. For example, cities can use IoT to optimize infrastructure, reduce energy consumption, and ultimately transform urban management.

IoT enables transformation through distinct features and capabilities:

- *Sensors-generated and Real-Time Environmental and Operational Data* inform smarter decisions and timely interventions,
- *Edge Computing* enables the processing of data locally to reduce latency and dependence on centralized and cloud-based systems, enabling fast responses for critical applications like safety monitoring,
- *Connectivity and Interoperability* seamlessly integrate with green-field and brown-field systems via standard communication protocols (e.g., Wi-Fi, 5G), and
- *Automation and Actuation* translate insights into actions on processes, such as opening valves or adjusting controls. For example, IoT-powered systems can streamline logistics, optimize resource allocation, and enable innovative business models.

Integration of digital twins, AI, and IoT: DX-enabling technologies can be deployed individually or combined, based on the use case specifics and objectives. The integration of digital twins, AI, and IoT creates unparalleled transformational synergy, enabling connected ecosystems that evolve continuously through data-driven insights. This integration powers advanced capabilities like real-time insights, performance analysis, simulation, advanced automation, business agility, operational optimization, and predictive maintenance. These technologies are foundational for transformative solutions such as product-as-a-service models, redefining customer value and efficiency. By bridging digital and physical realms, they offer dynamic intelligent systems that drive innovation and business agility, reshaping whole industries.

[20] Harvard Business School: Role of AI in Digital Transformation - *https://online.hbs.edu/blog/post/ai-digital-transformation*

4.3.4 DIGITAL ENGINEERING

Digital Engineering[21] is closely associated with digital twins, offering an integrated approach to engineering that leverages digital tools, models, and data to design, develop, and sustain complex systems. Digital twins are central to this approach, serving as authoritative sources of truth throughout product and system lifecycles, while improving stakeholder collaboration, decision-making, and process efficiency.

Digital Engineering impacts key areas of an enterprise:

- Product Development: Speeds up design and prototyping with simulations and modeling,
- Manufacturing: Improves production using predictive analytics and real-time monitoring,
- Supply Chain: Enhances visibility and efficiency through digital twins and IoT integration,
- Customer Experience: Enhances product quality and user-centered designs, and
- Workforce: Requires upskilling to adapt to new digital tools and methodologies.

Digital Engineering is a key enabler of DX. DX focuses on integrating digital technologies across business processes to enhance efficiency and innovation, while Digital Engineering provides the technical foundation for this transformation. For instance, it uses digital twins and AI-driven simulations to support the focus of DX on agility, nimbleness and data-driven decision making.

Digital Engineering also underpins the Digital Enterprise concept via its full integration of digital technologies into operations and the provision of tools and methodologies to digitize engineering processes. Digital Engineering is often led by the CTO or a direct report. This leader must collaborate closely with the DX leader to ensure alignment and impactful outcomes.

4.3.5 BROWNFIELD ENVIRONMENTS

Deploying digital twin, AI, and IoT technologies in brownfield environments dominated by legacy systems presents significant challenges, particularly in DX scenarios where integration complexities are amplified.

Digital twin implementations often require extensive retrofitting of sensors on legacy equipment for real-time data collection. The complexity of integration platforms with older systems can strain infrastructure and data integration capabilities, while challenges in demonstrating ROI, further slows adoption. Solutions may include middleware to facilitate integration, leveraging scalable platforms for real-time data processing. Pilot projects can highlight tangible benefits, and training programs can enhance team readiness for simulation-driven operations.

AI deployment faces challenges with fragmented datasets and inconsistent data quality from legacy systems, reducing model effectiveness. Older infrastructure may lack the capacity to support AI workloads, while operational disruptions during integration can create resistance among teams. Addressing these challenges involves cleaning and preparing data, leveraging

[21] Digital Engineering, US DoD Instruction 5000.97 - *https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodi/500097p.PDF?ver=bePIqKXaLUTK_Iu5iTNREw%3d%3d*

cloud-based AI platforms to bypass infrastructure limitations, and starting with practical, non-intrusive use cases like predictive maintenance.

IoT implementations bring technical difficulties like retrofitting older machinery, ensuring interoperability with existing systems, and addressing expected IoT data volumes. Security concerns and high retrofitting costs create additional organizational barriers. Effective strategies include using IoT technologies designed for retrofitting, adopting edge computing for local data processing, and starting with pilot projects to demonstrate measurable outcomes.

Implementing digital twin, AI, and IoT together in brownfield environments compounds these challenges. Achieving seamless integration and interoperability across technologies while accommodating the constraints of legacy systems remains a core technical priority. Data format compatibility and platform interoperability are essential to ensuring the smooth functioning of systems. Resistance to large-scale changes and limited expertise in managing interdependencies of these technologies are common hurdles. To overcome these, organizations should establish unified integration frameworks, use standardized data formats, and adopt phased and incremental rollouts.

4.4 FOSTERING INTERNAL SYNERGY

Effective DX requires understanding enterprise realities, addressing organizational complexities, and managing external uncertainties. Top-down, bottom-up, and middle-out program management approaches foster diverse perspectives and ensure broad engagement, particularly from the executive sponsor. Strategic foresight is vital for tackling brownfield challenges and aligning DX efforts with other enterprise initiatives.

4.4.1 TOP-DOWN, BOTTOM-UP, MIDDLE-OUT

DX goals must have a bold vision that is defined in business terms and not in technology implementation terms. One of the core responsibilities of the DX program team is to maintain a balance between the bold strategic vision and the pragmatic reality about the organization's ability to transform and how rapidly:

Top-down: Strategic DX vision, executive sponsorship, corporate vision, new business models, ROI objectives, time horizon, investment level, mandate, empowerment, and more.

Middle-out: Implementing the DX Program, mission statement, program leadership, cross-functional stakeholders, program management, tangible roadmap, risk management, program KPIs, executive communication, and more.

Bottom-up: Implement tactical DX projects, scope, project management, process transformation, alignment with program objectives, project oversight, project KPIs, and more.

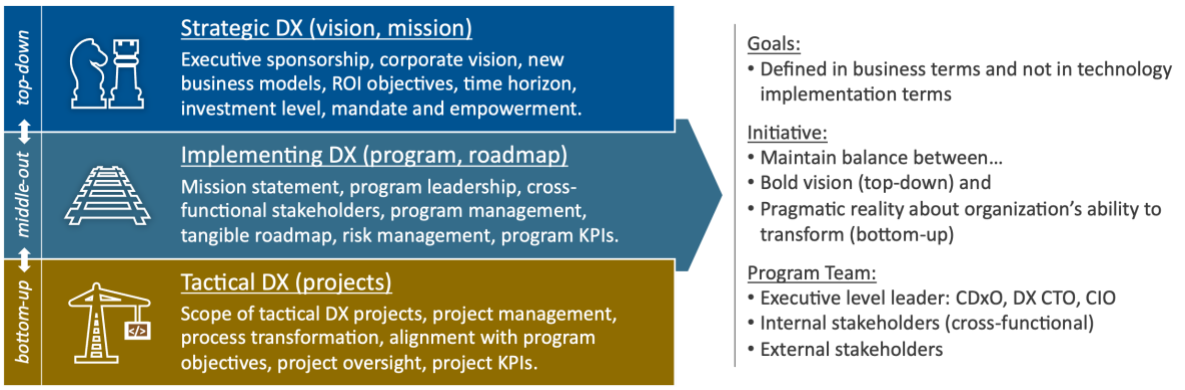

Figure 4-4: DX approaches - top-down, bottom-up, and middle-out. (Source: IIC.)

An in-depth description of the methodology for assessing and analyzing the multifaceted challenges facing an enterprise, as well as crafting and framing an innovative vision to address them and execute them will be detailed in future documents.

4.4.2 Dealing with Enterprise Realities & Market Uncertainties

When defining a DX vision and setting its execution priorities, organizations must consider their specific unique characteristics and realities:

- Corporate size, structure, regional distribution, industry verticals,
- Competitive landscape: disruption by emerging and emergent digital technologies and digital native competitors to business models
- Prioritization across other initiatives and projects,
- Workforce skillset, maturity and costs,
- Readiness and maturity of physical and equipment infrastructure, and
- Maturity of IT, OT, software, and data infrastructures.

Organizations must acknowledge that change and uncertainty are inherent in their environments and market conditions. To navigate these dynamic challenges, a robust DX strategy should adopt a discovery-driven and learning-oriented planning approach. This strategy should emphasize continuous interaction, enabling organizations to refine their understanding of shifting conditions and make informed adjustments.

An adaptive DX strategy requires mechanisms for ongoing assessment and feedback, allowing enterprises to adjust their strategies and roadmaps in response to emerging trends, new technologies, or unforeseen disruptions. The ability to pivot and evolve is critical for staying competitive and relevant.

In industrialized economies, DX initiatives often leverage skilled yet high-cost workforces and accumulated digitization and digitalization efforts. These efforts create new external outcomes–tangible value delivered to customers, markets and stakeholders.

In underdeveloped economies, where workforces are less skilled by also less costly, organizations generally have low levels of accumulated digitization and digitalization. Success in these economies hinges on prioritizing the creation of innovative external outcomes. The resulting DX is thus expected to be different from the one in industrialized economies and efforts to digitize and digitalize internal processes should be implemented in order to draw out the innovative external outcomes. Frugal innovation approaches[22, 23] can be particularly effective in driving DX. Developing economies generally require a balanced approach, tailored to their specific circumstances and needs.

4.4.3 Aligning with other Enterprise Initiatives

Beyond DX, organizations often run parallel initiatives like safety compliance, carbon emission reporting and reduction, material circularity, and other strategic programs. These efforts compete for limited resources, like skilled personnel, budget allocations, and time. Consequently, DX initiatives must compete with these programs for prioritization and resource allocation, creating potential conflicts or delays.

To address these challenges, DX program teams should collaborate with other program teams to set clear priorities and manage resource overlaps. This may include creating a unified roadmap aligning DX objectives with broader organizational goals, identifying synergies, and leveraging shared resources to maximize impact. For example, digital twins and IoT technologies developed under DX could also aid carbon emission tracking or enhance safety monitoring systems.

4.5 Implementing the DX Initiative

Before executing an enterprise DX strategy, organizations should evaluate the phased approach outlined below, ensuring alignment with their strategic goals and operational needs.

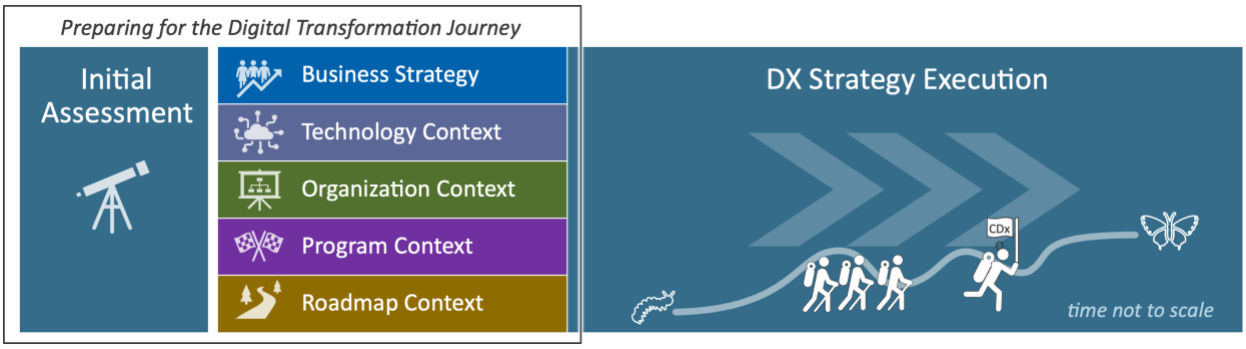

Figure 4-5: Implementing the digital transformation initiative. (Source: IGnPower.)

The table below outlines some of the important tasks in the preparation stages:

[22] Lim C, Lee JH, Sonthikorn P, Vongbunyong S. Frugal innovation and leapfrogging innovation approach to the Industry 4.0 challenge for a developing country. Asian Journal of Technology Innovation. 2021;29(1):87-108. *https://www.tandfonline.com/doi/abs/10.1080/19761597.2020.1786707*

[23] Springer: Frugal Innovation - *https://jfrugal.springeropen.com/articles/10.1186/s40669-016-0005-y*

Preparation Stage	Description
Initial DX Assessment	• Identify key market drivers and determine competitive positioning • Identify opportunities from disruptive technologies • Select core processes with most proximity to profits, stakeholders' priorities, and IT/OT convergence and integration challenges • Assess integration constraints existing in IT and OT infrastructures • Assess current data governance practices • Identify unmet needs using voice-of-the-customer insights • Identify stakeholders and their alignment requirements • Assess potential organizational resistance and financial constraints • Benchmark assessment accuracy
Define DX Business Strategy	• Build on assessment • Define transformational business models to address challenges • Explore digitization, digitalization, and DX approaches • Assess DX-enabling role of technologies and their business benefits • Develop the DX vision (think big/start small), ROI goals, and success metrics • Identify potential partnerships • Identify investment needs • Select key processes for proof-of-concept (POC), proof-of-value (POV) implementations and real customer use-cases.
Define Technology Context	• Build on business strategy • Evaluate and select enabling technologies to be used: suitability, necessity, maturity, scalability, etc. • Align innovative technical solutions with business strategy • Address considerations around DX-enabling technologies: usage, functional, implementation, trustworthiness, compliance, etc. • Assess the impact on core processes • Evaluate the impact of technologies on sustainability • Outline the technical aspects of IT/OT convergence
Define Organizational Context	• Build on business strategy • Appoint leaders to drive transformation • Address resistance to change and foster adaptability • Close skill gaps through training • Promote digital-first culture, innovation, advocacy and collaboration • Update workflow metrics • Implement agile strategies and change management to reduce inefficiency
Define DX Program Context	• Build on business strategy • Transform the DX vision into strategic program and clear roadmap • Validate ROI and investment needs • Align top-down and bottom-up (project centric) DX activities • Establish feedback mechanisms • Define communication strategy: executive sponsor, internal stakeholders, ecosystem stakeholders • Monitor and sustain engagement of executive sponsor
Define Roadmap Context	• Build on the above steps • Outline strategic milestones with achievable timeframes

Preparation Stage	Description
	• Prioritize projects based on ROI objectives, stakeholder impact, alignment with business strategy, and potential for scalability • Create phased plan to integrate DX-enabling technologies into core processes while addressing IT/OT convergence challenges • Identify risks and mitigation strategies associated with implementation • Develop risk mitigation strategies for black sheep and white sheep projects • Allocate resources strategically, ensuring roadmap goals are met efficiently • Establish KPIs and success metrics that align with roadmap goals

Table 4-2: Implementing the digital transformation initiative. (Source: IGnPower.)

The preparation steps outlined in this table serve as general guidance. These steps should be adapted to align with the organization's type, size, industry, market conditions, and the vision of the DX initiative—whether strategic or tactical. Future papers will offer detailed insights and practical guidance for the subsequent roadmap implementation phase.

5 Conclusions And Final Thoughts

The Industry DX Framework is a critical guide for organizations tackling the complexities of DX. It empowers them to leverage emerging and emergent technologies and bridge the IT/OT divide.

The framework emphasizes innovation and maps the path to creating transformative solutions that meet customer and stakeholder needs, enhance service delivery, unlock new revenue streams and improve customer satisfaction. It underscores the relationship between tactical and enterprise DX strategies and emphasizes the importance of aligning the former with the latter in order to achieve cohesive transformation. It provides a structured pathway for enterprises to realize their DX vision, whether tactical or strategic, helping them to innovate and transform efficiently and effectively.

Embracing DX is a necessity for future success. By leveraging innovative technologies and aligning strategic and tactical initiatives, organizations can unlock new opportunities, drive growth, improve ROI, and create lasting value. The journey may be challenging, but the rewards of a well-executed DX are immense, paving the way for a brighter, more resilient future.

6 Examples Of Digital Transformation

6.1 Blockbuster vs Netflix

This classic DX use case is not an industry use case, but it highlights the importance of anticipating the disruptive impact of digital and connected technologies and the need to innovate in order to create new outcomes and business models.

In the 1990s, Blockbuster thrived with its brick-and-mortar business model, renting out video tapes and DVDs. However, it failed to anticipate the disruptive power of technologies such as cloud computing and high-bandwidth internet. Netflix capitalized on these advancements, launching a convenient, affordable, unlimited streaming subscription model, quickly drawing customers away from Blockbuster[24, 25]. Netflix later enhanced customer engagement by offering personalized content suggestions using AI-driven recommendation engines. Blockbuster decline was irreversible, ending with bankruptcy by 2010.

6.2 OLD ROLLS ROYCE VS NEW ROLLS ROYCE (PROPULSION-AS-A-SERVICE)

Rolls-Royce's TotalCare® program offers long-term service agreement, ensuring predictable and reliable engine maintenance, repair, and overhaul (MRO) services to airlines. It shifts time-on-wing and maintenance cost risks back to Rolls-Royce, benefiting jet engine operators[26, 27].

Key Features:

- Advanced engine health and performance monitoring to support proactive maintenance and reducing downtime,
- Comprehensive off-wing repair and overhaul through Rolls-Royce's extensive global service network,
- Predictable cost per engine flying hour to improve budget management,
- Rolls-Royce's high standards expertise and global reach to enhance aircraft availability, reliability, and operational efficiency,
- Transfers both time-on-wing and shop visit cost risks back to Rolls-Royce, providing airlines with peace of mind and operational certainty.

Benefits:

- Aircraft with TotalCare® are more valuable and marketable due to well-documented and predictable maintenance histories,
- Operational Efficiency: Optimized engine performance minimizing unplanned maintenance and improving efficiency,
- Flexibility: Offers flexibility for long-term agreements, catering to different airline needs.

[24] Netflix surpasses Blockbuster market share in 2004 (Forbes) *https://www.forbes.com/sites/garydrenik/2018/09/04/how-netflix-beat-blockbuster-an-exemplar-of-emerging-technologies-and-changing-business-models*

[25] 7.5 million subscribers by 2007 (Statista 2023) *https://www.statista.com/statistics/250934/quarterly-number-of-netflix-streaming-subscribers-worldwide/*

[26] ALS selects Rolls-Royce TotalCare® for engine servicing *https://www.rolls-royce.com/media/press-releases/2019/20-11-19-rr-als-confirms-selection-of-rolls-royce-totalcare-for-engine-servicing.aspx*

[27] Example Jet-propulsion-as-a-Service offering from Rolls Royce *https://www.linkedin.com/pulse/rolls-royce-jet-propulsion-as-a-service-kristofer-hunt*

7 AUTHORS AND LEGAL NOTICE

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