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THE DRIVER OF INDUSTRY 4.0 DEVELOPMENT: THE KEY ROLE OF IT-SERVICE COMPANIES

The transition to Industry 4.0 signifies a transformative shift in manufacturing and industrial operations, driven by the convergence of advanced digital technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), digital twins, and smart automation. This fourth industrial revolution promises unprecedented improvements in operational efficiency, product quality, and overall productivity. However, the implementation of Industry 4.0 technologies is inherently complex, requiring significant expertise and coordination that many organizations lack internally. This article delves into the essential role of IT-service companies in enabling successful Industry 4.0 transformations. Through a comprehensive analysis of the service offerings and frameworks of seven leading IT-service providers—LTTS, Wipro, TCS, Cognizant, HCL Technologies, Accenture, and Capgemini— it is illustrated how these companies leverage their extensive experience and structured methodologies to support businesses in navigating the intricacies of digital integration. Each of these companies has developed robust frameworks and specialized solutions that encompass various aspects of Industry 4.0, including smart manufacturing, real-time data analytics, IoT integration, digital twins, and autonomous systems. The detailed comparison reveals that these IT-service providers bring critical advantages to the table: their ability to anticipate and mitigate potential pitfalls, their partnerships with technology giants like SAP and AWS, and their comprehensive approach to integrating digital and physical systems. By analyzing successful case studies, it is demonstrated how these companies have consistently delivered high-quality outcomes, optimized production processes, and achieved significant economic benefits for their clients. Conversely, the article also examines the challenges faced by organizations that attempt to undertake Industry 4.0 transformations without external support. These challenges include the high costs and extended timelines associated with building in-house expertise, the risk of implementation failures due to a lack of experience, and the difficulty in managing the complex integration of diverse technologies. In conclusion, this article underscores the critical importance of engaging experienced IT-service providers for Industry 4.0 initiatives. Their structured frameworks, extensive knowledge, and proven methodologies not only streamline the implementation process but also ensure that organizations can fully realize the transformative potential of Industry 4.0 technologies. By leveraging the expertise of these top IT-service companies, businesses can navigate the complexities of digital transformation with greater confidence and achieve substantial, sustainable economic benefits.

Key words: Industry 4.0, digital transformation, IT-service companies, IoT, AI, smart manufacturing, digital twins, operational efficiency.

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ДРАЙВЕР РОЗВИТКУ ІНДУСТРІЇ 4.0: КЛЮЧОВА РОЛЬ ІТ-СЕРВІСНИХ КОМПАНІЙ

Перехід до Індустрії 4.0 означає трансформаційний зсув у виробничих та промислових операціях, зумовлений конвергенцією передових цифрових технологій, таких як Інтернет речей (IoT), штучний інтелект (AI), цифрові двійники та розумна автоматизація. Ця четверта промислова революція обіцяє безпрецедентні покращення в операційній ефективності, якості продукції та загальній продуктивності. Однак впровадження технологій Індустрії 4.0 є складним завданням, що вимагає значного досвіду та координації, яких багато організацій не мають внутрішньо. Ця стаття досліджує важливу роль ІТ-сервісних компаній у забезпеченні успішних трансформацій до Індустрії 4.0. Через всебічний аналіз пропозицій та структур семи провідних ІТ-сервісних провайдерів — LTTS, Wipro, TCS, Cognizant, HCL Technologies, Accenture та Capgemini — ілюструється, як ці компанії використовують свій великий досвід та структуровані методології для підтримки бізнесу у навігації складнощами цифрової інтеграції. Кожна з цих компаній розробила надійні методики та спеціалізовані рішення, що охоплюють різні аспекти Індустрії 4.0, включаючи розумне виробництво, аналітику даних у реальному часі, інтеграцію IoT, цифрові двійники та автономні системи. Детальне порівняння показує, що ці ІТ-сервісні провайдери мають переваги: здатність передбачати та зменшувати потенційні ризики, їхні партнерства з технологічними гігантами, такими як SAP та AWS, а також їхній комплексний підхід до інтеграції цифрових та фізичних систем. Аналізуючи успішні кейси, демонструється, як ці компанії постійно забезпечують високоякісні результати, оптимізують виробничі процеси та досягають значних економічних вигод для своїх клієнтів. Навпаки, у статті також розглядаються виклики, з якими стикаються організації, що намагаються здійснити трансформації до Індустрії 4.0 без зовнішньої підтримки. Ці виклики включають високі витрати та подовжені терміни, пов'язані зі створенням внутрішнього досвіду, ризик невдач впровадження через відсутність досвіду та складнощі в управлінні інтеграцією різноманітних технологій. На завершення, ця стаття підкреслює критичну важливість залучення досвідчених ІТ-сервісних провайдерів для ініціатив Індустрії 4.0. Їхні структуровані рамки, значні знання та перевірені методології не лише спрощують процес впровадження, але й забезпечують, що організації можуть повністю реалізувати трансформаційний потенціал технологій Індустрії 4.0. Використовуючи досвід цих провідних ІТ-

сервісних компаній, бізнеси можуть впевненіше орієнтуватися у складнощах цифрової трансформації та досягати значних, сталих економічних вигод.

Ключові слова: Індустрія 4.0, цифрова трансформація, ІТ-сервісні компанії, IoT, AI, розумне виробництво, цифрові двійники, операційна ефективність

INTRODUCTION

The contemporary profound transformations of the global economy and society signify the onset of the fourth industrial revolution, characterized by the advancement of smart industry. Smart industry embodies a new paradigm of industrial development, emerging from the integration of digitalization, automation, and innovation within the manufacturing sector. These processes enhance production efficiency, competitiveness, and environmental sustainability, while also fostering the creation of new products and services that align with the needs and expectations of modern society [1]. In [2] smart industry is defined as a cyber-physical industry, the elements of which are interconnected in a network space (IoT) and controlled by AI using a digital twin system (integration of digital technology into industrial value chains). Indeed, the intellectualization or smartization of production and the integration of digital technologies into industrial value chains are considered key factors of the Fourth Industrial Revolution, which is transforming the conditions and rules of the global economy. The advent of Industry 4.0 marks a transformative era for manufacturing and industrial sectors, characterized by the integration of advanced digital technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), digital twins, and smart automation. This fourth industrial revolution promises significant improvements in operational efficiency, product quality, and overall productivity. However, the implementation of advanced Industry 4.0 technologies in many enterprises, including Ukrainian ones, is still in its early stages [4, 5].The complexity of implementing Industry 4.0 technologies presents considerable challenges for many organizations. IT-service companies play a pivotal role in facilitating these transformations. With their extensive experience and structured frameworks, these companies offer the necessary expertise to navigate the intricacies of digital integration. Leading IT-service providers, such as LTTS, Wipro, TCS, Cognizant, HCL Technologies, Accenture, and Capgemini, have developed comprehensive methodologies and robust solutions to support businesses in their Industry 4.0 journey. This article explores the critical role of IT-service companies in driving Industry 4.0 transformations. By analyzing the offerings and frameworks of seven industry leaders, article illustrates how their extensive experience, technological prowess, and strategic partnerships contribute to successful digital transformations. Article also highlight the potential challenges faced by organizations attempting to undertake these complex projects independently, underscoring the value of engaging experienced IT-service providers. Through a comparative analysis, it is demonstrated that the structured approaches of these companies not only streamline implementation but also ensure high-quality outcomes and significant economic benefits.

THEORETICAL BACKGROUND OF THE RESEARCH

Industry 4.0, or the Fourth Industrial Revolution, represents a transformative approach to manufacturing and industrial processes through the integration of advanced technologies. Key technologies underpinning Industry 4.0 include the Internet of Things (IoT), artificial intelligence (AI), machine learning, big data, robotics, and automation. These technologies collectively enhance operational efficiency, productivity, and flexibility in manufacturing and service sectors. Industry 4.0 aims to provide a significant improvement in cost-effectiveness. For instance, conceptual guidelines for optimizing costs in energy sector enterprises through systematic, informational, and project-based approaches are highly relevant to Industry 4.0 [1]. The focus on real-time data analysis, integration of advanced tools like WSJF and Six Sigma, and the goal of operational efficiency and sustainability align with the core principles of Industry 4.0. Another study focuses on key factors for selecting cost optimization projects and the plan to establish a PMO for better project coordination, which aligns well with Industry 4.0 principles. By integrating smart decision-making, real-time monitoring, and advanced data analytics, enterprises in the energy sector can enhance their cost optimization efforts [3, 7]. Additionally, research on the integration of reflexive management of herd behavior provides a solid foundation for Industry 4.0, offering a powerful approach to managing collective behavior within enterprises [8]. The transition of Ukrainian enterprises to a market economy requires flexibility, responsiveness, and continuous development, which are all key principles of Industry 4.0 [9]. A comprehensive investigation into the state, trends, and key drivers of the data integration services market analyzes the impact of Industry 4.0. It identifies the strategies of leading market players and outlines possible development scenarios for companies within this market [10-11]. The Internet of Things (IoT) and artificial intelligence (AI) play crucial roles in Industry 4.0 by enabling smart factories and predictive maintenance. IoT allows for seamless communication between devices and systems, while AI provides the capability to analyze large datasets and make informed decisions in real-time [12]. Big data and machine learning are fundamental to the analytical capabilities of Industry 4.0. These technologies facilitate the processing and analysis of vast amounts of data generated by industrial operations, leading to insights that drive efficiency and innovation [12, 13]. Cloud computing and edge computing technologies support Industry 4.0 by providing scalable computing resources and enabling real-time data processing closer to the data source. Cloud computing offers centralized data storage and analysis, while edge computing allows for decentralized processing, reducing latency and enhancing responsiveness [14]. IT-service companies play a vital role in implementing Industry 4.0 solutions by providing technological expertise,

infrastructure, and innovation. Blue Bird, a leading transportation service company in Indonesia, illustrates the transition IT-service companies undergo to adapt to Industry 4.0. By evolving their IT roles from support to strategic functions, they have managed to survive and thrive amidst disruptive innovations such as online transportation services. In Central and Eastern Europe, the growth of ICT services has been pivotal in improving these regions' positions in global production linkages. This transition highlights the significant role IT-service companies play in enhancing regional competitiveness and technological capabilities [16].

IDENTIFIED GAPS IN LITERATURE

While the existing literature provides a comprehensive understanding of Industry 4.0 concepts and technologies, there are several gaps that need further exploration, particularly concerning the role of IT-service companies in driving Industry 4.0. **Also, there are missing analzys of case studies of how IT-service companies help their clients with digital transformation and implementation of Industry 4.0 principles.** By addressing these gaps, future research can provide a more detailed understanding of how IT-service companies can drive the progress of Industry 4.0, thereby offering valuable insights for both academia and industry practitioners. The goal of the article is to highlight the essential role of IT-service companies in facilitating successful Industry 4.0 transformations.

MAIN PART

To explore how IT service companies helping their customers to progress with Industry 4.0 it will be used market assessment performed by Everest group [17]. Based on this assessment it was identified 7 major market leaders LTTS, Wipro, TCS, Cognizant, HCL Technologies, Accenture, Capgemini. In scope of this research it will be analyzed offerings and cases proposed by these companies to their customers.

Capgemini

Starting with the leader of this group Capgemini, analyzing their experience with Industry 4.0 [18] it was remarkable that Capgemini has developed it is own Industry 4.0 framework. The Capgemini Consulting Industry 4.0 Framework is meticulously designed to guide manufacturing companies in adopting Industry 4.0 technologies. It emphasizes the integration of the physical and digital worlds, focusing on leveraging digital technologies to enhance business models, operations, and customer value. The framework delineates key building blocks, including developing a vision and transformation roadmap, understanding core value drivers, and achieving corporate transformation. It provides a comprehensive structure, offering a detailed approach to understanding and implementing Industry 4.0, addressing both technological and organizational aspects. The framework underscores the importance of leveraging digital technologies to drive operational efficiency, innovation, and the creation of new business models. Despite its thorough nature, the framework might lack specific, actionable steps for companies at various stages of Industry 4.0 adoption. Additionally, it could benefit from more tailored guidance for different manufacturing sectors, each with unique challenges and requirements. While offering valuable guidance for manufacturing companies navigating the complexities of Industry 4.0, it may require adaptation and additional detail to address specific industry needs and practical implementation challenges. Capgemini's Industry 4.0 offerings focus on four main areas: Smart Solutions, Smart Innovations, Smart Factory, and Smart Supply Chains. Smart Solutions leverage digital technologies to enhance customer value by providing innovative products and services, integrating digital capabilities into existing products to create new business models. Smart Innovations drive product and service innovation, fostering collaboration and enabling the creation of new, innovative solutions. The Smart Factory concept emphasizes the use of advanced technologies like IoT, robotics, and analytics to create highly efficient, flexible, and automated manufacturing processes, aiming to improve operational efficiencies and reduce costs. Smart Supply Chains enhance visibility, control, and efficiency in supply chain operations through real-time data analytics and automation to optimize performance [18]. The assessment of these offerings reveals that Smart Solutions and Smart Innovations are robust in fostering innovation and customer-centric improvements. They emphasize creating new business models and integrating digital capabilities into products, ensuring that companies remain competitive and can offer enhanced value to customers. The Smart Factory addresses core operational efficiencies in manufacturing, focusing on automation, real-time data analytics, and integrating IoT and robotics, significantly reducing costs and improving flexibility. Smart Supply Chains are crucial for modern manufacturing, focusing on real-time data and automation to optimize performance, improving the responsiveness and efficiency of supply chains, which is increasingly important in a globalized market. However, the complexity of implementing such advanced technologies can be daunting for many companies. Clear, step-by-step guidance and support during the implementation phase are crucial but might be underemphasized. Furthermore, the solutions may need more customization to cater to specific industry needs, as different manufacturing sectors have unique challenges that require tailored approaches. While Capgemini's offerings are well-structured to help manufacturing companies transition into Industry 4.0, there is a need for more detailed implementation support and industry-specific customization to address unique challenges.

Wipro

Wipro's offerings for Industry 4.0 are encapsulated within their S.M.A.R.T. (Sustainable, Modular, Agile, Responsive, and Transformative) framework [19]. This framework integrates both digital and physical automation

to enhance productivity, flexibility, resilience, and sustainability for manufacturing companies. Their strategic consulting services help manufacturers define and implement their Industry 4.0 initiatives, including intelligent physical automation solutions designed to streamline operations and increase efficiency. Wipro emphasizes the convergence of Operational Technology (OT) and Information Technology (IT) to create a more integrated and responsive manufacturing environment, enabling real-time decision-making and enhancing operational agility. The company offers comprehensive digital transformation services focusing on the digitalization of manufacturing processes [20]. This includes the use of advanced analytics to provide insights and improve decision-making across the value chain. By leveraging real-time data analytics, Wipro helps manufacturers optimize their operations, reduce downtime, and increase overall efficiency, supporting more informed and agile business decisions. Wipro's solutions cater to a wide range of industries, including automotive, consumer packaged goods, food and beverage, high-tech, industrial, oil and gas, metals, chemicals, healthcare, and pharmaceuticals, ensuring their offerings are tailored to the specific needs of different sectors. Wipro's S.M.A.R.T. Manufacturing framework has been implemented in over 2,000 automation solutions, with 250-plus turnkey line setups and the development of over 100 intellectual properties and solutions. Their team of 11,000 industry experts has collaborated with more than 50 global companies to transform their manufacturing processes [21]. In comparison, Capgemini's Industry 4.0 offerings focus on four key areas: Smart Solutions, Smart Innovations, Smart Factory, and Smart Supply Chains. Capgemini aims to enhance operational efficiencies and innovation through digital technologies, leading to new business models and service offerings. They emphasize the need for a comprehensive corporate transformation to leverage Industry 4.0 value drivers, including digital infrastructure, governance, and new capabilities for employees. Overall, both Wipro and Capgemini offer robust Industry 4.0 solutions. Still, Wipro's S.M.A.R.T. framework stands out for its emphasis on the convergence of digital and physical automation, real-time data analytics, and broad industry applicability. Capgemini, on the other hand, focuses more on driving operational efficiencies and innovation through structured corporate transformation and new business models. Wipro also has developed its own framework, SDI (Smart, Digital, Intelligent). Wipro's Smart, Digital, and Intelligent (SDI) Framework addresses the challenges enterprises face in scaling Industry 4.0 initiatives. The SDI Framework integrates advanced technologies and processes to create value across industries by providing a comprehensive and scalable methodology for Industry 4.0 adoption. Wipro's SDI Framework provides a clear, scalable, and effective methodology for enterprises to navigate their Industry 4.0 journey. By addressing key challenges and integrating advanced technologies and processes, SDI enables enterprises to realize significant efficiency, flexibility, productivity, and quality improvements, ensuring long-term value creation and competitiveness in the evolving industrial landscape [19], [21]. Wipro and Capgemini offer distinct yet complementary approaches to Industry 4.0, each with its unique strengths and focus areas. Wipro emphasizes a holistic approach with real-time data analytics and the integration of Operational Technology (OT) and Information Technology (IT). Their S.M.A.R.T. framework is designed for seamless orchestration across various manufacturing processes, ensuring that digital and physical systems work in harmony to optimize efficiency and productivity. Capgemini, on the other hand, focuses on creating new business models through smart innovations and solutions. Their framework emphasizes corporate transformation and leveraging digital technologies to enhance operational efficiency. This approach is geared towards driving innovation and enabling businesses to develop new, competitive business models that can adapt to the changing market landscape. Technologically, Wipro has a strong emphasis on real-time data analytics, the Internet of Things (IoT), artificial intelligence (AI), and digital twins. Their focus on dynamic decision-making and optimizing operational agility is designed to help businesses respond swiftly to market changes and operational challenges. Capgemini's technological focus also includes automation, IoT, advanced analytics, and smart factory solutions. Their approach integrates innovation with digital transformation to drive new business models, aiming to combine efficiency with cutting-edge technological advancements. In terms of customer value, Wipro aims to enhance productivity, flexibility, and sustainability across various industries. Their offerings are tailored to meet specific industry needs, with a strong focus on providing real-time insights and agile operations. This industry-specific customization ensures that Wipro's solutions are relevant and effective in addressing the unique challenges faced by different sectors. Capgemini prioritizes smart solutions and innovations to drive operational efficiencies and new business models. Their goal is to enhance customer value and create competitive advantages through digital transformation. By focusing on both operational improvements and innovative solutions, Capgemini aims to provide a comprehensive package that addresses the needs of modern businesses.

The implementation approaches of Wipro and Capgemini also differ. Wipro utilizes an extensive S.M.A.R.T. framework with a focus on the practical integration of digital and physical systems. Their approach includes strategic consulting and intelligent automation, providing a hands-on, detailed pathway for companies looking to adopt Industry 4.0 technologies. Capgemini, on the other hand, advocates for a comprehensive vision and transformation roadmap. Their framework includes detailed corporate transformation strategies and the integration of advanced technologies, offering a more structured and strategic approach to implementing Industry 4.0 solutions. Overall, while both Wipro and Capgemini offer robust Industry 4.0 solutions, Wipro's S.M.A.R.T. framework stands out for its emphasis on the convergence of digital and physical automation, real-time data analytics, and broad industry applicability. Capgemini's focus on driving operational efficiencies and innovation through structured

corporate transformation and new business models offers a strategic pathway for businesses looking to leverage digital technologies for competitive advantage.

Accenture

Another large players from Everest report is Accenture. Accenture provides a comprehensive suite of services and frameworks for Industry 4.0 through its Industry X.0 practice [22]. This approach emphasizes the integration of advanced digital technologies to transform core operations, enhance efficiency, and unlock new revenue streams. Accenture's Industry 4.0 offerings are comprehensive and multifaceted, centered around several key frameworks and services designed to drive digital transformation in manufacturing and operations. **Digital Engineering and Manufacturing Services** form a core part of their offering. This includes digitizing R&D processes to lower development costs and accelerate time-to-market for new products. They also focus on creating smart-connected products that drive organizational change and provide vital digital intelligence. Accenture modernizes product platforms to bring new ideas and services to market more efficiently, and they help clients adapt to as-a-service business models to enhance revenue streams. In the realm of **Digital Production & Operations**, Accenture establishes connected factories and plants across multiple sites to enhance management and operational efficiencies. They use data and digital technologies to increase asset reliability through self-optimizing operations and redesign manufacturing processes for more productive human-machine collaboration using autonomous robotic systems. **Infrastructure & Capital Projects** are also a key focus, with Accenture delivering future-ready assets on time and within budget by digitizing large infrastructure and capital projects. Their **Innovation Centers and Ecosystem** include the Industrial IoT Innovation Center located in Garching, Germany. This center assists clients in designing and prototyping innovative digital solutions, offering capabilities like Industrial Design Thinking, Connected Products Studio, and access to an industrial ecosystem that connects clients with technology partners, startups, and academia. **Cybersecurity** is another critical area, where Accenture ensures end-to-end security for industrial networks participating in IIoT, thereby maintaining robust cybersecurity across the value chain. Accenture's emphasis on **Collaborative R&D** involves co-innovating with leading vendors like AWS, Dassault Systèmes, GE, Microsoft, PTC, Schneider Electric, and Siemens to develop market-ready solutions. Distinctive features of Accenture's Industry 4.0 offerings include a holistic transformation approach that integrates advanced technologies, processes, and organizational changes to drive Industry 4.0 transformation. Accenture leverages its extensive ecosystem and partnerships, strengthened by recent acquisitions, to deliver comprehensive solutions. Their global innovation network supports industrial automation, digital asset management, and industrial software, ensuring clients have access to the latest innovations and expertise [22]. Accenture, Wipro, and Capgemini each offer distinct approaches and strengths in their Industry 4.0 solutions, providing comprehensive support for digital transformation across various industries. Accenture emphasizes a holistic approach, integrating advanced digital technologies across the entire value chain. They are particularly strong in digital engineering, connected factories, and intelligent asset management. This comprehensive integration allows Accenture to offer seamless and cohesive solutions that span the entire manufacturing process. Wipro focuses on the convergence of digital and physical automation, with a strong emphasis on real-time data analytics and comprehensive integration of Operational Technology (OT) and Information Technology (IT). Their approach ensures that all aspects of manufacturing are connected and optimized, providing a unified and responsive manufacturing environment. Capgemini concentrates on smart solutions and innovations, integrating digital technologies to drive operational efficiencies and develop new business models. Their framework emphasizes corporate transformation, leveraging digital technologies to create more efficient and innovative business processes. Accenture has a robust focus on IoT, AI, autonomous systems, and comprehensive cybersecurity. They emphasize the role of IoT in driving Industry 4.0 transformations, ensuring that all connected devices and systems are secure and optimized for peak performance. Wipro emphasizes real-time data analytics, IoT, AI, and digital twins. Their focus is on dynamic decision-making and smart factory solutions, providing manufacturers with the tools they need to make real-time, data-driven decisions that enhance efficiency and productivity. Capgemini centers on automation, IoT, advanced analytics, and supply chain optimization. Their approach focuses on corporate transformation and creating new business models, leveraging these technologies to improve operational efficiencies and drive innovation. Accenture aims to enhance operational efficiency, create new revenue streams, and enable product-as-a-service models through advanced digital technologies. Their holistic approach ensures that customers can leverage digital transformation to achieve significant improvements in efficiency and profitability. Wipro enhances productivity, flexibility, and sustainability across various industries with tailored solutions and strong real-time insights. Their solutions are designed to meet the specific needs of different sectors, ensuring that each customer receives the support they need to optimize their operations. Capgemini focuses on operational efficiencies, smart innovations, and driving new business models to enhance customer value. Their approach combines digital technologies with innovative solutions to provide significant improvements in efficiency and competitiveness. Accenture employs a holistic, business-first approach with a strong emphasis on innovation centers and global partnerships. This ensures that their solutions are not only technologically advanced but also aligned with the strategic goals of their clients. Wipro utilizes a methodical and scalable approach, with strong consulting, remote support, and collaborative R&D. Their approach is designed to provide practical and effective solutions that can be scaled to meet the needs of large and small enterprises alike. Capgemini advocates for a comprehensive transformation strategy with a focus on smart solutions and innovations.

Their approach ensures that clients can leverage the latest technologies to drive significant improvements in efficiency and innovation, supporting long-term growth and competitiveness. Overall, while Accenture, Wipro, and Capgemini each offer robust Industry 4.0 solutions, their approaches and focuses differ, allowing them to meet the diverse needs of their clients in various ways. Accenture's holistic and integrated approach, Wipro's focus on real-time data and OT-IT integration, and Capgemini's emphasis on smart innovations and corporate transformation each provide unique strengths that cater to different aspects of Industry 4.0 transformation.

Cognizant

Cognizant has developed a comprehensive suite of offerings [23] to support Industry 4.0 initiatives, focusing on leveraging digital and smart manufacturing technologies. Their approach integrates cutting-edge technologies, data analytics, and innovative frameworks to transform manufacturing processes and improve operational efficiencies. Cognizant's Industry 4.0 offerings are extensive and designed to facilitate comprehensive digital transformation in manufacturing. Their **Smart Manufacturing** services focus on building intelligence into production systems to provide real-time visibility and self-optimization, enhancing overall operations. This includes embedding IT and OT solutions at scale and utilizing automation, data analytics, and AI to reduce downtime and extend system value. The OnePlant methodology helps define and map strategic visions for smart manufacturing, identifying how new technologies can improve operations through pre-built accelerators that rebalance IT and OT solutions. **Operations+** includes smart IoT solutions that optimize industrial and production supply chains, creating resilient operations by unlocking IoT technology investments. It supports end-to-end integration across multiple locations and manufacturing systems, providing frameworks, reference architectures, and roadmaps to enhance business performance. In the **Digital Strategy Solutions** domain, Cognizant creates digital strategies to accelerate value creation by leveraging insights, agile approaches, and execution expertise. Their managed innovation services establish an innovation culture within organizations, enabling rapid development of client solutions and prioritizing initiatives with the greatest return on investment (ROI). **Workforce Transformation** focuses on digital enablement, reskilling talent, and integrating new tools to create optimal workplaces. This includes comprehensive digital strategies for large-scale transformation, expediting digital adoption, and improving organizational agility. Through **Acquisitions and Partnerships**, such as the integration of TQS and Zenith Technologies, Cognizant enhances smart manufacturing capabilities, particularly in the life sciences industry, contributing significantly to Industry 4.0 transitions. Cognizant's strengths include a holistic approach that integrates smart manufacturing, IoT solutions, and digital strategy to drive comprehensive Industry 4.0 transformations. They emphasize the creation and nurturing of an innovation culture within organizations, ensuring the long-term sustainability of digital transformation initiatives. Their global presence, with centers of excellence and strategic partnerships, particularly in the life sciences sector, further strengthens their offerings. However, the comprehensive nature of Cognizant's offerings might lead to complex implementations that require extensive coordination and integration efforts. Cognizant focuses on integrating IT and OT solutions at scale, emphasizing real-time visibility and smart manufacturing, and offers robust frameworks and methodologies for transformation. Wipro emphasizes the convergence of digital and physical automation through the S.M.A.R.T. framework, with a strong focus on real-time data analytics and comprehensive OT-IT integration. Capgemini concentrates on smart innovations and digital transformation, integrating digital technologies to drive operational efficiencies and new business models. Cognizant is strong on real-time data analytics, IoT, AI, and workforce transformation, emphasizing smart IoT solutions and managed innovation. Wipro focuses on IoT, AI, digital twins, and dynamic decision-making, with a strong emphasis on comprehensive integration of OT and IT. Capgemini centers on automation, IoT, advanced analytics, and smart factory solutions, focusing on corporate transformation and creating new business models. Cognizant aims to enhance operational efficiency, speed to market, and new business model creation through smart manufacturing and IoT solutions. Wipro enhances productivity, flexibility, and sustainability across various industries with tailored solutions and strong real-time insights. Capgemini prioritizes operational efficiencies, smart innovations, and driving new business models to enhance customer value. Overall, Cognizant's offerings are well-rounded, with a strong emphasis on smart manufacturing, IoT solutions, and digital strategy, providing a holistic approach to Industry 4.0 transformations.

HCL Technologies

HCL Technologies offers a comprehensive suite of Industry 4.0 solutions under its Industry NeXT framework [24]. This framework is designed to help enterprises transition into digitally enhanced, intelligent operations by integrating advanced technologies such as IoT, AI, and digital twins. HCL focuses on creating a cognitive ecosystem of connected experiences, resilient operations, and responsible business practices. HCL's Industry 4.0 offerings focus on comprehensive digital transformations through their Industry NeXT framework. Their smart manufacturing solutions provide real-time visibility and self-optimization in manufacturing operations. Using the OnePlant methodology, HCL helps define and map strategic visions, identifying how new technologies can improve operations. Pre-built accelerators increase productivity, reduce costs, and enhance waste control, allowing scalability from single operations to multiple global sites. In the smart grid sector, HCL delivers cross-functional solutions for grid transformation, enhancing operational efficiency and optimizing systems for utilities. HCL's digital transformation solutions include building a strong digital core for intelligent insights and decision-making, helping businesses unlock the full potential of their data. Their IoT solutions offer a "Define, Build, and Run" approach to connect things, data, processes, and people across various adoption levels. Through collaborations

and partnerships, particularly with SAP, HCL provides IoT packaged offerings and services, simplifying and accelerating Industry 4.0 transformations. The acquisition of Quest Informatics enhances HCL's Industry 4.0 and IoT capabilities, particularly in aftermarket services. Their engineering and R&D services cover the entire spectrum of digital engineering solutions, including new product development, network engineering, and software product engineering. HCL's application services focus on enhancing user experience, boosting uptime, and eliminating tech debt. Their infrastructure management services are known for executing complex global IT transformations and running efficient IT services for leading companies. HCL's strengths include a holistic transformation approach, strong collaboration with SAP, and a global reach with deep industry expertise, supporting comprehensive digital transformations. However, the broad scope of services and deep integration required can make implementation complex and resource-intensive. In comparison with Accenture, Wipro, and Capgemini, HCL focuses on comprehensive digital transformations with a strong emphasis on smart manufacturing, IoT solutions, and digital grid transformation through the Industry NeXT framework. Accenture adopts a holistic Industry X.0 approach integrating advanced digital technologies across the value chain, emphasizing IoT, AI, and cybersecurity. Wipro emphasizes the convergence of digital and physical automation through the S.M.A.R.T. framework, focusing on real-time data analytics and OT-IT integration. Capgemini concentrates on smart innovations and digital transformation, integrating digital technologies to drive operational efficiencies and create new business models. Technologically, HCL is strong on IoT, AI, digital twins, and smart grid solutions, focusing on connecting data, processes, and people. Accenture emphasizes IoT, AI, autonomous systems, and comprehensive cybersecurity, integrating digital technologies to enhance efficiency. Wipro focuses on IoT, AI, digital twins, and dynamic decision-making, with comprehensive OT-IT integration. Capgemini centers on automation, IoT, advanced analytics, and smart factory solutions, driving corporate transformation and new business models. HCL aims to enhance operational efficiency and resilience through smart manufacturing and grid transformation solutions. Accenture focuses on creating new revenue streams and enhancing operational efficiency through advanced digital technologies. Wipro enhances productivity, flexibility, and sustainability across various industries with tailored solutions. Capgemini prioritizes operational efficiencies, smart innovations, and driving new business models to enhance customer value.

TCS

Tata Consultancy Services (TCS) offers a robust suite of services and solutions for Industry 4.0, leveraging their deep industry expertise and advanced technological capabilities. Their offerings are centered around the **Neural Manufacturing™** framework, which integrates AI, IoT, 5G, and cloud technologies to create connected, cognitive, and collaborative ecosystems [25]. TCS's Neural Manufacturing™ framework supports the creation of smart, autonomous manufacturing operations by leveraging advanced digital technologies. It enables manufacturers to build connected ecosystems that drive advanced analytics and enable autonomous plant operations. TCS deploys IoT sensors on machinery to collect real-time data, which is then analyzed using advanced analytics and machine learning to predict maintenance needs, optimize production schedules, and improve overall efficiency. Their smart factory solutions include quality and safety inspection systems leveraging AWS Wavelength for ultra-low latency and high bandwidth, enhancing real-time processing capabilities. TCS's consulting-led approach, known as the Value Discovery Approach, involves collaborating with business stakeholders to define digital factory visions, advanced manufacturing strategies, and implementation roadmaps. They provide comprehensive support for the deployment, integration, and management of Industry 4.0 solutions. TCS collaborates with leading technology vendors such as AWS to enhance their Industry 4.0 offerings. For instance, their partnership with AWS enables the deployment of low-latency solutions using AWS Wavelength, facilitating real-time quality and safety inspections in manufacturing environments. TCS leverages digital twins and simulation technologies to create virtual replicas of physical systems, which help in optimizing operations, predicting maintenance needs, and improving product quality. With a strong global presence, TCS can support large-scale transformations across various industries, including manufacturing, consumer packaged goods, automotive, aerospace, energy, utilities, healthcare, life sciences, and high-tech sectors. The strengths of TCS include the comprehensive approach of the Neural Manufacturing™ framework, the emphasis on real-time data and advanced analytics to enhance operational efficiency and decision-making, and strong partnerships with major technology providers like AWS. However, the broad scope of TCS's offerings might lead to complex implementations that require extensive coordination and integration efforts. Additionally, while TCS focuses on data security, the integration of multiple IoT devices and systems can present significant cybersecurity challenges. In comparison with Accenture, Wipro, and Capgemini, TCS offers a comprehensive approach with the Neural Manufacturing™ framework, emphasizing IoT, AI, and cloud integration, with a focus on real-time data and advanced analytics. Accenture's Industry X.0 framework integrates digital technologies across the value chain, emphasizing IoT, AI, and cybersecurity. Wipro's S.M.A.R.T. framework focuses on real-time data analytics and OT-IT integration, emphasizing digital and physical automation. Capgemini focuses on smart innovations and digital transformation, integrating digital technologies to drive operational efficiencies and create new business models.

Technologically, TCS is strong on IoT, AI, digital twins, and cloud technologies, emphasizing real-time data analytics and advanced manufacturing solutions. Accenture emphasizes IoT, AI, autonomous systems, and comprehensive cybersecurity, integrating digital technologies to enhance efficiency. Wipro focuses on IoT, AI,

digital twins, and dynamic decision-making, with comprehensive OT-IT integration. Capgemini centers on automation, IoT, advanced analytics, and smart factory solutions, driving corporate transformation and new business models. TCS aims to enhance operational efficiency and resilience through smart manufacturing and IoT solutions, with a strong focus on real-time data and analytics. Accenture focuses on creating new revenue streams and enhancing operational efficiency through advanced digital technologies. Wipro enhances productivity, flexibility, and sustainability across various industries with tailored solutions. Capgemini prioritizes operational efficiencies, smart innovations, and driving new business models to enhance customer value.

L&T Technology Services

L&T Technology Services (LTTS) offers a robust suite of Industry 4.0 solutions designed to help enterprises transition into smart, connected, and efficient manufacturing operations. Their offerings span various verticals, including transportation, medical devices, and high-tech industries, leveraging advanced technologies like AI, robotics, 3D-vision systems, and connected machines [26-29]. LTTS's Industry 4.NOW framework focuses on transforming manufacturing operations with advanced digital solutions, including AI, IoT, and 3D-vision systems to optimize production processes, enhance product quality, and reduce downtime. Their smart factory solutions integrate advanced manufacturing technologies to create intelligent and autonomous production environments, aiming to improve operational efficiency, safety, and flexibility in manufacturing processes. They also offer solutions for creating digital twins of manufacturing processes and assets, enabling real-time monitoring, predictive maintenance, and optimization of operations. LTTS helps businesses manage their supply chains more effectively by leveraging digital tools to identify and assess suppliers, ensuring a robust and agile supply chain to meet critical needs. Their integrated asset management service focuses on enhancing the lifecycle management of assets through real-time data analytics and IoT integration, improving asset utilization and reducing operational costs. Additionally, LTTS offers end-to-end product design and engineering services, including simulation, proof of concept, and prototyping capabilities, helping clients accelerate product development and bring innovative solutions to market faster. They collaborate with clients to develop tailored solutions that meet specific industry needs, leveraging their deep expertise in engineering and R&D. The 1DigitalPlace Center of Excellence in Peoria, Illinois, focuses on developing and implementing next-generation manufacturing technologies, including AI, robotics, and digital twins. It provides turnkey solutions covering everything from product design to delivery and aftermarket services. LTTS's strengths include their comprehensive Industry 4.NOW framework, global reach and expertise, and strong focus on innovation. However, the comprehensive nature of their offerings may lead to complex implementation processes that require extensive coordination and integration efforts, and ensuring robust data security and privacy can be challenging. In comparison with Accenture, Wipro, and Capgemini, LTTS offers a comprehensive digital transformation framework with strong capabilities in smart manufacturing, digital twins, and connected assets, emphasizing real-time data analytics and advanced manufacturing solutions. Accenture's holistic Industry X.0 framework integrates digital technologies across the value chain, emphasizing IoT, AI, and cybersecurity. Wipro's S.M.A.R.T. framework focuses on real-time data analytics and OT-IT integration, emphasizing digital and physical automation. Capgemini focuses on smart innovations and digital transformation, integrating digital technologies to drive operational efficiencies and create new business models. Technologically, LTTS is strong on IoT, AI, digital twins, and smart factory solutions, emphasizing real-time data analytics and predictive maintenance. Accenture emphasizes IoT, AI, autonomous systems, and comprehensive cybersecurity, integrating digital technologies to enhance efficiency. Wipro focuses on IoT, AI, digital twins, and dynamic decision-making, with comprehensive OT-IT integration. Capgemini centers on automation, IoT, advanced analytics, and smart factory solutions, driving corporate transformation and new business models. LTTS enhances operational efficiency and resilience through smart manufacturing and IoT solutions, with a strong focus on real-time data and analytics. Accenture aims to create new revenue streams and enhance operational efficiency through advanced digital technologies. Wipro enhances productivity, flexibility, and sustainability across various industries with tailored solutions. Capgemini focuses on operational efficiencies, smart innovations, and driving new business models to enhance customer value.

To summarize analysis of the Industry 4.0 leaders it was compiled comparison table 1.

CONCLUSION

The transformation to Industry 4.0 is a complex endeavor that demands a deep understanding of advanced technologies, extensive experience in digital integration, and the ability to foresee and mitigate potential pitfalls. Leading IT-service companies such as Accenture, Capgemini, Wipro, HCL, TCS, LTTS, and EPAM have repeatedly demonstrated their capabilities in driving successful Industry 4.0 transformations for numerous clients across various industries. Their extensive experience and structured frameworks are crucial in ensuring the success of such initiatives. These IT-service companies have a wealth of experience derived from implementing digital transformation projects for a diverse array of clients. They possess in-depth knowledge of the advantages and challenges associated with Industry 4.0 technologies such as IoT, AI, digital twins, and advanced analytics. This experience enables them to anticipate and navigate potential issues efficiently, reducing the risk of costly delays or failures. Each of the top IT-service providers has developed robust frameworks and methodologies to guide their Industry 4.0 offerings (for instance HCL's Industry NeXT Framework, TCS's Neural Manufacturing™ Framework, LTTS's Industry 4.NOW Framework). These structured approaches provide a clear roadmap for transformation,

ensuring that every aspect of the project is covered comprehensively. The frameworks are designed to be scalable and adaptable, catering to the unique needs of different industries and business models. The expertise and structured frameworks of these IT-service companies translate into efficient implementation and high-quality outcomes.

Table 1

Comparison analysis of the framework of Industry 4.0 leaders among IT-Service companies

Attribute	LTTS	Wipro	TCS	Cognizant	HCL Technologies	Accenture	Capgemini
Framework Name	Industry 4.NOW	S.M.A.R.T.	Neural Manufacturing™	Not specified	Industry NeXT	Industry X.0	Not specified
Key Technologies	AI, IoT, 3D-vision systems, digital twins	IoT, AI, digital twins, real-time data analytics	IoT, AI, digital twins, cloud technologies	IoT, AI, digital twins, data analytics	IoT, AI, digital twins, smart grid solutions	IoT, AI, autonomous systems, cybersecurity	IoT, AI, automation, advanced analytics
Focus Areas	Smart manufacturing, smart factory solutions, connected assets	Digital and physical automation, OT-IT integration	Smart manufacturing, IoT integration, digital twin and simulation	Smart manufacturing, IoT solutions, workforce transformation	Smart manufacturing, digital core, smart grid	Digital technologies across value chain, operational efficiency, new business models	Smart innovations, digital transformation, operational efficiencies
Strengths	Comprehensive digital transformation, global reach, strong focus on innovation	Real-time insights, tailored solutions, strong OT-IT integration	Real-time data analytics, advanced manufacturing solutions, strong partnerships	Holistic approach, innovation culture, global presence	Wide range of integrated solutions, strong SAP collaboration, global expertise	Holistic approach, strong IoT and AI focus, comprehensive cybersecurity	Smart solutions, innovation-driven, corporate transformation focus
Weaknesses	Complex implementation, data security challenges	Complexity in integration, scalability issues	Implementation complexity, cybersecurity challenges	Implementation complexity, data security issues	Complex implementation, resource-intensive	Implementation complexity, integration challenges	Scalability issues, integration complexity

Source: created by Reznikov R.

This systematic approach ensures that the solutions are not only innovative but also reliable and scalable, providing clients with the confidence that their transformation initiatives will succeed. Attempting to undertake Industry 4.0 transformations without the support of experienced IT-service providers can be fraught with challenges. Most end customers lack the in-house expertise and scale required to implement such complex technologies from scratch. Building the necessary infrastructure and skill sets independently can be prohibitively expensive and time-consuming, significantly reducing the likelihood of success. Engaging IT-service companies to adopt Industry 4.0 is not just beneficial but crucial. Their comprehensive frameworks, extensive experience, and deep technological expertise provide the necessary support to navigate the complexities of digital transformation. The analysis of the top-7 industry leaders highlights that all of them have structured frameworks and methodologies in place, which are instrumental in delivering successful Industry 4.0 solutions with predictable quality and high success rates. Therefore, partnering with these IT-service providers is essential for businesses aiming to stay competitive in the rapidly evolving industrial landscape. The future research topic could focus on conducting a detailed quantitative analysis of Industry 4.0 implementation cases and their economic impacts. This research would involve analyzing various Industry 4.0 components implemented by top IT-service companies, including IoT, AI, digital twins, and smart manufacturing solutions. The goal would be to measure the economic effects achieved, such as improvements in production efficiency, cost reductions, increased revenue, reduced downtime, and enhanced product quality. By collecting and analyzing data from multiple case studies across different industries, the research would identify common success factors and the extent of economic benefits realized. A promising direction for further research is the detailed examination and evaluation of case studies to assess the economic impact of Industry 4.0 implementations facilitated by IT-service companies. This could involve analyzing specific metrics related to operational efficiency, cost savings, productivity improvements, and return on investment (ROI) achieved by organizations that have successfully adopted Industry 4.0 technologies with the support of these IT-service providers. Additionally, exploring the long-term benefits and sustainability of such transformations across different industries could provide valuable insights into the broader economic implications and potential for scalability.

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