
Digital Transformation in the Era of Big Data and Cloud Computing

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Abstract: Digital transformation is the application of innovative digital technology to fundamentally change the model of how business operates, and the way technology is delivered to support the overall business. The evolution of digital transformation has taken place in different stages, from automation to radical shifts of business models via disruptive technologies of modern times. The emergence of Big Data and cloud computing has fundamentally changed the paradigm of computing in data transformation and delivery. Mountains of data of huge volume, velocity, and variety are converted into actionable intelligence that can be delivered in real-time on demand, anywhere and anytime around the globe. This paper examines the technology drivers for digital transformation that include Big Data, advanced analytics and artificial intelligence under an integrated cloud platform that provides ubiquitous on-demand services to modern enterprises driven by knowledge and relationship. Data from different sources are transformed into actionable intelligence via traditional and Big Data analytic platforms. It is distributed via an everything-as-a-service model to a community that consists of organizations, people, things and systems, anywhere and anytime around the globe. Analysis of business cases points to the importance of investing in digital transformation as illustrated by the success and failure of companies coping with the recent coronavirus pandemic. This paper provides an architecture that serves as a roadmap for the digital transformation of modern-day business enterprises.

Keywords: Digital Transformation, Big Data, Cloud Computing, Analytics, Artificial Intelligence

1. Introduction

Digital transformation (DT) of an enterprise is the application of innovative digital technology to fundamentally change the model of how business operates, and the way technology is delivered to support the overall business. It aims at achieving the business objectives of operational and product excellence, delivering value to customers and constituencies, sustaining survival strategy and attaining competitive advantages. Digital transformation has gone through different stages of technology advancements from automation of manual tasks to the radical changes of business models using the Internet, to the latest trends in Big Data analytics and cloud computing supporting a knowledge-driven and on-demand enterprise.

The economy has evolved alongside technology changes from the industrial production economy of the 19th century, to the digital economy of the information and internetworking

age of the 20th century, to the knowledge and relationship economy of the 21st century. The information age is accentuated by the emphasis of effective management and governance of enterprise information assets. The data management strategy has evolved from computer file systems, to database management systems, data warehousing, and business intelligence. Big Data and cloud computing emerged in the late 1990s as the later stages of technology advancement in business. The rise of Big Data addresses the growth of data volume, velocity and variety. Analytics evolve together with the advancement of information management from basic query and reporting, to business intelligence, advanced analytics and machine learning. The user community has expanded from organizations and people to include the Internet-of-things and systems. The enterprise has become more connected, mobile and intelligent. Cloud computing provides an integrated platform to deliver services to users, which is pull-based, on-demand anytime and anywhere around the globe.

This paper provides a conceptual model around emerging technology trends for the digital transformation of an organization to a real-time, sense-and-response, knowledge- and relationship-driven intelligent enterprise. The methodology deployed in the development of the model utilizes content analysis of literature in essential areas that include Big Data analytics, cloud computing, mobile technology, the Internet of Things, artificial intelligence, machine learning, and application program interfaces [1]. Business cases involving five companies are analyzed. The result demonstrates the success and failure of companies, depending on their capability of adopting the path of digital transformation proposed in this paper.

The organization of the paper is as follows. The beginning section explores the Big Knowledge Enterprise, which discusses the knowledge and relationship imperatives and Big Data. It is followed by a discussion of mobile computing and artificial intelligence in transforming business enterprises. It then explores cloud computing and describes an integrated cloud architecture, followed by a discussion on analytics that creates actionable insights for business performance. The new digital community of users that consists of organizations, people, things and systems is explained. The paper concludes by analyzing the business implications illustrated by recent cases during the coronavirus pandemic.

2. The Big Knowledge Enterprise

2.1. The Knowledge and Relationship Imperatives

Reference [2] described that the new economic order of the twenty first century is driven by knowledge, based on the value of relationships throughout the extended enterprise. Enterprise relationship management (ERM) deals with the processes of marketing, sales, purchasing and service, spanning customer relationship management (CRM), supplier relationship management (SRM) and partner relationship management (PRM). Knowledge management (KM) concerns the processes of knowledge acquisition, creation, sharing, storage, and utilization. The merging of ERM and KM creates new disciplines that involve applying knowledge to enterprise relationship operations [3].

2.2. The Big Data Enterprise

The rise of Big Data was facilitated by the trends in the growth of data, processing power, and the availability of open source technology and commodity hardware [4]. Reference [5] characterized Big Data by its volume, velocity, and variety, where veracity and value were later added by other researchers. Hundreds of gigabytes of data would be considered as Big Data in the 1980s, while in today's environment, Big Data is measured by a higher order of magnitude in terabyte, petabyte or exabyte. Reference [6] put it in perspective, "It took from the dawn of civilization to 2003 to create 5 exabytes (10^{18} bytes) of information; we now create the same volume in just two days."

The growth of social media and machine-to-machine

communication contributes to the high volume, velocity and variety of data. It is estimated that 6,000 tweets are sent every second [7], and the number of active users of Facebook exceeds 2.6 billion monthly as of the first quarter of 2020 [8]. Data variety addresses data beyond structured data to include semi-structured and unstructured data that contain text, video, audio, documents and images. Unstructured data contributes to the high growth of Big Data and will account for 90% of all data created in the next decade [6]. Veracity and value of Big Data address the credibility of the data source and the alignment to business objectives.

Other contributors to Big Data include the Internet of Things (IoT) and geospatial data. IoT integrates device and sensor data with Big Data, analytics and other enterprise applications [9]. Reference [10] predicts there will be 50 billion devices connected to the Internet by 2020. Geospatial data specifies locations of the boundaries of the earth via coordinates and topologies. Reference [11] described geospatial data as Big Data enabled by real time sensor observations, fast geometric processing of vector geodata, and big processing through cloud computing and analytics.

3. Mobility and Intelligence

Mobile technology is another driver in the technology stack for digital transformation. According to [12], the current number of smartphone users in the world is 3.5 billion, which means around 45% of the world's population owns a smartphone. Reference [13] described that 62% of smartphone users have made a purchase online using mobile devices in the last six months. Reference [14] predicted that in 2021, 54% of all retail e-commerce will be generated via m-commerce. Many applications in addition to m-commerce are created, which include location-based services, banking, advertising, payment, games and others. Reference [15] described the concept of mobile-first, which is seen in some companies as a matter of mobile optimization, ensuring that all web pages are responsive on mobile devices. It stated that 51% of all digital ad budgets in 2016 were spent on mobile. Reference [13] explained the mobile-first digital transformation strategy as an all-encompassing catalyst for applications, virtual reality, artificial intelligence and other future innovations.

The field of artificial intelligence (AI) has been around for many decades since the 1950s, with initial promises to build intelligent machines that can exceed human intelligence. Major areas of AI include expert systems, natural language processing, speech understanding, robotics, computer vision, neural network and others [16]. Smart computers that exhibit human intelligence emerged. They included the Deep Blue supercomputer which defeated the world chess champion Gary Kasparov in the late 1990s, and the smart computer Watson introduced in 2011 with natural language processing capabilities which defeated human Jeopardy champions. Watson used machine learning, a type of AI that replaces hard-coded logic with the insights and patterns it gleans from large data sets and is more effective in fields where defining the rules are difficult [17].

Artificial intelligence has become a disruptive technology in the digital transformation of business enterprises. Reference [18] predicted that in 2019, 40% of all digital transformation initiatives and 100% of all effective IoT efforts will be supported by AI capabilities. It described AI's application in many business areas that include IT and security, business operations and decision support, finance and accounting, and human resources. Robotic process automation (RPA), an AI technology, is gaining importance in accelerating digital transformation initiatives. Its worldwide market grew 63% in 2018 [19]. Machine learning, a branch of AI, has been around since the late 1950s and is gaining significance in advanced analytics deployed in digital transformation. It involves computers to learn from experience and make decisions with minimal human intervention. It has found applications across many industries. Reference [20] projected that the global machine learning market is expected to reach \$20.83B in 2024, attaining a compound annual growth rate of 44% since 2017.

4. Enterprise Under the Cloud

Cloud computing emerged in the last decade utilizing the advances in hardware virtualization and grid computing [21]. It provides a scalable platform for pull-based on-demand services based on user needs around the world. By eliminating the need for building expensive data centers and providing a "pay-as-you-go" service model, the cloud model provides the potential for significant savings in IT infrastructure costs.

The knowledge and relationship imperatives in the new economy are enabled by the cloud platform which is massively collaborative between people, objects and devices [22]. Reference [23] described the utilization of Big Data sources for different components of knowledge management in the acquisition, creation, dissemination, storage, and application of knowledge. The cloud model deploys knowledge-as-a-service that monitors the knowledge pushed to the market as well as the market itself to align with the needs of customers [24]. It provides a pull-based knowledge service model supporting the knowledge management life cycle.

At the core of digital transformation is the way that value is delivered to the internal and external enterprise. The build-to-shelf model of the past is replaced by a ubiquitous real-time sense-and-response service model based on the needs of constituents, transcending geographical and temporal boundaries. Basic cloud services include software-as-a-service (SaaS), infrastructure-as-a-service (IaaS) and platform-as-a-service (PaaS).

As the digital transformation of the enterprise has become more data and knowledge centric, areas of interest include data-as-a-service (DaaS) and knowledge-as-a-service (KaaS). Reference [25] described DaaS as collating data and compiling into relevant streams that subscribers can access on-demand. It is a business-centric service that transforms raw data into meaningful and reusable data assets and delivers these data assets on-demand via a standard connectivity protocol [26]. Knowledge-as-a-service (KaaS) can be conceived as an on-demand knowledge store, capable of

searching, analyzing and restructuring its knowledge sources [27]. The cloud provides an integrated platform for the generation and distribution of knowledge throughout the enterprise. Everything-as-a-service (XaaS) emerges as the latest trend in the cloud-based service model. Reference [28] described XaaS as the business capabilities, products, and processes not as discreet vertical offerings operating individually in silos, but rather, as a collection of horizontal services that can be accessed and leveraged across organizational boundaries.

4.1. Figure (Cloud Architecture)

Figure 1 illustrates a cloud architecture for digital transformation that includes key elements of technology, community (of people, organizations, things and systems), enterprise processes and data. The technology infrastructure resides in the integrated platform that comprises the cloud, on-premise and hybrid components.

4.2. The Cloud Deployment

There are different cloud deployment models that include the public cloud, private cloud and hybrid cloud. The public cloud service is offered to the general public. The cloud provider owns, manages, and operates all computing resources located within the provider's facilities. The private cloud is operated for a single organization. It could be managed by the organization or a third party and can be hosted on-premise or at a third-party site. A hybrid cloud structure is composed of public and private clouds or on-premise resources. Hybrid cloud is a common strategy to migrate basic and non-sensitive applications to public clouds and keeping business-critical applications on-premise. Hybrid cloud also provides the ability to scale on-premise infrastructure to the public cloud to handle overflow and pay for the resources they temporarily need. Another consideration is single versus multi-cloud. A single cloud deployment uses a single provider serving all services or applications, whereas a multi-cloud deployment utilizes different providers. A multi-cloud approach may be chosen to prevent vendor lock-in and leverage best-of-breed solutions. Reference [29] reported that 80% of organizations prefer a multi-cloud approach to cloud computing.

4.3. An Integrated Platform

One of the age-old problems in enterprise information management is the integration across data silos and disparate systems. Integration is an integral part of digital transformation that provides connectivity and access, optimizing business processes and data sharing across the enterprise. Reference [30] described integration-platform-as-a-service (iPaaS) as a suite of cloud services, enabling the development, execution and governance of integration flows connecting any combination of on-premise and cloud-based processes, services, applications and data within individual or across multiple organizations. The iPaaS market is expanding and is becoming an essential

offering from cloud vendors. Another platform for cloud integration is application programming interfaces (API). APIs define communication methods between software components.

In the cloud environment, it offers connectivity between applications on-premise and across clouds.

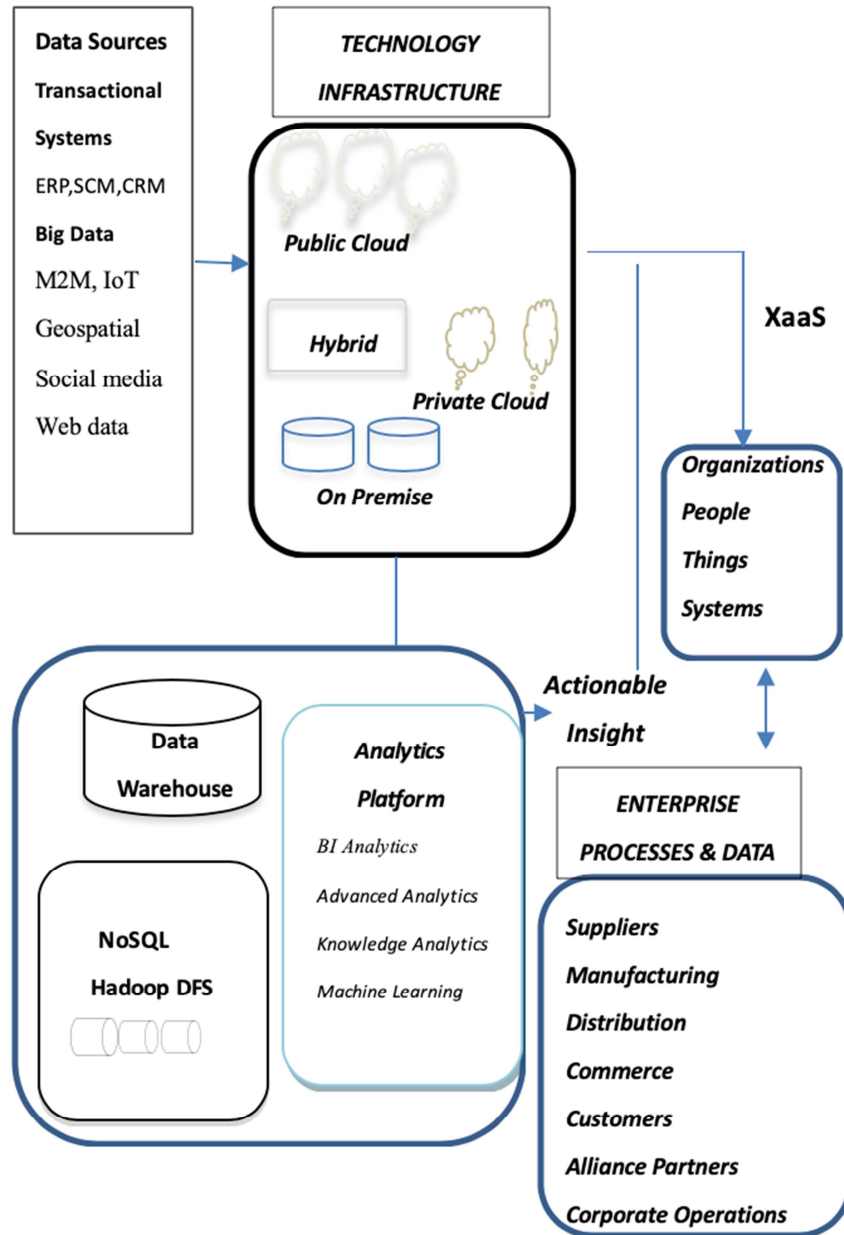


Figure 1. Digital Transformation Under the Cloud.

Reference [31] described API management as the process of publishing, securing, promoting, and overseeing APIs and that iPaaS as cloud services that enable the development, execution, and governance of integration flows. It pointed out the shortcoming of API management alone in putting the focus on publishing the app as if it's an island, where an app is now commonly associated with an aggregation of its own or third-party services. It proposed a platform of the convergence of API management and iPaaS.

4.4. Big Knowledge Analytics

The architecture described in Figure 1 illustrates that

transaction and Big Data sources are ingested and processed respectively through traditional data warehousing and business intelligence (BI) analytics and Big Data platforms that are scalable and can handle large volume of data. Reference [32] described an architecture for Big Data that distributes computations over large server clusters. A common platform is Apache Hadoop, which consists of client machines and clusters of loosely coupled commodity servers that provide distributed data storage utilizing the Hadoop Distributed File System (HDFS) and distributed processing via MapReduce. Real-time NoSQL databases such as HBase can be used in conjunction with Hadoop to provide real-time read/write of Hadoop data.

Data acquired and stored utilizing traditional platforms such as data warehouses and Big Data platforms such as Hadoop and NoSQL will go through analytic platforms that include business intelligence analytics, Big Data analytics, and knowledge analytics. Reference [4] explained that business intelligence deploys statistical methods to describe what and when things happened. Big Data analytics uses predictive and prescriptive analytics to describe what is likely to happen in the future and what is the best outcome given uncertainty. Techniques deployed in predictive analytics include data mining, predictive modeling and machine learning, where prescriptive analytics utilizes various techniques in optimization to direct future activities to achieve optimal or near optimal results [4]. Big knowledge source can be processed through contextualized knowledge analytics applied to the domain of organizational knowledge. Knowledge analytics utilizes technologies such as semantic web, machine learning, data and text mining techniques for knowledge discovery and identification to draw insights on knowledge domains [22]. Actionable insights created through analytics are utilized to enhance enterprise performance.

4.5. The Digital Community

In the knowledge and relationship economy, businesses have extended from the internal focus of operational and product excellence to the external focus of managing relationships in the extended enterprise that include customers, suppliers and alliance partners. Digital transformation further extends the universe of the enterprise to include organizations, people, things and systems (Figure 1). Value creation has taken a new paradigm of interactions beyond traditional boundaries. For example, the Internet of Things (IoT) has created new products, new opportunities and value propositions. The new digital community has become the driver and enabler of enterprise processes and data in the digital transformation of the value chain.

5. Business Implications

The capability to follow the path of digital transformation has differentiated winners from losers in business. The recent coronavirus pandemic has tested the readiness of businesses to quickly respond to necessary changes. Some companies gained and many lost. A few cases are analyzed below. They include the success stories of Walmart and Target, the failure of Sears and JCPenney, and a warning sign for IKEA.

5.1. The Success of Walmart and Target

Reference [33] described the secrets to Walmart's success include a continuous history of incremental innovation, which comprises the key ingredients for the transformation to a modern digital enterprise. Its early Retail Link system allows suppliers to receive real-time point-of-sale data for continuous replenishment of its inventory based on actual customer demands [34]. Big Data Analytics was used to anticipate market demand, provide quick responses, and drive business

performance [35]. It expanded its investment in IoT technology utilizing biometric sensors in shopping carts [36]. Social media were employed to engage customers, gain insights into customers' response to promotions, and give individual stores their relevance to customers [37]. It leveraged cloud strategies to create a best-in-class global e-commerce platform to power anytime, anywhere shopping for its customers [38]. Artificial intelligence was deployed in a wide range of applications ranging from managing customer experiences to inventory management. In 2008, it launched an AI Lab inside one of its stores [39]. Reference [33] described that Walmart expanded to 350 stores using autonomous artificial intelligence computer vision mobile robots (AMRs) to provide real-time on-shelf product data. It deployed computer vision technology with artificial intelligence powered cameras to monitor checkouts in more than 1,000 stores. It leveraged knowledge and relationship to build loyalty and trust among its customers and enhance efficiency in service delivery and customer care ([40, 41]). Reference [42] reported in the Wall Street Journal that Walmart is reaping the rewards of being one of the few retailers positioned to successfully navigate a global pandemic, surging in quarterly sales as consumers turned to its giant stores to stock up on food and household goods. E-commerce sales jumped 74% as millions of customers switched to ordering online for home delivery or picking up groceries in the company parking lots.

Target was slow in embracing e-commerce, but its efforts to catch up in the transformation has paid off with strong digital results. It saw an increase of 141% in digital sales in the first quarter of 2020 [43]. Reference [44] reported that Target remodeled 400 stores and equipped them with new technology over the last two years. It further described that the retailer already used a combination of augmented reality, artificial intelligence and virtual reality, and wanted to build out a holistic digital strategy for deeper customer personalization. Reference [45] reported that Target advanced during the coronavirus pandemic, with comparable sales through stores or digital channels operating for at least 12 months rose 10.8% for the quarter ended May 2, 2020. The success is attributed to its heavy investment in recent years to add e-commerce buying options for shoppers, including home delivery and curbside pickup.

5.2. The Fallout of Sears and JCPenney

Sears went through bankruptcy less than two years ago. The company was in trouble for many years. Its problems spanned many areas, including the lack of a core branding strategy, failing online competition and failure to adapt to market demands. Contributing to the failure is Sears' disconnect with its customers in not anticipating and adapting to the changing customer needs ([46, 47]). Its failing strategy in shedding core brands includes selling Black & Decker before filing for bankruptcy, and recently its DieHard batteries and delivery and installation business. Reference [48] indicated that Sears closed hundreds of stores after exiting bankruptcy in February 2019. It questions Sears' survival during the coronavirus pandemic when purchases are shifting rapidly online. It

pointed out that older shoppers are more likely to stay home during the pandemic and that the average age of Sears shopper is 50. The pandemic may finally deal an end to Sears with its unpreparedness to meet the challenge.

Reference [49] reported on May 16, 2020 that JCPenney filed for bankruptcy, the latest retail giant to see its downfall hastened by the coronavirus crisis. The pandemic was the final blow to a 118-year-old company struggling to overcome a decade of bad decisions, executive instability and damaging market trends [49]. Reference [50] summarized some noticeable points leading to Penney's demise. They include the failed strategy in the late 2011 of ditching top private-label brands with loyal followers and ending coupons and clearance sales, alienating Penney's shoppers en masse. It changed its marketing and store design to make it more palatable to wealthier shoppers with little relevance to low- and middle-income customers. Penney was behind in its digital strategy compared to its rivals. Losing connection and trust with its customers and the lack of a digital strategy that enables a quick sense-and-response to market demands contributed to its failure. Like in Sears' case, the pandemic created a particular problem for JCPenney, given that they have older shoppers who are likely to stay home during the crisis [48]. As the pandemic accelerates the shift towards online retail, the failure to capture the e-commerce opportunity to serve the shelter-in-place customers delivers the final death blow to both Sears and JCPenney.

5.3. Warning for IKEA

Reference [51] reported that IKEA is starting to recall furloughed workers to help with online orders and customer service. It described IKEA's e-commerce challenge when orders have doubled since March 2020. The article summarized the business issues as follows. The pandemic would have created a great opportunity for furniture stores as the shelter-in-place orders prompted workers to work remotely and set up workspace at home. IKEA's slow embrace of e-commerce before the pandemic has left customers across the U.S. struggling with operational issues such as tracking and receiving orders. Unlike companies like Target and Walmart who have been investing to retool their operations, IKEA wasn't prepared for the sudden surge in online demand created by the pandemic. The company was flooded with customer complaints of issues such as delayed and undelivered orders. Its food division was still using paper and spreadsheets to track the flow of products. It is apparent that IKEA should invest in digital transformation to upgrade its operations and digital capability including a readiness in e-commerce to avoid becoming the next casualty of surging new market demands.

6. Conclusions

The digital transformation of the enterprise in the 21st century goes beyond automation and incremental process improvement. This paper examines the latest trends in technology innovations that drive the transformation of

modern enterprises. The new economy characterized by knowledge and relationship requires the new capabilities of business in real-time sense-and-response, anticipation of rapidly changing market demands, and connectedness to their customer base. Analysis of recent business cases during the coronavirus pandemic shows an alarming theme behind the failure of companies in addition to common problems in leadership, financials, products, and marketing strategies. It includes the failure to adapt to market demands, the failure to connect to customers and adapt to changing customer tastes, the lack of a digital strategy and slow embrace of e-commerce. The business cases also show that winners emerged for those companies which committed to and invested in a digital transformation strategy.

This paper provides a framework of technology drivers for the digital transformation of modern enterprises. They include Big Data, cloud computing, advanced analytics and artificial intelligence. The transformation creates actionable intelligence from mountains of data to improve business operations and processes. The digital transformation revives an enterprise to a proactive sense-and-response mode that can anticipate the rapidly changing market demands and fulfill user needs anywhere and anytime around the globe. The transformation turns a static, disparate and disconnected enterprise into a connected and collaborative community with mobility and intelligence. The cloud transformation presented in this paper provides a highly scalable, on-demand pull-based service model, which allows massive collaboration between people, objects and devices, transcending traditional geographic and temporal boundaries.

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