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The Impact of Digital Transformation on Costs in the Egyptian Companies: An Empirical Study

Manar Omar Ali [a,▪] . Mohamed Mahmoud Yousef [a] . Bassant Bader El-Dien Sharawy [a]

[a] Faculty of Commerce, Cairo University, Egypt.
▪ ***Corresponding author**:* manar.omar@foc.cu.edu.eg

Abstract

This paper examines the impact of Digital Transformation (DT) on costs using a panel of 30 Egyptian companies listed in the EGX100, employing the panel-corrected standard error (PCSE) methodology over the period from 2010 to 2023, resulting in a total of 420 firm-year observations. The study found that the four dimensions of DT: Internet of Things (IoT), Cloud Computing (CC), Big Data Analytics (BDA), and Robots (R) reduce costs in these companies. Specifically, industrial companies listed on the Egyptian Stock Exchange exhibit significant cost reductions due to DT. DT eliminates inefficiencies in traditional companies and improves internal and external collaborations. This enhances operational performance, profitability, and competitive positioning. Digital transformation enhances a company's ability to predict future scenarios and outcomes, thereby improving decision-making and the efficient utilization of resources.

Keywords

Digital Transformation; Costs; Internet of Things; Cloud Computing; Big Data Analytics; Robots; Manufacturing Companies; Performance; Operational Performance

Article history

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1. Introduction

Competition among companies has intensified significantly due to the increased openness of markets and the growing diversity of brands. Customers find the same product with the exact specifications and quality provided by more than one supplier. Consequently, for companies to succeed in attracting and retaining customers, they must make a significant effort to provide products with specifications, quality, and pricing that customers accept (Palange & Dhatrak, 2021). Price can play a vital role in customers' choices, as they often opt for the lowest-priced product when the product specifications and quality are equal. Therefore, companies rely on cost reduction as a tool to achieve customer satisfaction, and as a result, cost reduction has become a prominent and strategic goal for most companies. To achieve the goal of cost reduction, companies must reduce costs across the entire organization, not just at the product level. In other words, companies should not only focus on reducing the costs of manufacturing activities, but also seek all available opportunities to minimize costs. These opportunities could be found in production, marketing, selling, and other activities (Akeem, 2017). In this regard, companies can benefit from the Fourth Industrial Revolution.

The industrial sector witnessed many revolutions. Each industrial revolution was characterized by an invention that led to modernization in the industrial sector. The first industrial revolution was characterized by steam energy, and the second one was characterized by electric power. Electronics and computers characterized the third industrial revolution, and it is considered the foundation of the fourth industrial revolution. To explain, the Internet, the ability to store large amounts of data, and the unlimited possibilities of access to knowledge are the basis for artificial intelligence technologies (Lu, 2017; Rojko, 2017). The fourth industrial revolution, like other revolutions, is expected to affect the industrial sector. Companies can take advantage of the technologies provided by artificial intelligence to achieve successful DT that leads to significant performance improvements (Abdallah et al., 2021).

Digital transformation enables companies to achieve numerous advantages. First, digital transformation provides analytics-based business insights, enhancing the company's ability to predict future scenarios and outcomes, and improving decision-making and the efficient utilization of resources. Second, digital transformation fosters a collaborative work environment, leading to significant changes in internal cooperation between employees. This enables greater sharing of data and information, ultimately resulting in faster responses. Third, digital transformation enables digital cooperation with customers, allowing for the exchange of data in both directions between the company and its customers. This exchange enables the company to improve and develop products for customers, achieve customer satisfaction, and reach a larger segment of customers, ultimately increasing revenues. Fourth, digital transformation facilitates digital cooperation with suppliers, enabling real-time information exchange between the company and its suppliers, which allows for improved inventory management and reduced lead times (Abdallah et al., 2021; Duraivelu et al., 2022; Jones et al., 2021; Opazo-Basáez et al., 2023).

In light of the above, it can be said that digital transformation contributes to reducing costs and increasing profits by improving operational performance. To illustrate, digital transformation enhances the efficiency of resource utilization, quality, customer engagement, work environment, operations analysis and management, and decision-making (Albukhitan, 2020; Butt, 2020; Duman & Akdemir, 2021; Horvat et al., 2019; Kamble et al., 2020; Singh et al., 2021; Yu et al., 2022; Zhai et al., 2022). Although many studies have indicated that DT improves the operational and financial performance of manufacturing companies, none of these studies have been conducted in the Arab business environment, in general, or in the Egyptian one, in particular. Moreover, none of these studies measured the extent of digital maturity in the country under study. Furthermore, the direct relationship between DT and total production, sales, and administrative costs has not been examined in any of the previous studies. Based on this, the paper aims to investigate whether DT contributes to cost reduction. It will examine the impact of artificial intelligence technologies (the IoT, CC, BDA, and Robots) on costs in manufacturing companies in Egypt.

2. Literature Review

Digital transformation has a significant impact on various cost structures within enterprises, affecting equity, debt financing, operational, and labor costs. The adoption of digital technologies enhances efficiency, reduces information asymmetry, and streamlines processes, leading to cost savings across various areas. The process of digital transformation mitigates informational opacity and fortifies governance frameworks, resulting in a reduction in equity capital costs. This phenomenon is especially evident within private sector enterprises, wherein augmented transparency and governance exert a more significant influence (Wang & Feng, 2024). Digital transformation is correlated with a decrease in debt financing costs. This phenomenon is predominantly attributable to a decrease in information asymmetry and agency issues, which are pivotal determinants of debt costs. The impact is particularly pronounced in enterprises with sound financial standings and those subjected to audits by prominent international firms (Sun et al., 2022; Wang & Zhu, 2023; Xu & Pan, 2024).

In industries such as paints and coatings, the implementation of digital transformation has the potential to reduce operational costs by as much as 48% significantly. This enhancement is achieved through the reduction of required laboratory tests, thereby expediting the development timeline and reducing related costs (Kern et al., 2020). In the drilling sector, digital transformation plays a crucial role in detecting and mitigating Invisible Lost Time (ILT), resulting in a 7% decrease in overall well delivery duration, which corresponds to significant financial savings (Al-Aufi et al., 2018).

2.1. Internet of Things and Cost Reduction

Table 1: *A Summary of Literature on IOT and Cost Reduction*

Author(s)	Title	Data Collection Method	Final Sample	Main Result
(Lee et al., 2022)	Investigating the impact of benefits and challenges of IOT adoption on supply chain performance and organizational performance: An empirical study in Malaysia	Questionnaire	▪ 43 Responses ▪ Malaysia.	There is a positive relationship between IoT, supply chain, and organizational performance.
(Al-Khatib et al., 2023)	Internet of things, big data analytics, and operational performance: the mediating effect of supply chain visibility		▪ 225 Responses ▪ Jordan.	There is a positive relationship between IOT, supply chain visibility, and operational performance.

The previous table indicates a positive relationship between IoT and operational performance in a sample of Malaysian manufacturing companies (Lee et al., 2022). Similarly, Al-Khatib et al. (2023) found that the IoT enhances operational performance for a sample of pharmaceutical companies in Jordan. The IoT integrates all the elements of the supply chain by synchronizing the information flow with the physical flow. This leads to improved product quality, enhanced material tracking, optimized inventory management, and increased operational efficiency. It is believed that analyzing large datasets collected from various sources using IoT enhances decision-making and develops highly accurate predictive models, ultimately leading to improved supply chain performance. Additionally, the process of integrating and sharing real-time information stimulates collaboration, improves internal processes, and mitigates potential operational risks. This ultimately leads to improved operational performance (Fatima et al., 2022; Garg et al., 2022; Tan & Sedhu, 2022). In light of the above, it can be reiterated that the IoT enhances resource utilization, quality, and the decision-making process, ultimately leading to reduced costs. Hence, the current paper intends to test the following hypothesis:

H1: There is a negative relationship between IoT and costs in manufacturing companies listed on the Egyptian Stock Exchange.

2.2. Cloud Computing and Cost Reduction

Table 2: *A Summary of Literature on Cloud Computing & Cost Reduction*

Author(s)	Title	Data Collection Method	Sample	Main Result
(Vasiljeva et al., 2017)	Cloud computing: business perspectives, benefits, and challenges for small and medium enterprises (case of Latvia)	Questionnaire	▪ 86 Responses. ▪ Latvia.	There is a negative relationship between cloud computing and costs.

(Khayer et al., 2020)	Cloud computing adoption and its impact on SMEs' performance for cloud-supported operations: A dual-stage analytical approach	Questionnaire	▪ 311 Responses. ▪ Bangladesh	There is a positive relationship between cloud computing and performance.
(Chen et al., 2022)	Estimating the impact of cloud computing on firm performance: An empirical investigation of listed firms	Content Analysis	▪ 369 announcements. ▪ Worldwide listed companies ▪ 2010-2016	There is a positive relationship between cloud computing and profitability and market value.

Vasiljeva et al. (2017) argued that small and medium-sized enterprises (SMEs) in Latvia achieve many advantages by using CC. First, CC enhances cooperation among employees, as well as between companies and their customers. Second, CC improves innovation and development. Third, CC helps companies enter new markets. The study also indicated that most of the study sample (68%) believe that CC contributes significantly to reducing costs. For example, using CC reduces energy costs as cloud providers build their infrastructure in cooler and less electricity-consuming locations. Additionally, CC enhances the performance of SMEs in Bangladesh. The positive relationship between CC and performance in these companies results from CC's contributions to achieving many strategic and operational benefits. Increased annual revenues, reduced operational costs, and increased focus on the company's core operations are among these benefits (Khayer et al., 2020). Moreover, Chen et al. (2022) found that CC has a positive effect on firm profitability and market value. The results also showed that the positive impact of CC on profitability is stronger in small and manufacturing companies. However, the impact of CC on market value is stronger in large service companies. Furthermore, the study results demonstrated that the positive impact of CC on market value is evident in the short term, primarily due to improved investor expectations regarding financial performance. Hence, the current study intends to test the following hypothesis:

H2: There is a negative relationship between CC and costs in manufacturing companies listed on the Egyptian Stock Exchange.

2.3. Big Data Analytics and Cost Reduction

Table 3: *A Summary of Literature on BDA & Cost Reduction*

Author(s)	Title	Data Collection Method	Sample	Main Result
(Popovic et al., 2018)	The impact of Big Data analytics on firms' high-value business performance	A comparative case study	3 manufacturing companies use different BDA levels	There is a positive relationship between BDA and operational performance.

(Belhadi et al., 2019)	Understanding big data analytics for manufacturing processes: insights from the literature review and multiple case studies	Literature review of journal articles & A Case Study	▪ 62 papers. ▪ 2004-2019. ▪ Three plants of a chemical company	BDA provides a company with many capabilities, such as enhanced transparency, improved performance, supported decision-making, and promoted knowledge.
(Sang et al., 2021)	A big data approach for workers' performance evaluation in IoT-enabled manufacturing shop-floors.	A case study	▪ RFID tags and readers recorded 3 3-month of operation data.	There is a positive relationship between BDA and productivity.

Table 3: *A Summary of Literature on BDA & Cost Reduction (Cont'd)*

Author(s)	Title	Data Collection Method	Sample	Main Result
(Kang & Zhong, 2023)	A methodology for production analysis based on the RFID-collected manufacturing big data	A Case Study	▪ 413472 pieces of data recorded by RFID	(Kang & Zhong, 2023)
(Schoenherr, 2023)	Supply chain management professionals' proficiency in big data analytics: Antecedents and impact on performance	Questionnaire	▪ 531 responses ▪ The U.S.	BDA has a significant positive impact on cost performance, while the positive impact of BDA on quality was not significant.

The literature argued that BDA enables companies to achieve many benefits. Using BDA helps companies improve quality, reduce energy consumption, lower emissions, enhance workplace safety, derive insights from real-time data, and identify the causes of low efficiency. This leads to improved organizational performance (Belhadi et al., 2019). Popovic et al. (2018) explored the impact of BDA on operations management in three manufacturing companies operating in different fields (building materials, pharmaceuticals, and electrical appliances). The researchers found that using BDA in the three companies improved planning, quality, and production processes. These improvements led to enhanced forecasting and increased availability of production equipment, resulting in reduced losses, fewer defective products, and lower rework costs.

The first company (building materials) revealed that its production volume fluctuates due to irregular demand. Therefore, it may experience periods of high production, and at other times, the volume of production decreases, resulting in unutilized resources during those periods. However, using BDA allowed the company to correlate the volume of orders with holidays, national incentives, and the announcements of new projects. The second company (pharmaceuticals) uses data to improve operational performance. For example, it utilizes delivery delay data in forecasting, which results in lower inventory costs. Additionally, the use of BDA has improved the decision-making process. For instance, BDA provides accurate and reliable data on costs, leading to more informed pricing decisions. The third company (electrical appliances) has benefited from BDA in predicting its ability to deliver on time.

Moreover, Sang et al. (2021) analyzed data collected using RFID over three months in a manufacturing company to assess labor performance on a daily, weekly, and monthly basis. The results indicated that the workers' performance declined from midnight until early morning, which may be attributed to drowsiness. Also, there was a decrease in workers' performance after breaks, which may have been caused by the lunch effect (post-lunch slump). Besides, there was a noticeable decrease in performance on Sunday and Monday. This may have occurred because of the bad feeling that the workers have at the beginning of the week (Blue Monday). In addition, these two days are often occupied by part-time workers. Furthermore, performance quality drops significantly at the beginning of the month, after which production quality stabilizes throughout the rest of the month. This is believed to occur because new workers begin performing their tasks during the first few days of the month.

Similarly, Kang and Zhong (2023) analyzed production in one manufacturing company to demonstrate how BDA can contribute to improving performance. They relied on identifying and analyzing the causes of inefficiency on the shop floor. This analysis helped identify workers with high performance rates and those with high error rates. Also, this analysis helped identify inefficiency rates in machines that may be related to the design of machines or processes. Furthermore, Schoenherr (2023) surveyed a sample of U.S. manufacturing companies. Contrary to his expectations, he found that there was no strong positive impact of BDA on quality. He believes that the reason for this result is that these companies were already using traditional analysis methods. Therefore, complex BDA did not have a significant impact on quality. On the other hand, the results showed that BDA contributes significantly to reducing costs. The researcher indicated that the reason for this is the contribution of BDA to identifying cost factors and trends. For example, costs can be reduced by analyzing raw material data and determining price trends to complete purchases at the most advantageous time.

In light of the above, it can be reiterated that better performance can be achieved by analyzing manufacturing data and defects during production. This analysis enables better decisions to be made, improvements to be implemented, and quality issues to be identified and addressed before they arise, ultimately reducing costs. Hence, the current paper intends to test the following hypothesis:

H3: There is a negative relationship between BDA and costs in manufacturing companies listed on the Egyptian Stock Exchange.

2.4. Robots and Cost Reduction

Table 4: *A Summary of Literature on Robots & Cost Reduction*

Author(s)	Title	Data Collection Method	Sample	Main Result
(Barozes et al., 2020)	Eefficiency analysis of the manufacturing line with industrial robots and human operators	Simulation Experiment & Case Study	▪ An Automotive Company. ▪ Poland.	There is a positive relationship between robots and productivity.
(Bu et al., 2022)	Robotic process automation: a new enabler for digital transformation and operational excellence	Case Study	▪ A pharmaceutical company. ▪ South Korea.	There is a positive relationship between RPA and operational excellence.

As the previous table shows, Barozes et al. (2020) found that replacing humans with robots in the automobile industry results in an approximately 30% improvement in production line productivity. Additionally, Bu et al. (2022) found that the use of Robotic Process Automation (RPA) contributes to reducing labor costs and enhancing operational performance in a pharmaceutical manufacturing company in South Korea. Using RPA has eliminated repetitive and daily manual data entry processes. This resulted in improved work accuracy and reduced working hours. Using RPA has saved 50,000 working hours and more than one billion Korean Won (KRW) annually. Hence, the current paper intends to test the following hypothesis:

H4: There is a negative relationship between Robots and costs in manufacturing companies listed on the Egyptian Stock Exchange.

2.5.Digital Transformation and Cost Reduction

Table 5: *A Summary of Literature on DT & Cost Reduction*

Author(s)	Title	Data Collection Method	Final Sample	Main result(s)
(Horvat et al., 2019)	Researching the effects of automation and digitalization on manufacturing companies' productivity in the early stage of Industry 4.0	Questionnaire by the Fraunhofer Institute for Systems and Innovation Research	▪ 1594 Responses. ▪ Germany.	▪ Digitalization and automation have a positive impact on labor productivity ▪ Automation has a positive impact on total factor productivity. ▪ There is no relationship between digitization and total factor productivity.
(Duman & Akdemir 2021)	A study to determine the effects of Industry 4.0 technology components on organizational performance	Questionnaire	▪ 79 Responses. ▪ Turkey.	Digital transformation has a positive impact on operational performance.

(Gue & Xu, 2021)	The effects of digital transformation on the firm performance: Evidence from China's manufacturing sector	Content Analysis	▪ 2254 observation. ▪ 2010-2020. ▪ China.	▪ There is a positive relationship between digital transformation and operational performance. ▪ There is a U-shaped relationship between digital transformation and financial performance. There is a negative relationship between digital transformation and costs.
(Manresa et al., 2021)	Investigating the impact of new technologies and organizational practices on operational performance: Evidence from Spanish manufacturing companies	Questionnaire by the Fraunhofer Institute for Systems and Innovation	▪ 101 Responses. ▪ Spain.	There is a positive relationship between digital transformation and operational performance.
(Zhai et al., 2022)	Does digital transformation enhance a firm's performance? Evidence from China	Content Analysis	▪ 18318 observations. ▪ 2009-2019 ▪ China.	▪ There is a positive relationship between digital transformation and financial performance. ▪ There is a negative relationship between digital transformation and operating costs.
(Zhang et al., 2022)	Enterprise digital transformation and production efficiency: mechanism analysis and empirical research	Content Analysis	▪ 11131 observations. ▪ 2009-2017. ▪ China.	▪ There is a positive relationship between digital transformation and production efficiency.
(Opazo-Basáez et al., 2023)	Is digital transformation equally attractive to all manufacturers? Contextualizing the operational and customer benefits of smart manufacturing?	Questionnaire	▪ 351 responses. ▪ Spain.	▪ There is a positive relationship between digital transformation and operational performance.
(Tian et al., 2023)	The role of digital transformation practices in the improvement of the operation in manufacturing firms: A practice-based view	Content Analysis	▪ 10115 Observations ▪ 2016-2020. ▪ China.	There is a positive relationship between digital transformation and operational efficiency.

Researchers are interested in studying the impact of DT on performance in manufacturing companies. Some of them were interested in operational performance (Horvat et al., 2019; Manresa et al., 2021; Opazo-Basáez et al., 2023; Tian et al., 2023; Zhang et al., 2022), while others were interested in financial performance (Gue & Xu, 2021; Zhai et al., 2022), and the overall performance (Duman & Akdemir, 2021). However, it is noted that most studies focused on operational performance. This is because the effect of DT on operational performance is evident in a relatively short time, which may not be the case with financial performance. After all, initial investments in digital technologies may require huge financial resources. This may impact profits, especially if the company relies on loans to finance its debt. Thus, the effect of DT on financial performance may take longer to appear than operational performance. Regarding data collection methods, they varied among previous studies.

Some of them (Horvat et al., 201; Manresa et al., 2021) relied on surveys conducted by regulatory organizations, while others used questionnaires prepared by the researchers (Duman & Akdemir, 2021; Opazo-Basáez et al., 2023). On the other hand, some researchers have used databases and financial reports (Gue & Xu, 2021; Tian et al., 2023; Zhai et al., 2022; Zhang et al., 2022). Hence, it can be said that there is a noticeable difference in data collection methods between previous studies. This is because each researcher employed the data collection method most suitable for the sample they studied.

However, there is agreement among previous studies to use Return on Assets (ROA) as an indicator of financial performance (Gue & Xu, 2021; Zhai et al., 2022), although they have employed different operational performance indicators. Among operational performance indicators are workers efficiency and overall productivity (Horvat et al., 2019), production lead time, orders delivered on time, and percentage of defects and returns (Manresa et al., 2021; Opazo-Basáez et al., 2023), customer complaints (Manresa et al., 2021), production costs (Opazo-Basáez et al., 2023), operating costs (Gue & Xu, 2021), production efficiency (Zhang et al., 2022), labor productivity, physical asset efficiency, and working capital efficiency (Tian et al., 2023). On the other hand, previous studies differed significantly in terms of DT indicators. Some studies have measured DT using a specific set of digital technologies and considered each of these technologies as a binary variable (Duman & Akdemir, 2021; Horvat et al., 2019; Manresa et al., 2021; Opazo-Basáez et al., 2023). Others have used content analysis of financial reports (Gue & Xu, 2021; Tian et al., 2023; Zhai et al., 2022; Zhang et al., 2022). It is worth noting that all studies using content analysis were conducted only in China. This means that Chinese companies disclose information about DT in their financial reports, while companies operating in other countries do not.

Regarding the results of previous studies, there is agreement among them regarding the relationship between DT and operational performance. They have proven that there is a positive impact of DT on operational performance in Germany, Turkey, Spain, and China (Duman & Akdemir, 2021; Gue & Xu, 2021; Horvat et al., 2019; Manresa et al., 2021; Opazo-Basáez et al., 2023; Tian et al., 2023; Zhang et al., 2022). Noting that the indicators used to measure DT and operational performance varied, as explained previously. In addition, a study conducted in Spain revealed that local companies, compared to international ones, need a longer period to realize the positive impact of DT on operational performance. This is because DT in local companies is gradual due to the weak capabilities and resources available to local companies compared to international companies (Opazo-Basáez et al., 2023). Also, competition in China influences the relationship between DT and operational performance. Low competition allows companies to allocate the necessary resources for DT efficiently. On the other hand, high competition may lead to decisions that are not commensurate with the companies' financial position, only to keep pace with changes in the business environment. Consequently, companies may not achieve the desired results from DT, and it sometimes has a negative impact on performance (Tian et al., 2023).

Regarding the impact of DT on financial performance, there is a partial discrepancy between the results of previous studies. Duman and Akdemir (2021) and Zhai et al. (2022) found a positive relationship between DT and financial performance. On the other hand, Gue and Xu (2021) demonstrated that the relationship between them is U-shaped. This means that the positive impact of DT on financial performance may not be apparent until after a period ranging from 2 to 5 years. It is worth noting that despite both Gue and Xu (2021) and Zhai et al. (2022) conducting their studies in China, the statistical analysis results differed. The period range could be the reason for this difference. Gue and Xu (2021) covered the period from 2010 to 2020, and Zhai et al. (2022) covered a period ranging from 2009 to 2019. Thus, it is almost the same period, but the study by Gue and Xu (2021) included 2020, suggesting that the COVID-19 pandemic may have influenced the results.

Some researchers have examined the impact of DT on operational performance, using costs as an indicator of operational efficiency (Gue & Xu, 2021; Opazo-Basáez et al., 2023; Zhai et al., 2022). Some studies used content analysis for financial reports to measure DT in a sample of Chinese manufacturing companies (Gue & Xu, 2021; Zhai et al., 2022). Content analysis is considered a subjective indicator because it is subject to the personal estimates of researchers. Opazo-Basáez et al. (2023) distributed a questionnaire based on a Likert scale to measure production costs as one of the operational performance indicators. However, they focused on only three digital technologies (MES, CRM, and ERP). Moreover, the costs used by Zhai et al. (2022) were one of the control variables in their study, and they only used the production costs, neglecting marketing, selling, and administrative costs. Furthermore, the periods concerned by these studies ranged from 2009 to 2019 (Zhai et al., 2022) and 2010 to 2020 (Gue & Xu, 2021).

In light of the above, it can be stated that the results of the previous studies indicate that DT improves the operational and financial performance of manufacturing companies. However, none of these studies have been conducted in the Arab business environment, in general, or specifically in the Egyptian one. Moreover, no study has developed a comprehensive measure of DT that encompasses a wide range of digital technologies companies can utilize. Also, none of these studies measured the extent of digital maturity in the country under study. Furthermore, the direct relationship between DT and total production, sales, and administrative costs has not been examined in any of the previous studies. Building on the results of previous studies and their findings regarding DT in the manufacturing sector, this paper aims to measure the level of DT achieved by Egyptian manufacturing companies. Additionally, it aims to assess the impact of DT on manufacturing costs in companies listed on the Egyptian Stock Exchange. To do this, the researchers test the following hypothesis:

H5: There is a negative relationship between DT and costs in manufacturing companies listed on the Egyptian Stock Exchange.

3. Research Methodology

In line with Egypt Vision 2030, which aims to achieve a competitive and knowledge-based economy through digital transformation, this study aims to measure the impact of digital transformation on costs in the industrial sector in Egypt to highlight the role of digital transformation in improving operational performance in manufacturing companies, and consequently, enhancing the industrial sector. To achieve this objective, this paper examines the impact of DT on costs using data from 30 Egyptian companies with 420 firm-year observations, all of which are listed on the EGX100. It is worth noting that these 30 companies form the final sample, which comprises companies that utilize digital transformation technologies and have also agreed to provide researchers with data related to their digital transformation efforts. In addition, companies for which data was not available during the study period from 2010 to 2023 were excluded. Researchers chose a 13-year study duration because the impact of using digital transformation applications may not be immediately apparent. Table 6 summarizes the distribution of the study sample.

Table 6: *The Distribution of the Study Sample*

Sectors	N	(%)	observations	(%)
Basic resources	2	6.67	28	6.67
Construction Materials	2	6.67	28	6.67
Food and beverage	13	43.33	182	43.33
Healthcare Products	7	23.33	98	23.33
Industrial goods and services	1	3.33	14	3.33
Textiles and durable goods	3	10.00	42	10.00
Chemicals	2	6.67	28	6.67
Total	30	100	420	100

The previous table indicates that most of the study sample belongs to the food and beverage sector (43% of the total sample companies), followed by the healthcare sector (23%). Then, the textiles and durable goods sector (10%), and the basic resources, construction, and Chemicals sectors at a rate of 6.67% for each. Finally, the lowest sector included in the study sample is the industrial goods and services sector, at a rate of 3.33%. Based on the following equations, the impact of DT on the total costs of Egyptian companies was explored:

Equation 1: *Impact of DT on the Total Costs of Egyptian Companies*

$$C_{i,t} = \beta_0 + \beta_1(IoT_{i,t}) + \Sigma_{i=1}^{n} \beta_i \, CONTROLS_{i,t} + \varepsilon_{i,t} \quad (1)$$

$$C_{i,t} = \beta_0 + \beta_1(CC_{i,t}) + \Sigma_{i=1}^{n} \beta_i \, CONTROLS_{i,t} + \varepsilon_{i,t} \quad (2)$$

$$C_{i,t} = \beta_0 + \beta_1(BDA_{i,t}) + \Sigma_{i=1}^{n} \beta_i \, CONTROLS_{i,t} + \varepsilon_{i,t} \quad (3)$$

$$C_{i,t} = \beta_0 + \beta_1(R_{i,t}) + \Sigma_{i=1}^{n} \beta_i \, CONTROLS_{i,t} + \varepsilon_{i,t} \quad (4)$$

$$C_{i,t} = \beta_0 + \beta_1(DT_{i,t}) + \Sigma_{i=1}^{n} \beta_i \, CONTROLS_{i,t} + \varepsilon_{i,t} \quad (5)$$

$$\frac{Prod_t}{TS_{t-1}} = \beta_0 + \beta_1 \frac{1}{TS_{t-1}} + B_2 \frac{NSales_t}{TS_{t-1}} + B_3 \frac{\Delta NSales_t}{TS_{t-1}} + \varepsilon_t \quad (6)$$

Where:

Prod is the cost of production at the end of the year (t) and is measured using the cost of goods sold.

TS t-1 is the total assets at the end of the previous year (t-1).

NSalest is the net sales at the end of the current year (t).

ΔNSalest is the change in net sales, measured using the difference between sales at the end of the current fiscal year (t) and sales at the end of the previous fiscal year (t-1).

Ɛt is the positive residuals expressing the extent of manipulation in production at the end of the current year (t).

Equation2: *Estimated Expenses*

$$\frac{Disc_t}{TS_{t-1}} = \beta_0 + \beta_1 \frac{1}{TS_{t-1}} + B_2 \frac{NSales_t}{TS_{t-1}} + \varepsilon_t \quad (7)$$

Where:

Disct is estimated expenses at the end of the current year (t) and is measured using the total selling, administrative, and general expenses.

Ɛt is the negative residual that expresses the extent of manipulation in estimated investment expenditures at the end of the current year (t).

The following table illustrates the measurement of the variables:

Table 7: *Variables Measurement*

Variables	Proxies			Sources	Ref.	Ex Sig
	Name	Abb.	Measure			
Independent Variable DT (DT)	Internet of Things	IoT	**IoT = Dummy variable**, it gets a value of one (1) if the company uses one of the IoT applications, otherwise it gets a value of zero (0).	Calculated by the Authors	Chen et al. (2022)	-
	Cloud Computing	CC	**CC = Dummy variable**, it gets the value of one (1) if the company uses one of the CC services; otherwise, it gets zero (0).			-
	BDA	BDA	**BDA = Dummy variable**, it gets the value of one (1) if the company applies BDA, otherwise it gets the value of zero (0).			-
	Robots	R	**R = Dummy variable**, it gets the value of one (1) if the company uses any of the robot types, otherwise, it gets zero (0).			-

Table 7: *Variables Measurement (Cont'd)*

Variables	Proxies			Sources	References	Ex Sig
	Name	Abb.	Measure			
Independent Variable DT (DT)	**DT**	**DT**	**DT = Dummy variable**, it gets the value of one (1) if the company applies a high level of DT, otherwise it gets zero (0).		Gue & Xu (2021), Zhai et al. (2022), Zhang et al. (2022)	-
Dependent Variable Cost (C)	**Cost**	**C**	C =Cost of Goods Sold (COGS) + Marketing and Selling Cost (MSC) + General and Administrative Cost (GAC), all divided by the Total Assets	Annual reports and financial statements are published on the Muabsher website.	Zhai et al. (2022)	-
Control Variables	**Free Cash Flow**	**FCF**	Net cash flows from operating activities minus investment spending scaled by total assets			+\-
	Tax Planning	**TP**	Cash tax expense scaled by accounting income before taxes			+\-
	Production Manipulating	**PM**	The positive residuals express the extent of manipulation in production at the end of the current year (t).			+\-
	Discriminant Manipulating	**DiscM**	The negative residuals express the extent of manipulation in estimated investment expenditures at the end of the current year (t).			+\-
	COVID-19	**COVID**	A dummy variable takes the value (1) for the pandemic periods during the period (2020-2021) and otherwise takes the value (zero).			+\-

4. Empirical Results

4.1. Descriptive Statistics

Table 8: *Discrete Variables*

Discrete Variables		N	%
IoT	Zero	258	61
	One	162	39
CC	Zero	253	60
	One	167	40
BDA	Zero	215	51
	One	205	49
R	Zero	237	56
	One	183	44
DT	Low (0)	277	66
	High (1)	143	34
COVID	During	60	14
	Otherwise	360	86
Total		420	100

Table 8 shows that the IoT ratio in companies listed on the Egyptian Stock Exchange was 39%, followed by CC (40%), BDA (49%), and R (44%). BDA is the most applied dimension of DT in Egyptian companies, followed by R and CC. The least applied dimension of DT in Egyptian companies is the IoT. It was also found that 34% of Egyptian companies belong to the high-level DT category, and 65% belong to the low-level one.

Based on the previous results, it can be noted that nearly half of the sample uses BDA. The low costs of BDA could be the reason for this. For example, the salary of a data analyst in a company is considered the cost for BDA, and they may depend only on simple analysis applications, such as Excel. Thus, companies do not need great financial resources to apply data analytics. It was also observed that although not all sample companies use collaborative robots or AGVs, software robots are being used at a high rate. The justification for this could be that software robots are considered computer applications that have become common among a large segment of Egyptian society. Therefore, the lack of knowledge about software robots and the fear of using them are relatively low compared to collaborative robots and AGVs.

In addition, although a relatively large number of Egyptian companies utilize CC, concerns about data retention and processing by a third party remain an obstacle to its widespread adoption. On the other hand, a relatively low percentage of companies use IoT. However, this percentage may increase if more attention is paid to DT in factories. Most IoT applications used by companies are biometric devices and cameras in administrative buildings. However, in the case of using collaborative robots or AGVs in factories, sensors will be utilized more frequently, thereby increasing the percentage of IoT usage. Furthermore, it was noticed that the proportion of companies with low DT levels was high compared to those with high DT levels. Many reasons can justify this. Among these are the low awareness of the importance of DT, the lack of knowledge about DT and its technologies, the fear of implementing DT, or the insufficient financial resources required to obtain AI technologies and implement DT.

Table 9 presents the descriptive statistics for the variables at the observation and company levels during the study period. The average ratio of total operating costs to company revenues (C) in the study sample was 1.041 for companies listed on the Egyptian Stock Exchange. The standard deviation at the observation level was low (0.251), indicating homogeneity in the operating costs ratio regardless of sectors and different years. Additionally, the standard deviation at the company level was low (0.167), and the standard deviation during the study period was low (0.190), indicating homogeneity in the operating costs ratio throughout the study period. The average free cash flow (FCF) in the study sample was 0.018. The standard deviation for the entire sample was high (0.086). This suggests that free cash flows are heterogeneous in the study sample observations. The standard deviation between the companies in the study sample (30 companies) was high (0.062) relative to the mean, indicating heterogeneity among these companies. Similarly, the high standard deviation during the study period for each company individually (0.060) suggests that the fluctuation in free cash flows for each company was relatively high during the study period.

The average effective cash tax rate or tax planning was 0.173. The standard deviation for the entire sample was relatively high (0.191). This suggests that the effective cash tax rate varies across the study sample observations. The standard deviation between the companies in the study sample was low (0.0141) relative to the mean, indicating homogeneity among the companies. Similarly, the standard deviation during the study period for each company individually was low (0.131), indicating homogeneity in the effective cash tax rate or tax planning during the study period. The average production manipulation (PM) was (1.094). The standard deviation for the entire sample was low (0.662). This suggests that production manipulation is homogeneous in the study sample observations. The standard deviation between the companies in the study sample (30 companies) was low (0.551) relative to the mean, indicating homogeneity among these companies. Similarly, the low standard deviation during the study period for each company individually (0.379) suggests that the fluctuation in production manipulation for each company was relatively low during the study period.

Table 9: *Descriptive Statistics*

Variable		Mean	Std. Dev.	Min	Max	Observations	Skewness	Kurtosis
	Overall	1.041	0.251	0.791	1.466	N = 420		
C	Between		0.167	0.791	1.466	n = 30	.778	2.056
	Within		0.190	0.533	1.666	T = 14		
	Overall	0.018	0.086	-0.123	0.158	N = 420		
FCF	Between		0.062	-0.097	0.151	n = 30	-.003	2.078
	Within		0.060	-0.187	0.194	T = 14		
	Overall	0.173	0.191	0	0.596	N = 420		
TP	Between		0.141	0	0.424	n = 30	.997	2.996
	Within		0.131	-0.189	0.684	T = 14		
	overall	1.094	0.662	-0.005	2.115	N = 420		
PM	between		0.551	0.016	2.098	n = 30	-.147	2.086
	Within		0.379	0.011	2.880	T = 14		
	overall	0.061	0.014	0.040	0.082	N = 420		
Discm	between		0.012	0.042	0.081	n = 30	.068	1.793
	Within		0.008	0.036	0.097	T = 14		

The average discretionary cost manipulation (Discm) was 0.061. The standard deviation for the entire sample was relatively low (0.014). This indicates that discretionary cost manipulation is homogeneous in the study sample observations. The standard deviation between the companies in the study sample was low (0.012) relative to the mean, indicating homogeneity among the companies. Similarly, the standard deviation during the study period for each company individually was low (0.008), indicating homogeneity in discretionary cost manipulation. Deviations from the normal distribution do not significantly affect the results of statistical analysis if the skewness coefficients are within the range of (-3 to +3) and the kurtosis coefficients are within the range of (-10 to +10). The values of skewness and kurtosis are within acceptable limits, indicating that the deviation from the normal distribution does not significantly affect the results of the statistical analysis.

4.2. Correlation Matrix

Table 10 indicates a negative correlation between free cash flow (FCF) and the operating cost ratio (C) at the 5% significance level. Also, there is a non-significant correlation between tax planning (TP) and the ratio of operating costs (C), as the significance level is greater than 5%. There is a non-significant correlation between production manipulation (PM) and the ratio of operating costs (C). There is a negative correlation between discretionary cost manipulation (Discm) and the ratio of operating costs (C) at the 5% significance level.

Table 10: *Correlation Matrix*

Variables	(1)	(2)	(3)	(4)	(5)
(1) C	1.000				
(2) FCF	-0.251*	1.000			
(3) TP	0.088	-0.036	1.000		
(4) PM	-0.024	0.073	0.378*	1.000	
(5) Discm	0.135*	-0.125*	0.210*	0.745*	1.000

* p<0.05

4.3. Regression Analysis and Diagnostic Tests

Table 11 presents the econometric issues that arise after estimating the model using the ordinary least squares (OLS) method. There is no problem of multicollinearity, as the variance inflation factor (VIF) for all explanatory variables of operating costs is less than 10. There is heteroscedasticity in the study model, as indicated by the P-value being less than 5%. This suggests heterogeneity in the operating costs among the companies in the study sample. There is autocorrelation in the random error, as indicated by the P-value being less than 0.05%. This suggests that the current operating cost levels are related to those of the past. The model exhibits good specification, as the P-value for the Ramsey RESET test is greater than 5%.

Table 11**:** *Diagnostics Tests*

Variable	VIF	1/VIF
IoT	1.08	.93
FCF	1.09	.914
TP	1.20	.834
PM	2.76	.363
Discm	2.47	.405
COVID	1.05	.955
Mean VIF	1.61	.

Table 11: *Diagnostics Tests (Cont'd)*

Diagnostics Tests		p-value
Heteroskedasticity	Chi2(1) = 16.38	Prob > chi2 = 0.001
Autocorrelation	F(1, 28) = 11.07	Prob > F = 0.002
Ramsey RESET test	F(3, 334) =2.49	Prob > F = 0.06

The Panel Corrected Standard Error (PCSE) model was employed to address measurement issues related to heteroscedasticity and autocorrelation at the sample level for companies listed on the Egyptian Stock Exchange. This approach helps correct for the identified econometric problems, ensuring more reliable and robust estimates. The results are presented in the following table:

Table 12: *Regression Analysis using PCSE*

Variable			PCSE		
IoT	-0.065*				
CC		-0.122***			
BDA			-0.079**		
R				-0.127***	
DT					-0.073**
FCF	-3.365*	-0.524***	-0.469**	-0.541***	-0.322**
TP	0.139	0.129	0.123	0.131	0.010
PM	-0.148***	-0.145***	-0.137**	-0.138**	-0.150***
Discm	6.775***	6.396***	5.784**	5.994***	6.890***
COVID	-0.103***	-0.092***	-0.053***	-0.031	0.010
Industry fixed effect	Included	Included	Included	Included	Included
Year fixed effect	Included	Included	Included	Included	Included
cons_	0.834***	0.859***	0.945***	0.918***	0.932***
Obs.	420	420	420	420	420
Wald chi2	368.83	282.08	299.28	309.30	341.46
Prob > F	0.000	0.000	0.000	0.000	0.000
R^2	0.22	0.24	0.22	0.25	0.20

*** p<.01, ** p<.05, * p<.1

Table 12 shows that all five models are significant at the 1% level, with explanatory values ranging from 20% to 25%. The results indicate the following:

First, there is a significant negative impact of the IoT on operating costs at the 10% significance level (β = -0.065, P < 0.1). This suggests that the IoT has an inverse effect on operating costs for companies listed on the Egyptian Stock Exchange. As the use of IoT increases, operating costs decrease, and vice versa. Thus, the first hypothesis is accepted. Second, there is a significant negative impact of CC on operating costs at the 1% significance level (β = -0.122, P < 0.01). This suggests that CC has an inverse effect on operating costs for companies listed on the Egyptian Stock Exchange. As the use of CC increases, operating costs decrease, and vice versa. Thus, the second hypothesis is accepted. Third, there is a significant negative impact of BDA on operating costs at the 5% significance level (β = -0.079, P < 0.05). This suggests that

BDA has an inverse effect on operating costs for companies listed on the Egyptian Stock Exchange. As the use of BDA increases, operating costs decrease; conversely, as operating costs decrease, the use of BDA increases. Thus, the third hypothesis is accepted. Fourth, there is a significant negative impact of robots on operating costs at the 1% significance level (β = -0.127, P < 0.01). This suggests that robots have an inverse effect on operating costs for companies listed on the Egyptian Stock Exchange. Thus, the fourth hypothesis is accepted. Fifth, there is a significant negative impact of DT on operating costs at the 5% significance level (β = -0.072, P < 0.05). This suggests that DT has an inverse effect on operating costs for companies listed on the Egyptian Stock Exchange. Thus, the fifth hypothesis is accepted.

5. Discussion

In the current competitive environment, it is challenging for companies to maintain control over the prices of their products. Therefore, these companies focus on cost reduction to maximize profitability. Consequently, companies are now emphasizing the efficient use of the available resources, minimizing waste and inefficiency, and improving overall operational efficiency. In other words, great attention is given to reducing costs in all aspects of the company. To do so, companies focus on optimizing the usage of production elements. These elements include raw materials, human resources, machinery, time, data, and information. Cost reduction enables companies to offer high-quality products at the lowest possible costs and competitive prices while quickly responding to customers' demands to achieve customer satisfaction. This, in turn, enables companies to succeed and continue in the market. Companies can reduce costs using DT. DT provides business insights based on data analytics and facilitates internal collaboration among employees within companies, as well as external collaboration with customers and suppliers. This, in turn, enhances operational performance and reduces costs.

Our statistical results demonstrate a significant negative impact of IoT on costs in industrial companies listed on the Egyptian Stock Exchange. This result supports the positive relationship between IoT and operational performance. This positive relationship stems from the IoT's contribution to enhancing inventory management, mitigating operational risks, and facilitating real-time integration between supply chain elements (Al-Khatib et al., 2023; Lee et al., 2022). In addition, this study found a significant negative impact of CC on the costs of industrial companies listed on the Egyptian Stock Exchange. This result is consistent with Vasiljeva et al. (2021), who found a negative relationship between CC and costs in Latvia. This negative relationship explains the positive impact of CC on performance (Khayer et al., 2020), profitability, and market value (Chen et al., 2022).

Moreover, the results demonstrate a significant negative impact of BDA on the costs of industrial companies listed on the Egyptian Stock Exchange. This confirms the positive relationship between BDA and cost performance (Schoenherr, 2023), quality (Kang & Zhong, 2023), productivity (Sang et al., 2021), and overall operational performance (Popovic et al., 2018). These relationships led to improved transparency, better decision-making, and increased knowledge (Belhadi et al., 2019). Also, there is a significant negative impact of robots on costs in industrial companies listed on the Egyptian Stock Exchange. This confirms the positive relationship between robots and productivity (Barozes et al., 2020), as well as reductions in labor costs, improvements in work accuracy, and operational excellence (Bu et al., 2022).

Furthermore, the current study confirms that there is a significant negative impact of DT on overall costs in companies listed on the Egyptian Stock Exchange. This result is consistent with studies conducted in Germany, Turkey, Spain, and China, which have found that DT positively affects operational performance (Duman & Akdemir, 2021; Gue & Xu, 2021; Horvat et al., 2019; Manresa et al., 2021; Zhang et al., 2022). The positive relationship between DT and operational performance leads to improved financial performance (Duman & Akdemir, 2021; Zhai et al., 2022). However, the positive impact of DT on financial performance may not be apparent until after a period of time, ranging from 2 to 5 years (Gue & Xu, 2021).

Based on previous results, it is recommended that the Federation of Egyptian Industries organize conferences. Through public speaking at these conferences, manufacturing companies in Egypt will gain a thorough understanding of how artificial intelligence can contribute to cost reduction and productivity enhancement. This, in turn, will ensure economic growth. In addition, these conferences will provide companies with good knowledge about the most effective artificial intelligence technologies that may be used to enhance our industrial sector. Moreover, these conferences will alleviate the concerns of company managers regarding DT, which may be caused by cultural or organizational barriers or a lack of knowledge. On the other hand, it is recommended that new courses be developed to be taught to the undergraduate students at business schools. These courses should focus on the integration between artificial intelligence and various accounting majors, including cost accounting, financial accounting, taxation, finance, and auditing. This will enhance graduates' skills and qualifications, enabling them to meet the criteria and requirements of the competitive labor market.

6. Conclusion

This paper examines the impact of DT on the costs of Egyptian companies listed on the EGX100 using panel-corrected standard errors (PCSE) from 2010 to 2023. The industrial sector has undergone numerous changes due to the use of technology. Initially, manufacturing relied on steam power, then electricity, followed by computers, and now artificial intelligence, all of which have significantly impacted the operational performance of manufacturing companies. Artificial intelligence enables companies to shift from digitalization to DT. DT helps companies eliminate many inefficiencies typically faced in traditional operating systems and provides numerous advantages that enhance their competitive position. These advantages include improved internal and external collaboration, enhanced operational performance, reduced costs, and increased profits.

Companies may use many of the artificial intelligence technologies to achieve successful DT, such as IoT, CC, BDA, and R. Each one of these technologies contributes to cost reduction. First, the IoT enables real-time data collection, resulting in better asset utilization, improved quality, and more effective decision-making, leading to cost reduction. Second, CC allows for storage and processing of vast amounts of data by a third party, enabling the dealing of infrastructure, systems, or applications as services. This improves flexibility, reduces unused capacities, and avoids capital expenditure, resulting in cost reduction. Third, BDA enables the extraction of meaningful information by analyzing large datasets to identify patterns and correlations. This leads to improved quality, reduced energy consumption, enhanced maintenance processes, and more informed decision-making, thereby lowering costs. Fourth, using R instead of human labor reduces energy consumption, minimizes the risk of workplace injuries, and enhances performance, all of which contribute to cost reduction. Thus, it can be stated that DT leads to cost reduction. The statistical results showed that the four dimensions of DT (the IoT, CC, BDA, and R) increase costs in Egyptian companies listed on the Egyptian Stock Exchange. Additionally, there is a significant negative impact of DT on costs in companies listed on the Egyptian Stock Exchange.

Digital transformation mitigates the phenomenon of cost stickiness by reducing both adjustment costs and agency costs. This influence is particularly pronounced in organizations characterized by high levels of asset specificity and environmental volatility, as well as those with high management costs (Chen, 2022). Conversely, the phenomenon of digital transformation may result in augmented labor costs, particularly concerning the general workforce. This occurrence is attributable to modifications in the human capital structure, which frequently necessitate higher wages for proficient workers within digital environments. This impact is particularly pronounced in privately owned enterprises, as well as in the information technology sector (Wu et al., 2023). While the phenomenon of digital transformation typically leads to reductions in costs related to equity, debt financing, and operational areas, it may conversely result in increased labor costs due to the demand for skilled workers. These results confirm the influence of digital transformation on costs, thereby necessitating a strategic framework to effectively navigate both the advantages and obstacles linked with digital integration.

This research has several implications: managerial, practical, and social. First, managerial implications: managers shall have a better understanding of digital transformation, its applications, and benefits. In addition, they should recognize the importance of digital transformation in enhancing performance and overcome their concerns about implementing digital transformation within their organizations. Second, the research has practical implications, as implementing its recommendations is expected to increase Egypt's gross domestic product (GDP). This is because the industrial sector, which holds the largest share of the GDP in Egypt, is likely to benefit from the recommendations. In addition, this study helps correct the prevailing belief that digital transformation will lead to an increase in the unemployment rate, as this research demonstrates that digital transformation will lead to a change in the skills needed by the labor market in the digital environment; however, it will not lead to a decrease in job opportunities. Third, the research has social implications. This research serves as a valuable incentive for university professors to encourage their students to reconsider the skills they need to be competitive in today's business market.

Based on the previous studies and the current study's descriptive results, it can be said that many companies have taken actual steps toward DT, mainly industrial companies. Thus, future studies on the following topics are recommended:

- Developing a framework to help companies disclose DT information in published financial reports.
- Studying the feasibility of DT within companies through a multi-case study comparing the costs of DT and its benefits.
- Examining the impact of DT on costs in commercial and service companies.
- Investigating the effect of DT on financial performance in industrial companies listed on the Egyptian Stock Exchange.
- Exploring the relationship between women's participation on corporate boards and DT.
- Studying the relationship between the personal traits of managers, such as overconfidence, and DT.
- Examining the impact of DT on the relationship between managers' traits and the performance of companies.
- Investigating the relationship between free cash flow and costs in Egyptian companies listed on the Egyptian Stock Exchange.
- Exploring the relationship between tax planning and costs in Egyptian companies listed on the Egyptian Stock Exchange.
- Studying the relationship between earnings management and costs in Egyptian companies listed on the Egyptian Stock Exchange.

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