**Original Research Article**

**Transformational Leadership in the Digital Era: Enhancing Operational Efficiency through Technology in Industry 4.0**

**Abstract**

The purpose of this study is to investigate the effect of transformational leadership (TL) on operational efficiency (OE) with the mediating role of digitalization in Industry 4.0 (manufacturing firms). This research fills the gap by combining the dynamic capabilities theory (DCT) to describe how leadership can help in adopting the digital transformation and improve efficiency. This research used a quantitative approach and primary data, which were collected via structured closed-ended questionnaires. 400 questionnaires were distributed using convenience-based sampling among employees of manufacturing firms, and 331 complete responses were received. The current study used a deductive approach with the positivist philosophy, and the Partial Least Squares Structural Equation Modeling (PLS-SEM) technique was used for analysis using smart PLS 4. The findings of the study reveal that TL has a significant positive effect on OE. Digitalization fully mediates the relationship between TL and OE. The findings signify the impact of the leadership in assisting the technological advancements to optimize the processes and increase productivity. The research helps managers and policymakers emphasize the need for positive leadership development trainings that highlight digital adoption. Manufacturing firms have to integrate automation, digital tools, and decision-making to improve OE. The government should support digital transformation by providing incentives and training. This study assists the literature by emphasizing digitalization as an important mediator between TL and OE. This offers manufacturing industries, new approaches in how leadership and technology can drive efficiency.

**Keywords:** Transformational Leadership, Digitalization, Operational Efficiency, Manufacturing Firms, Dynamic Capabilities Theory, PLS-SEM.

1. **Introduction**

Manufacturing businesses have to face tremendous operational inefficiencies, which include supply chain disruptions, high productioncosts, slow decision-making, and resource wastage due to outdated processes (Belhadi et al. 2022). These difficulties decrease the productivity and competitiveness of the firms, making it critical for businesses to adopt modern solutions (Djellal et al. 2008). TL helps to reduce these problems by implementing a culture of innovation, adaptability, and improvement. This type of leader assists in the adoption of the latest technologies like IoT, AI, and automation that make production operations streamlined and increase the efficiency of the system (Pawar et al. 2024). Digitalization is a technique that assists in automating work procedures, decision-making in real time, and optimizing resource usage (Aldoseri et al. 2023). With the integration of TL with digitalization, businesses can attain higher efficiency in their operations, optimize costs, and increase productivity, which assists them in attaining a competitive advantage and long-term sustainability (Martinez et al. 2023).

The existing literature has widely utilized TL in different organizational practices like job satisfaction, employee performance, and innovation (Alwali et al. 2022; Farooq et al., 2023). In contrast to this, few number of studies have been conducted on OE, which is an important factor to consider in terms of manufacturing firms that are struggling to reduce operating costs and increase productivity (Sanders et al. 2016). Previous researchers had focused implicitly on digital transformation as an important parameter for the success of the business, which is mostly ignored as the mediating role between leadership and OE (Hongyun et al. 2025). This research assists in filling the gaps by determining that TL increases the OE of manufacturing firms through the implementation of digitalization. The important question in improving this research is: How does digitalization mediate the relationship between TL and OE in the case of manufacturing firms? To fill the gap, this research helps to contribute to the current literature by giving a model that links leadership, adoption of technology, and improving efficiency through offering practical solutions for businesses to adopt digital transformation.

This research is specifically considered for emerging countries like Pakistan, where Industry 4.0 struggles to implement efficient production systems, prevent outdated technologies, and mitigate resource limitations. By improving OE, these firms can remain innovative in this rapidly growing market. When TL is combined with digitalization, it can achieve sustainable growth by implementing process optimization, innovation, and asset efficiency. The foundation of this study is on the GDC model, which helps an organization to build, integrate, and reconfigure the internal and external assets to get sustainable and competitive advantages. In this way, TL assists the firms in attaining digital capabilities, which increases OE and creates eco-friendly and sustainable manufacturing firms in Pakistan.

This research used the quantitative research method to investigate the relationship between digitalization, TL, and OE in the manufacturing companies of Pakistan. A deductive approach was employed in this research while aligning with the positivist research method, which determines the objectives and hypothesis testing. The primary data was collected via a structured questionnaire, and 331 responses were taken for the statistical analysis. This study utilized convenience-based sampling, which targets the manufacturers' population (owners, professionals, managers, decision-makers, and employees) involved in digital transformation and operations. 400 questionnaires were distributed, among which 331 valid responses were received from the professionals. This study employed the PLS-SEM by using the Smart PLS 4 to investigate the hypotheses and decide the mediating role of digitalization. This approach ensured the novel findings while providing valuable approaches for academia and the manufacturing industries.

This study analyzed the mediation approach of Baron and Kenny, which confirmed that TL has a significant effect on OE, both directly and through the mediating role of digitalization. The results demonstrate that the leaders who use digital transformation can help to achieve efficiency by reducing costs, optimizing processes, and increasing real-time decision-making. This study provides a valuable contribution by extending the linkage of leadership and digitalization in the literature to enhance efficiency in manufacturing companies. From a practical approach, these results highlight the need for businesses to invest in digital technologies and leadership programs to increase efficiency. The government and firm leaders can use these findings to design a long-term model for implementing digitalization, talent development, and operational enhancements, which promote sustainability and competitiveness in manufacturing firms.

This paper is organized as follows: Section 1 contains the introduction, and Section 2 comprises a literature review. Section 3 presents the methodology, Section 4 consists of results. Section 5 presents the conclusions of the study.

1. **Literature Review**

**2.1 Transformational Leadership and Operational Efficiency**

TL is a style that influences and inspires employees to exceed their expectations by emphasizing vision, innovation, and commitment to the organizational goals (Udin et al. 2020). The leaders containing the transformational qualities focus on the individuals and try to increase their intellectual stimulation, motivation, and influence (Gonfa et al. 2019). However, OE deals with the capability of an organization to utilize its assets wisely, minimize waste, and increase the productivity of the firm, which improves the profitability and sustainability of the firm (Bakare et al. 2024). In the manufacturing industries, OE is a critical factor in establishing competitiveness, decreasing production costs, and gaining excellence (Keskar et al. 2024). Through rapid technological growth, manufacturing firms are relying on leadership to motivate change and increase the adoption of digital techniques and innovative approaches to enhance the efficiency of their firms (Dega et al. 2024).

The current literature focuses on a strong relationship between TL and OE, however, visionary leaders focus on adopting alignment with business operations (Mien et al. 2023). Previous studies suggested that transformational leaders emphasize a society that strives to achieve the skills of solving problems, continuous improvement, and decision-making in real-time, which in turn significantly increases operational performance (Madi Odeh et al. 2023). Moreover, the research conducted by Nasir et al. (2022) demonstrated that leaders who highlight digital technology and employee empowerment in the firms assist them in gaining operational productivity and process optimization. However, prior researchers examined transformational leadership about employee performance rather than the impact on OE (Jiang et al. 2017). This study fills this gap by evaluating transformational leadership, which enables process standardization, adoption of new technologies, and cost efficiency in the manufacturing industries.

The DCT (Teece et al. 2016) provided a theoretical foundation for understanding that transformational leadership promotes operational efficiency. According to this theory, organizations must inherit dynamic abilities, like seizing innovations, sensing opportunities, and efficient utilization of assets, to gain competitiveness in a rapidly evolving world (Sullivan et al. 2023). TL helps firms gain their capabilities by implementing a culture that increases digital transformation and adaptability and promotes strategic flexibility (Dong et al. 2024). They enhance the abilities of the firm to work efficiently concerning the market needs, technological adoptions, and operational challenges, to improve the overall efficiency of the firm (Cui et al. 2023). Since the prior researchers have linked dynamic abilities with the innovation and performance of the firm, their studies have not focused on the OE of the firm. So, this research has focused on emphasizing TL as a method to improve dynamic capabilities, which ultimately optimizes the operations of manufacturing firms. Based on the literature, the following hypothesis was developed.

***H1: Transformational leadership has a significant impact on operational efficiency.***

* + 1. **Digitalization and Operational Efficiency**

Digitalization is the implementation of digital techniques inside business operations to transform the systems, enhance decision-making, and increase efficiency (Naeem et al., 2024a). It involves the automation of workflows, using data analytics, and implementing digital tools to increase productivity and decrease costs. In manufacturing companies, digitalization is an important procedure to increase operational efficiency by improving the production process, increasing supply chain management, and mitigating resource wastage. Organizations that adopt digital innovation attain higher flexibility, higher market responsiveness, and higher overall performance.

The available literature indicates the significant role of digitalization in enhancing the OE of the firm. The studies propose that digital tools such as AI, IoT, and cloud computing assist firms in increasing productivity and mitigating operational bottlenecks (Rocha et al. 2022; Naeem et al., 2024b). According to the study conducted by Bargoni (2024), digitalization increases the decision-making process in real-time, which leads to optimized resource allocation and cost minimization methods. The research conducted by Ononiwu (2024) indicated that digital transformation assists in moving rapidly with the market and adaptation of new technologies, helping firms attain competitiveness in continuously evolving environments. Regardless of these advantages, few studies declared that digitalization does not guarantee efficiency on its own; instead, it needs strong leaders and a flexible organizational culture to be implemented successfully.

DCT provides a powerful basis for interpreting the relationship between digitalization and OE. The DCT theory, developed by Teece (1997), recommends that enterprises must continue to develop and enhance their capabilities to attain a competitive advantage in the market. Digitalization assists enterprises in sensing, seizing, and transforming capabilities, which allows them to identify and grasp opportunities, using the technology, and enhances processes efficiently. Through the implementation of digital tools, enterprises enhance their abilities to attain resource allocations and assist with market fluctuations, ultimately enhancing OE. Therefore, with digitalization linked with transformational leadership, firms can attain the dynamic capability that enables them to increase efficiency, sustain resilience, and implement long-term competitiveness. Considering the previous literature following hypothesis is developed.

***H2: Digitalization has a significant effect on operational efficiency.***

* + 1. **Transformational Leadership and Digitalization**

TL is an important parameter in enhancing digitalization inside organizations by implementing an innovative culture and increasing adaptability. Leaders with transformational qualities influence the employees to adapt to the change, transform digital solutions, and implement the technology into daily operations (Ardi et al. 2020). These leaders increase organizational agility, helping businesses to adapt to market demands and advance technology. Concerning the DCT (Teece et al. 1997), businesses must improve and use their limited resources to attain a competitive advantage. TL influences its followers to recognize digital opportunities and allocate the resources to attain digital transformation. The vision and dynamic approach of these leaders facilitate the adoption of the latest technologies, helping enterprises for long-term success in continuously evolving markets.

Additionally, digitalization is not just a technological enhancement but a strategic process that requires effective leadership to incorporate digital tools with business goals and objectives. TL encourages knowledge enhancement, experimentation with novel things, and employee engagement, which are essential for the successful implementation of digitalization. Continuous improvements and adopting innovation, the leaders assist the firms in growing dynamic capabilities, helping them to adapt the technology, grasp digital opportunities, and transform their operational models (Teece, 2016). The researchers have indicated that enterprises with transformational leaders are investing more in the areas of big data, AI, and automation, therefore, improving their OE and performance (Xinyue et al., 2024). Instead of the growing number of studies on leadership and digitalization, only some studies have investigated the particular mechanisms through which transformational leadership inspires digital adoption in manufacturing firms, emphasizing the need for further study in this area. Considering the above literature, the following hypothesis is developed.

***H3: Transformational leadership has a significant effect on digitalization.***

* + 1. **Mediating Role of Digitalization**

Digitalization has evolved as an innovative need in modern business environments, significantly impacting organizational performance. A huge number of studies emphasize its role in increasing the efficiency of operational processes, lowering inefficiencies, and improving decision-making. The researchers reasoned that digitalization helps smart technology integration, automation, and real-time data analytics, above all contributing to higher efficiency levels (Sarcea et al., 2024). The efficiency of the digitalization process depends on the leader's vision and strategic goals. TL, by emphasizing a culture of novelty and adaptability, can help to adapt to the digital transformation, which leads to increased OE (Schiuma et al., 2024). Instead of its ability, digitalization is not a standalone answer; its effect changes across the firms, requiring an integrated method that aligns leaders with the technological advancements of the firm (Gillani et al., 2024).

The mediating role of digitalization in leadership and firm efficiency has not been explored in the literature, particularly in manufacturing firms. Previous research has emphasized the adoption of technology and firm performance (Orero-Blat et al., 2024), however, the digitalization process transforms the leadership and its efforts into operational gains, which remains inadequately present. Digitalization is a bridge that integrates TL with organizational outcomes via increasing process automation, assisting decision-making, and implementing interdepartmental collaboration (Benini et al., 2019). The non-availability of digitalization may decrease the effectiveness of leadership, as conventional operational methods often strive to meet the demands of a digital economy. So, the knowledge of how digitalization can mediate the association between transformational leadership and OE is important for businesses that seek a sustainable competitive advantage. Considering the above literature, the following hypothesis was developed;

***H4: Digitalization mediates the relationship between transformational leadership and operational efficiency.***

* 1. **Conceptual Framework**

The conceptual model of this research contains the independent variable, dependent variable, and mediator, which are given in Figure 1.



**Figure 1: Conceptual Model of this Research**

1. **Methodology**

This study used the quantitative research method with a deductive approach, which aligns with the positive research philosophy. The primary data was obtained via a structured questionnaire, which consisted of five Likert scales from 1 (strongly disagree) to 5 (strongly agree), designed to investigate the impacts of TL, digitalization, and OE. The questionnaire was adapted from previous studies (TL 6 items from De Poel et al., 2012), (digitalization 5 items from Fichman et al., 2014), and (OE 5 items from Nawanir et al., 2016). Convenience-based sampling was utilized to get data from the target audience (owners, professionals, managers, decision-makers, and employees) from the manufacturing industries since these firms are emphasizing digital transformation and face numerous challenges in the OE of the firms. Enhancing the global impact of Industry 4.0 and digital integration, manufacturing firms can examine the role of leadership and technology in enhancing efficiency. This research uses the PLS-SEM for data analysis, since it is suitable for complex frameworks having multiple relationships, works better with small-to-medium sample sizes, and does not need strict normality assumptions. The PLS-SEM also helps in the exploratory analysis, making it a valuable tool for determining the mediation effects and obtaining the key business outcomes.

1. **Results** 
   1. **Demographic Result**

The demographic results are presented in Table I, which consists of the gender and qualification of respondents. The result shows that 51.96% of respondents are male (172 individuals) and 48.03% are female (159 individuals).

Concerning educational qualifications, the highest number of groups of respondents have an intermediate qualification (25.98%), followed by the degree of bachelor (23.86%), and matriculation (20.84%). A significant ratio of respondents have higher education degrees, with 15.70% having a degree in master and 13.59% having a degree of Ph.D. The change in the educational qualifications proposed an efficient sample, containing respondents of different levels of expertise in the firms. This ratio increases the reliability of outcomes, as individuals with varying educational qualifications help to get varied perspectives on OE, leadership, and digitalization in the manufacturing industries.

**Table I: Demographic Statistics**

|  |  |  |
| --- | --- | --- |
| **Demographics** | **Frequency** | **Percentage** |
| **Gender** |  |  |
| Male | 172 | 51.96% |
| Female | 159 | 48.03% |
| **Qualification** |  |  |
| Matriculation | 69 | 20.84% |
| Intermediate | 86 | 25.98% |
| Bachelors | 79 | 23.86% |
| Masters | 52 | 15.70% |
| PhD | 45 | 13.59% |
| **Total** | 331 | 100.0% |

* 1. **Measurement Model**

The measurement model demonstrates the reliability and validity of the constructs used in this study. Factor loadings for all items exceed the acceptable limit of 0.70 (Anser et al., 2024; Naeem et al., 2025a; Naeem et al., 2025b), indicating stronger individual item reliability. In the case of TL, the loadings range from 0.792 to 0.919, assuring that the selected variables effectively capture the construct. Similarly, digitalization (DIG) produces factor loadings between 0.739 and 0.857, however, the OE contains loadings ranging between 0.780 and 0.893, assuring the adequate representation of these constructs.

Cronbach’s alpha (α) values are above the limit of 0.70, assuring the internal consistency of the constructs, with TL at 0.827, DIG at 0.809, and OE at 0.781. Moreover, the composite reliability (CR) values for all constructs are higher than 0.80, assuring the reliability of the model. The average variance extracted (AVE) values are higher than 0.50 for all constructs (TL = 0.621, DIG = 0.601, OE = 0.612), assuring the convergent validity, saying that the items explained a substantial amount of the variance in their respective constructs. Variance Inflation Factor (VIF) values remain below 3, ensuring that multicollinearity is not a concern. These findings establish the validity and reliability of the measurement model, supporting its suitability for further structural analysis.

**Table II: Discriminant Validity**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Items retained | Abbreviation | Factor Loadings | Cronbach’s alpha | CR | AVE | VIF |
| Transformational Leadership | TL1 | 0.817 | 0.827 | 0.893 | 0.621 | 1.319 |
| TL2 | 0.797 | 1.607 |
| TL3 | 0.810 | 1.508 |
| TL4 | 0.792 | 2.026 |
| TL5 | 0.895 | 1.561 |
| TL6 | 0.919 | 1.322 |
| Digitalization | DIG1 | 0.739 | 0.809 | 0.814 | 0.601 | 2.190 |
| DIG2 | 0.826 | 2.321 |
| DIG3 | 0.857 | 1.563 |
| DIG4 | 0.794 | 1.439 |
| DIG5 | 0.783 | 1.313 |
| Operational Efficiency | OE1 | 0.832 | 0.781 | 0.820 | 0.612 | 2.171 |
| OE2 | 0.881 | 1.552 |
| OE3 | 0.780 | 1.672 |
| OE4 | 0.815 | 1.321 |
| OE5 | 0.893 | 1.119 |

The assessment of discriminant validity via the Heterotrait-Monotrait (HTMT) ratio and Fornell–Larcker criterion reveals that the constructs in this research are sufficiently different. In Table III, the HTMT values for all construct pairs are below the 0.85 thresholds (TL-DIG = 0.618, TL-OE = 0.603, DIG-OE = 0.689), demonstrating each construct measures a unique result and does not overlap with the others. This helps to evaluate that transformational leadership, digitalization, and operational efficiency are conceptually and theoretically distinct.

In the same way, Table IV (Fornell–Larcker criterion) assists the distinct validity by showing that the square root of the AVE (diagonal values) is higher than the correlation values between constructs. For example, the square root of TL’s AVE (0.621) is larger than its correlations with DIG (0.671) and OE (0.592). Similarly, DIG’s AVE (0.629) and OE’s AVE (0.658) surpass their respective correlation parameters with other constructs, believing that each construct demonstrates more variance with their indicators than with other constructs. These outcomes validate the ability of the model to make a difference between leadership, digitalization, and efficiency, ensuring the study's findings are efficient.

**Table III: Heterotrait-Monotrait ratio (HTMT) matrix**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **TL** | **DIG** | **OE** |
| **TL** |  |  |  |
| **DIG** | 0.618 |  |  |
| **OE** | 0.603 | 0.689 |  |

**Table IV: Farnell–Larcker criterion matrix**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **TL** | **DIG** | **OE** |
| **TL** | 0.621 |  |  |
| **DIG** | 0.671 | 0.629 |  |
| **OE** | 0.592 | 0.537 | 0.658 |

* 1. **Hypothesis Testing** 
     1. **Direct Effect**

Table V presents the result of the direct effect of variables. Hypothesis 1, which consists of the relationship between TL and OE. The result shows that TL has a significant positive effect on OE. This supports H1, demonstrating that TL plays a crucial role in enhancing OE by fostering a vision-driven and adaptive work environment.

Similarly, the second hypothesis consists of digitalization and the OE relationship. The study results show that digitalization has a significant positive effect on OE. These results focused on the important role of digital transformation in enhancing operational processes, increasing resource utilization, and increasing the overall efficiency of manufacturing firms. Lastly, the third hypothesis consists of the TL and digitalization relationship. The result shows that the p-value is 0.003. It is suggested that TL significantly inspires digitalization initiatives. These outcomes highlight the role of leaders in promoting digital transformation inside manufacturing firms, ultimately leading to higher operational performance. The significant p-values (p < 0.05 and p < 0.001) found concerning all the hypotheses validated these relationships, validating the theoretical and practical contributions of this study.

**Table V: Direct Effect**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Path | Path Coefficient | T-Statistics | P-value | Hypotheses Decision |
| TL → OE | 0.293 | 2.73 | 0.000\*\*\* | H1: Accepted |
| DIG → OE | 0.219 | 3.19 | 0.000\*\*\* | H2: Accepted |
| TL → OE | 0.138 | 2.97 | 0.003\*\* | H3: Accepted |

* + 1. **Full Model Result**

The indirect effect analysis produced strong evidence in terms of the mediating effect of digitalization in the relationship between TL and OE. The path coefficient (0.185) was positive and provided significant results, with a T-statistic of 3.13 and a p-value of 0.001, which was below the threshold limit of 0.05. These outcomes helped to accept the hypothesis (H4), assuring that TL increases operational efficiency via digitalization.

The outcomes were aligned with the DCT model, which emphasized that the firms must dynamically integrate, adapt, and reconfigure assets to get a competitive advantage in the market. Transformational leaders are the key people to implement innovation and technological adoption in the firms, assisting them to use digital tools for enhancing the efficiency of the operations, increasing decision-making in real-time, and enhancing the productivity of the systems. Digitalization assists in terms of increasing OE through automating processes, decreasing redundancies, and increasing workflow-integrated systems. The results of this study assist the literature by highlighting digitalization as a key parameter in enhancing the efficiency of the leader, specifically in terms of manufacturing firms that strive to obtain sustainable competitive advantages.

**Table VI: Indirect Effect**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Path | Path Coefficient | | T-Statistics | P-value | Hypothesis Decision |
| TL → DIG → OE | 0.185 | 3.13 | | 0.001\*\*\* | H4: Accepted |

1. **Conclusion**

This study investigated the relationship between TL and OE, using digitalization as a mediator. The results assessed that TL significantly increases OE, and digitalization plays an important mediating role in this relationship. The leaders promote a visionary, innovative, and flexible work culture to help in the adoption of digital technologies, which in turn increases efficiency by optimizing processes and decreasing operational hurdles. These findings validate the DCT, focusing on the organizations that must dynamically evolve via leadership and technological advancements to gain competitive advantages. This research gives evidence that TL, when integrated with digitalization, can enhance the efficiency of manufacturing firms, making them competitive in a continuously evolving business environment.

This research assists in gaining significant contributions to the current literature on leadership, digitalization, and OE. Since previous studies focused on other mediators, like Green HRM, this study integrates digitalization, which is a transformative force that connects leadership with OE. Moreover, the previous literature examined the impact of TL on the performance variables; its specific role in increasing OE via digitalization had been largely ignored. Through filling this gap, our research states that leadership behaviors give digital adoption and efficiency improvements, providing new ideas for scholars in the fields of strategic management, digital transformation, and organizational performance.

From the managerial perspective, the above findings suggest that manufacturing firms should invest in leadership development approaches that foster transformational leadership. The managers who focus on the vision, employee empowerment, and technological innovation can enhance the digital transformation process, leading to greater OE. Moreover, organizations should actively inculcate digital tools, automation, and data-driven decision-making into their workflows to increase productivity. Governments can assist businesses by providing training programs, financial incentives, and infrastructure to promote digital transformation, particularly in developing economies where resource hurdles may hinder technological adoption.

This research has some limitations that open chances for future research. Firstly, the study emphasizes manufacturing industries, restricting the general findings to other industries, like service or technology sectors. Future researchers could focus on the cross-industry comparisons to validate the results in various businesses. Secondly, this study focuses on primary data, which may influence the biases; future researchers could incorporate longitudinal data or objective performances for greater comprehensive analysis. Moreover, this study determines that digitalization is a mediator, and other mediators can be incorporated, like organizational learning or knowledge management, which could be explored in future studies. Lastly, future research could evaluate the moderating role of organizational culture to investigate how cultural factors inspire the effective behaviors of transformational leaders in promoting digital adoption and efficiency.

**Informed consent:**  Informed consent was obtained from all individual participants included in the study.

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