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## Driving Efficiency and Sustainability: Integrating Industry 4.0 and Sustainable Human Resource Management Practices in the Logistics Service Sector

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### Abstract

*This study investigates the impact of Industry 4.0 technologies, including IoT, big data, and smart factories, on logistics sector performance, along with the moderating role of sustainable Human Resource Management (HRM) practices. Data from 552 respondents in Pakistan's logistics industry were analyzed using structural equation modeling. The results demonstrate that Industry 4.0 implementations positively influence logistics service sector performance, while sustainable HRM practices significantly mediate between Industry 4.0 and performance. Specifically, integrating technologies from Industry 4.0 facilitates operational optimization, cost reduction, and enhanced efficiency in goods delivery. This study underscores the importance of strategic alignment between technological advancements and sustainable HRM practices in fostering logistics service resilience and competitiveness. By leveraging Industry 4.0 innovations and prioritizing sustainable HRM practices, logistics companies can effectively navigate the evolving market landscape and achieve long-term success. Moreover, this study offers a novel roadmap for logistics companies, showing how the synergy between sustainable HRM practices and Industry 4.0 can pave the way for resilience and success in an ever-evolving market landscape.*

**Keywords:** Sustainable HRM Practices, Industry 4.0, Logistics Service Sector, Structural Equation Modeling.

### Introduction

Increasing environmental concerns that threaten humanity have underscored the importance of environmental conservation (Agyabeng-Mensah et al., 2020; Zagloel et al., 2024). In particular, the manufacturing and logistics sectors have been scrutinized because of their significant contribution to CO2 emissions (Sharma et al., 2023; Amir, Malik, & Ali, 2024). Efforts to mitigate the impact of increasing vehicle numbers, traffic congestion due to e-commerce growth, and global warming have highlighted the need to examine and implement green initiatives in the logistics sector (Anosike et al., 2023; Shaukat et al., 2023). Prior studies have highlighted that companies are now shifting towards using the latest technology and sustainable HRM practices to boost their operations worldwide without harming humanity (Feng, Lai, & Zhu, 2022; Rahman et al., 2022). Bag et al. (2021) found that the use of technology, such as in Industry 4.0,

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has improved the functionality of companies. With this help, companies are becoming more vital, with improved efficiency and competitiveness.

Beier et al. (2020) stated that Industry 4.0, such as the Internet of Things (IoT), cloud computing, cognitive computing, Big Data (BD), and Smart Factory (SF), illustrates the goal of enhancing technological infrastructure and reshaping future employment opportunities for individuals. In the present era, most production and service companies are increasingly embracing advanced technology by adopting Industry 4.0, a concept (Imran, Hameed, & Haque, 2018; Sun et al., 2022; Al-Banna, Yaqot, & Menezes, 2024). Industry 4.0 implementation in different countries and companies has revealed the influence of innovation and technology in working companies (Zaid, Jaaron, & Bon, 2018). These industries are the cornerstones of national economies and contribute substantially to their overall prosperity. Nevertheless, Pakistan's logistics sector has not experienced noteworthy growth in recent years primarily because of limited technological advancements (Ali & Xie, 2021).

Continuous economic growth has highlighted the need for sustainable transportation, distribution, and green monitoring. Sustainable human resource management (SHRM) practices have gained prominence in research (Ali & Xie, 2021; Feng et al., 2022; Sharma et al., 2023). Studies have examined how companies face challenges when implementing sustainable HRM practices. However, companies' operational practices are questioned because of the continuous stress on the planet's natural resources given the need to adopt greener practices (Kumar, Tyagi, & Sachdeva, 2023; de Oliveira & de Oliveira, 2024). Traditional linear economies seek circular models, structures, and practices to achieve better logistical performance in emerging nations. Thus, more studies are required to examine the gap in companies' current practices, particularly in emerging nations, such as Pakistan.

Emerging countries are increasingly recognizing the importance of retaining customers, enhancing customer satisfaction, and fostering employee retention to generate value and bolster company performance (AlMalki & Durugbo, 2023; Al-Banna et al., 2024). As contemporary companies become more sophisticated and professionally managed, top management acknowledges the pivotal role of efficient logistics performance and growth potential inherent in sustainable HRM practices. Human interaction is ubiquitous within logistic-oriented companies, underscoring the need for robust, sustainable HRM practices (Yadav et al., 2020). Kamble, Gunasekaran, and Dhoni (2020) advocated innovation in HRM practices across all company levels to meet evolving demands. Recognizing a competitive landscape, sustainable human resource management (HRM) has emerged as a critical factor in facilitating advanced technologies, strategies, and societal contributions (Tortorella, Giglio, & Van Dun, 2019; Luthra et al., 2020; Sharma et al., 2023).

Customer satisfaction is of paramount importance in the logistics service sector, with dissatisfied customers potentially shunning repeated transactions. The successful integration of Industry 4.0 practices in logistics operations in countries such as the UK, Finland, the US, and many others has increased customer satisfaction and loyalty (Piccarozzi, Aquilani, & Gatti, 2018; Nassani et al., 2023). Conversely, emerging economies such as Pakistan have faced challenges in adopting advanced technology and suffer from high logistics costs that impede customer retention efforts (Imran et al., 2018; Umar et al., 2021; Malik et al., 2024). Furthermore, poor implementation of technological solutions hampers the performance of the logistics sector globally, exacerbating operational inefficiencies and escalating costs (Sun et al., 2022). As emerging countries like Pakistan endeavor to modernize and innovate, the imperative to integrate Industry 4.0

technologies into logistics becomes apparent (Sharma et al., 2023). By leveraging advanced technology and sustainable HRM practices, these nations can enhance their logistics sectors' performance and drive economic growth.

This study investigates the impact of Industry 4.0, including the IoT, BiD, and SF, on the logistics service sector and its performance. Additionally, it seeks to examine the moderating role of sustainable HRM in this context, addressing the interplay between Industry 4.0, logistics service sector, and performance outcomes. This study's significance extends its theoretical, practical, and policy implications. Theoretical insights into Industry 4.0's simplification and components offer valuable guidance for researchers and practitioners. Moreover, empirical testing of the relationship between industry and sustainable HRM practices in the logistics service sector provides a foundation for policy interventions that facilitate technology adoption and foster sectoral development. Additionally, at the state level, governments of similar countries can formulate policies and strategies to assist and support service-providing companies in adopting Industry 4.0. These benefits may be in the form of availability of the latest technology at low prices.

The first section discusses the background, problem statement, and significance of the study. The second section presents the study hypotheses based on a literature review. Section three provides the methodological design and structure of the analysis. The fourth section presents the empirical findings and hypothesis testing. Section five presents a discussion of the study results, and section six presents the conclusions and implications of the study.

## **Literature Review and Hypotheses Development**

The technology–organization–environment (TOE) framework, influenced by Institutional Theory, forms the theoretical underpinning of our study (Ganguly, 2024). As we explore Industry 4.0 adoption and sustainable HRM practices within the logistics service sector of Pakistan, we aim to uncover the interplay between technological advancements, company dynamics, and institutional pressures (Khan et al., 2017). By delving into these dimensions, our study explores how Industry 4.0, technologies, and sustainable initiatives collaboratively enhance operational efficiency, sustainability, and competitive advantage in the logistics service domain (Nghah, Zainuddin, & Thurasamy, 2017).

This inquiry is driven by the need to align technological innovation with company practices and environmental considerations, acknowledging the paramount importance of adaptation amidst the rapid digital transformation and escalating emphasis on sustainability that characterize today's business landscape (Centobelli, Cerchione, & Esposito, 2017; Evangelista, Santoro, & Thomas, 2018; Imran, 2018). Through a theoretical lens informed by the TOE framework and Institutional Theory, our study seeks to provide insights into how companies can navigate the complexities of Industry 4.0, its integration, and sustainable adoption to achieve superior performance. This study contributes to the evolving discourse on strategic management, technological innovation, and sustainable business practices, and offers practical implications for companies operating in the logistics service sector in Pakistan and beyond.

### **Industry 4.0 and Logistics Service**

Numerous disciplines are linked to Industry 4.0, as it is an umbrella that involves several concepts (Rahman et al., 2022). da Silva, Frederico, and Garza-Reyes (2023) explain that such concepts can change a company's production and service patterns. Industrial technologies can shift the paradigm within a company's operations (Nghah et al., 2017; Al-Banna et al., 2024).

Industry 4.0 is also referred to as a push for adopting the latest technology through which companies can change their behavior patterns and satisfy the needs of their consumers. Thus, production and service companies could adopt this concept to achieve more significant benefits. Ansari, Hold, and Sihh (2018) explained that prior studies discussed the importance of Industry 4.0 from various aspects, for instance, in countries where the cost of labor is very high, such as the UK, France, the USA, and Italy. These companies can exploit new technology to reduce labor costs and thus bring about lower prices for goods, which can benefit the company in the form of enhanced sales growth (Ngah et al., 2017; Ali & Xie, 2021; Kumar et al., 2023; Sharma et al., 2023). Other studies (Imran et al., 2018; Feng et al., 2022; Anosike et al., 2023) have also mentioned the value of the IoT, BiD, and implementation of SF factories by stating that the first industrial revolution took place in the 18th century.

However, in the 21st century, owing to the emergence and introduction of industry 4.0, we are experiencing a fourth industrial revolution (Rahman et al., 2022). Prior studies have also argued that the concept of Industry 4.0 is essential in the logistics or services sector, and companies have faced significant growth with the proper implementation of Industry 4.0 (Sun et al., 2022). The basis of this concept is the solution to the problems faced by many logistics companies in managing and storing BiD and data analysis. The implementation of BiD has removed management barriers for large amounts of data (Popkova & Sergi, 2018).

Additionally, SF implementation has gained significant importance, and many researchers in the service sector have studied this concept (Imran et al., 2018; Feng et al., 2022; Anosike et al., 2023; da Silva et al., 2023). The empirical findings suggest that SF helped achieve the company's goals. With the help of the IoT, SF has become increasingly important, and researchers have argued that BiD and SF are not possible without IoT (Belmonte et al., 2023). The company can maintain shipment and supplier details in its dataset because IoT can enable data collection, distribution, and availability of manufacturing information and logistics. Bahrin et al. (2016) explained that SF refers to assistance in production for companies facing a dynamic business environment (Belmonte et al., 2023; da Silva et al., 2023). Hence, we propose the following hypotheses:

H1: The impact of the IoT on logistics services is positive and significant.

H2: The impact of BiD on logistics services is both positive and significant.

H3: The impact of SF on logistics services is positive and significant.

### **Logistics Services and Logistics Sector Performance**

Logistics refers to the transportation of goods by companies to their customers, and how the company handles physical storage and inventory systems (Bahrin et al., 2016). Because the costs of this sector are linked to inventory management, to obtain new opportunities, it focuses on reducing costs and maintaining a new inventory control system through which companies can secure higher profits (Oliveira and Martins, 2017; Oliveira and Martins, 2011). Pakistan's logistics sector plays a beneficial role in developing the country's overall economy because it generates significant exports. Thus, foreign exchange reserves are increasing, owing to the better performance of this sector. Industry 4.0, helps logistics companies manage inventory systems (Nagy et al., 2018; Noor & Bano, 2024).

However, business globalization has made company operations more complex (Mabkhot et al., 2018). Such complex industries require the implementation of Industry 4.0 to maintain and

achieve their objectives. Technology is the only solution to each problem. Implementing the IoT and SF benefits logistics companies worldwide and can also benefit the Pakistani logistics sector (Imran, 2018). Therefore, the researcher studied the importance of logistics sector performance and found that, to improve the efficiency of delivering goods inside and outside the country, a company requires Industry 4.0. As previous researchers have identified, companies have faced challenges in the past owing to the increased costs of shipping goods, but technology implementation has reduced their logistics costs. Industry 4.0 continuously helps the company transform its logistics capabilities into competitive weapons instead of cost centers (Lun et al., 2015; Yamna, Khan, & Rehman, 2024). Thus, we propose the following hypothesis:

**H4:** *The impact of logistics services on logistics sector performance when implementing Industry 4.0 is significant.*

### **Sustainable HRM Practices, Logistics Service and Sector Performance**

Imran (2018) mentioned the importance of sustainable human resource practices as a critical element for companies to achieve success because, according to the viewpoint of researchers, the logistics sector contributes to society by doing good and environmentally sound processes in their operations (Chavez et al., 2017; Oliveira & Martins, 2011). Thus, sustainable processes can lead to better internal management by society and companies. Khan et al. (2017) suggested that the success of a company's sustainable HR plays a crucial role because sustainable business models have always been proven feasible for companies (Lam & Dai, 2015; Ali et al., 2023). Socially viable and responsible recruitment systems for the workforce that use future-oriented views and feasibilities can significantly improve employees' work performance. Through these policies, the logistics sector can gain significant benefits. Gani (2017) highlighted that sustainable HRM practices can increase logistics sector performance as motivated employees put their best efforts into the shipment of goods and related services, leading to customer satisfaction (Liu et al., 2018; Anosike et al., 2023; Ganguly, 2024). Based on this discussion, we propose the following hypotheses:

**H5:** *Sustainable HRM practices significantly impact logistics services.*

**H6:** *Sustainable HRM practices significantly impact logistics service sector performance.*

### **Moderation of Sustainable HRM Practices**

At the core of Industry 4.0, intelligence is involved in the networking and operating processes. Centobelli et al. (2017) found that production and service-providing processes grew significantly with the implementation of IoT, BiD, SF, and cyber-physical systems. As the Internet has revolutionized every process in a company, it has significantly impacted the logistics service sector and its performance (Anosike et al., 2023; Ganguly, 2024). As a collaborative community, the machines are connected to a logistics company and the delivery systems are well aligned with the daily work objectives. With the help of SF, the workforce is given daily tasks to complete, and its performance is improved by implementing Industry 4.0. Evangelista et al. (2018) suggest that Industry 4.0, which plays a role in human resource practices. Moreover, sustainable human resource practices satisfy the present human resource requirements.

There are few studies on the concept of sustainable human resource practices, even though many have been conducted on the sustainable environment of a company. However, Chen et al. (2017) highlighted that sustainable human resources significantly impact the logistics sector, as it involves different concepts studied by Gabriel and Pessl (2016). Proper, transparent employee

management and reward systems can increase employee motivation and improve job performance. Thus, worker job performance can be enhanced at every level (Agyabeng-Mensah et al., 2020; Sun et al., 2022; Sharma et al., 2023). Based on the above discussion, the following hypotheses are proposed.

*H7: The moderating role of sustainable HRM practices between the IoT and logistics services is significant.*

*H8: The moderating role of sustainable HRM practices between BiD and logistics services is significant.*

*H9: The moderating role of sustainable HRM practices on the relationship between SF and logistics services is significant.*

Figure 1 presents the research framework of the study.

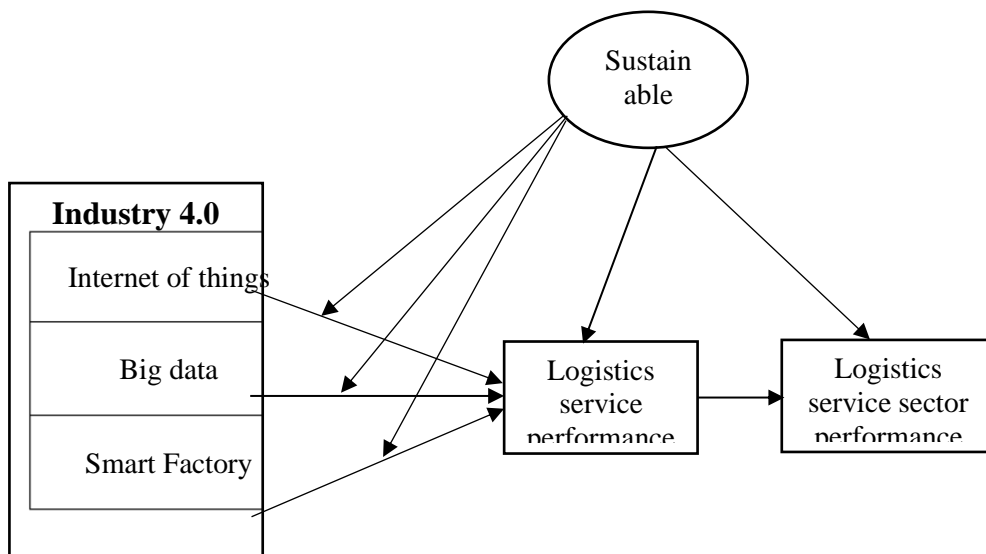


Figure 1. Research Framework

## Methodology

This study employed a quantitative research approach to examine the impact of Industry 4.0, focusing on the moderating role of sustainable HRM practices on the performance of Pakistan's logistics sector. The target population comprises individuals working in the logistics sector. According to the ESP (2021-2022), 2022), an estimated 2.5 million people are working in this sector, but the exact population is challenging. A non-probability sampling method, precisely a purposive sampling technique, was used to address the challenges of accessing the entire population. The sample size was determined to be 650 respondents to enhance the generalizability of the findings. This decision was informed by guidance from the Krejcie and Morgan (1970) sample size table and recommendations from G\*Power software, which indicated a minimum sample size of 193 respondents based on predictors at level 0.05. Multiplying this minimum by three, the sample size was set to 579 for generalizability. Finally, considering the higher number, we set it to 650.

The participants were identified and recruited through multiple channels. Initially, information was gathered from the Chambers of Commerce and Industry of Pakistan; the total number is 59, but we reached around 42—the rest of the leave due to resource constraints and non-availability of accessibility. Considering the principles of research ethics and integrity, it is essential to acknowledge that the institution with which the author, who is responsible for data collection and analysis, is associated with PUGC, which presently does not possess an Institutional Review Board (IRB). However, in light of the data collection location in Pakistan, suitable measures were implemented to ensure ethical approval. Prior to initiating the data collection process, the Director General of PUGC was informed of the study's objectives and granted authorization to approach respondents for participation. Subsequently, potential participants were contacted through telephone calls or email forms, and their consent was obtained orally prior to the collection of data from them. Upon obtaining consent, respondents were sent the questionnaire via postal delivery and in personal visits; due to lower lateness on responses, an online version was later made available, and criteria for participation were clearly outlined to ensure that respondents met the specified criteria. Moreover, in adherence to rigorous ethical standards, stringent measures were implemented to uphold the integrity of the study and mitigate any potential undue influence on participants or implicated businesses concerning findings or outcomes. Paramount importance was placed on safeguarding the autonomy and confidentiality of all stakeholders involved throughout the research process.

Data were collected from July to September 2023, spanning three months. During this period, 574 responses were received: 227 through personal visits, 138 via postal delivery, and 209 through online surveys. After screening for completeness and accuracy, 552 responses were deemed suitable for the analysis.

### **Questionnaire Design and Variable Measurements**

The questionnaire consisted of three distinct sections. First, an introductory segment elucidated the study's objectives and assured the respondents of the confidentiality of their data, thereby establishing a sense of trust and transparency. Second section was dedicated to gathering respondents' demographic and professional profile information, offering insights into their backgrounds, and contextualizing their perspectives within the study framework. Finally, third section features objective statements about the variables under scrutiny. The measures of the dependent, independent, mediating, and moderating variables were adopted from prior studies. To measure industry 4.0, scale from the study of Imran (2018) was utilized, further dimensions such as IoT, BID and SF, all based on four items each. To measure LS and LSP scale utilized by the Rahman et al. (2022) was adapted in this study. The moderating variable, sustainable HRM, was measured through competence-related and employee relation practices based on five items as utilized by from Wikhamn (2019).

### **Data Analysis and Software**

Data analysis was conducted using Structural Equation Modelling (SEM) with the AMOS software and preliminary screening using SPSS. Initially, the data were coded and added to the SPSS software for preliminary screening, including tests for reliability and factor loading of variables. Subsequently, confirmatory factor analysis was performed in AMOS to evaluate the model fit, discriminant validity, and convergent validity. Finally, SEM was used to test the study hypotheses concerning the relationships between Industry 4.0, sustainable HRM practices, and sector performance within Pakistan's logistics sector.

### Common Method Bias and Endogeneity

Jakobsen and Jensen (2015) highlighted the risk of standard method bias arising from correlated dependent and independent variables owing to shared survey respondents. Using Harman's single-factor test, Podsakoff et al. (2003) use a common approach to address this bias. With a variance of 43.6% below the 50% threshold, our study showed no evidence of common method bias. Furthermore, by employing the NLBCDR ratio, our study revealed a value of 0.80, indicating minimal endogeneity.

### Empirical Findings

The data collected for this study were analysed using SPSS and SmartPLS software. The initial analysis produced valuable findings, as depicted in Table 1, which illustrates the participants' profiles in the study. Males accounted for 54.9% and females accounted for 45.1% of the participants, reflecting the gender distribution in the industry and potentially impacting diversity initiatives and workplace culture reforms. The age distribution revealed a substantial proportion (40.6%) aged 25-35, likely representing midcareer professionals who contribute significantly to industry innovation and leadership roles. Furthermore, the substantial presence of individuals aged to 18-25 (32.1%) suggests a robust influx of young talent, shaping the sector's future trajectory.

| Profile    |                    | Frequency | Percent |
|------------|--------------------|-----------|---------|
| Gender     | Male               | 303       | 54.9    |
|            | Female             | 249       | 45.1    |
| Age        | 18 - 25 Year       | 177       | 32.1    |
|            | 26 to 35 Years     | 224       | 40.6    |
|            | 36 to 45 Years     | 136       | 24.6    |
|            | More Than 45 Years | 15        | 2.7     |
| Education  | Bachelor           | 71        | 12.9    |
|            | Master             | 213       | 38.6    |
|            | MS/MPhil           | 167       | 30.3    |
|            | Diploma/Other      | 101       | 18.3    |
| Experience | Less than 2 Year   | 71        | 12.9    |
|            | 2 to 5 Year        | 232       | 42.0    |
|            | 5 to 8 Year        | 197       | 35.7    |
|            | More than 8 Year   | 52        | 9.4     |

Table 1. Respondents Report

However, the miniature representation of individuals over 45 (2.7%) indicates potential challenges in knowledge transfer and succession planning within the workforce. Regarding education, the prevalence of master's degrees (38.6%) signifies a highly educated cohort that could contribute to advanced problem solving and strategic decision-making. Regarding experience, 71 individuals had less than two years, 232 had two–five years, and 52 had over eight years. These diverse experience level data, ranging from novice practitioners to seasoned experts, underscore the dynamic workforce spectrum crucial for understanding skill gaps and talent development needs.

Factor loading is a critical aspect of factor analysis as it measures the strength of the association

between observed variables and latent factors (Tabachnick, Fidell, & Ullman, 2013). Convergent validity assesses the consistency of results obtained from different measures of the same construct (Campbell & Fiske, 1959). Both measures are essential for ensuring the reliability and validity of the measurement instruments. The results in Table 2 demonstrate moderate correlations between the variables and their items, with most values meeting or exceeding the 0.7 threshold recommended by Hair et al. (2019). However, IOT2 and SF2 fell below this threshold and were consequently excluded from further analysis.

Additionally, composite reliability values exceeding 0.7 indicate positive correlations among variables. The AVE values surpassing 0.5 suggest substantial variance captured by latent constructs, aligning with Fornell and Larcker (1981) criteria. Furthermore, the lower MSV values compared to the AVE values confirm convergent validity, indicating the convergence of the observed variables around the underlying constructs. Collectively, these findings indicate the reliability and validity of the measurement instruments, supporting the suitability of the data for further analysis.

| Items | Loading | CR    | AVE   | MSV   |
|-------|---------|-------|-------|-------|
| IOT1  | .754    | 0.801 | 0.509 | 0.366 |
| IOT2  | .489    |       |       |       |
| IOT3  | .758    |       |       |       |
| IOT4  | .808    |       |       |       |
| BID1  | .833    | 0.917 | 0.734 | 0.358 |
| BID2  | .831    |       |       |       |
| BID3  | .875    |       |       |       |
| BID4  | .887    |       |       |       |
| SF1   | .734    | 0.835 | 0.560 | 0.366 |
| SF2   | .474    |       |       |       |
| SF3   | .729    |       |       |       |
| SF4   | .847    |       |       |       |
| LS1   | .819    | 0.925 | 0.757 | 0.265 |
| LS2   | .825    |       |       |       |
| LS3   | .919    |       |       |       |
| LS4   | .912    |       |       |       |
| LSP1  | .712    | 0.889 | 0.668 | 0.326 |
| LSP2  | .823    |       |       |       |
| LSP3  | .887    |       |       |       |
| LSP4  | .838    |       |       |       |
| SHRM1 | .808    | 0.930 | 0.727 | 0.358 |
| SHRM2 | .793    |       |       |       |
| SHRM3 | .870    |       |       |       |
| SHRM4 | .859    |       |       |       |
| SHRM5 | .926    |       |       |       |

Table 2. Loading, Reliability, and Convergent Validity

**Abbreviations:** *IoT*; Internet of Things, *BiD*; Big data; *SF*, smart factories; *LS*, logistics services; *LSP*, logistic sector performance; *SHRM*, sustainable HRM.

Table 3 illustrates the mean and standard deviation (SD) values for each construct, reflecting the distribution and variability of the data within the dataset. The mean values ranged from 3.147 to 3.4746, indicating moderate to high agreement with the items measuring each construct. The standard deviation values ranged from 0.911 to 0.997, suggesting a relatively narrow dispersion of data points around the mean for all constructs. Discriminant validity was confirmed, as each construct's correlation with itself was consistently higher than its correlations with other constructs. Specifically, the correlation coefficients between each construct and its variables were significant, with values typically exceeding 0.7. This signifies a strong relationship between constructs and their respective variables, indicating that they are sufficiently distinct. Therefore, the discriminant validity of the measurement model was supported by the observed correlations, thus validating the distinctiveness of the constructs within the study.

| Constructs  | Mean   | SD    | LSP          | IOT          | BID          | SF           | LS           | SHRM         |
|-------------|--------|-------|--------------|--------------|--------------|--------------|--------------|--------------|
| <b>LSP</b>  | 3.388  | 0.983 | <b>0.818</b> |              |              |              |              |              |
| <b>IOT</b>  | 3.4746 | 0.911 | 0.571        | <b>0.713</b> |              |              |              |              |
| <b>BID</b>  | 3.3397 | 0.917 | 0.290        | 0.491        | <b>0.857</b> |              |              |              |
| <b>SF</b>   | 3.2704 | 0.912 | 0.550        | 0.605        | 0.471        | <b>0.749</b> |              |              |
| <b>LS</b>   | 3.147  | 0.997 | 0.379        | 0.515        | 0.306        | 0.440        | <b>0.870</b> |              |
| <b>SHRM</b> | 3.392  | 0.986 | 0.509        | 0.559        | 0.598        | 0.562        | 0.425        | <b>0.853</b> |

Table 3: Mean, SD, and Discriminant Validity

**Abbreviations:** *IoT*; Internet of Things, *BiD*; Big data; *SF*, smart factories; *LS*, logistics services; *LSP*, logistic sector performance; *SHRM*, sustainable HRM.

The validation of the adequacy of the model is of paramount importance. To achieve this, we employed Confirmatory Factor Analysis (CFA) and evaluated Model Fit indices such as Chi-square, CFI, and RMSEA against predetermined criteria to assess the model's congruence with the observed data (Campbell & Fiske, 1959; Hair et al., 2019). Table 4 reports the model fit indices, as the CMIN/DF value with modification was 2.902, slightly lower than the unmodified value of 3.497, indicating a slight improvement after adjustments. The GFI, TLI, IFI, CFI, and RMSEA values fell within acceptable ranges, aligning with their respective thresholds. The CMIN/DF ratio assesses the fit between the observed and expected covariance matrices, with values below 3 or 5 suggesting a good fit. In our analysis, the original and modified models exhibited acceptable CMIN/DF ratios, with marginal enhancement observed post modification. Additionally, the GFI, TLI, IF, and CFI indices evaluated the model's ability to account for variance and covariance relative to a null model, with values above 0.90, indicating a good fit. While the original model marginally falls short of this threshold for GFI, the modified model meets or surpasses it, indicating an overall improvement in the model fit.

| Indicators     | Standard Values   | Without Modification | With Modification |
|----------------|-------------------|----------------------|-------------------|
| <b>CMIN/DF</b> | Below 3 or 5      | 3.497                | 2.902             |
| <b>GFI</b>     | Greater than 0.90 | 0.883                | 0.906             |
| <b>TLI</b>     | Greater Than 0.90 | 0.936                | 0.952             |
| <b>IF</b>      | Greater than 0.80 | 0.926                | 0.944             |

|            |                   |       |       |
|------------|-------------------|-------|-------|
| <b>CFI</b> | Greater Than 0.90 | 0.936 | 0.952 |
| <b>RMS</b> | Lesser than 0.09  | 0.067 | 0.059 |

Table 4: Model Fit Measurement

**Abbreviations:** CMIN/DF; Chi-Square Minimum/Degrees of Freedom, GFI; Goodness of Fit Index, TLI; Tucker-Lewis Index, IF; Incremental Fit Index, CFI; Comparative Fit Index, RMS; Root Mean Square Error of Approximation.

SEM was employed to analyze intricate relationships among variables, allowing for the simultaneous examination of observed and latent constructs (Hair et al., 2012). Its application has facilitated the comprehensive testing of theoretical models and hypotheses, thus enhancing the understanding within the research domain. Using it in this study, the hypotheses were tested, and the results are presented in Table 5. The impact of IoT on LS strongly supports a significant relationship, with a beta coefficient of 0.281 and p-value of 0.000. This suggests that IoT technologies are crucial for shaping positive logistics services. In contrast, the hypothesis suggesting an influence of BID on LS is not supported, as indicated by a beta coefficient of -0.017 and p-value of 0.667, suggesting that BID may not directly impact logistics services in the studied context. Moreover, SF exhibits a significant influence on LS, with a beta coefficient of 0.149 and p-value of 0.000, underscoring the importance of innovative manufacturing technologies in shaping logistics services within the framework of Industry 4.0.

| Hypothetical Paths |   |     | Beta  | S.E. | P    | Decision      |
|--------------------|---|-----|-------|------|------|---------------|
| <b>IOT</b>         | → | LS  | .281  | .047 | .000 | Supported     |
| <b>BID</b>         | → | LS  | -.017 | .044 | .667 | Not Supported |
| <b>SF</b>          | → | LS  | .149  | .046 | .000 | Supported     |
| <b>LS</b>          | → | LSP | .212  | .037 | .000 | Supported     |
| <b>SHRM</b>        | → | LS  | .243  | .042 | .000 | Supported     |
| <b>SHRM</b>        | → | LSP | .395  | .039 | .000 | Supported     |
| <b>IoT x SHRM</b>  | → | LS  | .007  | .031 | .854 | Not Supported |
| <b>BID x SHRM</b>  | → | LS  | .069  | .029 | .047 | Supported     |
| <b>SF x SHRM</b>   | → | LS  | .083  | .034 | .033 | Supported     |

Table 5: Hypothesis Testing

**Abbreviations:** IoT; Internet of Things, BiD; Big data; SF, smart factories; LS, logistics services; LSP, logistic sector performance; SHRM, sustainable HRM.

The relationship between LS and LSP is also strongly supported, with a beta coefficient of 0.212 and a p-value of 0.000, indicating that efficient logistics services contribute positively to the overall logistics sector performance. Furthermore, SHRM practices have emerged as significant predictors of LS and LSP. The findings reveal a substantial influence of SHRM on LS (beta coefficient of 0.243, p-value of 0.000) and LSP (beta coefficient of 0.395, p-value of 0.000), emphasizing the critical role of sustainable HRM practices in enhancing logistics services and overall sector performance within the industry 4.0 paradigm. However, when examining the interaction effects, the relationship between IoT and SHRM on LS was not supported, with a

beta coefficient of 0.007 and a p-value of 0.854. Conversely, the interaction effects between BID and SHRM, and SF and SHRM on LS are both supported, indicating significant relationships that warrant further investigation.

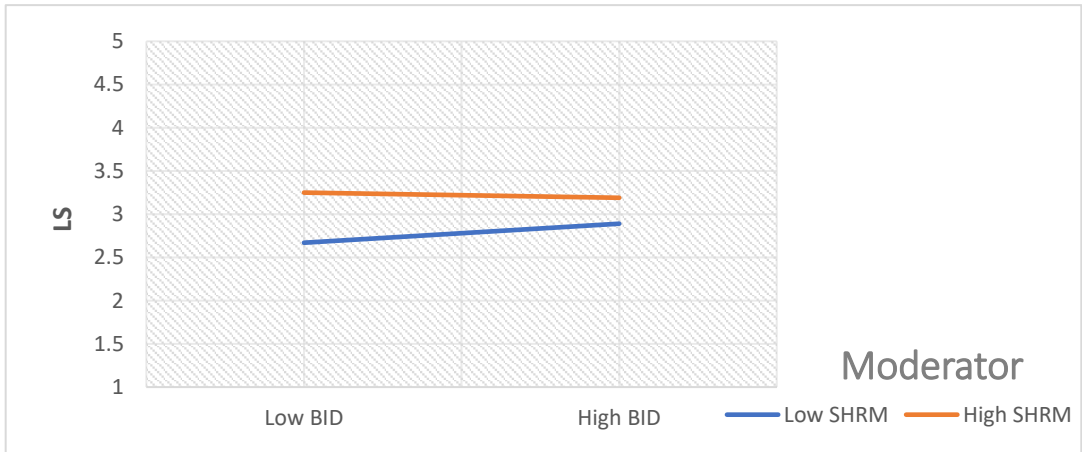


Figure 1: Moderating Effect of SHRM between BID and LS

As mentioned in the previous tables, the significant moderation of SHRM between SF and LS is evident in Figure 1, which depicts a positive relationship. Low SHRM levels corresponded to an upward trend, whereas high SHRM levels amplified the impact between SF and LS. This emphasizes the pivotal role of SHRM in influencing the dynamics between SF and LS, underscoring its relevance in logistic service performance enhancement.

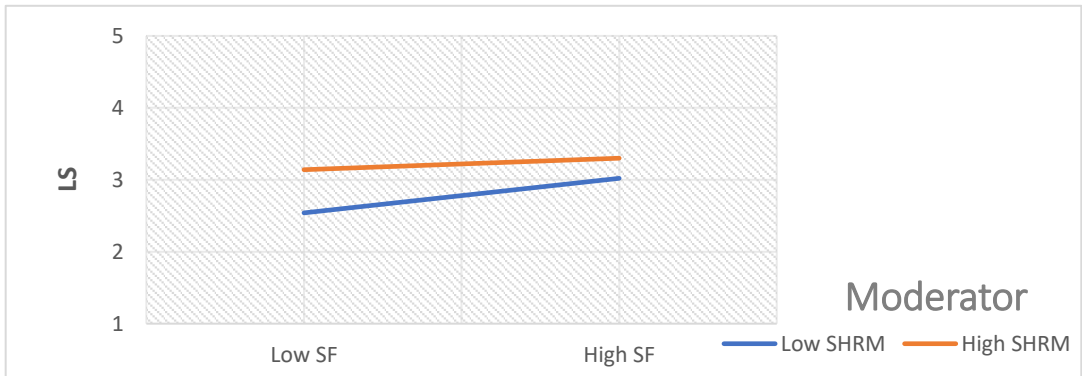


Figure 2: Moderating Effect of SHRM between SF and LS

Moreover, SHRM significantly moderates the relationship between SF and LS. Figure 2 shows a positive correlation. When SHRM is low, there is an upward trend, indicating an increase in the impact between SF and LS. Conversely, as the SHRM levels increase, the impact between SF and LS intensifies. This highlights the influential role of SHRM in shaping the interaction dynamics between SF and LS, potentially impacting logistic service effectiveness and performance.

### Discussion on Results

The empirical findings offer insight into the outcomes of our study’s hypotheses and elucidate

the results. It is necessary to discuss these findings with the existing literature. First, the influence of the IoT on logistics services is supported ( $\beta = 0.281$ ,  $p < 0.001$ ). This finding suggests that as the adoption and implementation of IoT technologies increase, there is a corresponding improvement in logistics services, highlighting the significance of IoT in enhancing operational efficiency and service quality within the logistics sector (Imran, 2018; Rahman et al., 2022; Al-Banna et al., 2024). Similarly, SF positively influenced LS ( $\beta = 0.149$ ,  $p < 0.001$ ). This result underscores the importance of leveraging SF technologies to optimize manufacturing processes and supply chain management and enhance overall logistics service performance (Imran, 2018; da Silva et al., 2023; Sharma et al., 2023). However, the BiD was not significant, which is consistent with (Sharma et al., 2023). Furthermore, the relationships between sustainable HRM and both LS (beta = 0.243,  $p < 0.001$ ) and logistics service performance (beta = 0.395,  $p < 0.001$ ) were supported. This finding suggests that company factors specific to the SHRM context significantly shape logistics service delivery and performance outcomes. In contrast, some hypothesized interactions, specifically IOT  $\times$  SHRM (Beta = 0.007,  $p = 0.854$ ), were not supported, indicating that the combined effect of IOT and sustainable HRM practices does not significantly influence logistics service performance (Imran et al., 2018; Ganguly, 2024).

However, interactions such as BID  $\times$  SHRM (Beta = -0.069,  $p = 0.047$ ) and SHRM (Beta = -0.083,  $p = 0.033$ ) were supported, highlighting the moderating role of SHRM practices in the relationship between business intelligence, SF, and logistics service performance (Imran et al., 2018; Agyabeng-Mensah et al., 2020; Kumar et al., 2023; Sharma et al., 2023). According to Dalenogare et al. (2018) to the performance and efficiency of the sector. On the other hand, the study of Dalenogare et al. (2018) suggested that Industry 4.0 significantly impacts the performance of the logistics sector. Moreover, the study of (Davis, Sessions, & Check, 2015) concluded that companies dealing in logistics could improve their efficiency and performance can also be enhanced through the implementation of sustainable HR practices (Gorecky et al., 2014; Imran, 2018; Sun et al., 2022; Belmonte et al., 2023; Sharma et al., 2023).

## Study Conclusion

Our study employs a quantitative research method with a deductive approach and a cross-sectional time horizon and aligns with positivist philosophy. It offers significant insights into Pakistan's logistics sector dynamics by drawing from a sample of 552 employees. All the hypotheses were accepted except for two, and our findings shed light on the influence of Industry 4.0, and the moderating role of sustainable HRM practices in Pakistan's logistics sector. The empirical findings highlight the pivotal role of Industry 4.0, such as the IoT and SF, in enhancing logistics service performance. Specifically, the adoption of IoT and smart-factory technologies was found to positively impact operational efficiency and service quality within the logistics sector. However, the influence of BiD on the logistics service sector is insignificant, emphasizing the need for further exploration in this area within Pakistan and other emerging nations. Consequently, this study emphasizes the importance of implementing sustainable human resource practices, as this aspect has not been extensively explored as a moderator in previous studies within the Pakistani context.

## Implications of the Study

The theoretical implications of this study highlight the symbiotic relationship between Industry 4.0, and sustainable practices within the logistics sector. Drawing from the TOE framework, integrating advanced technologies and eco-friendly initiatives is pivotal for logistics companies to develop distinctive capabilities and gain competitive advantage. Moreover, insights from

Institutional Theory underscore the influence of external factors such as regulatory frameworks and societal norms on shaping the adoption of Industry 4.0 and sustainability practices, emphasizing the need for company alignment with evolving institutional norms.

Practical implications emphasize the transformative potential of integrating Industry 4.0, technologies, and sustainable practices to enhance operational efficiency and performance in logistics. By strategically investing in automation, data analytics, and sustainable HRM practices, logistics managers can streamline processes, minimize resource wastage, and elevate key performance metrics, such as delivery speed and customer satisfaction. Moreover, prioritizing talent development programmes to equip employees with the necessary skills to leverage emerging technologies underscores the importance of fostering a culture of innovation and environmental consciousness.

Policy implications underscore the critical role of supportive regulations, incentives, and international collaboration in facilitating the adoption of Industry 4.0 and sustainable practices within the logistics sector. Policymakers are urged to enact measures that incentivize eco-friendly investments, promote research and development in green technologies, and foster cross-border knowledge exchange to accelerate the transition towards sustainable logistics operations. By aligning regulatory frameworks with global sustainability goals and facilitating industry collaboration, policymakers can catalyze positive environmental outcomes while driving innovation and competitiveness in the logistics sector.

### **Limitations of the Study and Future research**

The study's limitations include its narrow focus on the logistics system of the service sector in Pakistan, neglecting potential insights from Industry 4.0 adoption in production and other geographical contexts. Future research should address this by broadening the scope to include production sectors and exploring Industry 4.0 implementations across South Asian countries. Additionally, comparative studies and analyses of different timeframes and company types can enrich our understanding and provide actionable insights into sustainable integration and performance enhancement.

### **Statements on Compliance with Ethical Standards**

All work of this research is completed by the authors and all procedures performed in this study involving human participants were in accordance with the ethical standards and all data were kept confidential.

### **Conflict of Interest**

The authors declare that they have no conflicts of interest.

### **Data Availability**

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

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