IEEE Access
Multidisciplinary | Rapid Review | Open Access Journal

Received July 4, 2021, accepted July 14, 2021, date of publication July 26, 2021, date of current version August 5, 2021.

Digital Object Identifier 10.1109/ACCESS.2021.3100410

Statistical Assessment of Business Intelligence System Adoption Model for Sustainable Textile and Apparel Industry

SUMERA AHMAD[1], SURAYA MISKON[2], (Member, IEEE), RANA ALABDAN[3], AND ISKANDER TLILI[4]

[1]School of Computing, Faculty of Engineering, Universiti Teknologi Malaysia, Johor Bahru, Johor 81310, Malaysia
[2]Department of Information Systems, Azman Hashim International Business School, Universiti Teknologi Malaysia, Johor Bahru, Johor 81310, Malaysia
[3]Department of Information Systems, College of Computer and Information Sciences, Majmaah University, Al Majma'ah 11952, Saudi Arabia
[4]Department of Physics, College of Science, Al-Zulfi, Majmaah University, Al Majma'ah 11952, Saudi Arabia

Corresponding author: Iskander Tlili (l.tlili@mu.edu.sa)

ABSTRACT The textile and apparel industry is one of the biggest competitive industries in the world. Nowadays, industry 4.0 concepts put pressures on textile and apparel companies to integrate advanced technologies. Consequently, Business Intelligence (BI) systems are diffusing rapidly to process large data sets to harness the true value of smart technologies. Regardless of its potentials, most textile and apparel companies are lagging and hesitating to adopt this credible innovation in the presence of a high failure rate (70%-80%) especially in developing countries. To achieve the successful adoption of BI systems, statistical assessment is required to better understand this complex phenomenon. Therefore, a BI system model based on Technology-Organization-Environment (TOE) is developed to evaluate the role of potential determinants pertaining to the users, technology, organization, and environment. Data were collected using a survey with self-administered questionnaires from decision-makers with authoritative designations in the textile and apparel industry, academia, and software companies. Influential relationships among critical determinants were assessed and validated by using Decision-Making Trial and Evaluation Laboratory (DEMATEL) approach. The results of this study would contribute to the success of costly BI system projects and will motivate the industry experts to potentially assign investments for the BI projects in the developing countries to sustain in the competitive markets.

INDEX TERMS Textile and apparel industry, business intelligence system, TOE model, DEMATEL.

I. INTRODUCTION

The textile and apparel industry is the world's oldest and mature industry and has great importance in terms of employment, revenue, investment and trade that contribute to the world economy with a significant percentage [1]. The textile and apparel industry has played an important role in the development of many countries such as, four countries are identified as "Asian Tigers" (Taiwan, Singapore, Hong Kong, and Korea) with high growth rate [2]. All four have become developed countries because of high-income economies with a major role in their textile and apparel industry [2]. Therefore, the textile and apparel industry has become the gate of choice for developing countries to gain the status of developed nations [3]. India, Turkey, Vietnam, Bangladesh, and Pakistan are also striving hard to win this race but lagging in this competition. In addition, worldwide environmental organizations put pressure on the manufacturing industries to harmonize their operations with sustainability policies. The textile and apparel industry is one of the top polluting industries. For example, high energy consumption, high amount of water usage, large number of chemical loads, solid wastes, and odor formation are prominent environmental harms of the textile and apparel industry. In order to preserve competitiveness and sustainability in the fourth industrial revolution "Industry 4.0", the textile and apparel industry requires modern technologies and innovations [4], [5]. Therefore, industry experts are installing and integrating the Customer Relationship Management (CRM), Supply Chain Management (SCM), Enterprise Resource Planning (ERP), and Human Resource Management (HRM) systems to sustain in complex business environments [6]. These conventional value-based

The associate editor coordinating the review of this manuscript and approving it for publication was Biju Issac.

systems are certainly not designed to benefit all fields of industry and are unable to support effective organizational reporting and analytics [7], [8]. Additionally, some high-end textile and apparel companies have integrated advanced technologies to achieve the sustainable competitive edge [9] but they are facing the challenges of data integration, solutions, processes, and resources from end-to-end.

Most collected data is not fully utilized, only 10% of available data is analyzed and utilized in decision making processes and the rest of 90% generated data is not fully exploited [10]. To deal with these issues, industry needs reliable and efficient information systems (IS) that can support managers with informed knowledge and business analysis as well as officials of all levels. Adequate high-quality information is crucial for taking timely business decisions to sustain in dynamic markets, it can only be possible by the adoption and implementation of Business Intelligence (BI) system [5], [11]. The BI system based well informed decision-making is crucial to ensure competitiveness for sustainable business growth [12].

The BI system is known as an umbrella term that is used for collection of tools, techniques, systems, and strategies which are installed in industries to aggregate and process data to support operational, tactical, and strategic business decisions [9], [13]. The adoption of BI system is a complicated process that necessitates exploring the new research dimensions. The adoption defines the peoples' resolution to embrace full use of an innovation by accomplishing goals of an organization or individual [14], [15]. A technology is perceived successful when users adopt to leverage its value with proper utilization. The importance of BI system shows by its widespread adoption that attracted remarkable attention from scholars and industry experts. As BI system has revolutionized the worldwide economies such as 95% in Finland, 96% in Germany, 97% enterprises in Switzerland, total of 89% in Mexico, Brazil, and Asian territory, 73% in Norway 79% in Canada, 76% in the Netherlands, and 87% organizations across the world [16], [17].

According to Gartner's 2020 Magic Quadrant, 90% of the world's top 500 companies will take analytics governance initiatives to converge analytics into broader data analytics till 2023. Despite this potential growth, the high failure rate of BI systems is still a big question mark. The praxis demonstrated that companies are unable to harness the true potentials of the BI system projects [18]–[20]. It is observed that around 70% to 80% of BI system applications are not successful, the reasons for this failure are still unknown [21]–[23]. Therefore, it is challenging for policy makers to persuade the industrial administration and stakeholders for the BI system adoption. [24]. Technological, environmental, and organizational characteristics are predominant for innovation adoption in various industries but neglected individual characteristics in this perspective [21]. Industries need to consider the importance of users' role for the optimal success of the BI system [23]. According to the Qlik-Gartner report- 2019, data with analytics will grow three times more than the ratio of technology experts in industries by 2020, that drives the companies to redesign their organizational expertise, skills and models [21], [25]. A good quality theory or model has great importance to add the knowledge of practitioners and scholars within the theoretical domain [26], [27]. Despite its great importance within IS discipline, the development of new theoretical framework and refinement of existing theories/ models, particularly for the BI system adoption process is scarce [21], [27], [28].

In addition, literature revealed that scholarly investigations about the adoption of BI system in the textile and apparel industry are limited [9], [29], [30]. Till date, no study has discovered any theory or model used for the adoption of BI system in the textile and apparel industry with the lens of individual, technological, organizational, and environmental perspectives. To fill these research gaps, a decision-making model based on a hybrid of technology-organization-environment (TOE) framework is developed with potential determinants and dimensions related to the adoption of BI system in the textile and apparel industry. Then, Decision-Making Trial and Evaluation Laboratory (DEMATEL) techniques are used to show the interrelationship among the determinants of each dimension and map them according to their significance in a decision-making model. Hence the studies are reviewed to design the main objective of this research and achieved to fill the existing research gaps, the research objectives are as follows:

1-To investigate the determinants in individual, technological, organizational, and environmental dimensions that affect the adoption of BI system in the textile and apparel industry.

2- To develop a conceptual model for the adoption of BI system in the textile and apparel industry.

3- To validate the BI system adoption model by revealing the interrelationship among significant dimensions and determinants.

The findings of this study with a novel model enrich the scholars and practitioner's knowledge pertaining to the BI system adoption and would guide them to consider what kind of factors to consider which contribute to the success of this costly complex system. It may also lead researchers and practitioners to perform effectively and efficiently within the theoretical domain.

The rest of the paper organization is as follows: Section 2 illustrates a model development process based on literature review. A comprehensive detail of applied methods for data analysis is provided in Section 3. Results are discussed with managerial and theoretical implications in Section 4. Research limitations and suggestions for future work are presented with conclusion in last Section 5.

II. LITERATURE REVIEW

The importance of BI system in the textile and apparel industry and earlier studies on the BI system adoption are discussed in this section.

A. THE IMPORTANCE OF BI SYSTEM IN THE TEXTILE AND APPAREL INDUSTRY

Increasing global population growth and improvement in living standards have led to increase the apparels manufacturing and consumption in recent decade. The textile and apparel industry has played a major role in the economies of many developed nations because of its contribution to employment, foreign exchanges, and exports. Despite its economic potentials, it impacts the environment negatively due to greenhouse gas emission (GHG), pollution, and fast resource depletion [31]. Therefore, the textile and apparel industry are among the top polluting industries in the world, as all stages of supply chains of this industry endangers our planet and natural resources and affect the environment negatively. Also, N_2O and CO_2 are linked with GHG emission in the textile industry.

Furthermore, dust, Sulphur oxides (SOx) and Nitrogen oxides (NOx) add to air pollution [31]. Increasing resource scarcity, climate issues, and ecological deterioration are all the results of unsustainable production and manufacturing trends of industries [32]. Therefore, various international institutions are introducing various policies to enhance productivity and reduce environmental pollution. Evaluation of sustainability is assessed through a triple bottom line approach which includes finance, people, and planet principles being the most significant determinants of sustainability [33]. The transformation towards analytics contributes a critical share in the business sustainability of any industry which ultimately minimizes the utilization of emission of waste, toxic materials, natural resources, and pollutants over the life cycle of textile and apparel products. As a result, these practices will not jeopardize the future of further generations. As Paul Rogers, GE's chief development officer, explained his views at the Innovative for Global Environmental Leadership (IGEL) conference 2014 about the potentials of analytics to optimize efficiency in the corporate world. According to the facts presented by him, a ''meagre 1% improvement in performance in major sectors such as oil and gas, power, rail, aviation, and healthcare will save approximately $280 billion in the next 15 years.'' This scenario reflects the type of profit that companies can earn with minimizing the environmental impact. Therefore, the BI system is becoming an essential innovation with decision-making powers that can deal with carbon management issues, greenhouse issues, and energy scarcity issues.

Well-informed decision-making with the adoption of BI system can help in promoting resource efficiency and reducing ecological pollution that will contribute to the sustainability-focused aspects to better production and manufacturing practices [9], [33]. These practices provide a means to transform societies and economies to develop a sustainable culture for the benefit of humankind. A significant contribution of BI system is to help the industries to optimize usage of resources. However, most enterprises are not skilled and have no appropriate guidelines in the form of framework which is required for the successful adoption of BI system; another reason is the high failure rate of BI system adoption as BI system research field is not yet investigated broadly [23], [34]. The above-mentioned statements logically support the need to address the BI system concepts in the textile and apparel industry.

B. PREVIOUS STUDIES ON BI SYSTEM ADOPTION

A systematic literature review is conducted by Ahmad *et al.* [21] They reviewed 84 studies related to the BI system adoption and acceptance that included the studies published between 2011 to 2020. The outcomes of the study presented a comprehensive detail of most utilized theories, determinants, methods, and regional distribution of the studies. According to the findings, TOE, diffusion of innovation (DOI) were the most utilized theories for the BI systems adoption at organizational level and technology acceptance model (TAM) for the BI systems acceptance at individual level. Competitive pressure, relative advantage, compatibility, complexity, organization size, cost, and ease of use determinants were utilized frequently by researchers to investigate the BI system adoption.

Moreover, researchers have focused more on the financial industry of developed countries in the perspective of BI system research. In another study by Ahmad *et al.* [9] explored the role of BI system with Industry 4.0 technologies regarding the sustainability in the textile and apparel industry. They selected 12 worldwide high-end companies for data collection and explored sustainability challenges for the textile and apparel industry. They discussed the reasons and improvement with adoption of some advanced BI solutions, and some major barriers in the way of successful adoption of BI system. According to the findings, top management support, integration with existing systems, change management and cost are important factors that influence the BI system adoption.

Another systematic literature review was conducted by Ain *et al.* [23] that included 111 studies which have been published from 2002 to 2019. This study covered three categories such as the BI system success, utilization, and adoption. The findings presented the most adopted methods, factors, theories and reviewed some critical challenges related to the BI system research. Grublješič *et al.* [35] conducted a survey of 195 medium & large size Slovenian organizations to investigate the behavioral intention for BI acceptance. The findings of the study revealed that behavioral intention to use the BI & analytics with important determinants such as performance perceptions, effort perception, social influence, and result demonstrability in the perspective of behavioral belief, normative belief, and control belief were critical towards socio-organizational change for the BI system acceptance. Rouhani *et al.* [36] had conducted a survey of 135 banking firms in Iran to investigate the determinants which were considered by adopters and non-adopters of the BI system. The study results illustrated that top management support, complexity, perceived cost were significant determinants for the BI system adoption. The determinant

''perceived intangible benefits'' was identified as most crucial among the critical determinants in the context of environmental, organizational, and technological dimensions. Javad Khazaei Pool [37] collected data from 162 Information Technology (IT) and business managers by conducting a survey in Iranian industries to investigate the effects of BI adoption on agile supply chain performance. The study findings revealed that factors of organizational dimension have great impact as compared to other dimensions related to technology and environment. In addition, the environmental dimension has the least impact on the BI system adoption.

Puklavec *et al.* [34] explored the determinants for the BI adoption stages by conducting a survey in 181 small and medium industries. It is elaborated by the findings of the study that organizational readiness, management support and cost were proved insignificant determinants for the BI system adoption whereas relational decision-making culture, organizational data environment, and project champion are potential factors for the BI system adoption. The study findings were entirely contradictory to previous studies. Visinescu *et al.* [38] explored the role of BI system for improving the quality of decisions in multiple organizations from the USA by conducting a web-based survey of 61 BI system users. The study identified the problem space, information quality, complexity, and level of BI system use were potential determinants for improving the quality of decisions. It is evident by the study findings that if low quality information is provided to the BI system, then it leads to poor quality of decisions. Acheampong *et al.* [39] investigated the determinants relevant to the adoption of BI system in developing countries with an empirical analysis of survey which was conducted in 23 banks with 132 participants in Ghana. According to the study results, organizational readiness emerged as a potential determinant for banks in terms of the BI system implementation. Ahmad *et al.* [40] conducted an empirical study using a survey of 310 telecom companies in Malaysia. The study findings suggested that relative advantage, compatibility, complexity, and observability were important determinants for the successful BI deployment and trialability factor was not proved significant for the deployment of BI.

Chaveesuk *et al.* [41] proposed an integrated model for the BI adoption for logistics service companies in Thailand. The TOE model was used to investigate the potential factors such as relative advantage, compatibility, complexity, organization size, organizational readiness, top management support, government support and competitive pressure. The outcomes of this research claimed that government support factor in environment perspective and organization readiness factor in organizational perspective proved more significant for the successful adoption of BI system. Grublješič *et al.* [42] discussed the prominence of organizational factors for the BI acceptance in two organizations of Slovenia. It was an exploratory study consisting of interviews, documents review and project observation. The findings of this study revealed the importance of following determinants such as individual readiness, innovativeness, attitudes, beliefs, information quality and system quality for the BI system acceptance in organizations. Wang, H. C. [43] had conducted a study to explore the role of managers with personality profiles to investigate the difference between the adoption of BI system and their implementation. The empirical data collection was done from sixty-two managers from IT companies, banks, and insurance firms in Taiwan. The outcomes of the study suggested that the managers' intention is more important than organizational implementation intention for the BI system implementation and adoption. Foshay, N., & Kuziemsky [44] validated a framework regarding the BI system implementation issues in the healthcare sector. Total of 40 interviews were conducted for data collection from three hospitals in Canada. It is evident by the study findings, lack of decision-support capabilities were main issues for the BI system implementation in hospitals because managers were hesitant to use the BI system due to lack of timely accurate information. As a result, they wasted a lot of time for decision-making than normal required time. Managers were not sure about their decisions in the absence of the accurate information at the right time.

Olexová, C. [45] conducted a case study on BI adoption in the retail chain. He collected data by conducting 9 interviews with retail managers in Slovakia and triangulated the data with documents analysis which were provided by a retail chain company. The study findings confirmed that attributes of DOI theory have a significant role in the speed of diffusion of BI system. Additionally, he emphasized that detail of these attributes should be described to the end-users that will improve the ease of use because user's involvement has great importance for addressing requirement engineering. Ramakrishnan *et al.* [46] conducted an empirical investigation regarding determinants. Data were collected from multiple industries in the USA based on a survey from 63 BI developers. The authors recommended that institutional pressures are more significant as compared to competitive pressure that affects the organizations for the adoption of BI system with the aim of achieving stability. It is proved by existing literature, that most studies have focused on the financial and telecommunication industry and some government and educational institutions in the context of BI system adoption [47], [48]. However, there is no comprehensive research associated with the BI system adoption model and especially for the textile and apparel industry. Thus, many large groups of textile and apparel companies are using the BI system but statistical data about the BI system adoption are non-existent. All over the world, the researchers ignored this important industry in the perspective of BI system adoption [5], [9], [29], [30].

III. MATERIALS AND METHODS

This section consists of three subsections. First, the selected case is illustrated in detail. Secondly, the proposed model is developed with significant determinants and dimensions.

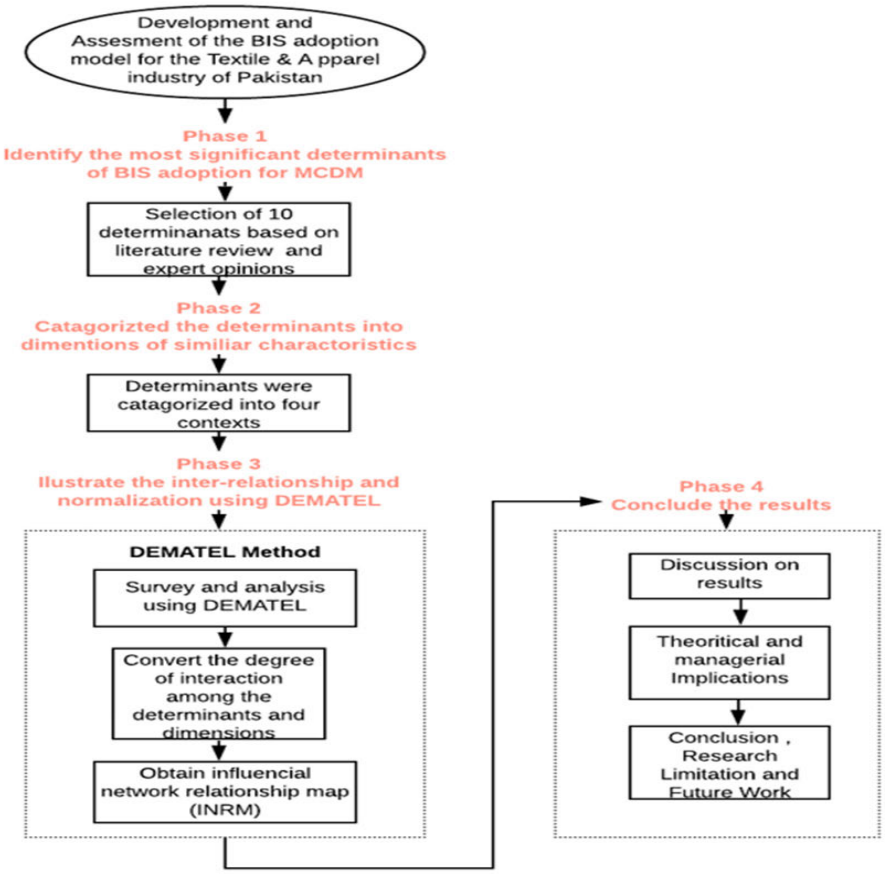

FIGURE 1. Model assessment process.

Thirdly, evaluation criteria and data collection procedure are discussed. In brief, the model assessment process is consisted of primary four contexts. (1) identify the most significant determinants for the adoption of BI system in the textile and apparel industry, (2) categorized the determinants into dimensions of same characteristics; (3) compute the inter relationships or interdependence relationships among determinants and dimensions of the proposed model for the adoption of BI system in the textile and apparel industry by using the DEMATEL technique. Map the cause-effect and dependency relationships in graphical diagrams. (4) discussion on results with managerial and theoretical implications and followed by conclusion, research limitations and suggested future work (see graphical representation in Figure 1).

A. CASE ILLUSTRATION

After detailed literature review and discussion with experts, this study proposed a BI system adoption model for the textile and apparel industry. The textile and apparel industry in Pakistan is selected to verify the feasibility of the evaluation criteria. Because the textile and apparel industry with a complete value chain like Pakistan is rare in the world (as shown by Figure 2). Many countries have just basic or finished textile and apparel industry [4].

Since the 19th century, the Pakistani textile and apparel industry has a long tradition with ample experience as well as a good repute across the world. It also ranked amongst the top textile industries of the world. Pakistan is one of the top ten exporters of textiles & apparels in the world [3], [49], [50]. It stands on the 4th largest position in world cotton producer countries, 6th largest raw cotton exporter, 3rd biggest cotton consumer in the global economy. This industry contributes 46% approximately to the 8.5% of Pakistan GDP [50]. The easy availability of raw cotton and cheap labor has played a major role to contribute more than 60% cotton-based textile exports. Recently, the emerging trends of manufacturing and production influenced the textile and apparel industry to a great extent [51], [52]. The value-added exports of Pakistani textiles are increasing at 28% in recent years [53]. Thus, the textile & apparel industry of Pakistan is not only growing and expanding rapidly, but also intensified because of its regional players which are Bangladesh, India, Vietnam, and China. In addition, in 2005, illumination of the international quota for textile products pressurized the industry stakeholders to struggle harder for its due share to sustain in international markets as indicated in Figure 3. The expanding international competitive environment and rapid growing trends of globalization have forced the industry to integrate robust organizational systems. These systems will make it possible to perform operations successfully and provide best offers to the consumers with intentions to achieve market leadership [54].

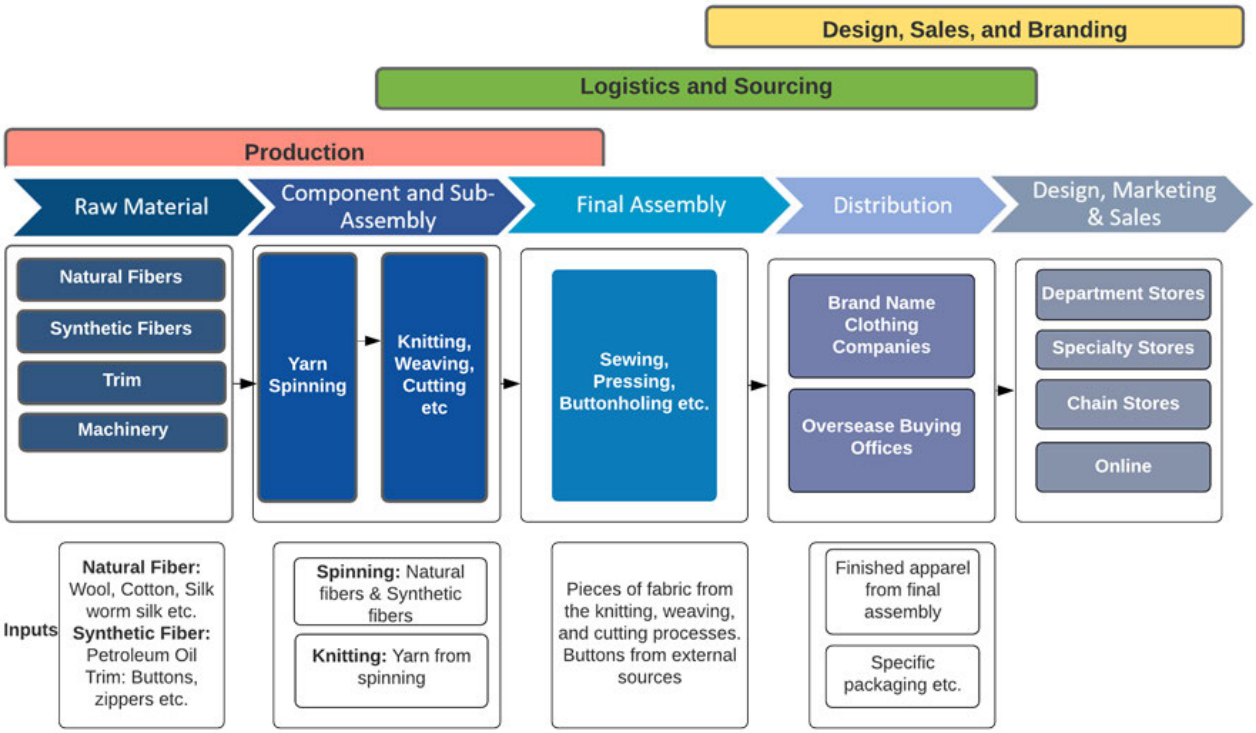

FIGURE 2. Textile and apparel industry of Pakistan (complete value chain).

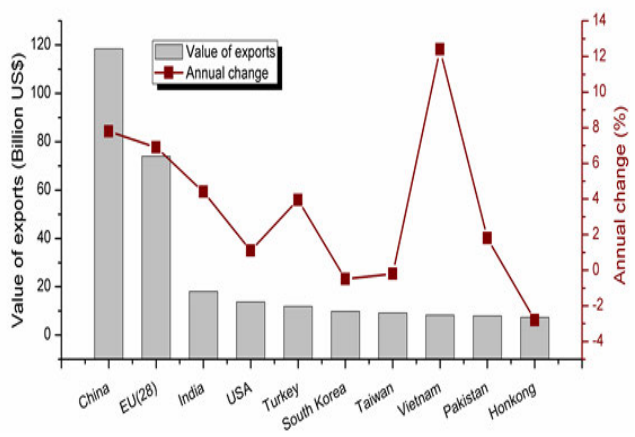

FIGURE 3. Top ten exporters of textiles (2018 vs 2017) (Data source by WTO 2019).

Therefore, Pakistani textile and apparel industry is prone to integrate advanced technologies and systems to compete in the international trade markets. In spite of contemporary remarkable investments in information technology (IT), It is lagging in the adoption of BI system. This study argues that these business conditions and market circumstances are considered for the assessment of significant determinants which influence the adoption of BI system in the textile and apparel industry.

B. PROPOSED MODEL FOR THE BI SYSTEM ADOPTION

From the detailed literature review, we found out that different industries and organizations utilized different determinants for the BI system adoption. Therefore, a team of experts from academia, software companies and from the textile and apparel industry were invited to validate the BI system adoption model with potential determinants. This study used the hybrid of TOE model and its determinants proposed by Ahmad *et al.* [21], [33]. The proposed BI system adoption model categorized the ten significant determinants into four dimensions (i.e. individual (D1), technological (D2), organizational (D3), and environmental (D4)) as shown in Table 1.

The aim of this study is to identify the significance of these determinants and dimensions as well as investigate the relationship among them that influence the BI system adoption. The findings can help to provide comprehensive elaboration of significant factors and vivid predictions that contribute to the success of the BI system in enterprises. It can also affect the decisions of industry experts before assigning huge investments for the integration of BI system in developing countries. It would lead the researchers to investigate and validate this novel model by applying different methodologies with more refined results that will maximize the benefits of this credible innovation.

C. DETERMINING THE EVALUATION CRITERIA AND DATA COLLECTION

A team is made which consists of 42 experts with multiple backgrounds such as academic researchers, industry experts, and BI vendors (see Table 2). Purposeful and snowball sampling techniques were adopted to approach the targeted participants. Data biases have been minimized by selection of

TABLE 1. Criteria and dimensions for the adoption of BI system in the textile and apparel industry.

Context	Determinants	Explanation
Individual (D_1)	Users' traits (I1)	The determinant users' traits refer to the personal innovative skills, expertise, and readiness that are considered significant individual virtues for any innovation acceptance and adoption. These users' traits motivate the users to use the BI system for analytical operations which are complex in use.
	Interpersonal communication (I2)	Each department of the textile and apparel industry is different in functionality with different issues and requirements. It is very important to establish the appropriate interpersonal communication platform for a holistic view of business which drives the decision-makers to adopt BI system.
Technological (D_2)	Technology maturity (T1)	Technology maturity refers to the technology status in terms of repute, support, and easy availability with reasonable price in any country. This determinant is considered as one of the significant determinants in developing countries for adoption of complex and costly innovations like BI system. It is the sole reason for lagging to adopt the BI system in developing countries [55].
	Compatibility (T2)	Compatibility refers to the existing infrastructure that influences the adoption decisions for innovation in organizations, it means if new technology is perceived as compatible with available technologies, values, systems, and procedures of the strong adopters in the context of infrastructure the more likely it will be adopted [56].
	Satisfaction with existing systems (T3)	The determinant "Satisfaction with existing systems" alludes to the degree of satisfaction with already in use technology or system in the perspective of BI system adoption. The higher satisfaction level with the existing systems direct to the less chances for the adoption of new innovation but it can lead to seeking new technological solutions [57]. It can be a driver and barrier at the same time for the BI system adoption.
Organizational (D_3)	Leadership commitment and support (O1)	Leadership commitment and support defined as an active involvement of top management for supporting long-term strategic vision of industry in terms of encouragement and resources throughout the BI system adoption and implementation [58].
	Sustainable Data Quality and Integrity (O2)	The textile and apparel industries are producing large data exponentially due to the adoption of advanced technologies [9]. Consequently, the quality of data is at risk, malicious data generates errors and leads not only to the financial loss and wastage of time but also erroneous decision-making. Sustainable data quality and integrity is crucial for accurate data driven decision-making with the BI system adoption.
Environmental (D_4)	Competitive pressure (E1)	Competitive pressure refers to "the level of pressure that enterprises go through by business environment" Low, C. et al. [59] stated; the organizations which are intensified by a highly competitive environment; are more prone to adopt innovations like BI system [59].
	Sustainability (E2)	Sustainability refers to the triple-bottom line approach that consist of social, environment, and economic contexts; in other words, it defines as people, planet, and profits. The sustainability determinant has great importance and is a well-known element that drives the industry experts to adopt technological innovations in industries [9].
	Market trends (E3)	Market trends refers to the development and changes in buying and selling in the market. This determinant forces the business to adopt innovation in order to serve better customers as compared to their peers. According to Rouhani at el [36], an organization adopts new technology to understand the market trends.

participants from different cities with different backgrounds and with statistical assessment using DEMATEL techniques. The data collection was conducted in five major cities in Pakistan such as Lahore, Faisalabad, Karachi, Sargodha, and Rawalpindi which are rich with high-tech technology hubs, the textile and apparel industry and universities with research and development (R & D) centers. The relevant criteria were established through discussions with industry experts for identifying the potential determinants which affect the adoption of BI system. Rational in industry practice, 10 criteria into 4 dimensions are identified (as shown in Table 1. These criteria were verified by experts using questionnaires and personal interviews. The experts were chosen in accordance with their experience, designation and familiarity.

D. APPLIED METHODS

This study presented a novel hybrid model based on the TOE framework. DEMATEL approach is used to analyze the data for obtaining the direct and indirect impact of the criteria. In 1973, the Battelle Memorial Institute of Geneva introduced the DEMATEL technique with the aim of obtaining integrated solutions for complex and intricate problems [60]. This approach has been broadly utilized as one of the means to demonstrate the cause-effect dependency relationship between evaluation criteria [61]. This method has many advantages on other Multi-Criteria Decision-Making Methods (MCDM) techniques such as Best-Worst Method (BWM), Analytics Hierarchy Process (AHP), and Analytical network process (ANP). As AHP and BWM, which only provide ranking of the determinants by calculating their weights but both techniques do not provide comprehensive understanding about interrelationships and dependencies among the determinants. Whereas ANP can deal with dependencies but needs equal weights for every element to provide an efficient weighted matrix that is not practical in many cases [62]. Further, classical structural equation

TABLE 2. Sample characteristics.

Characteristics	Item	Number	Percentage%
Gender	Male	42	100
	Female	0	0
Experience of BI system usage	10 years	6	14.2
	7-9	12	28.5
	5-7	15	35
	$\geq$ 5 years	9	21.4
Experts Background	Textile and Apparel Industry	31	73.8
	BI Vendors	5	11.9
	Researchers	6	14.3
City	Lahore	16	38
	Faisalabad	11	26
	Karachi	7	16.5
	Sargodha	6	14
	Rawalpindi	2	5

modelling (SEM) approach can be utilized to find the causal relationships among variables, but it requires a large size data sample [61]. Therefore, the DEMATEL is considered an appropriate technique according to the study requirement because it has the ability to give good results even with small data sample size [61]. The current study emphasizes on the adoption of BI system in the textile and apparel industry, survey required to possess a concise comprehension of this complex system and adoption related challenges. The available research sample size with these qualifications was scarce in the textile and apparel industry across the world due to non-explored phenomenon. Therefore, in accordance with applicability and characteristics of the DEMATEL described herein clearly fit the research aim of this study. It is also proven to guide the decision-makers with valuable information for understanding of a complex problem which has tangled inter-relationships among criteria. The strength and causal relationship among criteria are calculated to reveal the interdependency relationship of every determinant into a specific dimension. An illustration of the calculation steps and applied approach is presented as follows:

STEP 1. ALLOCATE DEGREE TO EACH DETERMINANT

Define the scale to evaluate the criteria for representation of degree of the influence. The five-point scale is used with values 0, 1, 2, 3, and 4, which are assumed to represent the degree of impact from "(0) No influence," "(1) Low influence," "(2) Medium degree influence," "(3) High influence," to "(4) Very high influence."

STEP 2. DEVELOP THE DIRECT INFLUENCE MATRIX

Take an average of the results from the n experts and generate an initial direct-influence matrix A. The direct-influence matrix, A, can be derived by indicating the impact of determinant 'i' on determinant 'j', as a_{ij}.

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1j} & \cdots & a_{1n} \\ \vdots & & \vdots & & \vdots \\ a_{i1} & \cdots & a_{ij} & \cdots & a_{in} \\ \vdots & & \vdots & & \vdots \\ a_{n1} & \cdots & a_{nj} & \cdots & a_{nn} \end{bmatrix} \tag{1}$$

STEP 3. NORMALIZE THE DIRECT INFLUENCE MATRIX

A direct influence matrix $S = [S_{ij}]_{n\times n}$ is achieved by normalizing matrix A using Equations (2) and (3)

$$S = Z \cdot A \tag{2}$$

$$Where\ Z = min\left\{ \frac{1}{\max\limits_{i} \sum_{j=1}^{n} |a_{ij}|}, \frac{1}{\max\limits_{j} \sum_{i=1}^{n} |a_{ij}|} \right\} \tag{3}$$

STEP 4. CALCULATE THE TOTAL DIRECT INFLUENCE MATRIX T

The total direct influence matrix $\mathbf{T} = [\mathrm{t_{ij}}]_{\mathrm{n\times n}}$ can be calculated by using the Equation (4) after producing the normalized direct influence matrix S and summing up all direct and indirect outcomes.

$$T = S + S^2 + \cdots + S^h = S(I - S)^{-1} \tag{4}$$

where $\boldsymbol{I}$ denote the identity matrix, and when $\lim_{h\to\infty} S^h = [0]\ n \times n$.

STEP 5. COMPUTE THE SUMS OF THE COLUMNS AND ROWS OF MATRIX T

The vectors R and D represent the sums of the rows and columns of the total-influence matrix T respectively which are illustrated in Equations (5) and (6)

$$R = [R_i]_{n\times 1} = \left[\sum\nolimits_{j=1}^{n} t_{ij}\right]_{n\times 1}, \quad i, j = 1, 2, \ldots, n \tag{5}$$

$$D = [D_j]_{1\times n} = \left[\sum\nolimits_{i=1}^{n} t_{ij}\right]_{1\times n}, \quad i, j = 1, 2, \ldots, n \tag{6}$$

where ' 'R_i' represents the row sum of the i^{th} row of the matrix 'T' and indicates the addition of the direct and indirect effects of determinant 'i' on the other determinant. Similarly, ' 'D_j' represents the column sum of the j^{th} column of matrix 'T' and indicates the sum of direct and indirect influences that determinant 'j' has received from the other determinant.

STEP 6. PRODUCING THE CAUSE-EFFECT RELATIONSHIP DIAGRAM

By mapping the dataset of $(R_i + D_j, R_i - D_j)$, a cause-effect diagram is constructed on threshold value considering the influence level for an appropriate map. The map is constructed on those determinants only which have influence level higher than the threshold value in matrix T. The threshold value is attained by calculating the average of the T matrix. The map would be complex, if the threshold value is too low, on contrary, if the threshold value is very high then many determinants would be independent, it means the

T will not show any relationships among the determinants or dimensions.

STEP 7. MAPPING THE INFLUENCE RELATIONSHIP BASED ON THE INNER DEPENDENCY MATRIX

The dependency matrix is constructed by taking the average of the T matrix and calculating the threshold value that is 0.644 in this study. A threshold value must be assigned to know the influence level to construct the appropriate map [63]. A threshold value is also a crucial step to determine the significance of critical determinants and it also differentiates the appropriate expert opinion. As an exceedingly high threshold value oversimplifies the problem and reduces the significance of expert opinions inappropriately, whereas an extreme low threshold value results in a lack of focus and in divergent opinions [63]. All items are discarded which have values less than threshold value and retained only those items which have values more than or equal to the threshold value. All relationships and dependencies among determinants are illustrated with a graphical map in Figure 4.

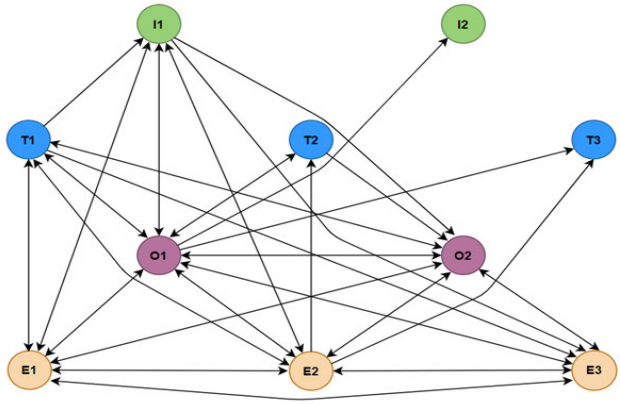

FIGURE 4. Determinants' influence relationship diagram.

IV. RESULTS AND DISCUSSIONS

First, the influential relationships are calculated among determinants in four dimensions by using DEMATEL technique. The practical illustration of the selected method is possible with the application of empirical analysis which is used for validating the significant determinants for the BI system adoption in the textile and apparel industry. The analysis, results, and final model development are presented in the following sections.

A. IDENTIFICATION OF SIGNIFICANT DETERMINANTS

In this section, collected data were analyzed by using the DEMATEL techniques. The influence relationships were determined among the determinants. The initial direct-influence matrix (A) of all determinants that influenced the BI system model is produced after calculating the average of all experts' given scores as displayed in Table 3. Then, normalized direct-influence matrix (S), constructed as shown in Table 4. The scale of dependency relationships is illustrated by constructing the total-influence matrix (T) among the determinants into four dimensions of the proposed BI system adoption model as displayed in Table 5. The significance of interactive relationships between determinants are shown in this table. Additionally, the prominent relationships among determinants are indicated in the sums of the cause-and-effect determinants as shown in Table 6. In a similar way, the criteria level (R − D) and (R + D) for the adoption of BI system is derived, as summarized in Table 6. A determinant with a D-R value greater than zero is indicated as a cause determinant, on the other hand, a determinant with a D-R value less than zero is represented as a determinant which is influenced by other determinants as shown in Table 6. Table 7 presents the inner dependency relationship among determinants.

B. FINAL MODEL FOR THE ADOPTION OF BI SYSTEM

Final model is refined with significant determinants which influenced the BI system adoption in the textile and apparel industry. After inner dependency analysis of the determinants (shown in Table 7 and Figure 4), two determinants proved insignificant such as interpersonal communication (I2) from individual dimension (D1) and satisfaction with existing systems from technological dimension (D2). The insignificant determinants have no dependency relationship with other determinants and do not influence the BI system model. As a result, they were discarded and not included in the final BI system adoption model for the textile and apparel industry as depicted in Figure 5.

C. ASSESSMENT OF THE CAUSE-EFFECT DETERMINANTS

In this study, each determinant is analyzed explicitly with the cause-effect concept to decide which is more likely significant for the BI system adoption. Thus, it is common perception that determinants from the cause group needed careful examination [64]. Because causal determinants can influence the overall model, their performance can greatly affect the overall objective. The analysis of results revealed that sustainability (E2), technology maturity (T1), leadership management and support (O1), users' traits (I1), and compatibility (T2), are more significant with highest (R-D) values, that shows, these determinants have greater influence on the entire model than other determinants. In addition, it is depicted by Table 6, that degree of their influence (R-D) E2 (0.427), T1(0.398), O1 (0.379), I1 (0.336), T2 (0.164) are ranking highest among all causal determinants. It reveals that these items have not only great influence on other determinants but also in case of their amelioration can cause the improvement of the entire model. It is proven that organizations including the textile and apparel industry from developing countries which are operating in a competitive environment are more susceptible to sustainability, compatibility, and technology maturity issues. Software vendor companies ensure the availability of software with reasonable prices in developing countries to resolve the compatibility and technology maturity challenges. On the other hand,

TABLE 3. Initial direct-relation (influence) matrix.

Criteria	I1	I2	T1	T2	T3	O1	O2	O3	E1	E2
I1	0.000	2.786	2.024	2.524	2.286	2.095	2.786	2.381	1.762	1.810
I2	0.952	0.000	1.071	2.381	1.500	2.810	1.381	2.310	1.333	2.310
T1	2.405	2.214	0.000	2.190	1.810	2.167	2.214	2.286	2.071	2.929
T2	2.167	1.310	2.429	0.000	2.833	2.452	2.310	1.619	1.881	1.833
T3	1.786	1.214	2.024	1.881	0.000	2.167	2.690	1.690	1.357	1.548
O1	3.048	3.048	2.881	2.524	2.833	0.000	1.548	2.095	3.238	1.690
O2	1.643	2.238	2.833	1.548	2.524	1.952	0.000	2.405	2.571	2.262
E1	2.929	1.238	2.905	1.429	1.310	2.738	3.048	0.000	2.690	2.738
E2	2.357	1.214	1.667	3.000	1.762	2.238	3.048	3.095	0.000	3.048
E3	1.738	2.690	0.976	0.905	1.524	2.905	3.190	3.167	3.048	0.000

TABLE 4. Normalized direct-relation (influence) matrix.

Criteria	I1	I2	T1	T2	T3	O1	O2	O3	E1	E2
I1	0.000	0.122	0.088	0.110	0.100	0.091	0.122	0.104	0.077	0.079
I2	0.042	0.000	0.047	0.104	0.065	0.123	0.060	0.101	0.058	0.101
T1	0.105	0.097	0.000	0.096	0.079	0.095	0.097	0.100	0.090	0.128
T2	0.095	0.057	0.106	0.000	0.124	0.107	0.101	0.071	0.082	0.080
T3	0.078	0.053	0.088	0.082	0.000	0.095	0.117	0.074	0.059	0.068
O1	0.133	0.133	0.126	0.110	0.124	0.000	0.068	0.091	0.141	0.074
O2	0.072	0.098	0.124	0.068	0.110	0.085	0.000	0.105	0.112	0.099
E1	0.128	0.054	0.127	0.062	0.057	0.120	0.133	0.000	0.117	0.120
E2	0.103	0.053	0.073	0.131	0.077	0.098	0.133	0.135	0.000	0.133
E3	0.076	0.117	0.043	0.040	0.067	0.127	0.139	0.138	0.133	0.000

TABLE 5. Total-relation matrix.

Criteria	I1	I2	T1	T2	T3	O1	O2	E1	E2	E3
I1	0.558	0.639	0.638	0.636	0.631	0.705	0.749	0.705	0.659	0.660
I2	0.497	0.430	0.497	0.528	0.500	0.615	0.577	0.587	0.536	0.567
T1	0.656	0.621	0.556	0.624	0.614	0.710	0.732	0.705	0.674	0.703
T2	0.610	0.551	0.617	0.502	0.617	0.676	0.691	0.637	0.625	0.622
T3	0.534	0.489	0.542	0.517	0.447	0.597	0.634	0.572	0.542	0.547
O1	0.740	0.706	0.728	0.699	0.710	0.690	0.776	0.763	0.775	0.722
O2	0.619	0.610	0.657	0.592	0.629	0.691	0.633	0.699	0.681	0.671
E1	0.705	0.614	0.699	0.624	0.623	0.760	0.795	0.647	0.728	0.728
E2	0.690	0.614	0.661	0.684	0.646	0.749	0.803	0.771	0.628	0.743
E3	0.634	0.638	0.602	0.579	0.603	0.738	0.768	0.740	0.713	0.592

TABLE 6. Sum of influences given and received on criteria.

Criteria	R_i	D_j	R_i+D_j	R_i-D_j
I1	6.579	6.244	12.823	0.336
I2	5.335	5.912	11.247	-0.577
T1	6.594	6.196	12.790	0.398
T2	6.148	5.984	12.131	0.164
T3	5.422	6.020	11.441	-0.598
O1	7.310	6.931	14.241	0.379
O2	6.481	7.158	13.639	-0.677
E1	6.924	6.828	13.752	0.096
E2	6.989	6.562	13.551	0.427
E3	6.607	6.555	13.162	0.052

to improve the adoption process of BI systems in the textile and apparel industry, leadership support and commitment determinant deserve serious attention to support the costly complex BI system. In addition, the other cause determinants are competitive pressure and market trends. They also influenced the model, and their improvement can lead to the efficiency and effectiveness of the BI system adoption process. It is a general concept that determinants in the effect group can be easily influenced by other determinants which are considered inappropriate as a significant determinant. Nonetheless, it is essential to discuss these determinants to recognize the significance of each one. The interpersonal

TABLE 7. Inner dependency matrix.

Criteria	I1	I2	T1	T2	T3	O1	O2	E1	E2	E3
I1						0.705	0.749	0.705	0.659	0.660
I2										
T1	0.656					0.710	0.732	0.705	0.674	0.703
T2						0.676	0.691			
T3										
O1	0.740	0.706	0.728	0.699	0.710	0.690	0.776	0.763	0.775	0.722
O2			0.657			0.691		0.699	0.681	0.671
E1	0.705		0.699			0.760	0.795	0.647	0.728	0.728
E2	0.690		0.661	0.684	0.646	0.749	0.803	0.771		0.743
E3						0.738	0.768	0.740	0.713	

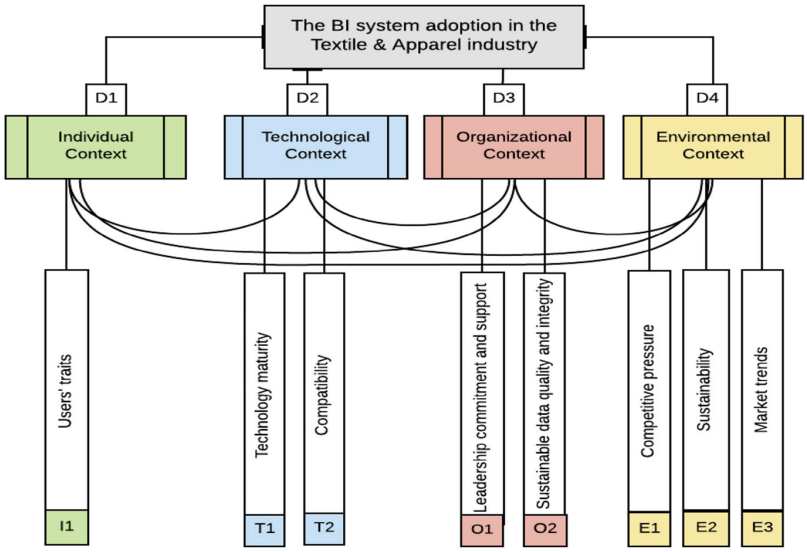

FIGURE 5. Final BI system adoption model for the textile and apparel industry.

communications (I2), sustainable data quality and integrity and satisfaction with existing systems (T3) are from the effect group determinants as presented in Table 6. As their (R-D) values are I2 (−0.577), T3 (−0.598), and O2 (−0.677) respectively, that indicate, they have not contributed significantly to the adoption process of BI system.

As a result, further analysis has been performed and one of the influenced determinants is identified as a significant determinant that is sustainable data quality and integrity (O2). In addition, it is divulged by the analysis that the degree of influence of effect group determinants is low. As a result, these determinants have a minimal effect on the entire model as well as being vulnerable to other determinants. Thus, effect group determinants have no vivid significance for the BI system adoption without making any adjustment by other determinants at an eminent level which belongs to the cause group. Further, two dimensions (D2) and (D4) have causal influence on other two dimensions (D1) and (D3) as it is depicted by Figure 6 and 7 "Total cause-effect relationship diagrams.

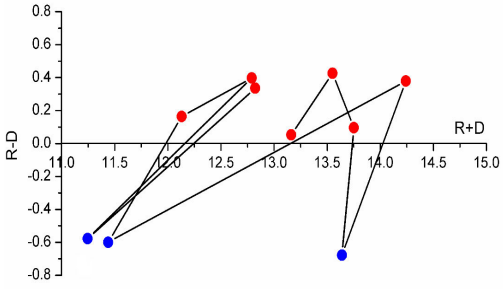

FIGURE 6. Determinants' influence relationship diagram.

The summary of direct and indirect effects of all criteria into four dimensions is presented in Table 6. Further, the causal relationships are elaborated among the criteria under individual, technological, organizational, and environmental dimensions as depicted in Figure 6, all procedure is summarized as follows.

1- As indicated in the individual context (D1) (as shown in Table 6). It is evident that users' traits criterion is ranked

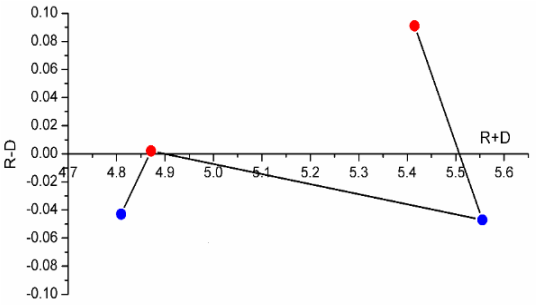

FIGURE 7. Total causal influence relationships among dimensions.

the fourth with the highest positive (R-D) value I1 (0.336) in all determinants. Interpersonal communications (I2) with a negative (R − D) value of -0.577 is from the effect group, it is indicated by the individual (I) context (dimension) of Figure 7, Thus, users' traits (I1) is relatively important with higher (R-D) value and influenced other criteria with cause net effect and has positive impact on whole framework.

2- Similarly in the technological context (D2), technology maturity (T1) has more impact with higher (R − D) value (0.398) as compared to other two determinants such as compatibility (T2) with (0.164) value and satisfaction with existing systems with net effect value (T3) (-0.598). Thus, technology maturity (T1) and compatibility (T2) have a direct influence on criterion (T3).

3- Whereas from the organizational context (D3), leadership support and commitment (O1) has the highest (R − D) value, 0.557, and ranked third among all determinants which directly influenced not only other criterion sustainable data quality and integrity (O2) which is with net effect value -0.677 but also influenced other determinants from other dimensions for the BI system adoption. Further, it is revealed by the analysis that leadership support and commitment is one of the most critical determinants since it influences almost all other criteria of all dimensions.

(4) Finally, in the environmental context (D4) in Table 6, Sustainability (E2) is the most significant determinant with the highest (R - D) value, (0.427), competitive pressure (E1) and market trends (E3) are also from cause group. Further, it is illustrated by the environmental context (D4) of Figure 6, all determinants are from the cause group with net cause values E1 (0.096), E2 (0.427), and E3 (0.052) respectively that means this dimension has great impact on other three dimensions and influenced the entire BI system model.

V. MANAGERIAL AND THEORETICAL IMPLICATIONS

This study considers qualitatively and quantitatively the comprehensive interactions among determinants and provides the validated BI system adoption model for the textile and apparel industry. This research proposed some countermeasures based on different criteria: short term measures based on effect determinants, long term measures based on cause determinants and critical measures based on the most significant determinants with highest (R-D) values. It can guide industry experts theoretically for allocation of resources reasonably and take various measures in different implementation phases to enhance the adoption rate of BI system not only in the textile and apparel industry but also in other industries with the same business domains such oil and gas, electric, power, rail, and aviation.

The study results drew the attention of software vendor companies to support the adoption processes of innovation in developing countries in terms of time, budget, and easy availability of software tools where the major concern is technology maturity. In modern business trends, it is pertinent for industry experts and scholars to understand the relationship between proposed technological solutions and business requirements. As a result, they can build and follow appropriate theoretical models that contributes not only to the success of the innovations but also improve the organizational sustainability by utilizing business data into actionable intelligence. A handful of developed theories and models were developed for the adoption of BI system in different industries at individual level or organizational level considered as two different scenarios. Theoretically, this study is one of the pioneers that investigated the individual determinants with technological, organizational, and environmental determinants addressing the BI system adoption at organizational level. As users are the main stakeholders of any innovation. Thus, users related determinants have great importance to harness the real value from the BI system adoption [21], [23].

Moreover, industry practitioners emphasized that ''sustainability'', ''competitive pressure'' and ''market trends'' determinants are pertinent prerequisites for the adoption of BI system for those businesses and industries, which are facing intensive competitive pressure and bringing attention towards environmental and socio-economic advantages in practice. For instance, natural resources are less wasteful because of well-informed decision-making, as it limits biological processes by analysing data in production and manufacturing industries, which results in socio-economic value creation from the environmental impact of industry processes. Since the research model will not only encourage the adoption of BI system but also other emerging innovations that appear to herald a future in which value chains of manufacturing enterprises are collaborative, shorter, and offer more sustainability advantages [33].

It is believed that this study results not only contributed to the recent body of knowledge but also attracted the attention of industry experts to integrate the BI system with advanced technologies in the era of fourth and fifth industrial revolutions and can attain desired results without trial and error. According to the data analysis, organizations should consider the significant determinants before implementing the BI system and diminish the chances of BI system projects' failure. In addition, the current empirical results add to the research relevant to the BI system adoption and would guide the scholars to consider the companies' choice of new determinants before proposing or validating any existing model or theory.

VI. CONCLUSION, RESEARCH LIMITATION, AND FUTURE WORK

This study investigated the BI system adoption model based on the hybrid of TOE model. This TOE model was extended with an additional dimension (Individual) with three conventional dimensions of TOE (technological, organizational, and environmental). Similarly, the preliminary findings from the interviews were applied to validate the adequacy of the proposed BI system adoption model. Subsequently, the proposed research model was validated by using a survey with questionnaire and DEMATEL techniques. The DEMATEL has determined the influential dependency relationships and prioritized the determinants into four dimensions for the adoption of BI system in the textile and apparel industry. The complicated inter-relationships are identified which revealed that sustainability in environmental context, users' traits in individual context, leadership support and commitment in organizational context and technology maturity in technological contexts have great importance with highest ranks and values. It also confirmed that environmental context (D4) has all causal determinants influencing the other dimensions such as individual (D1) technological (D2) and organizational (D3).

Total of seven determinants are from the cause group with positive values and three determinants are from the effect group with negative values. Additionally, it is depicted by the analysis of findings that users' traits (I1), technology maturity (T1), sustainability (E2), leadership commitment and support (O1), and compatibility (T2) are more significant with highest (R-D) values, that show, the determinants from causal group have greater influence on the entire model than other determinants which are from effect group such as interpersonal communications (I2) and satisfaction with existing systems (T3). They can be influenced easily by other determinants because the degree of influence of these determinants is low, and they have no vivid significance for the BI system adoption. Therefore, the determinants from the effect group were discarded for refining the final model of BI system adoption. Further, it is divulged by the analysis of data that two dimensions (D2) and (D4) have strong causal influence on other two dimensions (D1) and (D3).

Ahmad *et al.* [21] suggested that different determinants can influence the decisions of different industries for the adoption of BI system in different perspectives and it is proved by the current study results which contributed to the existing body of knowledge related to the BI system research with some new determinants such as sustainability, users' traits, interpersonal communication, technology maturity, and sustainable data quality and integrity. The study results suggest that software vendor companies and cloud technology service providers try to resolve the technology maturity and technology compatibility challenges in developing countries. As developing countries are hesitating to buy or integrate immature innovations due to high cost and unavailability of continued support from software vendors. Leadership support and commitment is also very important from the beginning stage to the return on investment (ROI) and better utilization of complex BI system to leverage the true value of this costly system. Additionally, this study results will guide the software vendors to make sure the easy availability of innovations with attractive offers in their target markets, specifically those regions which are going through by circular economy challenges due to mass shifting of manufacturing units because of easy and low-cost availability of material and labour.

Secondly, the ''users' traits'' determinant has a major role because the innovative and skilled policy makers can harness the real potentials from the BI system. Further, a decision-making by an individual department lagging in quality decision-making without involving other departments that enhance the quality of data [65]. Therefore, ''interpersonal communications'' and ''sustainable data quality and integrity'' are important determinants in this perspective. On the other hand, the ultimate objective of any manufacturing industry is achieving sustainability via integrating innovations, the determinant sustainability is assessed first time in this study. However, this study made a significant contribution with the assessment of the BI system adoption model but still has some limitations that can be further addressed by practitioners and researchers in the future. Recent research collected small data sets from the textile and apparel industry in Pakistan due to the BI systems implementation and adoption at limited scale. Consequently, large data sets from other countries can provide better comparisons and different results. At present, the results are snapshots based on judgments of a limited number of experts. The academic studies on the BI system adoption in the textile and apparel industry are rare. Additionally, no BI system adoption model was proposed in Pakistan nor across the world for the textile and apparel industry.

The researcher gathered a rich data, which can be a foundation for future research studies within or outside of Pakistan. In addition, it will also attract the Pakistani and worldwide researchers towards the BI system adoption by using the emerging determinants from the findings of this study as a base for proposing any novel theory or model that is generally neglected in the theoretical field [28]. The comprehension of each dimension of BI system adoption is important not only for practitioners but also for scholars to overcome the social and environmental risks associated with the manufacturing industries. It would be helpful to scholars, software companies, and industry experts in finding technological solutions with best strategies for solving the triple bottom line sustainability challenges in the era of ''Industry 4.0''.

Finally, the developed model can be used as a foundation in the future, especially validating the model in different contexts in different industries by applying different research methodologies. Additionally, the ambiguity of assessment and uncertainty of experts were not considered in this research; that is another limitation which requires to be addressed. Further, practical efforts are needed by practitioners in order to extend the results of the current research. Moreover, biases cannot be handled due to human

involvement in forced-set coding rules. Although, maximum efforts are made to minimize the biases by triangulating with literature and utilizing DEMATEL technique. The sensitivity analysis is recommended for future research to present the robustness of DEMATEL techniques for innovation adoption. A model that integrates the grey theory and fuzzy theory is one of possible directions for future development. Lastly, this study applied the TOE framework to develop the BI system adoption model. Other stakeholder and organizational theories are suggested to be explored in this research area. It is observed that further studies can be conducted to validate this model with large data sets by using Partial Squares based Structural Equation Modeling (PLS-SME) and propose more validated results.

REFERENCES

[1] W. Leal Filho, D. Ellams, S. Han, D. Tyler, V. J. Boiten, A. Paço, H. Moora, and A.-L. Balogun, "A review of the socio-economic advantages of textile recycling," *J. Cleaner Prod.*, vol. 218, pp. 10–20, May 2019, doi: 10.1016/j.jclepro.2019.01.210.

[2] M. Kim, "Export competitiveness of India's textiles and clothing sector in the United States," *Economies*, vol. 7, no. 47, pp. 1–17, 2019, doi: 10.3390/economies7020047.

[3] N. Hayat, A. Hussain, and H. D. Lohano, "Eco-labeling and sustainability: A case of textile industry in Pakistan," *J. Clean. Prod.*, vol. 252, pp. 1–12, Apr. 2020, doi: 10.1016/j.jclepro.2019.119807.

[4] A. K. A. Marwat and M. A. Khan, "Textile policy 2014-19," *Ministry Textile Ind. Government Pakistan*, Tech. Rep., Feb. 2015, pp. 1–22.

[5] S. Ahmad and S. Miskon, "The adoption of business intelligence systems in textile and apparel industry: Case studies," in *Emerging Trends in Intelligent Computing and Informatics*, G. N. Advances, F. Saeed, and F. Mohammed, Eds. Cham, Switzerland: Springer, 2020, pp. 12–23.

[6] Q. M. M. Abro, N. A. Memon, and P. Arshdi, "Dynamic capabilities and firm performance: A case of two SMEs in Pakistan," *Mehran Univ. Res. J. Eng. Technol.*, vol. 30, no. 3, pp. 521–530, 2011.

[7] M. I. Nofal and Z. M. Yusof, "Integration of business intelligence and enterprise resource planning within organizations," *Procedia Technol.*, vol. 11, pp. 658–665, Jan. 2013, doi: 10.1016/j.protcy.2013.12.242.

[8] B. S. Sahay and J. Ranjan, "Real time business intelligence in supply chain analytics," *Inf. Manage. Comput. Secur.*, vol. 16, no. 1, pp. 28–48, Mar. 2008, doi: 10.1108/09685220810862733.

[9] S. Ahmad, S. Miskon, R. Alabdan, and I. Tlili, "Towards sustainable textile and apparel industry: Exploring the role of business intelligence systems in the era of industry 4.0," *Sustainability*, vol. 12, no. 7, p. 2623, 2020, doi: 10.3390/su12072632.

[10] J. L. Hutchinson and H. D. Babcock, "Big data in industry," in *Materials Science and Engineering*, vol. 144, Nov. 2016, Art. no. 012006, doi: 10.1088/1757-899X/144/1/012006.

[11] J. Hojnik and M. Ruzzier, "The driving forces of process eco-innovation and its impact on performance: Insights from Slovenia," *J. Cleaner Prod.*, vol. 133, pp. 812–825, Oct. 2016, doi: 10.1016/j.jclepro.2016.06.002.

[12] D.-H. Jin and H.-J. Kim, "Integrated understanding of big data, big data analysis, and business intelligence: A case study of logistics," *Sustainability*, vol. 10, no. 10, p. 3778, Oct. 2018, doi: 10.3390/su10103778.

[13] M. Muntean, "Business intelligence issues for sustainability projects," *Sustainability*, vol. 10, no. 2, pp. 1–10, 2018, doi: 10.3390/su10020335.

[14] E. M. Rogers, "A prospective and retrospective look at the diffusion model," *J. Health Commun.*, vol. 9, no. 1, pp. 13–19, Jan. 2004, doi: 10.1080/10810730490271449.

[15] M. A. Wahsh and J. S. Dhillon, "An investigation of factors affecting the adoption of cloud computing for E-government implementation," in *Proc. IEEE Student Conf. Res. Develop. (SCOReD)*, Dec. 2015, pp. 323–328, doi: 10.1109/SCORED.2015.7449349.

[16] M. Bilandžić, "Business intelligence u hrvatskom gospodarstvu," *Posl. Izvr.*, vol. 6, no. 1, pp. 9–27, 2012.

[17] S. Pavkov, P. Poščic, and D. Jakšic, "Business intelligence systems yesterday, today and tomorrow—An overview," *Zb. Veleučilišta u Rijeci*, vol. 4, no. 1, pp. 97–108, 2016.

[18] O. Isik, M. C. Jones, and A. Sidorova, "Business intelligence (BI) success and the role of BI capabilities," *Intell. Syst. Accounting, Finance Manage.*, vol. 18, no. 4, pp. 161–176, Oct. 2011, doi: 10.1002/isaf.329.

[19] A. Schick, M. Frolick, and T. Ariyachandra, "Competing with BI and analytics at monster worldwide," *Int. J. Bus. Intell. Res.*, vol. 3, no. 3, pp. 1–13, 2011, doi: 10.1109/HICSS.2011.119.

[20] W. Yeoh and A. Popovič, "Extending the understanding of critical success factors for implementing business intelligence systems," *J. Assoc. Inf. Sci. Technol.*, vol. 67, no. 1, pp. 134–147, Jan. 2016, doi: 10.1002/asi.23366.

[21] S. Ahmad, S. Miskon, T. A. Alkanhal, and I. Tlili, "Modeling of business intelligence systems using the potential determinants and theories with the lens of individual, technological, organizational, and environmental contexts—A systematic literature review," *Appl. Sci.*, vol. 10, no. 9, pp. 1–24, 2020, doi: 10.3390/app10093208.

[22] C. M. Olszak, "Dynamic business intelligence and analytical capabilities in organizations," in *Proc. e-Skills Knowl. Prod. Innov. Conf.* Cape Town, South Africa: The Univ. of Cape Town, Nov. 2014, pp. 289–303.

[23] N. U. Ain, G. Vaia, W. H. DeLone, and M. Waheed, "Two decades of research on business intelligence system adoption, utilization and success—A systematic literature review," *Decis. Support Syst.*, vol. 125, pp. 1–13, Oct. 2019, doi: 10.1016/j.dss.2019.113113.

[24] A. Popović, B. Puklavec, and T. Oliveira, "Justifying business intelligence systems adoption in SMEs," *Ind. Manage. Data Syst.*, vol. 119, no. 1, pp. 210–228, Feb. 2019, doi: 10.1108/IMDS-02-2018-0085.

[25] H. J. Richardson, R. Sallam, K. Schlegel, A. Kronz, and J. Sun, "Magic quadrant for analytics and business intelligence platforms," Stamford, CT, USA, Tech. Rep. G00386610, Feb. 2020.

[26] S. Alter, "Nothing is more practical than a good conceptual artifact... which may be a theory, framework, model, metaphor, paradigm or perhaps some other abstraction," *Inf. Syst. J.*, vol. 27, no. 5, pp. 671–693, Sep. 2017, doi: 10.1111/isj.12116.

[27] J. Venable, J. Pries-Heje, and R. Baskerville, "FEDS: A framework for evaluation in design science research," *Eur. J. Inf. Syst.*, vol. 25, no. 1, pp. 77–89, Jan. 2016, doi: 10.1057/ejis.2014.36.

[28] A. Stjepić, L. Sušac, D. S. Vugec, and A. Bis, "Technology, organizational and environmental determinants of business intelligence systems adoption in Croatian SME: A case study of medium-sized enterprise," *Int. J. Econ. Manage. Eng.*, vol. 13, no. 5, pp. 725–730, 2019.

[29] S. Carvalho, F. Portela, M. F. Santos, A. Abelha, and J. Machado, "Step towards of a homemade business intelligence solution—A case study in textile industry," in *New Contributions in Information Systems and Technologies*, vol. 353. Cham, Switzerland: Springer, 2015, pp. 361–370, doi: 10.1007/978-3-319-16486-1_36.

[30] V. Istrat and N. Lalić, "Association rules as a decision making model in the textile industry," *Fibres Text. East. Eur.*, vol. 25, no. 4, pp. 8–14, 2017, doi: 10.5604/01.3001.0010.2302.

[31] S. Shiwanthi, E. Lokupitiya, and S. Peiris, "Evaluation of the environmental and economic performances of three selected textile factories in Biyagama export processing zone Sri Lanka," *Environ. Develop.*, vol. 27, pp. 70–82, Sep. 2018, doi: 10.1016/j.envdev.2018.07.006.

[32] F. T. Gbolarumi, K. Y. Wong, and S. T. Olohunde, "Sustainability assessment in the textile and apparel industry: A review of recent studies," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1051, pp. 1–15, Feb. 2021, doi: 10.1088/1757-899x/1051/1/012099.

[33] S. Ahmad, S. Miskon, R. Alabdan, and I. Tlili, "Exploration of influential determinants for the adoption of business intelligence system in the textile and apparel industry," *Sustainability*, vol. 12, no. 18, pp. 1–21, 2020, doi: 10.3390/su12187674.

[34] B. Puklavec, T. Oliveira, and A. Popovič, "Understanding the determinants of business intelligence system adoption stages: An empirical study of SMEs," *Ind. Manage. Data Syst.*, vol. 118, no. 1, pp. 236–261, Feb. 2017, doi: 10.1108/IMDS-05-2017-0170.

[35] T. Grublješič, P. S. Coelho, and J. Jaklič, "The shift to socio-organizational drivers of business intelligence and analytics acceptance," *J. Organ. End User Comput.*, vol. 31, no. 2, pp. 1–28, 2019, doi: 10.4018/joeuc.2019040103.

[36] S. Rouhani, A. Ashrafi, A. Z. Ravasan, and S. Afshari, "Business intelligence systems adoption model: An empirical investigation," *J. Organizational End User Comput.*, vol. 30, no. 2, pp. 43–70, Apr. 2018, doi: 10.4018/JOEUC.2018040103.

[37] J. K. Pool, H. B. Jamkhaneh, R. A. Tabaeeian, H. Tavakoli, and A. Shahin, "The effect of business intelligence adoption on agile supply chain performance," *Int. J. Product. Qual. Manag.*, vol. 23, no. 3, pp. 289–306, 2018, doi: 10.1504/IJPQM.2018.089802.

[38] L. L. Visinescu, M. C. Jones, and A. Sidorova, "Improving decision quality: The role of business intelligence," *J. Comput. Inf. Syst.*, vol. 57, no. 1, pp. 58–66, Jan. 2017, doi: 10.1080/08874417.2016.1181494.
[39] A. Owusu, G. C. Agbemabiasie, D. T. Abdurrahaman, and B. A. Soladoye, "Determinants of business intelligence systems adoption in developing countries: An empirical analysis from Ghanaian Banks," *J. Internet Banking Commerce* vol. 22, no. 8, pp. 1–25, 2017.
[40] A. Ahmad, R. Ahmad, and K. F. Hashim, "Innovation traits for business intelligence successful deployment," *J. Theor. Appl. Inf. Technol.*, vol. 89, pp. 78–89, 2016.
[41] S. Chaveesuk and S. Horkondee, "An integrated model of business intelligence adoption in Thailand logistics service firms," in *Proc. 7th Int. Conf. Inf. Technol. Electr. Eng. (ICITEE)*, Chiang Mai, Thailand, Oct. 2015, pp. 604–608.
[42] T. Grublješič and J. Jaklič, "Business intelligence acceptance: The prominence of organizational factors," *Inf. Syst. Manage.*, vol. 32, no. 4, pp. 299–315, Oct. 2015, doi: 10.1080/10580530.2015.1080000.
[43] H.-C. Wang, "Distinguishing the adoption of business intelligence systems from their implementation: The role of managers' personality profiles," *Behav. Inf. Technol.*, vol. 33, no. 10, pp. 1082–1092, Oct. 2014, doi: 10.1080/0144929X.2013.869260.
[44] N. Foshay and C. Kuziemsky, "Towards an implementation framework for business intelligence in healthcare," *Int. J. Inf. Manage.*, vol. 34, no. 1, pp. 20–27, Feb. 2014, doi: 10.1016/j.ijinfomgt.2013.09.003.
[45] C. Olexová, "Business intelligence adoption: A case study in the retail chain," *WSEAS Trans. Bus. Econ.*, vol. 11, no. 1, pp. 95–106, 2014.
[46] T. Ramakrishnan, M. C. Jones, and A. Sidorova, "Factors influencing business intelligence (BI) data collection strategies: An empirical investigation," *Decis. Support Syst.*, vol. 52, no. 2, pp. 486–496, Jan. 2012, doi: 10.1016/j.dss.2011.10.009.
[47] A. Muhammad, A. M. A. Khan, N. Amin, and N. Lambrou, "Drivers and barriers to business intelligence adoption: A case of Pakistan," in *Proc. Eur. Medit. Conf. Inf. Syst.*, Abu Dhabi, UAE, Apr. 2010, pp. 1–23.
[48] S. Ahmad and S. Miskon, "A conceptual model of business intelligence system adoption for the textile and apparel industry in Pakistan," *Mehran Univ. Res. J. Eng. Technol.*, vol. 40, no. 2, pp. 251–264, Apr. 2021, doi: 10.22581/muet1982.2102.01.
[49] J. A. Memon, A. Aziz, and M. Qayyum, "The rise and fall of Pakistan's textile industry: An analytical view," *Eur. J. Bus. Manag.*, vol. 12, no. 12, pp. 136–142, 2020.
[50] C. Koutra, K. Ali, A. D. Suleiman, and A. B. Shammout, "Environmental influences on the exercise of leadership in a family textiles business in Pakistan," *J. Hotel Bus. Manage.*, vol. 7, no. 1, pp. 1–12, 2018, doi: 10.4172/2169-0286.1000176.
[51] O. Ievtushenko and G. L. Hodge, "Review of cost estimation techniques and their strategic importance in the new product development process of textile products," *Res. J. Textile Apparel*, vol. 16, no. 1, pp. 103–124, Feb. 2012, doi: 10.1108/RJTA-16-01-2012-B012.
[52] S. Yayla, S. Yeniyurt, C. Uslay, and E. Cavusgil, "The role of market orientation, relational capital, and internationalization speed in foreign market exit and re-entry decisions under turbulent conditions," *Int. Bus. Rev.*, vol. 27, no. 6, pp. 1105–1115, Dec. 2018, doi: 10.1016/j.ibusrev.2018.04.002.
[53] A. Ali, M. Khan, A. Ishaq, A. Hussain, S. U. Rehman, I. A. Khan, and S. F. A. Shah, "Pakistan textiles can bounce back vigorously," *Int. Rev. Manage. Marketing*, vol. 10, no. 2, pp. 30–40, Mar. 2020, doi: 10.32479/irmm.9377.
[54] E. W. T. Ngai, S. Peng, P. Alexander, and K. K. L. Moon, "Decision support and intelligent systems in the textile and apparel supply chain: An academic review of research articles," *Expert Syst. Appl.*, vol. 41, no. 1, pp. 81–91, Jan. 2014, doi: 10.1016/j.eswa.2013.07.013.
[55] K. Gudfinnsson, M. Strand, and M. Berndtsson, "Analyzing business intelligence maturity," *J. Decis. Syst.*, vol. 24, no. 1, pp. 37–54, Jan. 2015, doi: 10.1080/12460125.2015.994287.
[56] A. Owusu, A. Ghanbari-Baghestan, and A. Kalantari, "Investigating the factors affecting business intelligence systems adoption: A case study of private universities in Malaysia," *Int. J. Technol. Diffusion*, vol. 8, no. 2, pp. 1–25, Apr. 2017, doi: 10.4018/IJTD.2017040101.
[57] P. Y. K. Chau and K. Y. Tam, "Factors affecting the adoption of open systems: An exploratory study," *MIS Quart.*, vol. 21, no. 1, pp. 1–24, 1997, doi: 10.2307/249740.
[58] V. Bhatiasevi and M. Naglis, "Elucidating the determinants of business intelligence adoption and organizational performance," *Inf. Develop.*, vol. 36, no. 1, pp. 78–96, Mar. 2020, doi: 10.1177/0266666918811394.
[59] C. Low, Y. Chen, and M. Wu, "Understanding the determinants of cloud computing adoption," *Ind. Manag. Data Syst.*, vol. 111, no. 7, pp. 1006–1023, 2011, doi: 10.1108/02635571111161262.
[60] A. Gabus and E. Fontela, "DEMATEL, innovative methods," Battelle Geneva Res. Inst., Lancy, Switzerland, Tech. Rep. 2, 1974.
[61] B. N. Hwang, C. Y. Huang, and C. H. Wu, "A TOE approach to establish a green supply chain adoption decision model in the semiconductor industry," *Sustainability*, vol. 8, no. 168, pp. 1–30, 2016, doi: 10.3390/su8020168.
[62] B. B. Gardas, R. D. Raut, and B. Narkhede, "Modelling the challenges to sustainability in the textile and apparel (T&A) sector: A delphi-DEMATEL approach," *Sustain. Prod. Consumption*, vol. 15, pp. 96–108, Jul. 2018, doi: 10.1016/j.spc.2018.05.001.
[63] C.-W. Li and G.-H. Tzeng, "Identification of a threshold value for the DEMATEL method using the maximum mean de-entropy algorithm to find critical services provided by a semiconductor intellectual property mall," *Expert Syst. Appl.*, vol. 36, no. 6, pp. 9891–9898, Aug. 2009, doi: 10.1016/j.eswa.2009.01.073.
[64] C.-W. Hsu and C.-C. Yeh, "Understanding the factors affecting the adoption of the Internet of Things," *Technol. Anal. Strategic Manage.*, vol. 29, no. 9, pp. 1089–1102, Oct. 2017, doi: 10.1080/09537325.2016.1269160.
[65] M. Jayakrishnan, A. K. Mohamad, and M. M. Yusof, "Assimilation of business intelligence (BI) and big data analytics (BDA) to-wards establishing organizational strategic performance management diagnostics framework?: A case study," *J. Digit. Inf. Manag.*, vol. 16, pp. 22–32, Feb. 2018.

SUMERA AHMAD received the Ph.D. degree in information systems from the School of Computing, Faculty of Engineering, Universiti Teknologi Malaysia, Johor Bahru, Malaysia, in 2021. Her research interests include business intelligence, artificial intelligence, machine learning, the IoT, big data, sustainability, and textile and apparel industry.

SURAYA MISKON (Member, IEEE) received the Ph.D. degree in computer science (information systems) from the Queensland University of Technology, Brisbane, QLD, Australia, in 2013. She is currently a Senior Lecturer in information systems with the Azman Hashim International Business School (AHIBS), Universiti Teknologi Malaysia, Johor Bahru, Malaysia.

RANA ALABDAN received the Ph.D. degree in information systems from Robert Morris University and the Faculty of Information Systems, Majmaah University. Her research interests include business intelligence, artificial intelligence, machine learning, knowledge management, and mobile banking.

ISKANDER TLILI received the B.Eng., M.Eng., and Ph.D. degrees from the National Engineering School of Monastir, Tunisia, in 2000, 2002, and 2010, respectively. He is currently working as an Associate Professor with Majmaah University, Saudi Arabia.