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Readiness of SMEs for Adopt Big Data: An Empirical Study in Vietnam

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Abstract: This study aims to characterize the readiness of big data adoption and identify important factors for assessing the readiness of Vietnamese SMEs to adopt big data. Consequently, divide SMEs into specific groups based on readiness aspects in order to establish individual group-related recommendations for adopting big data. Questionnaires were used to collect data from 274 SME managers in the manufacturing and service sectors. The key factors defining the readiness of big data application in SMEs were determined by Exploratory Factor Analysis. K-mean clustering analysis was used to group SMEs. The findings highlighted that SMEs are well prepared to adopt big data in decision-making culture, customer interaction, data security, and business strategy factors but not ready in human resources, technology resources, budget resources, government support, and vendor support factors. Big data adoption readiness was defined into three dimensions, namely, Resources, Governance, and Environment readiness. The findings of this study will be important for managers, providers, and policymakers to better understand the factors that assess readiness to adopt big data in SMEs. Hence, they could build effective strategies to incorporate big data and increase their business value and competitiveness.

Keywords: Big data adoption, Manufacturing sector, Readiness, Service sector, SMEs, Vietnam

1. INTRODUCTION

Vietnam's economy is characterized as vibrant and exponential. The average annual export has increased by more than 14% in the past five years [1]. In ASEAN, Vietnam ranks third in terms of import and export, just behind Singapore and Thailand. Small and medium enterprises (SMEs) are crucial players in Vietnam's boosting economy. In 2018, SMEs accounted for 97.2% of the total number of Vietnamese enterprises. Annually, SMEs account for about 40%, 30%, 33%, and 30-45% of GDP, State budget, Industrial output value, and Export value, respectively, and attract more than 5 million employees [2, 3]. However, business efficiency has recently had a drastic decrease as a result of COVID-19's global economic impact. Out of the 1600 SMEs in the Asia Pacific investigated by Hewlett Packard (HP), only 6% of respondents contemplated that labor productivity increased, while 43% of respondents reported that labor productivity decreased [4]. According to the result of the enterprises survey employed by the General Statistics Office (GSO) of Vietnam in April 2020, 85.7% of enterprises were affected by the COVID-19 outbreak.

To maintain and grow businesses during and after the pandemic requires SMEs to develop and devise appropriate policies. Hewlett Packard' research has shown that 60% of SMEs in the Asia Pacific (Australia, India, Indonesia, Japan, Korea, Singapore, Thailand, and Vietnam) consider adopting digital technology and analytical software as essential solutions for enterprises development in the present time when countries are still dealing with the complicated situation of COVID-19 pandemic [4]. To incorporate and encourage the application of e-commerce in enterprises, the Vietnamese government has implemented many policies. For instance, the Prime Minister of Vietnam approved a master plan for the 2021-2025 national e-commerce development (Decision No. 645-QD /TTg). The Government's e-commerce development strategies allowed the recognition of Vietnam as the third-largest e-commerce market in Southeast Asia in 2018 [1]. Moreover, Vietnam is considered to have the advantage of big data sources [5].

Thanks to the rapid increase in data sources globally. The number of companies that apply big data to bring competitive advantage has also increased significantly [6]. Companies are making profound changes in managing their businesses, customers, and business models [7]. Davenport [8] highlighted the enormous implications of big data analytics in reducing costs, improving products, and making

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faster decisions. Moreover, applying big data analytics to a company's value chain gives it a 5-6% increase in productivity hence increasing its competitive advantage [9]. Therefore, big data adoption has been abundantly studied in countries such as France, Bangladesh, the US, China, India, Korea, the UK, Malaysia, and Thailand [10–19]. However, SMEs seem slow to adopt big data [20]. Moreover, there is very little research covering big data adoption (BDA) in Vietnamese SMEs. The authors suggest that this study is the first to examine the readiness of BDA in Vietnamese SMEs. This study is very useful for the implementation of BDA in Vietnamese SMEs as well as SMEs in developing and underdeveloped countries.

Specifically, this study focuses on:

(1) Identification of the critical factors to assess Vietnamese SMEs' readiness to adopt big data in order to aid SMEs' preparedness for BDA;

(2) Classification of SMEs into specific groups and provision of suggestions and recommendations for each group to implement big data based on the readiness aspects of BDA

Understanding the pillars of big data adoption readiness (BDAR) helps SMEs gain comprehension in order to be better prepared to adopt big data. SMEs have a willingness for BDA, the success of adopting it will increase. It helps SMEs increase revenue as well as increase the contribution to the state budget. Therefore, these research objectives not only contribute theoretically but have practical and applicable implications for SMEs.

2. LITERATURE REVIEW

A. *Big Data Concept in Manufacturing Companies and Service Companies*

Big data is defined as a data source with a large volume and diverse data structures such as structured, semi-structured, and unstructured data [21, 22]. Thanks to the strong development of the digital world, big data sources created through the use of modern technology devices such as smartphones, smart TVs, smartwatches, and social networks like Facebook, WhatsApp, Twitter, Zalo, etc. are increasing rapidly [23, 24]. Big data plays an important role in organizations. It can help businesses change their decision-making mentality and exploit new opportunities [25]. The world's largest retailer, Walmart, uses Polaris, an internal platform for text analysis and machine learning, to analyze big data. The results helped the company increase the likelihood of successful online shoppers from 10% to 15%. Rolls-Royce uses a powerful and secure private cloud to store corporate data, and they use state-of-the-art data analysis to closely monitor incoming data. Thus, they design multiple products, maintain production efficiency and improve customer service. It is estimated that every month Amazon has about 187 million website visitors and more than two million sellers. Amazon used a Hewlett-Packard server running Oracle on Linux, to analyze the huge source of data coming from customers and sellers. As a result, Amazon's services business grew 81% in 2015 [26]. However, the firms that succeed in applying big data analysis are known today mostly as large companies, with branches in many countries around the world. For example, Google, Apple, Twitter, Uber, Walmart, Amazon, IBM Watson, Rolls-Royce, Toyota, etc. [26]. Previous studies have also shown that the application of big data analysis has brought many benefits to SMEs [20, 27–30]. However, BDA for SMEs in developing countries is still considered in an early stage. The slow BDA in SMEs are as a result of many obstacles [19, 20].

The manufacturing and service sectors are two indispensable areas in the economy of a country [31]. Manufacturing refers to the activities of people using tools and machines to produce raw materials into finished products, transport them to suppliers, and recycle products used [32, 33]. Services include areas such as finance, tourism, health, accommodation services, restaurants, etc., whereby the service sector provides services to consumers. The International Data Corporation reported that more than 1600 Exabyte of data were created in the manufacturing and service sectors in 2015 [33]. Several studies have been carried out to learn more about BDA in the manufacturing and service sectors. Moktadir, Ali, Paul and Shukla [12] conducted surveys on five manufacturing companies in Bangladesh to identify barriers to big data application. Bi and Cochran [34] identified barriers and opportunities of applying big data analytics through the collection, management, and storage of data in modern production systems and gave suggestions to improve manufacturing efficiency. Cohen [35] provided a synopsis of the BDA in the service sector to help companies improve their service quality. Fisher and Raman [36] evaluated the adoption of big data by retailers, and proposed solutions to improve the efficiency of big data adoption for retailers. Scholarly articles have presented aspects related to the adoption of big data in the manufacturing and service sectors such as benefits, barriers, and efficiency of BDA in two sectors. However, it seems that assessing the readiness to adopt big data in these sectors has not been found.

In Vietnam, based on the production characteristics of each sector, the Vietnamese government has established standards for each type of enterprise. Accordingly, SMEs include three types, microenterprises, small enterprises, and medium enterprises. Microenterprises have 1-10 employees and an annual turnover of less than 10 VND billion. Small enterprises have 11-100 employees and an annual turnover of less than 100 VND billion. Medium enterprises have 51-200 employees and less than 300 VND billion in annual revenue [37].

B. *The Readiness to Adopt Big Data in Enterprises*

Previous studies on big data are extensive. Verma and Bhattacharyya [38] used the Technology-organization-environment (TOE) framework to explore the factors influ-

encing BDA in companies in India. Sun, Cegielski, Jia, and Hall [39] investigated 26 factors that can affect BDA based on Diffusion of Innovation (DOI) and TOE frameworks, Lai, Sun, and Ren [40] used TOE to identify the determinants of BDA in companies. Yadegaridehkordi, Hourmand, Nilashi, Shuib, Ahani and Ibrahim [19] used DEMATEL-ANFIS approach to find out deteminants of BDA in Malaysian manufacturing firms. Baig, Shuib and Yadegaridehkordi [41] presented 42 factors within 4 dimensions (technology, organization, environment, and innovation) that are of significance to the adoption of big data. In Bangladesh, Moktadir, Ali, Paul and Shukla [12] applied Delphi method to demonstrate that 4 factors (data, technology, investment and organization were) influenced BDA in five manufacturing companies. According to Tabesh, Mousavidin and Hasani [42] technology and culture are two main barriers, related to organizations that apply big data. Moreover, a study using Kruskal-Wallis test and Chi-square test showcased the ups and downs of big data technology in companies [14]. Coleman, Göb, Manco, Pievatolo, Tort-Martorell and Reis [20] pointed out the benefits and barriers of SMEs when applying big data. Furthermore, some previous theories also mentioned technology readiness such as the Diffusion of Innovation theory [43] or Technology Readiness Index [44]. However, these theories assessed the technology readiness in general, but not specific to each technology area. Research assessing the readiness of manufacturing and service firms to adopt big data, especially SMEs, is still rare. In South Africa, Motau and Kalema [45] assessed the readiness of BDA in the public service sector based on technological infrastructure, security, reliability, finances, competitors, customers, and vendor support factors. Klievink, Romijn, Cunningham and Bruijn [46] conducted a study to evaluate the readiness BDA of businesses in the Dutch service sector. Mneney and Van Belle. [47] evaluated four categories (technology, organization, environment, and task technology fit) to permit retail organizations in South Africa to apply big data.

In summary, the studies have so far focused on the benefits, barriers, and factors influencing BDA without assessing the readiness of enterprises to adopt big data. Hence, this study assesses and identifies the readiness of BDA in SMEs following nine factors based on previous studies, as well as the recommendations of experts and professors. The nine factors used in this study include technology resource, budget resource, human resource, business strategy, decision-making culture, the interaction between customers and companies, data security, government support, and vendor support.

Budget resource: Refers to the enterprise's budget to invest in IT infrastructure, train human resources to ensure the operation, maintenance, and development of the system when enterprises adopt big data. The issue of the investment cost of BDA is also an important factor and barrier for companies to implement big data [12, 20]. Hence, it is necessary to consider this factor in the current concept of the readiness of BDA.

Human resource: Applying big data requires enterprises to have human resources to meet the requirements of statistical analysis, using algorithms in big data analysis, and data visualization. Thus, this is also a difficult issue for companies implementing big data analysis [22, 48]. In particular, Vietnam is assessed to be in the period of golden population, with an abundant labour force. However, the quality of Vietnamese labour is still low [49]. Thus, the quality of the labour force is a challenging issue for Vietnam when the 4.0 technology revolution is taking place [49]. Moreover, human resources are the driving force of innovation and play an important role in improving the production efficiency of enterprises [50]. Therefore, it is vital to assess the IT knowledge and skills of the enterprise's staff and experts before considering BDA.

Business strategy: Refers to the fact that the enterprise has set clear business goals and is prepared to achieve them. Business strategy is considered as the first factor that leads to the success of businesses in applying big data [51]. Enterprises need to develop a clear, specific strategy before adopting big data. The business strategy should specify the tools needed to build big data, tools' supplier, resources to invest, human resources applying big data analysis, benefits obtained, etc., The business strategy also forecasts the risks encountered when applying big data. Kaisler, Armour, Espinosa and Money [52] presented that a strategy that has high generalization, flexibility, and scalability is considered an effective strategy. Thence, building a detailed business strategy is important to assess the readiness of enterprises to adopt big data.

Decision-making culture: According to Baig, Shuib and Yadegaridehkordi [41], it refers to the belief that the adoption of big data is vital for achieving better organizational productivity. Data-driven decision-making culture has been described as decisions taken for the benefit of the company by members based on the results of data analysis [53]. Results of big data analysis should be used to help businesses make beneficial decisions for their business such as improving customer service, developing new product development strategies, and expanding markets for products [54]. However, many businesses still rely on business experience and the subjective opinions of leaders to make business decisions without relying on the results of data analysis. Therefore, the lack of a culture of decision-making based on data analysis is a barrier to BDA projects [22]. Thus, a decision-making culture is a factor that needs to be considered in assessing readiness for BDA.

Customer interaction: The rapid development of information technology, social networks, and e-commerce devices leads to a rapidly increasing interaction between customers and businesses. The customer-business interaction is the key factor that helps businesses get big data sources. Hence, companies can understand their customers

through the results of big data analysis [52]. In addition, increased interaction between customers and businesses helps businesses gain benefits such as product exposure. Thus, the number of customers buying their products will increase significantly [36]. Several companies such as Walmart, Amazon, eBay, Netflix, and Monster have been very successful in building a recommendation system through customer interaction [26]. Hence, this is also an essential factor in assessing the BDAR.

Data security: Refers to the data security of customers and businesses when data sources increase rapidly. Large data capacity increases rapidly every day. Analysis of this data source can be of benefit to several stakeholders. Therefore, third parties can illegally access and use the data source if the enterprises do not have measures to ensure data security [55, 56]. Moreover, SMEs were considered to have lower data security measures than large companies [57]. Therefore, data security is an issue that directly impacts the readiness of Vietnamese SMEs when adopt big data.

Government support: The policy mechanisms of each country have a direct influence on the adoption of big data by businesses [58]. Government support through incentive policies, financial support, and human resource training support is crucial to promoting the adoption of big data by companies. Therefore, the clear legal governmental policies supporting BDA significantly encourage businesses to adopt big data [59]. Most governments have policies in place to ensure the privacy of individuals and organizations to limit the unauthorized exploitation of data from unrelated parties [41]. This also helps encourage businesses to adopt big data. In Vietnam, enterprises are established and developed based on government mechanisms and policies. Thus, government policy also plays an important role in encouraging SMEs to adopt big data.

Vendor support: Supplier support activities are crucial to helping SMEs' solve problems when adopting new technology such as big data analytics [60]. SMEs still face many challenges in terms of technology factors and technical staff resources when applying big data [42]. The support of vendors should not be limited to consulting, providing tools and software, but also to assist businesses in solving technical issues during the business's big data application process. Therefore, to assess Vietnamese SMEs' readiness to adopt big data, the aspect of supplier support is an important factor to consider.

3. RESEARCH METHODOLOGY

In this study, a complete flow diagram of the study is clarified in Figure 1.

A. Sampling and Data Collection

Questionnaires were assigned and given out to small and medium Vietnamese enterprises to evaluate their BDAR using a 7-Point Likert scale ranging from 1 for "strongly disagree" to 7 for "strongly agree". Big data adoption in SMEs is a relatively new phenomenon in Vietnam.

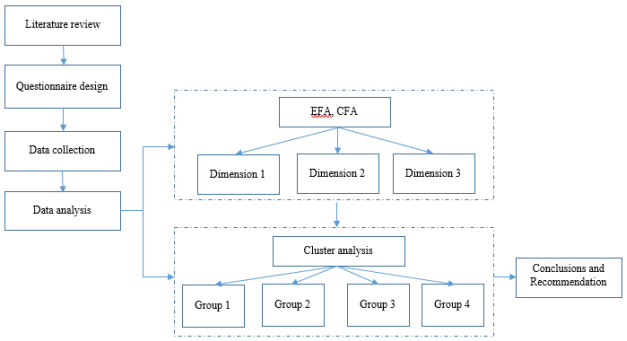

Figure 1. Flow diagram of the research

Thus, this study investigated SMEs that have big data understanding and have interest in adopting big data. SMEs were selected from six areas of Vietnam's main industries within the business information website of Vietnam: food and beverages, construction, garment, wholesale, retail, and accommodation services. To ensure validity and reliability of the data collected, it was requested that the survey be filled out by the Chief Executive Officer, or Executive manager, or Information technology manager in the SMEs since they should have better understanding, knowledge, and experience in the current and future IT trends of their firms [61]. A letter page briefly describing the purpose of the study and questionnaire was sent to email of SMEs' managers in six areas. The data were collected between September and December 2020. Overall, 274 questionnaires were used for analysis. To confirm the viability of the data collected in this study, a non-response bias analysis was conducted. Moreover, the Kolmogorov-Smirnov (K-S) test was conducted to compare the sample arrangement of early and late respondents [62]. According to the results, no statistical difference was evident among both sample groups. Hence, non-response bias did not create any conflict in this study.

Based on the analysis of the demographics of the 274 respondents, 85.04% of respondents held a Bachelor's degree and/or above, while 35.04% and 55.84% were Chief Executive Officers and Executive managers, respectively. Manufacturing enterprises, consisting of food and beverages, construction, and garment, account for 54.74%. The service sector, including wholesale, retail, and accommodation service, account for 45.26%.

The nine factors used to evaluate the readiness to adopt big data in SMEs in this study (Table I) include technology resource, budget resource, human resource, business strategy, decision-making culture, customers interaction, data security, government support, and vendor support.

B. Data Analysis

Data were analyzed using STATISTICA 13 to present the descriptive statistics, correlation analysis and test the reliability of measurement factors. Specifically,

TABLE I. FACTORS USED TO DETERMINE BDAR IN VIETNAMESE SMEs

Factors	Brief description	References
Technology resource	Technology infrastructures (e.g., software, hardware, storage system, network) are ready for adopting big data application	[39,41]
Budget resource	Financial support invested in technology infrastructure, human resource, and system maintenance for big data applications are ready	[12,13]
Human resource	There are enough experts and staff who have acquired sufficient information technology knowledge and skills used for big data application	[51,63] [63]
Business strategy	Top managers build a business strategy that can incorporate big data soon	[29,46]
Decision-making culture	The company builds a data-driven culture that allows making decisions in relation to data analysis results	[39]
Customer interaction	The interaction between customers and firms is increasing dramatically through various ways like social media, mobile, e-commerce sites, and stores	[45]
Data security	The firm has the availability of solutions (e.g., intrusion detection, access control, encryption...) to ensure security for the organization and customer's information and data	[64]
Government support	Policy mechanisms that are supported by the government are sufficient for organization's big data adoption (e.g., policies which support business organizations to approach preferential loans, ensure network security)	[39,65] [65]
Vendor support	The firm finds it easy to expose to the vendors who provide big data analytics technology (e.g., software, hardware, storage system, network, analytical tools)	[11]

(1) EFA was used to reduce the set of measurement variables that yielded biased factors [66]. The analysis aimed to identify critical factors that define the readiness of BDA in SMEs in Vietnam; then confirmatory factor analysis (CFA) was used to measure the reliability and validity of factors, and

(2) K-mean, in cluster analysis, is a group of algorithms that divide observations according to a user-specified number of clusters [66, 67]. This algorithm was used to classify enterprises into different groups based on the dimensions of readiness for BDA. Therefore, making separate policies to promote the adoption of big data in each cluster of SMEs.

4. RESULTS AND DISCUSSION

A. *The Readiness of Big Data Adoption in SMEs*

The descriptive statistics of the nine factors used to evaluate the BDAR in Vietnamese SMEs are presented in Table II. Four factors with a mean value higher than 6.0 include business strategy, data security, decision-making culture, and customer interaction. This is an indication that SMEs are well prepared for these factors. Specifically, business strategy (Mean=6.270) is the factor with the highest mean value, and it proves that top managers in SMEs have a well-established business strategy to implement big data. The results also indicate that SMEs already have solutions (i.e., intrusion detection, access control, encryption) to ensure the security of the organization's information and that of customers with a 6.215 mean value. Decision-making culture (Mean = 6.193) shows that SMEs have built a culture that allows staff and experts from different departments to share, access, and analyze information and make final decisions based on the result of data analysis.

Furthermore, SMEs agreed that interaction between customers and their enterprises has had a dramatic increase (Mean=6.007). This could be explained by the rapid rise in the proportion of Vietnamese people using the internet, mobile phones, computers, social networks, and e-commerce in the past five years. According to statistics, in 2017, the number of social network users in Vietnam was 43.8 million, and this figure increased to 50.9 million in the first quarter of 2021 [68]. The other factors (human resources, technology resources, budget resources, government support, and vendor support) have a mean value of less than 6.0, with the lowest for vendor support (Mean=5.347). This provided evidence that SMEs are not yet well prepared for these aspects. To be more specific, there are not enough experts and staffs who have acquired sufficient IT knowledge and skills used for BDA. Another reason is that firms don't have enough financial funds to invest in infrastructure that can match the demands of big data analysis. The lack of policies on the regulatory environment of the government can also be the reason why businesses are not ready to adopt big data. Furthermore, companies are still having difficulty in finding reliable suppliers of software, hardware, and technical support. These results are in agreement with past research challenges for big data implementations [12, 20, 22, 42, 64]. Therefore, Vietnamese SMEs need to improve on human, technology, and budget resources, as well as government and vendor support factors before considering to adopt big data. Correlation is used to evaluate the interdependence of the factors and indicates the strong or weak relationship between them [69]. The preliminary correlation analysis results of the original data indicated a reasonably strong relationship among the nine factors except for vendor support, which showed no significant correlation with decision-making culture, customer interaction, and data security factors. The technology

TABLE II. BASIC DESCRIPTIVE STATISTICS AND CORRELATIONS AMONG FACTORS

Factors	Mean	Std	HR	TR	BR	DC	CI	DS	BS	GS	VS
HR	5.865	0.839	1								
TR	5.734	0.769	0.694**	1							
BR	5.639	0.815	0.432**	0.576**	1						
DC	6.193	0.697	0.176**	0.274**	0.246**	1					
CI	6.007	0.721	0.153*	0.274**	0.204**	0.434**	1				
DS	6.215	0.658	0.132*	0.215**	0.200**	0.380**	0.382**	1			
BS	6.270	0.706	0.415**	0.423**	0.215**	0.400**	0.334**	0.347**	1		
GS	5.500	0.752	0.142*	0.212**	0.254**	0.122*	0.135*	0.137*	0.200**	1	
VS	5.347	0.751	0.237**	0.256**	0.271**	0.109	0.043	0.093	0.168**	0.554**	1

Note: *p¡0.05, **p¡0.01, ***p¡0.001; HR: Human resource, TR: Technology resource, BR: Budget resource, DC: Decision-making culture, CI: Customers interaction, DS: Data security, BS: Business strategy, GS: Government support, VS: Vendor support.

resources factor exhibited a high correlation with human (0.694**) and budget (0.576**) resources. Therefore, the proposed factors are a good premise for assessing BDAR in Vietnamese SMEs.

The value of Kaiser-Meyer-Olkin (KMO=0.750) and the Bartlett test of sphericity (χ2= 692.795, df = 36, p < 0.001) indicated the appropriateness for factor analysis EFA was conducted with varimax rotation on the nine factors. The results in Table III show that all factor load values ranged from 0.564 to 0.875 and were greater than the 0.4 lower limit value [66]. Cronbach alpha values were greater than 0.7 for all factors. According to Hair, Black, Babin and Anderson [66] Cronbach's alpha value higher than 0.7 indicate good internal consistency of questionnaire items in the data collection process. The analysis results in Table III showed that the nine factors were scattered within three readiness dimensions that (eigenvalues > than 1) account for 65.83% of the total variance. Data in this study were collected based on pre-built items, so Common Method Variance was assessed by a Harman' single-factor test [70]. The results presented that the first dimension was responsible for 36.14% of the variance (less than 50.00%). Hence, the variance method was not an issue in this research. CFA was used to measure the reliability, validity of three dimensions. The composite reliability of the three dimensions higher than 0.7 indicated good internal consistency [71]. The average variance extracted (AVE) was greater than 0.5 for all dimensions, demonstrating convergent validity. Literature mentions that the obtained ratio of the chi-square value to the degree of freedom should be lower than 5.000; the comparative fit index (CFI), the incremental fit index (IFI), and the Tucker–Lewis index (TLI) should be over 0.900; and the root means square error of approximation (RMSEA) should be below 0.080 [72]. In this study, the results of measurement model (χ2 = 45.350, d.f. = 21, χ2/d.f. = 2.160, CFI = 0.963, IFI = 0.964, TLI = 0.937, RMSEA=0.065) were in accordance to the proposed values good fit measurement model. Hence, three dimensions to assess Vietnamese SMEs' readiness to adopt big data ensured reliability and validity.

The next step was to identify and provide an appropriate name for each dimension. The first dimension with an

TABLE III. ANALYSIS OF THE PILLARS FOR BIG DATA ADOPTION IN VIETNAMESE SMEs

Variables	Dimension 1 (Resources readiness)	Dimension 2 (Governance readiness)	Dimension 3 (Environment readiness)
Human resources	.875		
Technology resources	.873		
Budget resources	.684		
Decision-making culture		.757	
Customers interaction		.754	
Data security		.739	
Business strategy		.564	
Government support			.875
Vendors support			.853
Eigenvalue	3.253	1.468	1.204
Cumulative %	36.143	52.454	65.829
Cronbach's Alpha	0.795	0.710	0.713

Notes: Extraction method: Principal components analysis, Rotation Method: Varimax with Kaiser Normalization, Factor loading less than 0.50 is not presented

eigenvalue of 3.253 and explained variance of 36.143% included human, technology, and budget resources factors. These factors are related to the resources aspect in the SMEs, so it was named "Resources readiness". The second factor with an eigenvalue of 1.468 and explained variance of 16.311% consists of decision-making culture, customer interaction, data security, and business strategy factors which are involved in the mechanism for the readiness of SMEs to apply big data, so this factor was named "Governance readiness". The third dimension represented government and vendor support factors with an eigenvalue of 1.204 and explained variance of 13.375%. Government and vendor support factors influence an SME's readiness to adopt big data, so the name given was "Environment readiness". Table III showed that Resources, Governance, and Environment readiness were the three pillars used to identify BDA readiness in SMEs in Vietnam.

The study results showed that the three pillars for developing definitions of BDAR for SMEs in Vietnam are relevant and reliable and essential for establishing enterprises' readiness to adopt big data. The Resources readiness dimension was the most important identifying readiness to apply big data in SMEs. It could be due to Vietnamese SMEs recurrent lack of investment capital, facilities, and human resources [49]. Therefore, Resources readiness is the dimension that all businesses were most concerned with. The second dimension, "Governance readiness" describes building business strategies, having a decision-making culture based on data, having solutions to ensure data security, and increasing customer interaction. The third dimension, "Environmental readiness," defines the support from external factors. Policy mechanism support from the government and support from vendors who provide software and big data analysis tools are factors that SMEs need to adopt big data. To be more detail-specfic and to be able to establish meaningful recommendations for the implementation of big data in enterprises within a specific type of industry and firm size, the current study subsequently divided SMEs into particular clusters.

B. Grouping Vietnamese SMEs

The cluster analysis was conducted via the k-means clustering method based on the three aforementioned readiness dimensions to adopt big data. The purpose of clustering was to classify SMEs into small groups with detailed information. A common problem in the clustering method is how to determine the number of clusters, how to name each cluster, and then offer suitable solutions for each cluster [73]. In this study, based on Akaike's Information Criterion (AIC) value, a total of 15 clusters were automatically created [74]. The AIC and AIC change values showed no significant variation from cluster number 6 to cluster number 15. Therefore, this study conducted the test root means square standard deviation (RMSSTD) and R^2 with clusters 3, 4, 5, and 6. Test results showed that clustering SMEs into 4 clusters is considered to be the best because the RMSSTD value is the smallest (0.35) and the R^2 value is the highest (0.56) [75].

Table IV described the characteristics of each cluster by the coordinates of the center. Based on the characteristics of SMEs in each cluster, four clusters were established: Starting from scratch, Governance focus, Environment enhancement, and Resource improvement, respectively.

Cluster 1-Starting from scratch

Cluster 1 is composed of 8 microenterprises, including seven construction companies (87.5%) and one accommodation services company (12.5%). The number of SMEs in each cluster by firm size and by type of industry is shown in Table V and Table VI respectively.

In cluster 1, enterprises' readiness to adopt big data is the lowest among the four clusters as shown in Table VI by the negative coordinates of the center in each dimension: Resources readiness-D1 (-3.437), Governance readiness-D2 (-1.509), and Environment readiness-D3 (-1.147). This shows that the seven construction microenterprises are not ready for BDA within a short time. Therefore, cluster 1 was named "Starting from scratch". However, this cluster only comprised of 8 cases, therefore in-depth analysis not carried out [76].

For microenterprises in this cluster to adopt big data, they have to prepare everything from the beginning, including all factors in the Resources, Governance, and Environment readiness dimensions. Therefore, it is strongly recommended that enterprises in this cluster should follow all suggestions provided to SMEs in the second, third, and fourth clusters since they are more prepared to adopt big data (Figure 2 and Figure 3). Moreover, it is recommended that microenterprises in cluster 1 should follow the "8-step big data analysis model" by Storey and Song [77]. This data analysis model has been proven beneficial for enterprises

TABLE IV. CLUSTER COORDINATES AND NUMBER OF MEMBERS

Dimensions	**Coordinates of center**			
	Cluster 1 *(n1=8)	**Cluster 2 (n2=128)**	**Cluster 3 (n3=82)**	**Cluster 4 (n4=56)**
Resources readiness - D1	-3.437	0.386	0.554	-0.646
Governance readiness - D2	-1.509	-0.470	0.236	0.720
Environment readiness - D3	-1.147	0.448	-1.242	0.260

Note: *(Number of members in a cluster)

TABLE V. NUMBER OF CASES IN EACH CLUSTER BY FIRM SIZE

Cluster	Microenterprises	Small enterprises	Medium-size enterprises	Total cases in cluster
Cluster 1	8	0	0	8 (2.92%)
Cluster 2	12	91	25	128 (46.72%)
Cluster 3	5	46	5	56 (20.44%)
Cluster 4	9	61	12	82 (29.92%)
Total cases by type of enterprise	34 (12.41%)	198 (72.26%)	42 (15.33%)	274 (100.00%)

TABLE VI. NUMBER OF CASES IN EACH CLUSTER BY TYPE OF INDUSTRY

Cluster	Manufacturing			Service			Total cases in cluster
	Food & Beverages	Construction	Garment	Wholesale	Retail	Accommodation services	
Cluster 1	0	7	0	0	0	1	8 (2.92%)
Cluster 2	56	3	14	6	14	35	128 (46.72%)
Cluster 3	3	20	4	4	23	2	56 (20.44%)
Cluster 4	9	5	29	23	15	1	82 (29.92%)
Total cases by type of industry	68 (24.82%)	35 (12.77%)	47 (12.88%)	33 (12.04%)	52 (18.98%)	39 (14.23%)	274 (100.00%)

starting to prepare for BDA

Cluster 2: Governance focus

The second cluster is composed of 12 microenterprises, 91 small enterprises, and 25 medium enterprises (Table V), which were categorized as 73 manufacturing companies (57.03%) and 55 (42.97%) service companies. This is the cluster with the largest number of SMEs. Table VI also shows that this cluster is dominated by food and beverage companies (43.75%) and accommodation and food services companies (27.34%). Table IV shows that the overall readiness to apply big data was fair for Resources readiness-D1 (0.36) and Environment readiness-D3 (0.448), but below average for Governance readiness-D2 (-0.470). This indicates that SMEs in this cluster are relatively ready to apply big data regarding Resources and Environment readiness factors but should put more effort into improving factors in the Governance readiness dimension. Therefore, this cluster was named "Governance focus".

The unpreparedness of cluster 2 in Governance readiness's factors is probably due to the limited top managements' thinking tank of some SMEs, which leads to absence of a precise determination in the application of big data. Similarly, previous studies have demonstrated that top management support has a significant influence on big data adoption [29, 40]. In addition, some SMEs still use outdated IT and internet systems, so the interaction between customers and businesses is limited [18]. Some company's top decision-making is based on the practical experience of managers in preference to data analysis outcomes. Besides, big data includes personal information and considerable valuable data source than can be easily abused by unassociated minor parties or by hackers if not well secured. These results are consistent with previous studies [18, 45, 56]. Therefore, to improve the Governance readiness dimension in this cluster, it is necessary to improve the authority's mind-set in decision-making based on data analysis results. Top management needs to understand that big data can be applied to SMEs and it will bring benefits for their enterprise if they are well prepared for big data implementation. According to Janssen, van der Voort and Wahyudi [25] improved decisions for businesses are made when formulated on the results of big data analysis. Suppliers should therefore enlighten SMEs with information about the benefits of BDA and provide evidence that firms have successfully applied big data analytics in the past. This will contribute to motivating them to apply big data analysis [29]. Moreover, the government should enhance training programs for SMEs' managers on BDA knowledge and guide them to prepare the necessary factors of BDA. Besides, top management needs to build a plan to invest

in information technology systems to enhance interaction between customers and enterprises, and have solutions to ensure data security (e.g., using threat detection and data encryption software).

Cluster 3: Environment enhancement

As evident in Table VI the third cluster includes 27 manufacturing companies (48.21%) mostly construction ones, and 29 service companies (51.78%), mostly retail businesses. Among them, 5 are micro-enterprises, 46 are small enterprises, and 5 are medium enterprises (Table V). According to the coordinates of the center, the SMEs in this group are well prepared to apply big data with regards to Resources (0.554) and Governance (0.236)readiness. The negative results on the Environment readiness dimension (-1.242) indicates that SMEs in this cluster should focus on enhancing their government and vendor support factors. This group was therefore named "Environment enhancement ".

It has been shown that even though government and vendor support are external factors to the enterprises, they have an critical impact on the BDAR in SMEs, which is consistent with prior investigations [11, 13, 78]. Therefore, helping SMEs improve this factor requires the support of the government and suppliers. First, the governments should have clear regulations on the use of data sources to ensure data security and the rights of SMEs when adopting big data. Second, vendors should not only provide tools, and software, but also incorporate strategies that offer problem solving consulting to SMEs during the BDA process. Thus, finding the suitable suppliers is very useful for SMEs to implement big data. In Vietnam, many firms offer to consult, and provide tools and software for big data analysis. However, it is difficult to find a reputable and suitable supplier for SMEs. Therefore, the Vietnam Small and Medium Business Association should provide a list of reputable companies providing services, software, and tools for big data analysis on the association's website to help SMEs easily access vendors' information.

Cluster 4: Resources improvement

As shown in Table V, cluster 4 consists of 9 micro-enterprises, 61 small enterprises, and 12 medium enterprises. Simultaneously, it comprises 43 manufacturing companies and 39 service companies (Table VI). Most are manufacturing garment companies (35.37%), wholesale companies (28.05%), and retail companies (18.29%). BDAR of Vietnamese SMEs in this cluster is good in Governance dimension (0.720) and fair in Environment dimension (0.260), suggesting an overall readiness to adopt big data. However, they have limited resources (-0.646). They need to improve their Resources readiness dimension. Therefore, this cluster was named "Resources improvement".

The results presented that SMEs lack of experts and staff who have sufficient IT knowledge and skills used for BDA.

Figure 2. Distribution of Resource and Governance readiness of each cluster

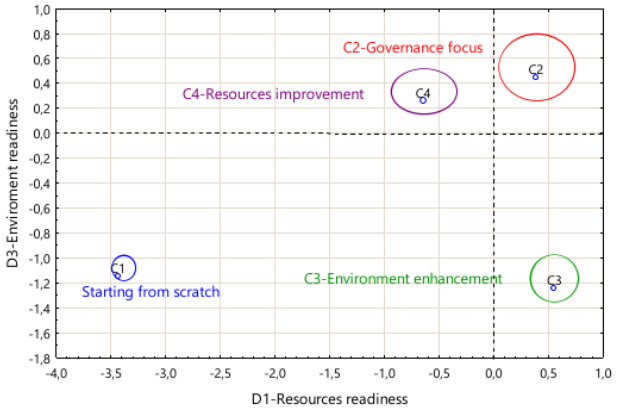

Figure 3. Distribution of Resource and Environment readiness of each cluster

The finding of this study is also consistent with some previous studies [22, 42]. SMEs are facing financial problems. They are also deprived of financial support for investment in technology infrastructure and system maintenance [20]. Similarly, Noonpakdee, Phothichai and Khunkornsiri [18] presented that some SMEs do not have the tool to manage database systems, data stored on books or computer hard drives. Furthermore, the limited investment budget also leads to the challenge of recruiting well qualified employees or to train their staff with skills in big data analysis. Therefore, SMEs in this group should place more effort to improve their human, technology, and budget resource factors. Nowadays, many tools and software exist for resource-constrained enterprises to analyze big data by choosing tools with low investment sources. For instance, Pendleton & Son is a small business in northwest London that provides Big-data-as-a-service with lots of expertise working with small companies that only charge for the job they are hired to do and also look for inexpensive sensor tools to apply [26]. This could be an alternative for SMEs instead of spending much money hiring experts and buying

expensive big data analytics software. Moreover, applying cloud computing technology in big data analysis can help SMEs reduce IT resource costs [79]. Besides, SMEs could train staff in big data analysis through cooperation with universities, and science and technology research centers.

5. CONCLUSIONS AND IMPLICATIONS

Big data adoption in this era of technological development is the best and rewarding decision for companies, especially SMEs. Given the complicated situation due to the COVID-19 pandemic, the adoption of big data is considered an essential and real-time solution for SMEs to develop their business. The findings of this study indicated that Vietnamese SMEs are well prepared in business strategy, data security, decision-making culture, and customer interaction factors but need to improve on human resources, technology resources, budget resources, government support, and vendor support factors. The critical pillars of SMEs' readiness to adopt big data in Vietnam were Resources readiness, Governance readiness, and Environment readiness. Furthermore, the results of the clustering study separated SMEs into four clusters based on the three pillars of preparedness to adopt big data. The information obtained through this study is essential for managers, providers, and policymakers to better understand the factors that assess readiness to adopt big data in SMEs. Managers can consider the three readiness pillars proposed by this study when assessing their enterprise's readiness to adopt big data. Therefore, managers will know how ready they are and what their weaknesses are with respect to factors that influence BDA. Further, our research has suggested meaningful recommendations to help businesses improve on the areas they are not ready yet. Hence, this study can aid managers build a clear strategy and be better prepared to implement big data into their enterprise. For the service providers, this study could help them recognize the factors that SMEs need and, therefore, build a strategy to provide products and services suitable for each type of SMEs. For example, this study revealed that SMEs are not ready in the aspect of financial resources and technological resources. Therefore, service vendors should have multiple support options at different prices so that SMEs can easily find suitable support options for their businesses. For the policymakers, the present investigation shows that SMEs need more support from the government to secure the regulatory environment and support access to loans to invest in big data analytics adoption. On that account, policymakers can utilize this study's findings to establish improved policies to support the future implementation of big data in SMEs. In addition, this study contributes an overview of factors assessing the readiness of BDA for SMEs in a developing country, which could serve as a reference for managers and policymakers in developing and underdeveloped countries to improve the implementation of big data for their manufacturing and service sectors. This study has several limitations. First, this study only considers nine factors to define readiness to adopt big data. Future research can expand and consider more aspects. Another possible limitation is the number of selected SMEs in six sub-industries, leaving out many other business areas such as banking, agriculture, healthcare service, machinery and equipment, etc. Literature shows that many studies on the application of big data in areas such as banking [11], agriculture [80], healthcare [81], machinery and equipment [29] have been carried out. Therefore, it is necessary to expand these fields in future studies.

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