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The role of industry 4.0 in supply chain sustainability: Evidence from the rubber industry

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The objective of the current study is to examine the role of Industry 4.0 in supply chain sustainability (SCS). To examine the effect of Industry 4.0 on SCS, the big data technology is considered. As the supply chain process requires a significant data handling system among the companies, however, companies are lacking in this area. Therefore, the relationship between data storage, data transformation, data utilization, order management and SCS were examined. Data was collected from the rubber industry. For the purpose of data collection, questionnaires were used, and data were collected from the rubber companies of Indonesia. Results of this study shows that Industry 4.0 has a vital role in SCS. Implementation of Industry 4.0 among the rubber companies shows a positive effect on SCS. Particularly, the applications of big data technology have a vital role in order management and SCS. Big data technology has a significant positive effect on SCS. Big data technology has a positive role to promote order management which further influences positively on SCS.

1. Introduction

Supply chain operations are the most significant part of companies in the current era of industrialization (Chienwattanasook, & Onputtha, 2022; Sukriket et al., 2022; Waiyawuththanapoom et al., 2022). Because supply chain operations are responsible for sustainability in the supply chain process. The sustainability in the supply chain can be achieved with the help of sustainable operations in companies. Low level of sustainability in supply chain operations has a negative role in the overall supply chain activity in the companies. Supply chain sustainability (SCS) is vital for companies to promote other operations. The supply chain is based on the supply of material to the company and supply of finished goods to the customers (Jittimanee, 2014; Tongkum, & Sasananan, 2014; Khamhaeng et al., 2015). Particularly, in the rubber industry, a significant amount of raw material is always required to make various products. These products require a heavy amount of rubber which should be reached in the company on a timely basis (Sirisuwat, & Jindabot, 2012). The better management of supply of products can only be achieved with the help of SCS. Therefore, among the rubber companies, SCS is most important (Dey et al., 2019; De et al., 2020). The supply of material and finished goods to the customer both are most important for the supply chain. Sustainability in these areas generate the overall sustainability among the operations related to the sustainability.

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Rubber industry is one of the most influential industries among other industries in the world. In various countries this industry produces heavy returns which have an effect on overall country revenue. Increase in the rubber industry revenue increases overall development in the economy. This industry is also very influential in Indonesia. Among all other industries of Indonesia, the rubber industry has a vital role in contributing to the economic development. Hence, this industry has vital importance for Indonesia and producing income generating opportunities for the people. This industry in Indonesia also has many small-scale companies which are linked with the various groups of the rubber industry and produce major contributions to this industry collectively. In the recent decade, the contribution of this industry is increasing day by day. Now this industry is competing in the world with other major rubber generating companies. Rubber industry is also one of the most famous industries in the world (Qiao et al., 2017; Kusworo et al., 2020) and generating high revenue along with the other industries. Figure 1 shows the production of the Indonesian rubber industry along with the production of the United States of America (USA), Japan, Germany, China and Australia. The United States of America (USA), Japan, Germany, China and Australia are the top five exporters globally. Now Indonesia becomes the third largest producer of rubber worldwide. This is one of the great achievements of the Indonesian rubber industry.

As mentioned above, Indonesia is one of the third largest producers of rubber, therefore, the Indonesian rubber industry is also dealing with the large supply chain process as compared to the other countries. Supply of rubber products to the country and various other countries require a better level of supply chain. To fulfill the demand of customers, the rubber industry requires quality as well as quick supply chain services. Indonesia is one of the big countries with a major population living in this country, therefore, the need for rubber products in Indonesia is also extensive which require better activities of supply chain. Along with the domestic supply, this Indonesian industry is also involved in exports to other countries. Therefore, domestic supply and exports required a quality supply chain department with sustainable practices. As it is discussed in previous studies that supply chain is important in the rubber industry (Chanchaichujit et al., 2017; Marimin et al., 2017). To expedite the supply chain and increase sustainability, Industry 4.0 has a central role. New technologies from Industry 4.0 have a vital role in the supply chain which is also evident from the previous studies (Mastos et al., 2020). Various elements of Industry 4.0 have an important role in SCS. Generally, supply chain requires quick and accurate information from the company and outside the company related to the market and customers. The management of the data and information supply chain in the rubber industry requires a systematic process. To cover this area, the current study introduced big data technology as one of the pillars of Industry 4.0. Big data is one of the most effective tools of the supply chain process (Zhong et al., 2016). To examine the effect of big data on SCS, this study examined the effect of data storage, data transformation and data utilization on order management in rubber companies. Hence, the objective of the current study is to examine the role of Industry 4.0 in supply chain sustainability (SCS). Therefore, the relationship between data storage, data transformation, data utilization, order management and SCS were examined. Various previous studies examined the big data in various industries (Arunachalam, Kumar, & Kawalek, 2018; Dubey, Gunasekaran, Childe, Luo, Wamba, Roubaud, & Foropon, 2018), however, big data is rarely discussed in the rubber companies of Indonesia.

2. Literature Review

In this current era, technology is increasing and replacing human activities. Technology in industry is based on various phases such as Industrial revolution phase one, phase two and phase three. The current industrial revolution is phase four which is known as fourth industrial revolution or Industry 4.0. Industry 4.0 has significant importance among the companies (Chinachoti, 2018). Most of the companies are now adopting various technologies related to Industry 4.0 (Haseeb et al., 2019; Jermsittiparsert, & Boonratanakittiphumi, 2019). As the introduction of latest technology in various operations causes to increase the production capacity, reduce the production time and also reduces the production cost. However, the applications of Industry 4.0 are not well established in the rubber industry. Number of industries are applying the applications of Industry 4.0 (Tortorella, Vergara, Garza-Reyes, & Sawhney, 2020) because applications of Industry 4.0 are most important to compete in the market. Increase in the market competition can be better managed with the help of latest technology related to the Industry 4.0. In this direction, the current study introduced big data technology (Liu et al., 2018) for the rubber industry of Indonesia to resolve various problems. Big data technology is introduced with the help of introducing four elements of big data such as data storage, data transformation and data utilizations. The effect of data storage, data transformation and data utilizations were examined in order management and SCS. Fig. 1 shows the relationship between data storage, data transformation, data utilization, order management and SCS.

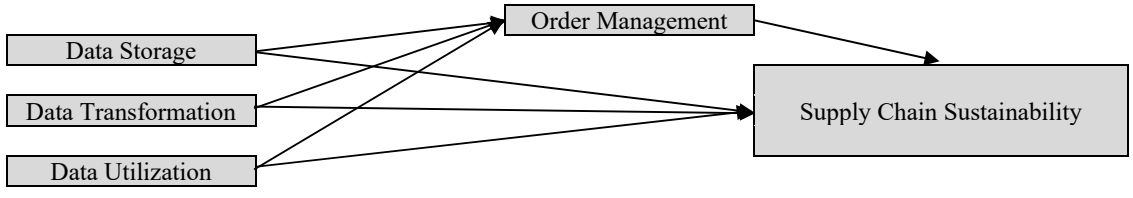

Fig. 1. Theoretical framework of the study showing the relationship between data storage, data transformation, data utilization, order management and SCS

3. Hypotheses Development

3.1 Data Storage, Order Management and SCS: Data storage is the most important element among the organizations which is now supported by the big data technology introduced by Industry 4.0. Rubber industry in Indonesia is one of the top industries. It has a vital influence on the whole world and exports the products in various countries. Due to the high performance and high coverage of this industry, the number of customers of this industry is more than other industries. The customer of this industry is based on local customers form Indonesia and majorly it has international customers from different countries who import the rubber as well as different rubber products. Therefore, to manage all these local and international customers, the availability of higher performance systems for data management is most important. Effective data management system can store huge data of customers. The other features of this technology are that the assessment of data is quite easy and companies can extract the data of each customer easily and can make the products as per their own choice. Therefore, in this direction, the role of data storage in order management is most important. Data management can be improved with the help of Industry 4.0 which facilitates the order management system. Hence, it shows that data storage has a positive influence on order management. The order management has critical importance among companies (Baykasoğlu et al., 2020) which lead to the success and higher performance. Therefore, along with the positive effect of data storage on order management, it also has a positive effect on SCS. It has the ability to increase the sustainability in the supply chain among rubber making companies of Indonesia. As the SCS has major importance in companies (Lim et al., 2017) that is the reason it requires better order management to enhance sustainable operations. Hence, data storage has a positive role in order management and order management has a positive role in SCS.

Hypothesis 1. *Data storage has a positive effect on order management.*
Hypothesis 2. *Data storage gas positive effect on SCS.*

3.2 Data Transformation, Order Management and SCS: Another important part of big data is data transportation. Data transformation is one of the most effective elements which can provide ease to the companies and in this direction Industry 4.0 is playing the effective role by introducing big data technology. Big data technology has several benefits and among all benefits, data transformation is also one of the major benefits which provides significant benefits to the companies. In computing, Data transformation is the procedure of changing data from one format as well as from one structure into another required format or required structure. It is a central aspect of most data combinations as well as data management tasks among a number of industries such as data wrangling, data warehousing, data integration along with data application integration. Better data transformation has a vital role in the operations of various companies which can save the time and increase the performance by decreasing the labor work. It has important relationships with the supply chain among various companies (Malyavkina et al., 2019; Roy et al., 2020). Data transformation technology has relationships with order management among various countries. Order management among rubber making companies has key importance which can be managed with the help of data transformation. Along with this, data transformation also has a direct effect on SCS. Increase in the data transformation increases the SCS. It is evident that data transformation has a positive role on order management which further increases the SCS. Because data transformation has vital importance among the companies (Jiang et al., 2020), therefore, it also has a major role in rubber making companies of Indonesia.

Hypothesis 3. *Data transformation has a positive effect on order management.*
Hypothesis 4. *Data transformation has a positive effect on SCS.*

3.3 Data Utilization, Order Management and SCS: Above discussion shows that data storage has a major role in order management and SCS. It is also observed that data transformation also has a vital influence on companies SCS. This section shows the importance of data utilization in rubber making companies. Data utilization is the procedure of using various types of data to support business missions. Data utilization is the process of effective data management. The companies obtain, maintain, access, as well as protect data all in order to use that data to support different missions and activities. There is always a lot of information related to the market, customers and other stakeholders, however, the extraction of valuable data is most important. The useful data extraction is important for new idea generation as well as for innovation. All the extracted data is not useful for the companies; therefore, it is required to extract the important data for proper utilization. The importance of data utilization of business companies is also given by several scholars (Crawford et al., 2019; Xu et al., 2019). Therefore, data utilization has a significant effect on order management which further leads to the SCS.

Hypothesis 5. *Data utilization has a positive effect on order management.*
Hypothesis 6. *Data utilization has a positive effect on SCS.*
Hypothesis 7. *Order management mediates the relationship between data storage and SCS.*
Hypothesis 8. *Order management mediates the relationship between data transformation and SCS.*
Hypothesis 9. *Order management mediates the relationship between data utilization and SCS.*

4. Research Methodology

The current study investigated the rubber manufacturing companies. Rubber manufacturing companies of Indonesia were selected for the current study. The reason to select these companies was because these companies in Indonesia were facing supply chain issues. In these companies, supply chain practices are very important, however, these companies were lacking

in supply chain sustainability. Therefore, to address the issue of supply chain, the current study introduced Industry 4.0 and big data proposed as the possible solution of this study. The features of big data such as data storage, data transformation and data utilization were considered in relation to order management and SCS. To measure the relationship between data storage, data transformation, data utilization, order management and SCS, this study designed a survey questionnaire (Bowling et al., 1999) to collect data from the rubber companies in Indonesia. To design a survey questionnaire, this study followed previous studies in the field of supply chain. While developing the questionnaire, this study considered how previous studies measured these variables. So, the current study used already developed measures by the previous studies. Hence, with the help of previous studies and by examining the literature, the current study designed the questionnaire to measure data storage, data transformation, data utilization, order management and SCS. Furthermore, this study distributed questionnaires among the respondents after the development of the questionnaire. Data were collected from the rubber companies of Indonesia and employees of these companies were considered for data collection. In this process, cluster sampling was preferred by the current study and clusters were developed with the help of states of Indonesia. After making the clusters, simple random sampling was preferred in the current study for data collection (Kaur et al., 1996). In this whole process, 500 questionnaires were used and 270 were returned and used in analysis.

5. Research Findings

Data statistics showing the mean, median, standard deviation and missing value. Data statistics was examined to observe the error in the data. This was performed to examine the missing value in the data (Aydin, & Şenoğlu, 2018). None of the missing values found in the data as shown in Table 1.

Table 1
Data Statistics

	No.	Missing	Mean	Median	Min	Max	SD	Kurtosis	Skewness
DS1	1	0	3.381	4	1	7	1.823	-0.836	0.309
DS2	2	0	3.343	3	1	7	1.985	-1.07	0.344
DS3	3	0	3.371	3	1	7	1.987	-1	0.374
DS4	4	0	3.324	3	1	7	1.92	-1.076	0.364
DS5	5	0	3.486	4	1	7	1.773	-0.628	0.408
DS6	6	0	3.238	3	1	7	1.828	-0.798	0.324
DT1	7	0	3.314	3	1	7	1.909	-0.891	0.324
DT2	8	0	3.276	3	1	7	1.875	-1.014	0.312
DT3	9	0	3.114	2	1	7	2.352	-1.101	0.721
DU1	10	0	2.971	2	1	7	2.336	-0.98	0.79
DU2	11	0	3.219	2	1	7	2.255	-1.078	0.653
DU3	12	0	3.095	2	1	7	2.291	-1.025	0.725
OM1	13	0	3.01	2	1	7	2.451	-1.127	0.776
OM2	14	0	2.933	2	1	7	2.153	-0.576	0.93
OM3	15	0	3.143	2	1	7	2.081	-0.791	0.739
OM4	16	0	2.943	2	1	7	2.013	-0.457	0.861
OM5	17	0	2.952	2	1	7	2.184	-0.701	0.858
OM6	18	0	2.905	2	1	7	2.1	-0.584	0.873
OM7	19	0	3.248	2	1	7	2.382	-1.216	0.637
SCS1	20	0	3.076	2	1	7	2.452	-1.176	0.728
SCS2	21	0	2.857	2	1	7	2.167	-0.567	0.939
SCS3	22	0	3.01	2	1	7	2.253	-0.845	0.865
SCS4	23	0	3.667	4	1	6	1.529	-1.057	-0.054
SCS5	24	0	3.552	4	1	6	1.762	-1.443	-0.162
SCS6	25	0	3.552	4	1	6	1.621	-1.333	-0.116
SCS7	26	0	3.59	4	1	6	1.584	-1.398	-0.132
SCS8	27	0	3.505	4	1	6	1.668	-1.475	-0.352

Data analysis of this study is started with the help of the latest technique used by the previous scholars. This technique is known as Structural Equation Modeling (SEM) which is applied with the help of Partial Least Square (PLS) (Henseler, & Chin, 2010; Hair Jr, Sarstedt, Hopkins, & Kuppelwieser, 2014; Henseler et al., 2015; Iqbal, & Kousar, 2018; Ul-Hameed et al., 2018). Figure 3 shows that data storage was measured by using six items. Data transformation was measured by using three items and data utilization was measured by using three items. Order management was measured by using seven items. Finally, SCS was measured by using eight items. It is found that; data storage, data transformation, data utilization, order management and SCS have factor loading above 0.7 for all the items which is also suggested in the previous studies.

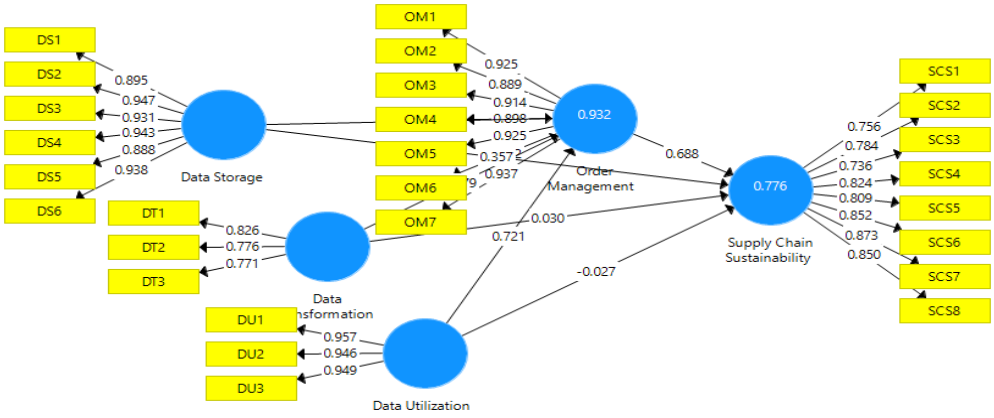

Fig. 2. Measurement Model

Table 2
Factor Loadings

	Data Storage	Data Transformation	Data Utilization	Order Management	Supply Chain Sustainability
DS1	0.895				
DS2	0.947				
DS3	0.931				
DS4	0.943				
DS5	0.888				
DS6	0.938				
DT1		0.826			
DT2		0.776			
DT3		0.771			
DU1			0.957		
DU2			0.946		
DU3			0.949		
OM1				0.925	
OM2				0.889	
OM3				0.914	
OM4				0.898	
OM5				0.925	
OM6				0.912	
OM7				0.937	
SCS1					0.756
SCS2					0.784
SCS3					0.736
SCS4					0.824
SCS5					0.809
SCS6					0.852
SCS7					0.873
SCS8					0.85

Reliability and validity of data is tested with the help of the PLS measurement model as given in Table 3. In the process of reliability and validity assessment, this examined composite reliability (CR) and discriminant validity which is shown in Table 4 by using the cross-loadings (Fornell, & Larcker, 1981). Convergent validity was achieved with the help of average variance extracted (AVE). Results in Table 3 shows that CR for data storage, data transformation, data utilization, order management and SCS is above 0.7. Previous studies such as (Hair, Sarstedt, Pieper, & Ringle, 2012; Hair, Hollingsworth, Randolph, & Chong, 2017) also suggested that CR should be above 0.7 and AVE should be above 0.5. Further results of AVE show that all the variables; data storage, data transformation, data utilization, order management and SCS have AVE above 0.5. Factor loadings are given in Table 2.

Table 3
Reliability and Convergent Validity

	Alpha	rho_A	CR	AVE
Data Storage	0.966	0.968	0.972	0.854
Data Transformation	0.733	0.755	0.834	0.626
Data Utilization	0.947	0.947	0.966	0.904
Order Management	0.967	0.968	0.973	0.836
Supply Chain Sustainability	0.927	0.93	0.939	0.659

Results of the hypotheses are started with the help of PLS structural model which is most recommended by the previous studies (Henseler et al., 2009; Henseler, & Chin, 2010; Hair Jr, Hult, Ringle, & Sarstedt, 2016; Hameed et al., 2018). In this process of hypothesis testing, the effect of data storage was examined on order management. The effect of data transformation

was also examined on order management. Furthermore, the direct effect of data utilization was examined on order management.

Table 4
Cross-Loadings

	Data Storage	Data Transformation	Data Utilization	Order Management	Supply Chain Sustainability
DS1	0.895	0.736	0.351	0.3	0.56
DS2	0.947	0.716	0.358	0.298	0.53
DS3	0.931	0.679	0.335	0.267	0.511
DS4	0.943	0.736	0.397	0.324	0.556
DS5	0.888	0.743	0.375	0.329	0.593
DS6	0.938	0.782	0.45	0.386	0.604
DT1	0.911	0.826	0.413	0.367	0.614
DT2	0.897	0.776	0.322	0.279	0.554
DT3	0.31	0.771	0.85	0.91	0.708
DU1	0.402	0.74	0.957	0.912	0.755
DU2	0.363	0.691	0.946	0.901	0.746
DU3	0.409	0.724	0.949	0.886	0.763
OM1	0.321	0.703	0.878	0.925	0.777
OM2	0.226	0.64	0.831	0.889	0.708
OM3	0.349	0.701	0.864	0.914	0.731
OM4	0.312	0.684	0.879	0.898	0.723
OM5	0.359	0.724	0.861	0.925	0.754
OM6	0.281	0.686	0.853	0.912	0.684
OM7	0.366	0.728	0.89	0.937	0.795
SCS1	0.3	0.724	0.866	0.921	0.756
SCS2	0.358	0.719	0.885	0.88	0.784
SCS3	0.285	0.667	0.853	0.883	0.736
SCS4	0.612	0.588	0.419	0.429	0.824
SCS5	0.641	0.598	0.379	0.389	0.809
SCS6	0.603	0.623	0.45	0.466	0.852
SCS7	0.648	0.652	0.533	0.513	0.873
SCS8	0.641	0.636	0.486	0.477	0.85

Furthermore, this study examined the direct effect of data storage, data transformation, data utilization and order management on SCS. Results of the hypotheses are given in Table 5 which shows that data storage has a positive effect on order management and SCS. Positive effect of data transformation was found on order management; however, it has no effect on SCS. Moreover, it is found that data utilization has a positive effect on order management and no effect on SCS. Finally, order management has a positive effect on SCS. Hence, increase in data management increases the SCS. This process of hypothesis testing is given in Fig. 3.

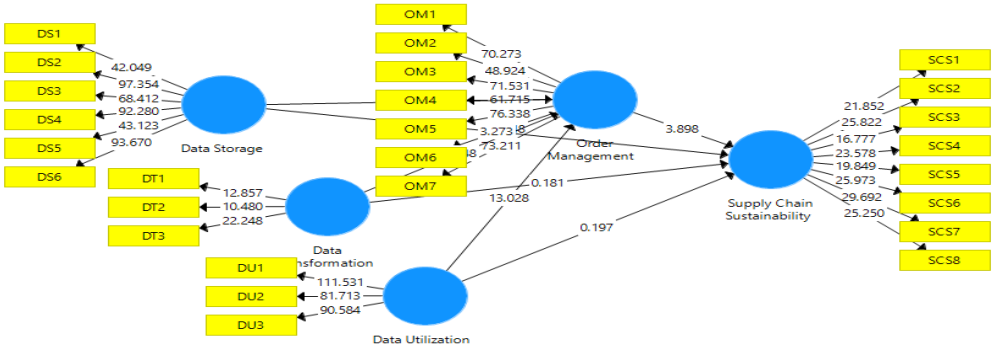

Fig. 3. Structural Model

Table 5
Direct Effect Results

	(O)	(M)	SD	t Statistics	P Values
Data Storage → Order Management	0.33	0.327	0.058	5.734	0
Data Storage → Supply Chain Sustainability	0.357	0.368	0.109	3.273	0.001
Data Transformation → Order Management	0.479	0.477	0.082	5.848	0
Data Transformation → Supply Chain Sustainability	0.03	0.016	0.164	0.181	0.857
Data Utilization → Order Management	0.721	0.718	0.055	13.028	0
Data Utilization → Supply Chain Sustainability	0.027	0.02	0.136	0.197	0.844
Order Management → Supply Chain Sustainability	0.688	0.692	0.177	3.898	0

In the next step of data analysis, the current study examined the mediation effect of order management. The mediation effect was examined by following the instructions of (Preacher, & Hayes, 2004, 2008). The mediation effect of order management

was examined between data storage and SCS. The mediation effect of order management was examined between data transformation and SCS. The third mediation effect of order management was examined between data utilization and SCS. Results of the mediation effect are given in Table 6. The results in the study highlighted that order management is a mediating variable between data storage and SCS with t-value 3.376. Order management transfers the positive effect of data storage on SCS. Moreover, it is found that order management is a mediating variable between data transformation and SCS with t-value 3.165. Finally, the order management is a mediating variable between data utilization and SCS with t-value 3.958. Furthermore, the variance explained in the SCS was examined with the help of the PLS measurement model as given in Fig. 3. The r-square is 0.776 which is strong (Chin, 1998). Thus, all the variables; data storage, data transformation, data utilization and order management are expected to bring 77.6% change in SCS. All the indirect effects are given in Fig. 4, Fig. 5 and Fig. 6.

Table 6
Indirect Effect Results

	(O)	(M)	SD	t Statistics	P Values
Data Storage → Order Management → Supply Chain Sustainability	-0.227	-0.225	0.067	3.376	0.001
Data Transformation → Order Management → Supply Chain Sustainability	0.329	0.331	0.104	3.165	0.002
Data Utilization → Order Management → Supply Chain Sustainability	0.496	0.494	0.125	3.958	0

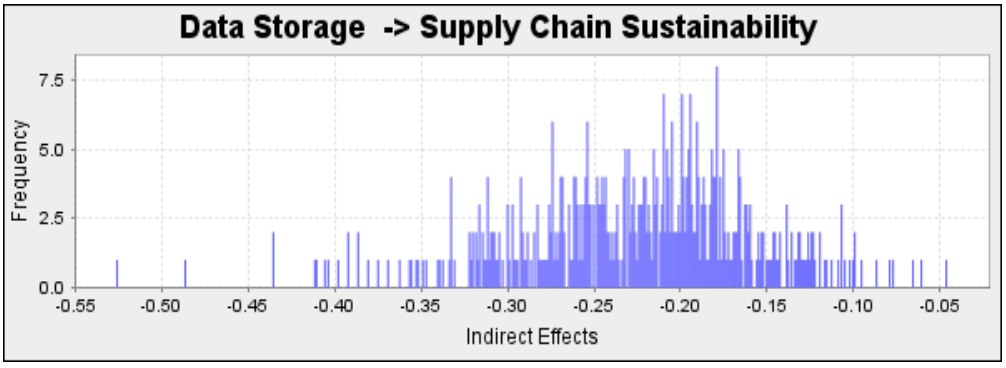

Fig. 4. Mediation Effect Histogram: Data Storage → Order Management → Supply Chain Sustainability

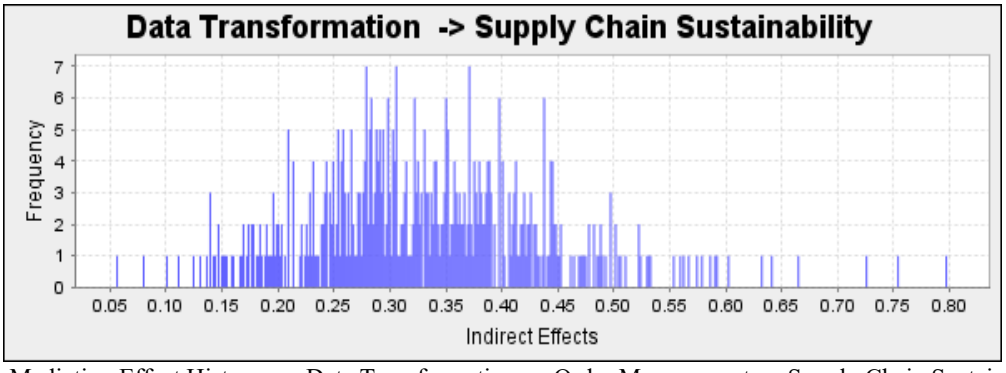

Fig. 5. Mediation Effect Histogram: Data Transformation → Order Management → Supply Chain Sustainability

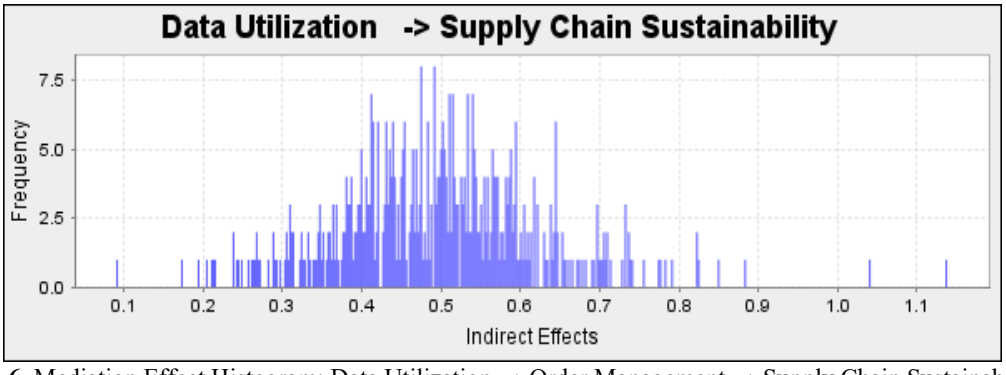

Fig. 6. Mediation Effect Histogram: Data Utilization → Order Management → Supply Chain Sustainability

6. Conclusion

This study examined the role of Industry 4.0 in SCS. The objective of the current study is to examine the role of Industry 4.0 in SCS and the relationship between data storage, data transformation, data utilization, order management and SCS were examined after collecting the data from the rubber industry of Indonesia with the help of a survey questionnaire. Results of the study highlighted that Industry 4.0 has a vital role in SCS. Implementation of Industry 4.0 among the rubber companies shows a positive effect on SCS. Among other applications of Industry 4.0, big data plays a vital role to enhance SCS. The applications of big data technology have a vital role in order management and SCS. It is found that data storage has a positive role to promote order management and SCS among the rubber making companies. Better data storage has the ability to increase the quality of order management and SCS. Moreover, data transformation also has a positive role in order management. Order from the customers related to the products can be well managed with the help of big data technology. Additionally, data utilizations also show the positive influence on order management in rubber companies. Finally, order management has a positive role in SCS. Hence, big data technology has a vital role to enhance order management which further increases the SCS in the rubber industry of Indonesia.

The current study has major implications for the literature. For instance, the introduction of Industry 4.0 in the rubber industry along with the supply chain has a major role in literature. This is the first study which introduced big data technology in the rubber industry of Indonesia. Big data technology to solve the issue of SCS in the Indonesian rubber industry is first time studied in the literature. Furthermore, this study also investigated the role of big data in relation to the three important features of big data such as data storage, data transformation and data utilization. Along with this, the current study also proved the mediating role of order management. Practically, the current study has vital importance for the Indonesian rubber industry to increase the sustainability in supply chain operations with the applications of big data.

References

Arunachalam, D., Kumar, N., & Kawalek, J. (2018). Understanding big data analytics capabilities in supply chain management: Unravelling the issues, challenges and implications for practice. *Transportation Research Part E: Logistics and Transportation Review, 114*, 416-436.

Aydin, D., & Şenoğlu, B. (2018). Estimating the Missing Value in One-Way ANOVA Under Long-Tailed Symmetric Error Distributions. *Sigma: Journal of Engineering & Natural Sciences,* 36(2), 523-538.

Baykasoğlu, A., Subulan, K., Güçdemir, H., Dudaklı, N., & Eren Akyol, D. (2020). Revenue management for make-to-order manufacturing systems with a real-life application. *The Engineering Economist,* 65(1), 27-65.

Bowling, A., Bond, M., Jenkinson, C., & Lamping, D. (1999). Short Form 36 (SF-36) Health Survey questionnaire: which normative data should be used? Comparisons between the norms provided by the Omnibus Survey in Britain, the Health Survey for England and the Oxford Healthy Life Survey. *Journal of Public Health,* 21(3), 255-270.

Chanchaichujit, J., Saavedra-Rosas, J., & Kaur, A. (2017). Analysing the impact of restructuring transportation, production and distribution on costs and environment–a case from the Thai Rubber industry. *International Journal of Logistics Research and Applications, 20(*3), 237-253.

Chienwattanasook, K., & Onputtha, S. (2022). The Impact of Inspirational Leadership on Green Supply Chain Management and Organizational Performance of Food and Beverage Companies. *Asian Administration and Management Review, 5*(1), 29-40.

Chin, W. (1998). The partial least squares approach to structural equation modeling. *Modern methods for business research,* 295(2), 295-336.

Chinachoti, P. (2018). The Readiness of Human Resource Management for Industrial Business Sector towards Industrial 4.0 in Thailand. *Asian Administration and Management Review, 1*(2), 123-131.

Crawford, J., Gasparis, A., Almeida, J., Elias, S., Wakefield, T., Lal, B. Osborne, N., Amery, S., & Labropoulos, N. (2019). A review of United States endovenous ablation practice trends from the Medicare Data Utilization and Payment Database. *Journal of Vascular Surgery: Venous and Lymphatic Disorders, 7*(4), 471-479.

De, D., Chowdhury, S., Dey, P., & Ghosh, S. (2020). Impact of lean and sustainability oriented innovation on sustainability performance of small and medium sized enterprises: a data envelopment analysis-based framework. *International Journal of Production Economics, 219*, 416-430.

Dey, P., Malesios, C., De, D., Chowdhury, S., & Abdelaziz, F. (2019). Could lean practices and process innovation enhance supply chain sustainability of small and medium-sized enterprises?. *Business Strategy and the Environment, 28*(4), 582-598.

Dubey, R., Gunasekaran, A., Childe, S., Luo, Z., Wamba, S., Roubaud, D., & Foropon, C. (2018). Examining the role of big data and predictive analytics on collaborative performance in context to sustainable consumption and production behaviour. *Journal of Cleaner Production, 196*, 1508-1521.

Fornell, C., & Larcker, D. (1981). Structural equation models with unobservable variables and measurement error: Algebra and statistics. *Journal of marketing research, 18*(3), 382-388.

Hair, J., Hollingsworth, C., Randolph, A., & Chong, A. (2017). An updated and expanded assessment of PLS-SEM in information systems research. *Industrial Management & Data Systems, 117*(3), 442-458.

Hair, J., Sarstedt, M., Pieper, T., & Ringle, C. (2012). The use of partial least squares structural equation modeling in strategic management research: A review of past practices and recommendations for future applications. *Long range planning, 45*(5-6), 320-340.

Hair Jr, J., Sarstedt, M., Hopkins, L., & Kuppelwieser, V. (2014). Partial least squares structural equation modeling (PLS-SEM) An emerging tool in business research. *European Business Review, 26*(2), 106-121.

Haseeb, M., Hussain, H., Slusarczyk, B., & Jermsittiparsert, K. (2019). Industry 4.0: A Solution towards Technology Challenges of Sustainable Business Performance. *Social Sciences, 8(*5), 184.

Hameed, W., Nadeem, S., Azeem, M., Aljumah, A., & Adeyemi, R. (2018). Determinants of E-Logistic Customer Satisfaction: A Mediating Role of Information and Communication Technology (ICT). *International Journal of Supply Chain Management, 7*(1), 105-111.

Henseler, J., & Chin, W. (2010). A comparison of approaches for the analysis of interaction effects between latent variables using partial least squares path modeling. *Structural Equation Modeling, 17*(1), 82-109.

Henseler, J., Ringle, C., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the academy of marketing science, 43*(1), 115-135.

Henseler, J., Ringle, C., & Sinkovics, R. (2009). The use of partial least squares path modeling in international marketing," in *New challenges to international marketing* (pp. 277-319), Bingley: Emerald Group Publishing Limited.

Iqbal, J., & Kousar, S. (2018). Antecedents of Sustainable Social Entrepreneurship Initiatives in Pakistan and Outcomes: Collaboration between Quadruple Helix Sectors. *Sustainability, 10*(12), 4539.

Jermsittiparsert, K., & Boonratanakittiphumi, C. (2019). The Supply Chain Management, Enterprise Resource Planning Systems and the Organisational Performance of Thai Manufacturing Firms: Does the Application of Industry 4.0 Matter?. *International Journal of Innovation, Creativity and Change, 8*(8), 82-102.

Jiang, P., Hong, C., & Agrawal, G. (2020). *A novel data transformation and execution strategy for accelerating sparse matrix multiplication on GPUs.* Paper presented at the 25th ACM SIGPLAN Symposium on Principles and Practice of Parallel Programming, California, USA.

Jittimanee, U. (2014). The Supply Chain Management of Khaotangkwa Pomeloin Chainat. *Journal of Interdisciplinary Research: Graduate Studies, 3*(1), 68-88.

Kaur, A., Patil, G., Shirk, S., & Taillie, C. (1996). Environmental sampling with a concomitant variable: a comparison between ranked set sampling and stratified simple random sampling. *Journal of applied statistics, 23*(2-3), 231-256.

Khamhaeng, S., Kotikul, K., Jinachan, K., Morasin, C., & Phonsongkram, P. (2015). The Study of the Development Process for the Logistics Ability and the Supply Chain of the Nutmeg Products, Nakhonsithammarat. *Journal of Interdisciplinary Research: Graduate Studies, 4*(2), 20-26.

Kusworo, T., Aryanti, N., Utomo, D., & Nurmala, E. (2020). Performance Evaluation of PES-ZnO nanohybrid using a combination of UV Irradiation and Cross-linking for Wastewater Treatment of the Rubber Industry to Clean Water. *Journal of Membrane Science and Research, 7*(1), 4-13.

Lim, M., Tseng, M., Tan, K., & Bui, T. (2017). Knowledge management in sustainable supply chain management: Improving performance through an interpretive structural modelling approach. *Journal of Cleaner Production, 162*, 806-816.

Liu, Y., Peng, J., & Yu, Z. (2018). *Big Data Platform Architecture under the Background of Financial Technology: In the Insurance Industry as an Example.* Paper presented at the 2018 International Conference on Big Data Engineering and Technology, Chengdu, China.

Malyavkina, L., Savina, A., & Parshutina, I. (2019). *Blockchain technology as the basis for digital transformation of the supply chain management system: benefits and implementation challenges.* Paper presented at the 1st International Scientific Conference "Modern Management Trends and the Digital Economy: from Regional Development to Global Economic Growth", Ekaterinburg, Russia.

Marimin, M., Wibisono, A., & Darmawan, M. (2017). Decision support system for natural rubber supply chain management performance measurement: a sustainable balanced scorecard approach. *International Journal of Supply Chain Management, 6*(2), 60-74.

Mastos, T., Nizamis, A., Vafeiadis, T., Alexopoulos, N., Ntinas, C., Gkortzis, D., Papadopoulos, A., Ioannidis, D., & Tzovaras, D. (2020). Industry 4.0 sustainable supply chains: An application of an IoT enabled scrap metal management solution. *Journal of Cleaner Production, 269*, 122377.

Preacher, K., & Hayes, A. (2004). SPSS and SAS procedures for estimating indirect effects in simple mediation models. *Behavior research methods, instruments, & computers,* 36(4), 717-731.

Preacher, K., & Hayes, A. (2008). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. *Behavior research methods,* 40(3), 879-891.

Qiao, H., Chao, M., Hui, D., Liu, J., Zheng, J., Lei, W., Zhou, X., Wang, R., & Zhang, L. (2017). Enhanced interfacial interaction and excellent performance of silica/epoxy group-functionalized styrene-butadiene rubber (SBR) nanocomposites without any coupling agent. *Composites Part B: Engineering, 114*, 356-364.

Roy, V., Schoenherr, T., & Charan, P. (2020). Toward an organizational understanding of the transformation needed for sustainable supply chain management: The concepts of force-field and differential efforts. *Journal of purchasing and supply management,* 26(3), 100612.

Sirisuwat, P., & Jindabot, T. (2012). The Rubber Export Industry in Thailand: An Analysis of Export Performance. *PSAKU International Journal of Interdisciplinary Research, 1*(1), 195-202.

Sukriket, P., Sriyakul, T., Jermsittiparsert, K., & Chienwattanasook, K. (2022). Food Supply Chain Quality Management Practices Impact on Quality Safety Performance in Thailand. *International Journal of eBusiness and eGovernment Studies, 14*(1), 134-149.

Tongkum, S., & Sasananan, M. (2014). Supply Chain of Organic Vegetables: A Case Study of Food Safety Program in Hospital. *Journal of Interdisciplinary Research: Graduate Studies, 3*(2), 23-34.

Tortorella, G., Vergara, A., Garza-Reyes, J., & Sawhney, R. (2020). Organizational learning paths based upon industry 4.0 adoption: An empirical study with Brazilian manufacturers. *International Journal of Production Economics, 219*, 284-294.

Ul-Hameed, W., Mohammad, H., & Shahar, H. (2018). Microfinance institute's non-financial services and women-empowerment: The role of vulnerability. *Management Science Letters,* 8(10), 1103-1116.

Waiyawuththanapoom, P., Thammaboosadee, S., Tirastittam, P., Jermsittiparsert, K., Wongsanguan, C., Sirikamonsin, P., & Aunyawong, W. (2022). The role of human resource management and supply chain process in sustainable business performance. *Uncertain Supply Chain Management, 10*(2), 517-526. DOI: 10.5267/j.uscm.2021.11.011.

Xu, T., Li, H., Zhang, H., & Zhang, X. (2019). *Improve Data Utilization with Two-stage Learning in CNN-LSTM-based Voice Activity Detection.* Paper presented at the 2019 Asia-Pacific Signal and Information Processing Association Annual Summit and Conference, Lanzhou, China.

Zhong, R., Newman, S., Huang, G., & Lan, S. (2016). Big Data for supply chain management in the service and manufacturing sectors: Challenges, opportunities, and future perspectives. *Computers & Industrial Engineering, 101*, 572-591.