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RESEARCH PAPER

An Exploratory Empirical Investigation on the Intervening Role of TQM & Big Data Analytics between Industry 4.0 and Firms Innovation Performance

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ABSTRACT

Today Industry 4.0 has restructured the manufacturing into a more sophisticated technology oriented smart industry, with features like IoTs, Big Data, and cloud computing in order to enrich the product quality and reliability with sustainability. However, the research on causal relationship of Industry 4.0 and TQM is under investigated. This study identified a set of quantitative indicators that, from a TQM perspective, can be used to determine the impact of implementing Industry 4.0 technology on any industrial enterprise. The study reviewed various TQM principles, identified quantitative indicators to evaluate, and suggested possible means of data collection and analysis techniques. Therefore, this study provides a solid foundation for determining the quantitative impact of Industry 4.0 on TQM and corporate innovation performance. Production managers need to understand the interchanging role of TQM and Industry 4.0 in leveraging innovation performance for long term organization sustainability in industrial era.

Introduction

The companies competing globally face intense competition from international companies while trying to become leading producers in the global market. Similarly, when the competition in the local market increases these companies face more pressure (Seth, Tripathi, 2005). Therefore according to Taj; Morosan, (2011), and Fettermann, (2017) organizations must put considerable effort into operational functions such as improving the quality and efficiency and undertaking managerial approaches that can help in achieving the desired outcomes. Production and operation management involves the use of two major approaches in order to achieve desirable outcomes these are Total Quality Management (TQM) and Innovation. According to Wang et al, (2012) and Dubey & Gunasekaran, (2015) TQM is a continuous process of improving the quality of processes, products, and services through increased focus on consumers' needs, wants and expectations thereby leading to increased customer satisfaction and better organizational performance. Throughout the years, TQM has been argued to have a positive impact on an organization, even though some researchers have analyzed the role of total quality management (TQM) as a pioneer of innovation. Nevertheless, the relationship between TQM and organizational innovation remains unclear and contradictory.

The main characteristics of Industry 4.0 encompass inter-related solutions, smart products, and systems, and the use of connected machines. These characteristics help in the development of smart and intelligent production units which are monitored by digital

devices (Kagermann et al., 2013; Lasi et al., 2014).An organization can achieve higher levels of operational performance through the incorporation of these smart technological advancements (Landscheidit; Kans, 2016).The potential benefits of industry 4.0 in TQM are quite evident from extant literature (Kolberg; Zuehlke, 2015; Sanders et al., 2016; Kolberg et al., 2016). However, little or no empirical evidence is available to justify these arguments.

Hence, based on these arguments we can raise two most important research questions as follows:

1) How the implementation of industry 4.0 influences the implementation of TQM and firm innovation?

2) Is there any empirical answer to how these approaches can exist simultaneously to improve innovation performance?

There are three important aspects of this study. Firstly it provides empirical evidence to justify extant literature. Secondly, the study aims to identify the relationship among these variables in an underdeveloped country like Pakistan and the potential benefits and challenges that hinder the successful adoption of industry 4.0 as the underdeveloped countries usually do not possess similar resources. Lastly, the integration of industry 4.0 and TQM to improve firm innovation performance will open new research gaps and areas for debate among researchers. Moreover, it can help in measuring the impact of various dimensions of industry 4.0 on TQM and firm innovation performance.

Literature Review

Industry 4.0 and TQM

TQM is one of the highly attributable management practices, well recognized as the source of the competitive advantage (Sader & Husti., 2019) for sustainable business development. It is widely applicable to each and every area of business (Sweis et al, 2019) to achieve a distinct place in the market by mastering in its products satisfying the requirements of their customers (Sader & Husti, 2019). Different academicians have adopted different sets of activities in the TQM approach (Zehir , 2012; Anil and Satish, 2016 ; Sader & Husti, 2019). After the introduction of the 4th industrial revolution, also known as Industry 4.0, the academics and managerial attention have shifted toward the integration of the industry 4.0 with all the business processes (Mohamed, 2019). With the industry 4.0 and smart factory implementation, the ways of doing things will be revolutionized by shifting the employees focus toward innovation and quality assurance (Hemning, Wolfgag & Johannes, 2013). Likewise, researchers and academicism believed that Industry 4.0 -TQM integrated regime could lead to success in achieving distinct market positions (Tortorella, Silva, & Vargas, 2018). The fewer empirical investigation is one of the biggest hurdles in thoroughly understanding of the mechanism through which Industry 4.0 can catalyze TQM practices for successful innovations. One of the most recent theoretical studies by Sader & Husti (2019) has highlighted the importance of industry 4.0 toward successful implementation of the TQM practices. In this research taking the perspective of RBV, we argue that Industry 4.0 could enhance TQM practices as an organizational resource that can provide a competitive advantage to the firm. Therefore, it is contended here that Industry 4.0 can complement many TQM practices and hence the relationship between the two is worth investigating for sustainable business outcomes

H1: Industry 4.0 is positively associated with TQM.

Big Data analytics and TQM

Big Data Analytics (BDC) as a key component of Industry 4.0 helps leaders in today's global marketplace in realizing the utility and benefits of big-data analytics in addressing their problems for continuous improvements and revealing innovative solutions (Marshall, Mueck, & Shockley, 2015) across a variety of industries For instance, TQM Leadership intents to establish unification in the purpose, in which the employees of the organization as a whole are involved to attain the quality objectives of the firm and innovation performance (Ooi, Lin, Teh, & Chong, 2012). Industry 4.0 with its inherent feature of IoT, help organizations to boost their customer satisfaction level in delivering quality, innovative products, (Sader & Husti, 2019) and customer service and after-sales (Hong et al, 2014). Another common feature of the TQM (Polese, Vesci, Troisi, & Grimaldi, 2019) and Industry 4.0 (Wang, Ma, Yang, & Wang, 2017) is its emphasis on creation of a collaborative environment in which all the customers can have their voice as actual part of the innovative production process instead of being the recipient only.

Supplier relationship management has a central role in any TQM program (Jiménez, Martínez-Costa, & Para-Gonzalez, 2019) as it develops a strong network with the key suppliers to certify the timely availability of the raw material. Another important function of the supplier relationship is to take advantage of the supplier capabilities that helps in timely launch of the product in the competitive market (Brettel et al., 2014).

Supplier risks jeopardize on-time or complete delivery of supply in a supply chain (Sanders, 2016) which makes it a critical aspect of any continuous improvement program such as TQM. Strategic change defines as the quality they are producing and its difference with the competitor's (Rajagopalan and Spreitzer 1997). This act of change by firm also affects the occurrence of strategic change. The application of big data enables the CPS to attain automated optimization capabilities in the current diverse industry environment (Bongdan 2015; Lee, Kao and yang; 2014).

H2: There is a positive association between BDC and TQM

TQM & Innovation Performance

The core drivers of innovation and technological improvements, i.e. dynamic capabilities, innovative capabilities, and work are the lifeblood of organizations to achieve high-performance levels (Gatingnon, 2002; Teece & Pisano, 1994; Teece, 1997). Innovation is regarded as an intangible resource of the organization, which is impossible to copy. Three typologies of innovation have been identified by various researchers like administrative and technical innovation, product and process innovation, radical and incremental innovations (Hung & Lien, 2010). The study conducted by Zehir (2010) showed the positive relationship of all dimensions of TQM and innovation. Another study conducted by Hung et al. (2011) affirmed the positive relationship of TQM practices with innovation performance.

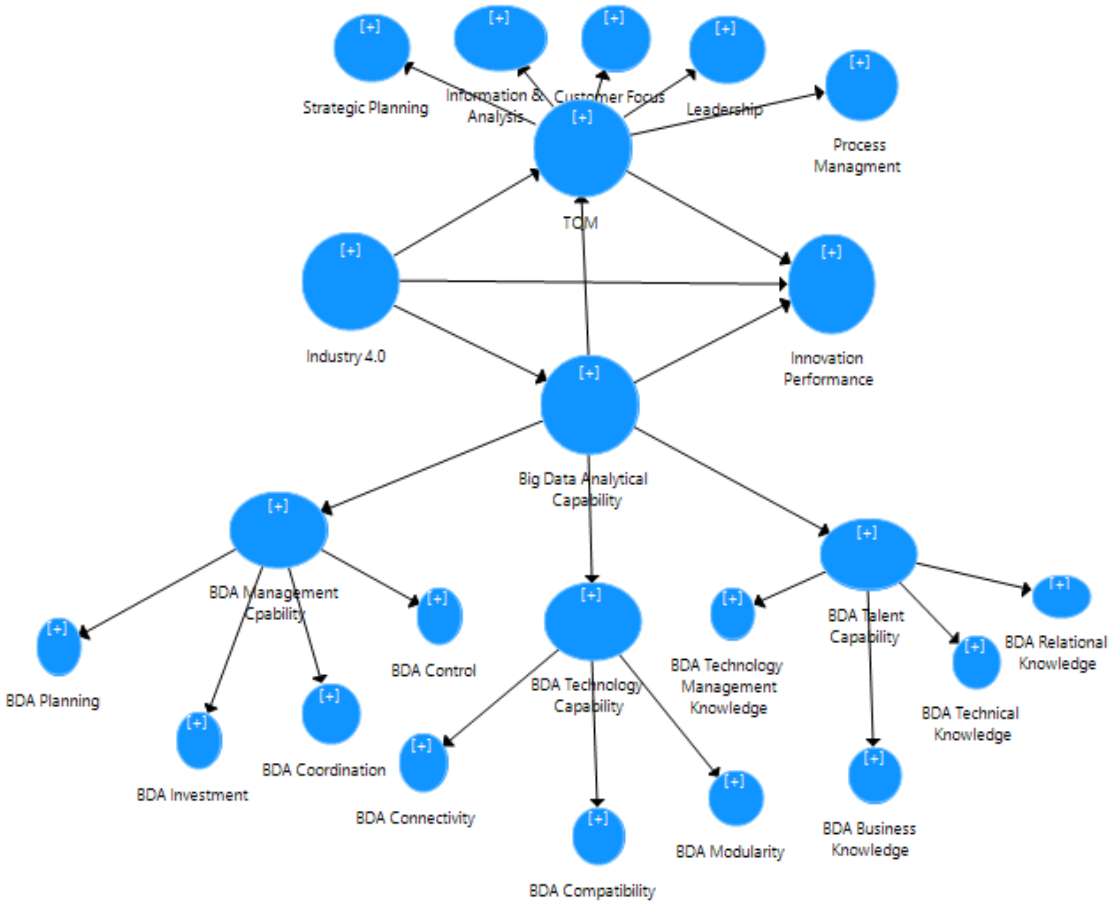

Figure 1. Research Framework

It has been observed through various studies that to what extent firms are innovative by practicing the TQM principles. (Zairi, 1994; Prajogo and Sohal, 2001, 2003, 2004a, 2004b, 2006a, 2006b;; Hoang, Igel; Laosirihongthong, 2006; Pinho, 2008; Abrunhosa; SÁ, 2008; Prajogo; Hong, 2008; Perdomo-Ortiz, Gonzalez-Bentto, Galende, 2009a, 2009b; Fernades; Felguira; Lourenco, 2010; Fernades and Lourenco, 2011). TQM is hence perceived as a management model that enhances innovation (Prajogo and Sohal, 2001). In the research work of Hoang, Igel and Laosirihongthong (2006), it is pointed out that TQM causes a positive influence on the innovation performance of the firms.

H3: TQM has a significant positive impact on innovation performance.

Big data leads to the new products and technologies which disrupts and diminish the old ones as obsolete (Danneels, 2004). The big data is perceived as an essential driver of the innovation as it creates innovative data combinations with minimized costs (Broek, 2017). In this study, Broek (2017), also argued that the fundamental purpose of the big data collaborations is to fulfil the needs of innovation and research. In the study of Yuan ZU & Kim (2017), it is discussed that the integration of big data is the productive factor to stimulate the product innovation process. Big information is a driver of supply chain innovation capabilities). Lozada& Pervez (2019), figured out that the big data analytical capabilities facilitate the innovation process resulting in successful product innovation as per customer demand.

H4: BDAC has a significant positive relationship with innovation performance.

Industry 4.0 & Innovation Performance

Industry 4.0 is highly connected to innovation processes. Ibarra (2018) figured out the significant influence of factors of industry 4.0 on business model innovation. Muller (2018), spotlighted the effective implementation of business model innovation along with the characteristics of industry 4.0 in SMEs. Schmitt (2015) have found the importance of industry 4.0 as a antecedent of innovation in modern economies. The industry 4.0 has shifted the paradigm of the market competition factors like market share, economies in production and exploitation of maximum resources to the innovativeness, intellectual property and big data innovations (Geiger & Sá, 2013). The nature of industry 4.0 is generalized as innovation and is considered as a social innovation (David, 2017). Reviewing previous literature, we intend to test the hypothesis. Hereby it is proposed;

H5: Industry 4.0 has a positive significant relationship with innovation performance.

TQM and Big Data Analytical Capability

With the increased dynamic business environment, big data is often seen as cause of many managerial issues. The big data analytics and cloud computing have served as a key to efficient problem solving for managerial purposes. In the literature, the customer orientation of the TQM is argued to be facilitated by the big data analytical capability which will lead to customer responsiveness, customized services according to choices of individual customers (Sader & Husti, 2019), the study also argued the assistance of big data analytics for the successful implementation of TQM principles like leadership in management, quality assurance and control. Chatfield& Reddick (2018) argued that the use of big data analytics leads to new insights into customer orientation by unveiling the market trends and customer preferences. A study of Shamin & Zeng (2019), it is proposed that the leader's decision-making abilities are enhanced and positively affected by the big data analytical capabilities. On the basis of the existing literature following hypothesis is submitted:

H6: TQM has a significant positive relationship with BDAC.

Mediation Hypothesis

RBV theory is of the view that organizations possess unique resources and capabilities that can be a source of sustainable competitive advantage (Halley and Beaulieu, 2009) Therefore, RBV considers organizations to be in possession of capabilities and resources, which leveraged distinctively, confer competitive advantage and also explain differences in performance (Barney, 1991). The study conducted by the Mikalef (2019) the mediating role of the dynamic and operational capabilities has been discussed between big data analytical capabilities and organizational performance. In the present study, the big data analytical capability, industry 4.0 and total quality management have been studied as the intangible resources or capabilities of the firm and their co-integration to achieve the successful innovation has been conceptualized. The casual relationships of all the variables have been established in the light of previous literature—different capabilities like the BDC, industry 4.0 impacts the firm's innovation. So on the basis of RBV, the basis that one resource facilitates the other to lead to a competitive Edge (Barney, 1991). We intend to study the mediating roles of total quality management and big data analytical capability in between the casual relationships of industry 4.0 and innovation performance as well as the mediating role of overall quality management in between industry 4.0 and big data analytical capability.

So, it can be proposed that;

H7: Industry 4.0 indirectly affects innovation performance through the mediation of TQM

H8: Industry 4.0 indirectly affects innovation performance through the mediation of the BDAC

H9: Industry 4.0 indirectly affects BDC through the mediation of TQM.

H10: TQM indirectly affects innovation performance with the mediation of BDAC

H11: The industry4.0 indirectly affects innovation performance with the mediation of TQM and BDC.

Material and Methods

Survey Instrument

The measurement scale has been adopted the past literature, which determined their validity and reliability in literature. Every Construct has been operational-zed using 5-point Likert scales because they take less time and are easy to answer (Fraser & Lawley, 2000). The TQM measures were mainly adopted from (Ooi et al., 2012) Business innovation culture was adopted from (O'Cass & Ngo, 2007a). Big Data Analytical Capability scale was adopted from (Akter, Wamba, Gunasekaran, Dubey, & Childe, 2016), Firm innovation performance was adopted from (Ghasemaghaei, Galic, 2020). Industry 4.0 was adopted from (Díaz-Chao, Ficapal-Cusí, & Torrent-Sellens, 2021).

Sample and Procedure

A survey was conducted in Pakistan's most technologically advanced industry (Pharmaceutical) was chosen for data collection. The unit of analysis for the current study is the pharmaceutical manufacturing organization of Pakistan having TQM, Industry 4.0 implemented in the organization and done innovation over the period of the last 5 years. As the list contained 142 industries that implemented industry 4.0 and hence were selected for further analysis. The study employed a cross-sectional sample. Furthermore, a representative sample in the probability sampling design is important for broader generalization purposes. The questionnaires were distributed to these 142 pharmaceutical firms, only 123 were returned, yielding an acceptable response rate.

Survey Results

Measurement Model

The study utilized the confirmatory factor analysis (CFA). Using (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003) criterion common method bias was established as the ratio of principal factor variance to total variance is 35.56% which is less than 50%. Cronbach's is between 0.697 and 0.956 as suggested by Kline (2011), and CR values are also within the limits as prescribed by (Fornell & Larcker, 1981) while Nunnally and Bernstein (1994), also recommended values as low as 0.6 as acceptable as shown in Table 1. Furthermore, all loadings were above 0.5 (more than 50%) (Hair, Black, Babin, Anderson, & Tatham, 2006) and the HTMT value is below 0.90, discriminant validity has been upheld between two reflective constructs (Hair Jr, Hult, Ringle, and Sarstedt, 2021). The VIF was found to be less than 2 as per the established criterion (Hair et al., 2021); hence the measurement model shows a good fit.

Table 1
Loading, CR and AVE

	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)
Big Data Analytical Capability (BDAC)	**0.837**	**0.872**	**0.621**
BDA Business Knowledge	0.784	0.903	0.822
BDA Compatibility	0.829	0.898	0.746
BDA Connectivity	0.778	0.871	0.693
BDA Control	0.821	0.823	0.610
BDA Coordination	0.771	0.868	0.686
BDA Investment	0.866	0.841	0.538
B]DA Management Capability	0.899	0.917	0.514
BDA Modularity	0.728	0.847	0.648
BDA Planning	0.838	0.903	0.756
BDA Relational Knowledge	0.854	0.853	0.744
BDA Talent Capability	0.896	0.915	0.521
BDA Technical Knowledge_	0.839	0.903	0.757
BDA Technology Capability	0.888	0.910	0.532
BDA Technology Management Knowledge	0.826	0.896	0.742
Industry 4.0	**0.866**	**0.827**	**0.615**
TQM	**0.889**	**0.906**	**0.521**
Information & Analysis	0.874	0.885	0.541
Leadership	0.823	0.877	0.591
Process Management	0.781	0.859	0.603
Customer Focus	0.700	0.816	0.526
Strategic Planning	0.722	0.827	0.545
Innovation Performance	**0.830**	**0.880**	**0.595**

Analysis of Structural Model

The direct path from Industry 4.0 to TQM and BADC is found to be statistically significant with (β =.455, p < 0.000) and (β =.574, p < 0.000) respectively. While the direct path from Industry 4.0 to Innovation performance was found to be insignificant (β =.121, p < 0.301). Similarly, the TQM to innovation performance is found to be statistically significant with (β =.207 p < 0.044). The direct path BADC to innovation performance and TQM was also found to be statistically significant (β =.510, p < 0.000) and (β =.321, p < 0.001).

The indirect effect of Industry 4.0 on innovation performance was exerted through TQM with (β =.094, p < 0.066), while the direct path of Industry 4.0 to Innovation performance was found to be insignificant (β =.121, p < 0.301) thus making the mediation to be indirect only effect. The indirect effect of Industry 4.0 on innovation performance was exerted through BADC with (β =.294, p < 0.000), while the direct path of Industry 4.0 to

Innovation performance was found to be insignificant (β =.121, p < 0.301) thus making the mediation to be indirect only effect.

The indirect effect of Industry 4.0 on TQM was exerted through BADC with (β =.184, p < 0.002), while the direct path of Industry 4.0 to Innovation performance was found to be insignificant (β =.121, p < 0.301) thus making the mediation to be indirect only effect. Lastly, the indirect effect of Industry 4.0 on innovation performance was exerted through BADC and TQM (Dual Mediation) with (β =.149, p < 0.003), while the direct path of Industry 4.0 to Innovation performance was found to be insignificant (β =.121, p < 0.301) thus making the mediation to be indirect only effect.

Table 2
Structural analysis between Industry 4.0 BADC, TQM & Innovation Performance

	B-Value	T-Statistic	P-Value	*B-Value*	T-Statistic	P-Value
Direct Effects						
Industry 4.0 ---TQM	0.455	5.287	0.000			
Industry 4.0 ---BADC	0.574	8.491	0.000			
TQM--- Innovation Performance	0.207	2.021	0.044			
BADC---Innovation Performance	0.510	5.240	0.000			
BADC-- TQM	0.321	3.369	0.001			
Industry 4.0 ----Innovation Performance	.121	1.035	0.301			
Indirect Effects						
Industry 4.0---TQM--- Innovation Performance				0.094	1.842	0.066
Industry 4.0---BADC--- Innovation Performance				0.293	3.906	0.000
Industry 4.0---BADC---TQM				0.184	3.072	0.002
Industry 4.0---BADC---TQM—Innovation Performance				0.149	2.674	0.003

Conclusion

The present study tried to empirically examine the relationship between industry 4.0 and innovation performance where TQM and Big data analytical capabilities were present as the mediators. Industry 4.0 provides considerable support to successfully implement the principles of TQM. However, this paper pointed out the seven TQM principles identified by ISO9001:2015 model. This study found that there is a significant positive relationship between industry 4.0 and TQM practices. Previous studies also support this result, such as (Sader & Husti, 2019), conducted a study to examine the relationship between industry 4.0 and TQM and alleged that industry 4.0 is a key facilitator of successful implementation of the important practices of TQM. Studies conducted by Beard-Gunter, Ellis & Found, (2019) and Gunasekaran, Subramanian, & Ngai, (2019) also claimed the importance of Industry 4.0 in TQM implementation. With the help of several technological developments such as Cyber-Physical Systems (CPS), Internet of Things (IoT), Cloud Computing and the Big Data industry 4.0 helps the application of all fundamental components of TQM such as product design, people management, leadership, information and analysis, customer focus.

The results of the study suggested that there exists a significant relationship between industry 4.0 and big data analytical capabilities. Technological developments in cyber-physical systems and big data can help in the application of industry 4.0 in resource

planning Rehman, et al. (2019) and (Mikalef, Krogstie, Pappas, & Pavlou, 2019), also conducted a research on the relationship between big data analytics and industry 4.0 and concluded that industry 4.0 boost up the big data analytical capabilities of the organization.

Moreover, the empirical results of this study showed that there is a significant positive relationship between big data analytical capabilities and innovation performance. Past studies also supported these results of present study such as L. Cao, (2015), stated that in big data analytics challenges and opportunities activate more critical data for better innovation performance. Niebel, Rasel, and Viete (2019), also conducted an empirical study to examine the relationship between the big data and innovation and demonstrated that firms use big data analytics to improve their innovative performance.

Furthermore, the study concluded that TQM has a significant positive relationship with innovation performance. This result is consistent with the results of previous studies which found a positive relationship between TQM and innovation (Honarpour, Jusoh, & Md Nor, 2018). Long et al. (2015), alleged that TQM makes a contribution towards the product and process innovation. According to Zeng et al. (2015), innovation and quality are coexistent, ongoing improvement, decision making, top management support, decision making (Fernandes et al. 2014) focus on customers, involvement of employees and efficiency in process are common to both quality management and innovation (Zhang et al., 2016). Hence, through continuous improvement, better decision making, customer focus, strategic planning and all other quality management practices, TQM helps the organizations in achieving higher innovative performance.

References

Abrunhosa, A., & Sá, P. M. E. (2008). Are TQM principles supporting innovation in the Portuguese footwear industry?. *Technovation*, *28*(4), 208-221.

Akter, S., Wamba, S. F., Gunasekaran, A., Dubey, R., & Childe, S. J. (2016). How to improve firm performance using big data analytics capability and business strategy alignment?. *International Journal of Production Economics*, 182, 113-131.

Anil, A. P., & Satish, K. P. (2016). Investigating the relationship between TQM practices and firm's performance: A conceptual framework for Indian organizations. *Procedia Technology*, 24, 554-561.

Barbosa, M. W., Vicente, A. D. L. C., Ladeira, M. B., & Oliveira, M. P. V. D. (2018). Managing supply chain resources with Big Data Analytics: a systematic review. *International Journal of Logistics Research and Applications*, 21(3), 177-200.

Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management,* 17(1), 99-120.

Beard-Gunter, A., Ellis, D. G., & Found, P. A. (2019). TQM, games design and the implications of integration in Industry 4.0 systems. *International journal of quality and service sciences. 11* (2), 235-247. https://doi.org/10.1108/IJQSS-09-2018-0084

Bogdan, P. (2015, September). Mathematical modeling and control of multifractal workloads for data-center-on-a-chip optimization. In Proceedings of the 9th *International Symposium on Networks-on-Chip* (pp. 1-8).

Camilleri, M. A. (2020). The use of data-driven technologies for customer-centric marketing. *International Journal of Big Data Management*, 1(1), 50-63.

Chatfield, A. T., & Reddick, C. G. (2018). All hands on deck to tweet# sandy: Networked governance of citizen coproduction in turbulent times. *Government Information Quarterly*, 35(2), 259-272.

Danneels, E. (2004). Disruptive technology reconsidered: A critique and research agenda. *Journal of product innovation management*, 21(4), 246-258.

Díaz-Chao, Á., Ficapal-Cusí, P., & Torrent-Sellens, J. (2021). Environmental assets, industry 4.0 technologies and firm performance in Spain: A dynamic capabilities path to reward sustainability. *Journal of Cleaner Production*, 281, 125264.

Dubey, R., & Gunasekaran, A. (2015). Exploring soft TQM dimensions and their impact on firm performance: some exploratory empirical results. *International Journal of Production Research*, 53(2), 371-382.

Fernandes, A. A. C. M., & Lourenço, L. (2011). *Quality, innovation and performance: an exploratory study*. European Concurrent Engineering Confference.

Fernandes, T., & Neves, S. (2014). The role of servicescape as a driver of customer value in experience-centric service organizations: the Dragon Football Stadium case. *Journal of Strategic Marketing, 22(6), 548-560.*

Foidl, H., & Felderer, M. (2015, November). Research challenges of industry 4.0 for quality management. In *International conference on enterprise resource planning systems* (pp. 121-137). Springer, Cham.

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

Ghasemaghaei, M., & Calic, G. (2020). Assessing the impact of big data on firm innovation performance: Big data is not always better data. *Journal of Business Research*, 108, 147-162.

Grover, V., Chiang, R. H., Liang, T. P., & Zhang, D. (2018). Creating strategic business value from big data analytics: A research framework. *Journal of Management Information Systems*, 35(2), 388-423.

Gunasekaran, A., Subramanian, N., & Ngai, W. T. E. (2019). Quality management in the 21st century enterprises: Research pathway towards Industry 4.0. *International journal of production economics*, 207, 125-129.

Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. (2006). *Multivariate data analysis* . Uppersaddle River.

Hair Jr, J. F., Hult, G. T. M., Ringle, C. M., Sarstedt, M., Danks, N. P., & Ray, S. (2021*). Partial Least Squares Structural Equation Modeling (PLS-SEM) Using* R: A Workbook.

Halley, A., & Beaulieu, M. (2009). Mastery of operational competencies in the context of supply chain management. Supply Chain Management: An International Journal. *Supply Chain Management* 14(1):49-63

Henning, K., Wolfgang, W., & Johannes, H. (2013). *Recommendations for implementing the strategic initiative INDUSTRIE 4.0.* Final report of the Industrie, 4, 82.

Hoang, D. T., Igel, B., & Laosirihongthong, T. (2006). The impact of total quality management on innovation: Findings from a developing country. *International journal of quality & reliability management*. 53, 516-529

Honarpour, A., Jusoh, A., & Md Nor, K. (2018). Total quality management, knowledge management, and innovation: an empirical study in R&D units. *Total Quality Management & Business Excellence,* 29(7-8), 798-816.

Hong, P., Ga (Mark) Yang, M., & D. Dobrzykowski, D. (2014). Strategic customer service orientation, lean manufacturing practices and performance outcomes. *Journal of Service Management,* 25(5), 699-723.

Hung, R. Y. Y., Lien, B. Y. H., Fang, S. C., & McLean, G. N. (2010). Knowledge as a facilitator for enhancing innovation performance through total quality management. *Total Quality Management*, 21(4), 425-438.

Hung, R. Y. Y., Lien, B. Y. H., Yang, B., Wu, C. M., & Kuo, Y. M. (2011). Impact of TQM and organizational learning on innovation performance in the high-tech industry. *International business review*, 20(2), 213-225.

Hung, R. Y. Y., Yang, B., Lien, B. Y. H., McLean, G. N., & Kuo, Y. M. (2010). Dynamic capability: Impact of process alignment and organizational learning culture on performance. *Journal of world business*, 45(3), 285-294.

Ibarra, D., Ganzarain, J., & Igartua, J. I. (2018). Business model innovation through Industry 4.0: A review. *Procedia manufacturing*, 22, 4-10.

Jiménez-Jiménez, D., Martínez-Costa, M., & Para-Gonzalez, L. (2019). Implications of TQM in firm's innovation capability. *International Journal of Quality & Reliability Management*. 37 (2), 279-304. DOI:10.1108/IJQRM-09-2018-0233

Kagermann, H., Helbig, J., Hellinger, A., & Wahlster, W. (2013). *Recommendations for implementing the strategic initiative INDUSTRIE 4.0: Securing the future of German manufacturing industry; final report of the Industrie 4.0 Working Group*. Forschungsunion.

Kolberg, D., & Zühlke, D. (2015). Lean automation enabled by industry 4.0 technologies. *IFAC-PapersOnLine*, 48(3), 1870-1875.

Kolberg, D., Knobloch, J., & Zühlke, D. (2017). Towards a lean automation interface for workstations. *International journal of production research*, 55(10), 2845-2856

Landscheidt, S., & Kans, M. (2016). Method for assessing the total cost of ownership of industrial robots. *Procedia Cirp*, 57, 746-751.

Lasi, H., Fettke, P., Kemper, H. G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. *Business & information systems engineering*, 6(4), 239-242.

Lee, J., Kao, H. A., & Yang, S. (2014). Service innovation and smart analytics for industry 4.0 and big data environment. *Procedia cirp*, 16, 3-8.

Li, X., Wang, L., Lian, Z., & Qin, X. (2018). Migration-based online CPSCN big data analysis in data centers. IEEE Access, 6, 19270-19277.

Liu, X., Cao, J., Yang, Y., & Jiang, S. (2018). CPS-based smart warehouse for industry 4.0: a survey of the underlying technologies. *Computers,* 7(1), 13.

Long, F., Zeiler, P., & Bertsche, B. (2016). Modelling the production systems in industry 4.0 and their availability with high-level Petri nets. *IFAC-Papers OnLine*, 49(12), 145-150.

Loshin, D. (2013). Understanding the Big Data Stack: Hadoop's Distributed File System. DataInformed, Published Jul, 15.

Lozada, N., Arias-Pérez, J., & Perdomo-Charry, G. (2019). Big data analytics capability and co-innovation: An empirical study. *Heliyon*, 5(10), e02541.

Marshall, A., Mueck, S., & Shockley, R. (2015). How leading organizations use big data and analytics to innovate. *Strategy & Leadership*, 43, 32-39.

Mikalef, P., Boura, M., Lekakos, G., & Krogstie, J. (2019). Big data analytics and firm performance: Findings from a mixed-method approach. *Journal of Business Research,* 98, 261-276.

Minelli, M., Chambers, M., & Dhiraj, A. (2013). *Big data, big analytics: emerging business intelligence and analytic trends for today's businesses (Vol. 578).* John Wiley & Sons.

Mohamed, N., & Al-Jaroodi, J. (2019, January). Applying blockchain in industry 4.0 applications. In 2019 *IEEE 9th annual computing and communication workshop and conference (CCWC)* (pp. 0852-0858). IEEE.

Niebel, T., Rasel, F., & Viete, S. (2019). BIG data–BIG gains? Understanding the link between big data analytics and innovation. *Economics of Innovation and New Technology*, 28(3), 296-316.

Ooi, K. B., Lin, B., Teh, P. L., & Chong, A. Y. L. (2012). Does TQM support innovation performance in Malaysia's manufacturing industry? *Journal of Business Economics and Management,* 13(2), 366-393.

Perdomo-Ortiz, J., Gonzalez-Benito, J., & Galende, J. (2009). An analysis of the relationship between total quality management-based human resource management practices and innovation. *The International Journal of Human Resource Management*, 20(5), 1191-1218.

Pinho, J. C. (2008). TQM and performance in small medium enterprises: The mediating effect of customer orientation and innovation. International journal of quality & reliability management. 25, 256-275.https://doi.org/10.1108/02656710810854278

Polese, F., Troisi, O., Grimaldi, M., & Romeo, E. (2019). A big data-oriented approach to decision-making: a systematic literature review. In 22nd *International Conference Proceedings* (pp. 472-496).

Prajogo, D. I., & Hong, S. W. (2008). The effect of TQM on performance in R&D environments: A perspective from South Korean firms. *Technovation*, 28(12), 855-863.

Prajogo, D. I., & Sohal, A. S. (2001). TQM and innovation: a literature review and research framework. *Technovation*, 21(9), 539-558.

Prajogo, D. I., & Sohal, A. S. (2003). The relationship between TQM practices, quality performance, and innovation performance: An empirical examination. *International journal of quality & reliability management* 20(8),901-918. https://doi.org/10.1108/02656710310493625

Prajogo, D. I., & Sohal, A. S. (2004). The multidimensionality of TQM practices in determining quality and innovation performance—an empirical examination. *Technovation*, 24(6), 443-453.

Rajagopalan, N., & Spreitzer, G. M. (1997). Toward a theory of strategic change: A multi-lens perspective and integrative framework. *Academy of management review*, 22(1), 48-79.

Rehman, M. U., Andargoli, A. E., & Pousti, H. (2019). Healthcare 4.0: Trends, Challenges and Benefits. In *30th Australasian Conference on Information Systems*

Roßmann, B., Canzaniello, A., von der Gracht, H., & Hartmann, E. (2018). The future and social impact of Big Data Analytics in Supply Chain Management: Results from a Delphi study. *Technological Forecasting and Social Change*, 130, 135-149.

Sadikoglu, E., & Olcay, H. (2014). *The effects of total quality management practices on performance and the reasons of and the barriers to TQM practices in Turkey*. Advances in Decision Sciences.

Sadikoglu, E., & Zehir, C. (2010). Investigating the effects of innovation and employee performance on the relationship between total quality management practices and firm performance: An empirical study of Turkish firms. *International journal of production economics*, 127(1), 13-26.

Sanders, A., Elangeswaran, C., & Wulfsberg, J. P. (2016). Industry 4.0 implies lean manufacturing: Research activities in industry 4.0 function as enablers for lean manufacturing. *Journal of Industrial Engineering and Management (JIEM),* 9(3), 811-833.

Sanders, N. R. (2016). How to use big data to drive your supply chain. *California Management Review,* 58(3), 26-48.

Schmidt, R., Möhring, M., Härting, R. C., Reichstein, C., Neumaier, P., & Jozinović, P. (2015, June). *Industry 4.0-potentials for creating smart products: empirical research results. In International Conference on Business Information Systems* (pp. 16-27). Springer, Cham.

Seth, D., & Tripathi, D. (2005). Relationship between TQM and TPM implementation factors and business performance of manufacturing industry in Indian context. *International Journal of Quality & Reliability Management*. 22(3):256-277

Shamim, S., Zeng, J., Shariq, S. M., & Khan, Z. (2019). Role of big data management in enhancing big data decision-making capability and quality among Chinese firms: A dynamic capabilities view. *Information & Management*, 56(6), 103135.

Sweis, R. J., Asma'a, S. I., Amayreh, I., & Al-Sayyed, N. (2019). The relationship Between Total Quality Management (TQM) implementation and organisation performance: evidence from the airlines companies in UAE. *International Journal of Information, Business and Management*, 11(1), 58.

Taj, S., & Morosan, C. (2011). The impact of lean operations on the Chinese manufacturing performance. *Journal of manufacturing technology management*, 22(2):223-240

Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic management journal*, 18(7), 509-533.

Teece, D., & Pisano, G. (1994). The dynamic capabilities of firms: an introduction. *Industrial and corporate change*, 3(3), 537-556.

Tortorella, G. L., Silva, E., & Vargas, D. (2018, October). An empirical analysis of total quality management and total productive maintenance in industry 4.0. In *Proceedings of the International Conference on Industrial Engineering and Operations Management (IEOM)* (pp. 742-753).

van den Broek, T., & van Veenstra, A. F. (2018). Governance of big data collaborations: How to balance regulatory compliance and disruptive innovation. *Technological Forecasting and Social Change*, 129, 330-338.

Wan, J., Tang, S., Shu, Z., Li, D., Wang, S., Imran, M., & Vasilakos, A. V. (2016). Software-defined industrial internet of things in the context of industry 4.0. *IEEE Sensors Journal,* 16(20), 7373-7380.

Wang, C. H., Chen, K. Y., & Chen, S. C. (2012). Total quality management, market orientation and hotel performance: The moderating effects of external environmental factors. *International journal of hospitality management*, 31(1), 119-129.

Zairi, M. (1994). Innovation or innovativeness? Results of a benchmarking study. *Total Quality Management,* 5(3), 27-44.

Zehir, C., Ertosun, Ö. G., Zehir, S., & Müceldilli, B. (2012). Total quality management practices' effects on quality performance and innovative performance. *Procedia-Social and Behavioral Sciences*, 41, 273-280.

Zeng, J., Phan, C. A., & Matsui, Y. (2015). The impact of hard and soft quality management on quality and innovation performance: An empirical study. *International journal of production economics,* 162, 216-226.

Zhang, J. A., Edgar, F., Geare, A., & O'Kane, C. (2016). The interactive effects of entrepreneurial orientation and capability-based HRM on firm performance: The mediating role of innovation ambidexterity. *Industrial Marketing Management*, 59, 131-143.