



Adoption of innovative strategies to mitigate supply chain disruption: COVID-19 pandemic

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Abstract

COVID-19 pandemic outbreak caused supply chain (SC) disruption and threatened human life across the world, which could be mitigated through innovative strategies. Based on this scenario, this study examines the impact of COVID-19 on green practices, SC crisis mitigation strategies, smart technologies, and sustainable supply chain performance in the Pakistani manufacturing industry. Data was collected from Pakistani firms and employed structural equation modeling for testing hypotheses. The empirical results found that the COVID-19 pandemic is statistically related to green practices, SC crisis mitigation strategies, and smart technologies, while it harms sustainable supply chain performance. Moreover, green practices, SC crisis mitigation strategies, and smart technologies positively contribute to sustainable supply chain performance. The results of this study also confirmed the mediating role of green practices, SC crisis mitigation strategies, and smart technologies and moderating role organizational commitment in the context of a developing economy's manufacturing industry. This study enhances awareness and understanding and contributes to the existing literature on verifying the link between COVID-19 pandemic and green practices, SC crisis mitigation strategies, and smart technologies to increase sustainable supply chain performance during a pandemic disruption in the Pakistani context. This study supports the managers of supply chain and manufacturing firms in adopting green practices and smart technologies. Also, it helps in the formation and successful implementation of SC crisis mitigation strategies during the crisis.

Keywords Supply chain disruption · Innovative strategies · Smart technologies · COVID-19 pandemic

1 Introduction

COVID-19 pandemic is not only life-threatening to human beings but also negatively impacting industries across the world. Therefore, businesses and societies have been exposed to the COVID-19 pandemic. The world manufacturing industry faces shortfalls in production and consumption

patterns, and their ultimate effect has also been recorded on sustainable supply chain operations. The COVID-19 outbreak resulted in lockdown and quarantine, which difficult the accessibility to markets, products, and materials; more specifically, any organization's workforces suffered emotionally, financially, and socially. Since COVID-19 declared a pandemic, world trade is critically affected and falls between

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13 and 32% (WTO 2020). Due to the enforcement of new laws and regulations, changes in customers' demands, and stringent working SOPs have forced manufacturing firms to manage their supply chain operations more efficiently and effectively considering the pandemic situation (Sharma et al. 2020b). No doubt COVID-19 has long and short-term impacts on the sustainable supply chain; organizations and governments need to introduce the ways of survival businesses to continue their operations without disruption during this situation regardless of increasing COVID-19 rate spread. While every department of any organization faces unprecedented challenges, adopting sustainable supply chain practices is bearing the brunt of the economic and social fallout of COVID-19. Since corona-virus starts spreading rather than China, Asian and European countries enforcing border restriction, quarantine, and lockdown caused the international trade deficit, the majority of global sustainable supply chains have become more vulnerable during this uncontrolled pandemic (Tirkolaee and Aydin 2021; Queiroz et al. 2020).

However, this epidemic's international cost might depend on the spread of COVID-19 in the world and on the required duration of quarantine and lockdown policies. At present, the COVID-19 pandemic is identified as a significant driver of adoption of green practices (Tiong et al. 2021), redesigning and re-imaging of SC (Sharma et al. 2020a), adoption of new technology (Shin and Kang 2020), international cost (Sharma et al. 2020b) and implementation of lockdown SOPs (Russell et al. 2021). The pandemic has affected countries' economies and societies and postures a significant challenge to every industry's sustainable supply chains across the world (Golan et al. 2020). Generally, the supply chain operations of the food and beverages, apparel, IT, agricultural, electronics industries are directly and significantly affected by COVID-19. Thus, 94% of the Fortune 1000 companies have been faced disruption in their supply chain operations due to the COVID-19 outbreak Fortune (2020). According to the data acquired by Resilience system world's largest 1000 SCs arranged more than 12,000 facilities in COVID-19 quarantine areas (Sharma et al. 2020b). A data analytics organization Dun and Bradstreet, informs that 51,000 international companies worldwide have at least one suppliers in Wuhan. Almost 5 million companies have tier-1 or tier-2 suppliers in Wuhan, the origin of the COVID-19 outbreak (Braw 2020). The threat spreading virus has significantly affected the traditional job culture; therefore, modern corporations are introducing remote working, working from home and flexible working hours to allow their workforce to be paid pandemic situation. Moreover, surviving firms can meet their social responsibilities with limited or flexible working hours.

The global sustainable supply chain practices contain environmental, economic, and social issues, motivating the companies to redesign and restructure their supply chain

practices to improve their relationship with suppliers through collaboration (Khan et al. 2020; Luo et al. 2021). However, supply chain governance and collaboration with suppliers are equally essential to build strong the relationship with end customers for acquiring sustainable competitive advantage (Kang and Kim 2017). Due to the fast spread of uncontrollable COVID-19 virus, more or less every person is facing life-threatening environment across the world that's why people are also facing unquestionable laws and regulations, safety equipment's and rule, temperature check, stock out the situation, controlled working hours and lockdown enforcing these SOPs all together poses massive responsibility on corporates stakeholders, regulators, and legislators to manage their supply chains activities in environmental, economic and social issues context (Sarkis et al. 2020). However, Ivanov (2020a) found that covid-19 has negatively affected the global supply chain and international logistics activities. Natural disasters such as earthquakes, covid-19 outbreak, legal disputes, and strikes have a substantial and immediate impact on global supply chain networks that result in a shortage of raw material, delays in deliveries, insufficient production, and sustainable supply chain performance (SSCP) degradation in term of financial and services loss (Goel et al. 2021).

However, the COVID-19 pandemic effect can be minimized by adopting green practices, supply chain crisis mitigation strategies, and smart technologies. Moreover, adopting green practices can also produce positive results in terms of SSCP and global supply chain performance, especially in the pandemic era. Similarly, the formation and application of SC crisis mitigation strategies also can positively contribute toward global supply chain performance and SSCP (Nguyen et al. 2020). However, to handle the COVID-19 impacts on SSCP and global supply chain performance, smart technologies in sustainable supply chain operation can generate better results and improve manufacturing firms' performance in the Pakistani context. Therefore, it is necessary to explore all these risk prevention strategies (green practices, SC crisis mitigation strategies, and smart technologies) in the Pakistani manufacturing and supply industry context.

Different studies related to supply chain sustainability in the COVID-19 era in prior literature only focused on exploring drivers, challenges (Karmaker et al. 2021; Kumar et al. 2020; Yu and Rehman Khan 2021). However, the literature review presents a research gap regarding the formulation of SC crisis mitigation strategies, implementation of green practices, and adoption of smart technologies. Moreover, no study has been found to identify and verify mediating green practices SC crisis mitigation strategies, smart technologies, and moderating organizational commitment between COVID-19 pandemic disruption and SSCP.

In the context of the rising concern of the world and for a better understanding of COVID-19 pandemic impacts on firms, this research extends the existing literature by

verifying the direct effect of COVID-19 on SSCP, green practices, SC crisis mitigation strategies, adoption of smart technologies and also verify the indirect relationship between COVID-19 pandemic and SSCP through mediators and moderator. To satisfy the objective of this study is to answer four main research questions:

- Q1. Does COVID-19 pandemic affect SSCP?
 Q2. Does the COVID-19 pandemic affect green practices, SC crisis mitigation strategies, and smart technologies?
 Q3. Do green practices, SC crisis mitigation strategies and smart technologies play mediating roles between the COVID-19 pandemic and SSCP?
 Q4. Does organizational commitment have a moderating effect on the relationship between green practices, SC crisis mitigation strategies, smart technologies, and SSCP?

This research will extend the existing literature and published work scholars by evaluating the synergistic relationship between COVID-19 pandemic and SSCP through mediating effect of green practices and SC crisis mitigation strategies and smart technologies and moderating effect of organizational commitment in the Pakistani supply chain industry in the context of COVID-19 pandemic. The novel's conceptual framework establishes significant supply chain management implications for Pakistani supply chain firms in this pandemic context.

The rest of the paper is structured in the following sections. In Sect. 2, the literature related to COVID-19 pandemic, green practices, SC crisis mitigation strategies, smart

technologies, organizational commitment, SSCP, and study proposed hypotheses. Section 3 presents the methodology. Section 4 contain analysis of the study and results. Section 5 covers discussion on the key findings with the support of previously published articles. Finally, research implications and future research direction of study are summarized in Sect. 6.

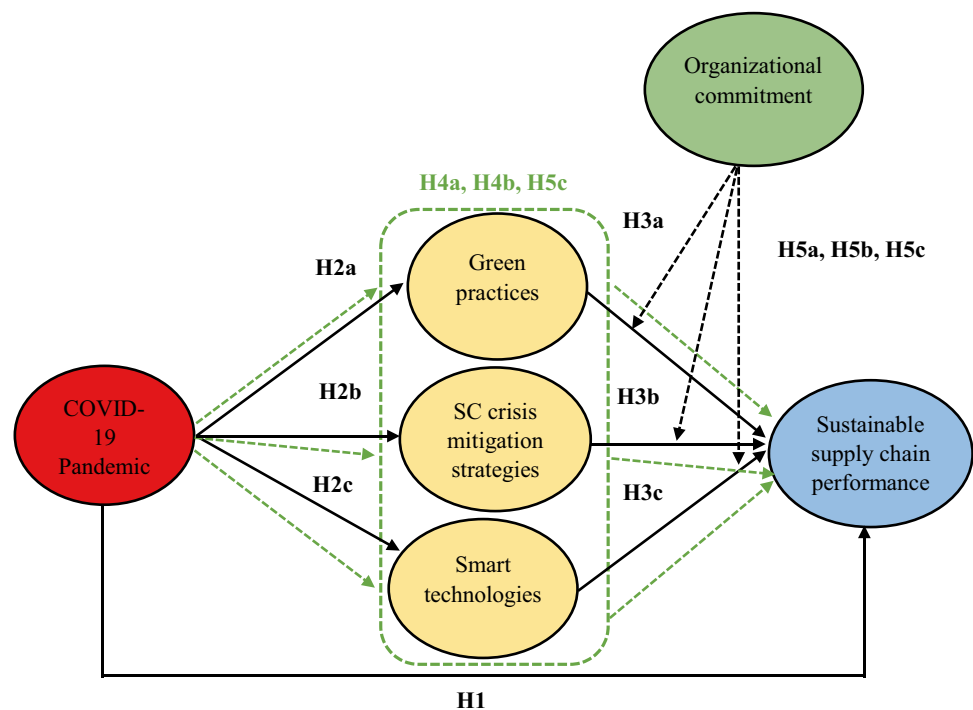
2 Literature review and proposed hypotheses

The objective of exploring extensive literature is to support this research's conceptual framework and verify the relationship between the COVID-19 pandemic and SSCP through a mediator and moderator path analysis. On behalf of the literature, hypotheses are proposed. A conceptual framework for green practices, SC crisis mitigation strategies, and SSCP, which verify causal effects with pandemic disruption, has also been proposed. Following the novel conceptual framework, different hypotheses have been proposed systematically, as shown in Fig. 1.

2.1 COVID-19 pandemic and sustainable supply chain performance

COVID-19 disruption is an indicator of the risk of loss, appropriate and effective strategies are required to overcome these disruptive events and minimized the financial damages (Pavlov et al. 2019). Several researchers in the

Fig. 1 Study conceptual framework



literature have verified the link between pandemic disruption and sustainable supply chain performance (El Baz and Ruel 2020; Singh et al. 2020). Earlier, scholars also worked on different conceptual models to overcome the supply chain disruption or uncertainties for maximizing the SSCP. For instance, Altay et al. (2018) introduced a conceptual framework for humanitarian supply chain performance for controlling the supply chain risk in "before," "during," and "after" disaster disruption stages. Same way, I discovered a dynamic conceptual framework for mapping the supply chain performance level according to the context of disruption, such as total and partial disruption. However, a systematic model has been developed by to observe supply loading and unloading sequences through smart and automatic robots for increasing the productivity of manufacturing units. Similarly, Tirkolae et al. (2021) introduced comprehensive model by employing mixed-integer linear programming for proposing sustainable multiple locations for handling and dumping infectious medical waste during COVID-19 outbreak.

Moreover, Ivanov et al. (2021) suggested a strategic framework to dealing with supply chain and logistics challenges and supply losses during strong, medium, and mild disasters. Ivanov (2020b) introduced a viable supply chain model that guided the supply chain firms to redesign and restructure their SCs during long or short term crises such COVID-19 epidemic to sustain its sustainable supply chain performance and survive in a fluctuating environment. Sharma et al. (2020c) and Yan et al. (2020) studies revealed the unprecedented risk during the COVID-19 pandemic that significantly impacts the agricultural supply chain. Thus, the sustainable supply chain pursues to reduce its negative impact on operations and improve firms' economic, environmental, and social performance. Therefore, based on the above literature, we hypothesized that:

H1. The COVID-19 pandemic negatively influences sustainable supply chain performance

2.2 COVID-19 pandemic and green practices

During the COVID-19 outbreak period, cleanliness implores the adoption of green practices and should be considered seriously to reduce the chances of transmission of viruses during supplying goods (Tiong et al. 2021). Tirkolae et al. (2021) explored and validated the different green solutions for disposal of medical waste through mathematical models to effectively control spread of COVID-19 virus. Similarly, Torkayesh et al. (2021) designed sustainable healthcare waste management networks for the objective of controlling and managing medical waste at minimum transportation cost and carbon emission to reduce the medical waste burden on environment and create the maximum jobs opportunities during pandemic. However, cleaner production is an

undeniable approach that manufacturing firms implement during the production processes to decrease their adverse effects on the environment (Dong et al. 2019). However, green practices continuously attract industry leaders, scholars, governments, authorities, and societies (Amankwah-Amoah 2020). According to Lahcen et al. (2020), industries' adoption of green practices from internal motivation to protect the environment or externally enforced by governments or regulators authorities decreases green gas emissions from industries activities during the pandemic crisis. Usually, green practices have significantly positively correlated with waste reduction, pollution reduction, green energy consumption, and recycled material consumption to ensure the sustainable product/service should be delivered to customers (Amankwah-Amoah 2020). Hence, minimizing the different kinds of pollution (i.e. water pollution, air pollution and land pollution) and waste supports manufacturing firms to minimize their operating costs and successfully implement the firm's green agenda (Yin et al. 2020). During stringent COVID -19 lockdown and quarantine strategies caused a significant reduction in road and non-road transportation, and businesses and industrial operations have also been stopped or reduced, which led to a significant reduction of water waste, chemical use, and healing ozone layer (Sicard et al. 2020). Hence, we hypothesized that:

H2a. COVID-19 pandemic is positively correlated with green practices

2.3 COVID-19 pandemic and SCs crisis mitigation strategies

During the COVID-19 outbreak, all countries, including World Health Organization (WHO), introduced different strategies such as (i.e., border hindrance, lockdown, quarantine, and social distance strategies) to stop or decrease the transmission of corona-virus to save human lives without stopping the supply of essential items such food and medicine to fight against infection. Therefore, better formation and successful implementation of SCs chain crisis mitigation strategies are the only solutions of SSCP in any crisis such as the COVID-19 pandemic (Beaunoyer et al. 2020). In earlier literature, Gupta et al. (2020) identified the various barriers to supply chain sustainability and recommended effective crisis mitigation strategies to deal with hindrance in adopting sustainable supply chain practices during the COVID-19 crisis. Singh et al. (2019b) introduced an ontology-based decision that intensifies the supply chain resilience during an emergency. Similarly, Vargo and Seville (2011) proposed a dynamic conceptual framework with crisis management strategies that engendering resiliency supply chain during supply chain disruption. Ivanov (2020b) suggested a viability model in the supply chain, which worked in both long

and short-term crisis disruption. A viable concept is the combination of three perspectives agile and resilience SC and sustainable practices. Coibion et al. (2020) investigated and found dreadful effects of COVID-19 crisis on societies and organizations across the world and their resulted suggested the solutions to controlled or minimized pandemic crisis impacts through adoption through successful adoption of crisis mitigation strategies. However, Weber et al. (2021) believed vaccination is only solution for world to return towards normalization and to reduce the COVID-19 severity on individuals and organizations. Therefore, we hypothesized that:

H2b. COVID-19 pandemic is positively correlated with SCs crisis mitigations strategies

2.4 COVID-19 pandemic and adoption of smart technologies

Adopting advanced smart technologies, i.e., autonomous mobile robots, automatic inspection systems, and additive manufacturing, might help decrease the effect of COVID-19 by reducing the workforce, which directly impacts coronavirus transmission (Chen and Lin 2020). Tavakoli et al. (2020) argued that the implementation of autonomous systems, smart wearable complements, and the adoption of robotic systems significantly reduced the risk of virus transmission during work in the healthcare industry. Chen and Lin (2020) the implementation of automatic technologies such as automated inspection systems can ensure the long-term operations of the manufacturing industry during lockdown situations and control the fast spread of novel COVID-19 virus. Tareq et al. (2021) suggested that adopting an additive manufacturing system can enable manufacturing firms to meet the explosive demand of customers worldwide during a pandemic context. According to Chen and Lin (2020) more robotics machines and automation systems are expected use in every field of life than earlier planned. Wright (2019) noticed the lasting boom robotics and automation industry. In the COVID-19 pandemic situation, automation's primary goal is shifting to tasks in which social distance strategy is inapplicable. Since the last two-decade, automation technologies such as cloud manufacturing and artificial intelligence have gained popularity and brought revolutions and financial benefits to the manufacturing industry, their application during a pandemic is questioned (Chen and Lin 2020).

Moreover, the automated machines are controlled and operated by a minicomputer with touch-pads or a keyboard that the corona-virus transmission might cause. To overcome these virus transmitting barriers, the computerized machines should be operated and controlled by voice commands, gestures, or remotely controlled by an application on

smartphones (La Mura and Lamberti 2020). Based on the above literature, we hypothesized that:

H2c. COVID-19 pandemic is positively correlated with smart technologies

2.5 Green practices, SC crisis mitigation strategies, smart technologies, and sustainable supply chain performance

In this pandemic era, adopting green practices, SC crisis mitigation strategies, and smart technologies play a bridging role in sustaining and enhancing sustainable supply chain performance. Fasan et al. (2021) adopting green supply chain practices served as an effective drug to improve supply chain performance in the US manufacturing industry during the pandemic context. Similarly, Trivellas et al. (2020) results indicated that green supply chain practices positively correlate with sustainable performance, business performance, and supply chain performance in the agriculture supply chain industry. Yang et al. (2021) confirmed that the formation of SC mitigation strategies and their implementation capabilities can reduce the pandemic impact on the supply chain and enhance supply chain resilience. However, Broadstock et al. (2021) explored the relationship between risk mitigation strategies and environmental, social, and governance performance during a global pandemic outbreak. Nandi et al. (2021) found that the adoption of blockchain technology enhances supply chain resilience and supply chain agility during a crisis. Similarly, tried to make the supply chain more resilient and introduced a simulation model for food distribution during COVID-19 outbreak. Therefore, based on the above literature, we hypothesized that:

H3a. Green practices are positively correlated with sustainable supply chain performance.

H3b. SC crisis mitigations strategies are positively correlated with sustainable supply chain performance

H3c. Smart technologies are positively correlated with sustainable supply chain performance.

2.6 The mediating role of green practices, SC crisis mitigation strategies, and smart technologies

In this era, an investment in environmental technologies has been increased by manufacturing industries that might help appreciate the adoption of green practices. COVID-19 pandemic pressure businesses to be responsible for making sure they control or stop the spread of coronavirus among their workforce during their business operations. Meanwhile, in this pandemic perspective, organizational COVID-19 proactive strategies and competencies can tackle the current situation and enable the firms to adopt green practices to generate

green innovations and increase SSCP. In prior literature, according to Khan and Qianli (2017), green practices are classified in literature into five different categories of green purchasing, green manufacturing, eco-design, green information system, and cooperation with customers. COVID-19 pandemic has enhanced the application of green practices to intensify SSCP (Yin et al. 2020). Amankwah-Amoah (2020) researched the global airline industry and verified the complementary association between the COVID-19 pandemic and environmental performance through green business practices. Pacheco et al. (2018) discovered that green absorptive capacity positively moderates the relationship between ecological factors and green innovation performance in the Brazilian electric power industry.

Liu et al. (2017) found that Crisis management strategies are remedies to minimize the negative impacts of product recall volumes in firms' long-term values and positively moderate the relationship between recall volume and firm long-term values. Nizamidou et al. (2019) confirmed that crisis management procedures play an active mediating role between organizations' safety and quality experience and all stages of the crisis of human resource departments to minimize the impact of the natural crisis. Ham and Kim (2019) proposed a conceptual framework that verified situational crisis communication play an essential role when the situation is accidental, such as COVID-19 pandemic and when corporate social responsibility (CSR) history is short and found that crisis responsibility mediated positive relationship between crisis type of behavioral intentions and CSR history (Table 1).

The infection of novel coronavirus is not going to fall without the vaccine. Still, its impacts on human being's safety and economy can be reduced by implementing smart technology to fight the pandemic. The application of innovations and innovative tactics has verified to reduce the risk of COVID-19 during working in industries effectively. In earlier literature, Li et al. (2020) discovered the digital supply chain platform mediating impact had enhanced the relationship between digital technologies and environmental and economic performance. Smart technological turbulence strengthens the relationship between marketing capabilities and marketing communication in Mexico (Martin et al. 2020). Nasiri et al. (2020) developed a dynamic conceptual model that confirmed smart technologies fully mediated the significant positive relationship between digital transformational and relationship performance in small and medium-sized companies. Thus, based on the above literature, we hypothesized that:

H4a. *Green practices mediate the relationship between COVID-19 pandemic and sustainable supply chain performance.*

H4b. *SC crisis mitigation strategies mediate the relationship between the COVID-19 pandemic and sustainable supply chain performance*

H4c. *Smart technologies mediate the relationship between the COVID-19 pandemic and sustainable supply chain performance.*

2.7 The moderating effect of organizational commitment

Organizational commitment is a complex factor and the primary driver of building and sustaining the corporate green image among manufacturing industries in the current volatile market (Almeida and Coelho 2019). When organizations are committed, they can be better positioned to implement green practices in their manufacturing operation, introduce crisis mitigation strategies to overcome the long and short-term crisis such as a pandemic, and adopt smart technologies to fight an uncertain situation COVID-19 outbreak (Athar 2020). Moreover, committed and good reputational companies also can reduce advertising costs and contracting costs with suppliers (Chen and Practice 2019). However, employee organizational commitment describes at which level the employees are connected with organizational goals and are delightful to personal sacrifices for their corporate performance (Sintaasih et al. 2019). Similarly, organizations' fair treatment with employees will lead an organization to a good relationship with employees, significantly impacting employees' task performance and customer satisfaction (Eliyana and Ma'arif 2019). In the existing literature, Cantele and Zardini (2018) found organizational commitment is the first-stage mediator and positively mediated the relationship between corporate social dimensions and competitive advantages. Patiar and Wang (2016) confirmed that organizational commitment has significantly partially mediated the relationship between transformational leadership and departmental performance in the Australian automobile industry. Wang et al. (2021) proposed a conceptual model that confirmed the moderated role of affective organizational commitment between supervisor narcissism and extra-role performance. Lim et al. (2020) verified the potential moderating effect of organizational commitment between emotional exhaustion and cyberloafing in the Malaysian public listed manufacturing industry. Thus, based on the above literature, we hypothesized that:

H5a. *Organizational commitment moderates the positive relationship between green practices and sustainable supply chain performance*

H5b. *Organizational commitment moderates the positive relationship between SC crisis mitigation strategies and sustainable supply chain performance*

H5c. Organizational commitment moderates the positive relationship between smart technologies and sustainable supply chain performance

3 Research methodology

Pakistani supply chain firms or supply chain departments of the manufacturing industry were the targeted populations of this study registered with the Securities and Exchanges Commission of Pakistan. Data was also collected from supply chain and logistics professors and supervisors in Pakistan universities to verify this study's hypotheses. Data collection was gathered from different provinces of Pakistan, including Punjab, Sindh, Khyber Pakhtunkhwa, and Balochistan; for more detail, see demographical information and data collection details in Tables 2 and 3, respectively.

Initially, the questionnaire was designed in the English language. Considering our targeted population, the questionnaire was translated into the Urdu language before its circulation among respondents. The authors invited two Urdu language specialists from the Urdu department of a university to validate the questionnaire content and ensure translation inconsistencies were removed. Once we received the Urdu language version of the questionnaire from experts, we wrote an invitation letter to each selected firm's CEOs to invite their firm to participate in this research. After the CEO's approval, an electronic survey option was considered for data collection. The survey questionnaire has sent to about 30 employee's respondents and 30 academics respondents for pilot testing. Once the pilot testing results have ensured the developed scale's reliability and the values of Cronbach's alpha and factor loadings were satisfied. After confirming the reliability developed scale, we shared web-based the final questionnaire links in different WhatsApp; Facebook groups created and controlled by supply chain & logistics, and manufacturing firms for their business activities. The questionnaire was also sent to respondents through e-mails, WhatsApp, and LinkedIn. This research gathered the data from the top-level, middle-level, and lower-level management, as they mentioned in their organizational policy responses. The data was also collected from those academics (Professors, Assistant professors, and Lecturers) who sound knowledge about production systems and the manufacturing industry's supply chain. However, most of the selected academicians respondents directly or indirectly provided their consultancies or serveries to the manufacturing industry to ensure their long-term survival during a lockdown situation. Therefore, the authors of this study decided to collect data from universities academicians to guide the manufacturing and supply chain firms on how they can modify their operations or adopt preemptive measures according to lockdown requirements. Finally, 230 filled responses were received;

however, 16 responses were received as incomplete. Moreover, 214 questionnaires were identified as useable for further analysis. Figure 1 presents how the authors have verified the relationship between the COVID-19 pandemic, SSCP through mediation effect of green practices, SC crisis mitigation strategies, smart technologies, and moderation role organizational commitment.

A "five-point Likert scale" ranging from 1 (strongly disagree) to 5 (strongly agree) adopted to answer the items in the questionnaire. The COVID-19 pandemic constructs focus on four items, and the scale has adopted from a prior study of El Baz and Ruel (2020) with a practical value of Cronbach's alpha ($\alpha = 0.88$). Respondents of this study were instructed to rate their responses to six items of green practices construct adopted from Khan and Qianli (2017) with an acceptable value of ($\alpha = 0.90$). We measured five items of the SC crisis mitigation strategies construct adopted from Beaunoyer et al. (2020) and Speier et al. (2011) with a standardized value of Cronbach's ($\alpha = 0.82$). The scale of ST (six items) has adopted from an earlier study by Chen and Lin (2020) (Cronbach's is $\alpha = 0.95$). The constructed scale of organizational commitment with (four items) has been adopted from Lim et al. (2020) ($\alpha = 0.86$). Lastly, seven items of SSCP were adopted from earlier literature from the study of Altay et al. (2018) and Sharma et al. (2020b) to measure the construct of SSCP (Cronbach's $\alpha = 0.93$).

4 Analysis of data and results

Mean and standard deviation (S.D) applied to verify the relationship between COVID-19 pandemic and SSCP through mediation path analysis of green practices, SC crisis mitigation strategies, smart technologies, and the moderation effect of organizational commitment also verify the relationship between green practices, SC crisis mitigation strategies, smart technologies, and SSCP. Mean and S.D values are ranging between 1.70–5.89, 0.338–0.873, respectively. The results analysis means that green practices, SC crisis mitigation strategies, and smart technology adoption have increased during the pandemic to sustain and increase the SSCP.

4.1 Reliability and validity

Cronbach's alpha test indicated values for internal consistency ranging from 0.82 to 0.95 of each construct, which meets the criteria of 0.70 suggested by Hair et al. (2010); further details see Table 4. Thus, these findings have confirmed the reliability of the developed scale.

In this study, authors have used AMOS 23.0 trial version statistical analysis software to perform Structural Equation Modeling (SEM), a research technique to verify the

relationship between COVID-19 pandemic, SSCP, green practices, SC crisis mitigation strategies, smart technologies, and organizational commitment. According to Sadikaj et al. (2021), SEM is a unique and widely used research technique that can eliminate biases effect and help build latent constructs. Kaiser–Meyer–Olkin (KMO) test has been performed to check sample adequacy. KMO value is (0.864) consistent with the criteria recommended by Kaiser and Rice (1974), which means the sample is suitable for performing factor analysis. Moreover, items with less than 0.40-factor loadings were deleted as the standards recommended by Hu and Bentler (1999). However, the factor loading of selected items is ranging between 0.583–0.948 that fulfill the criteria. EFA results are presented in Table 4.

4.2 Assessment and measurement of a structural model

In the next step, after performing EFA, Confirmatory Factor Analysis (CFA) has acted to testify and verify the construct validity of six constructs (32 items). AMOS 23.0 trial version was used to perform CFA, which is one of the significant research methods of SEM and is commonly applied in supply chain management (Khan and Qianli 2017). When researchers have inadequate information, the execution of a multi-variation regression test helps identify a complex relationship between selected factors. Moreover, the adequacy of the measurement model of all constructs was measured by factor loadings and composite reliability (CR), convergent and discriminant validity and average variance extracted (AVE). Thus, the convergent validity and discriminant validity was analyzed. To run this test, factor loadings of selected items should be higher than 0.60 (Byrne 2001). However, the AVE values in each construct were greater than 0.50, the criteria suggested by (El Baz and Ruel 2020). Lastly, CR values for all constructs were higher than the lower limit of criteria 0.60 suggested by (Byrne 2001). The CFA's final results, a correlation among different factors, and model fitness are presented in Tables 5 and 6.

Byrne (2001) Suggested nine fit indices indicators that confirm the fitness of measurement model such as Non-Normed Fit Index (NNFI), normative fit index (NFI), comparative fit index (CFI), the goodness of fit index (GFI), adjusted goodness of fit index (AGFI), Tucker-Lewis's index (TLI), Chi-square to the degree of freedom (CMIN/DF), root mean square error of approximation (RMSEA) and standardized root mean squared residual (SRMR). The values of fit indices, such as NNFI, NFI, CFI, GFI, and TLI, were greater than the limit criteria suggested (Waqas et al. 2018b). The measurement model results showed that the value of CMIN/DF is 1.932, which is lower than 2, as suggested by (Browne 1993), and meets lower than 3. The value of RMSEA was 0.038, which is lower than the standard value

of 0.08 proposed by (Browne 1993). Lastly, the value of SRMR 0.028 also fulfilled the criteria suggested by (Waqas et al. 2018b); for more details, see Table 5.

4.3 Results of hypotheses testing

In this study, the mediation and moderation hypotheses were verified through hierarchical multiple regression analysis according to the recommendations (Muller et al. 2005). Furthermore, considering the guidelines given in the study of Zhao et al. (2010), mediating and moderating path analysis was confirmed by performing scripts to examine the direct and indirect relationship. The mediation and moderation results are presented in Tables 7 and 8, respectively (Fig. 2).

Model 1, model 3, model 5, model 7, and Model 9 in Table 7 represent control variables impacting SSCP. Similarly, model 2, model 4, model 6, and model 8 show the direct relationship in Table 7. Model 2 (H2a, H2b, and H2c) proposes a positive direct relationship between COVID-19 pandemic and green practices, SC crisis mitigation strategies, and smart technologies. The study findings validate the positive direction relationship between COVID-19 and H2a green practices ($\beta=0.560$; $p\leq 0.001$); H2b SC crisis mitigation strategies ($\beta=0.446$; $p\leq 0.001$); and H2a smart technologies ($\beta=0.605$; $p\leq 0.001$). Model 8 (H3a, H3b, H3c) proposes a significant positive direct association between green practices, SC crisis mitigation strategies, smart technologies, and SSCP. Moreover, study results also verify the direct association between green practices and SSCP H3a ($\beta=0.356$; $p\leq 0.01$); SC crisis mitigation strategies H3b ($\beta=0.239$; $p\leq 0.05$) and smart technologies and SSCP H3c ($\beta=0.521$; $p\leq 0.001$). However, model 8 (H1) COVID-19 is not related to SSCP ($\beta=-0.235$; $p\leq 1$).

According to PROCESS recommendations, macro and bootstrapped analysis were applied to verify the mediation role of green practices, SC crisis mitigation strategies, smart technologies between the COVID-19 pandemic and SSCP. Mediation analysis was satisfied by applying 10,000 bootstrap samples & a 95% confidence interval (CI). If the values are higher and smaller than 95% and both CIs values will be above zero. Model 9, model 10, and model 11 (H4a, H4b, H4c) show the moderating role of green practices, SC crisis mitigation strategies, smart technologies between COVID-19 pandemic and SSCP. However, the results of this study confirmed that green practices positively mediate the relationship between COVID-19 pandemic and SSCP ($\beta=0.354$; $p\leq 0.01$); SC crisis mitigation strategies more strongly mediate relationship as compared to green practices between COVID-19 pandemic and SSCP ($\beta=0.468$; $p\leq 0.01$) and ST also positively mediate the relationship between green practices between COVID-19 pandemic ($\beta=0.638$; $p\leq 0.01$). Table 7 is presenting the mediation

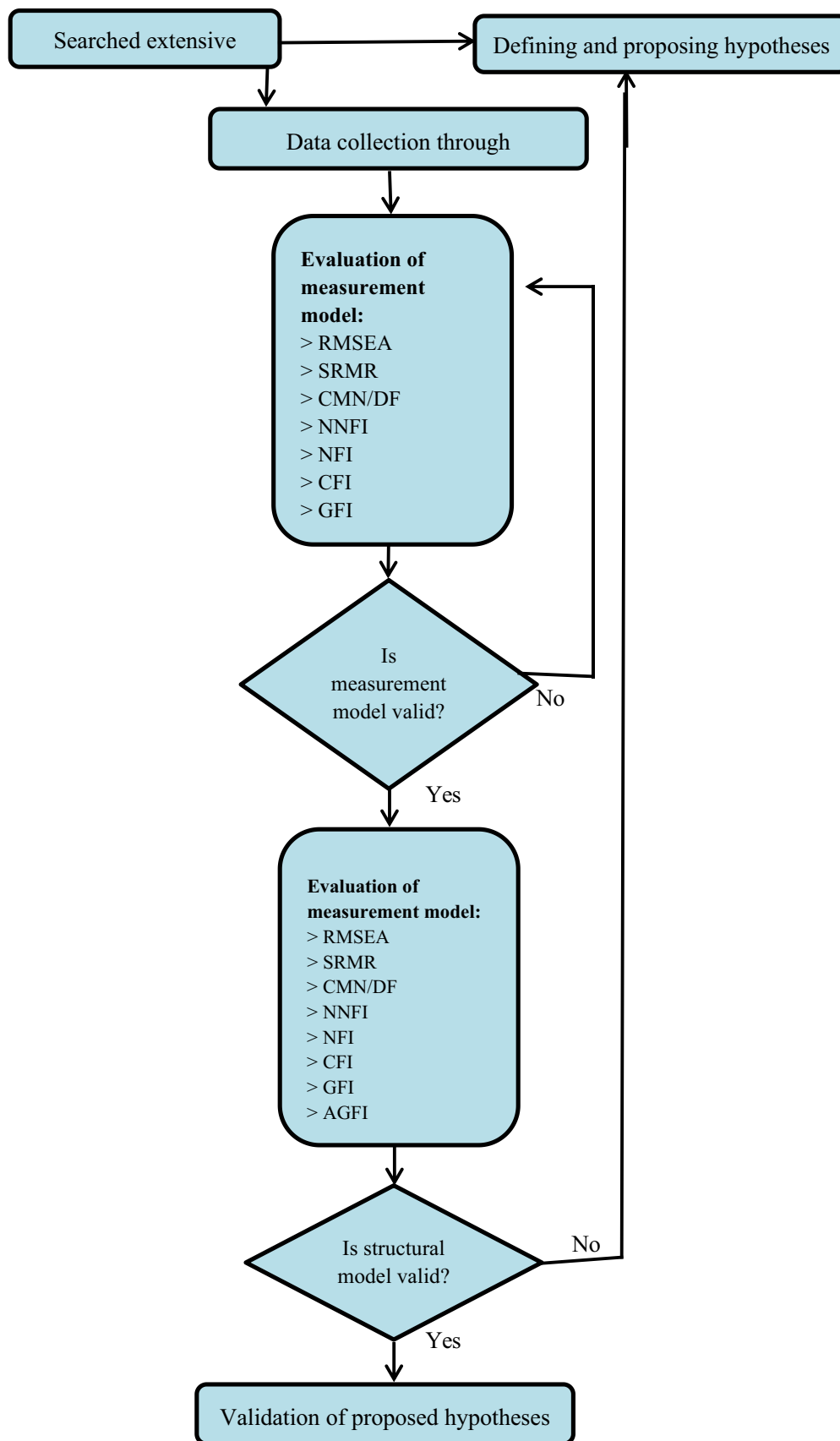


Fig. 2 Proposed data analysis scheme for hypotheses validation

Table 1 The tabular form of literature supporting industry 4.0 and circular economy practices

No	Industry 4.0 Study Findings and literature contribution	Source	Circular economy practices Study Findings and literature contribution	Source
1	Introduced a novel conceptual framework to measure the supply chain issues in the era of industry 4.0	(Singh et al. 2019a)	(Waqas et al. 2018a) identified and verified the top five barriers that hinder reverse logistics operation in the Pakistani manufacturing industry	(Waqas et al. 2018a)
2	New technologies positively influenced the green production of the manufacturing firms and improved sustainable firm performance during industry 4.0	(Kummitha 2020)	Singh et al. (2019b) Has introduced a novel research model that controls supply chain disruptions through knowledge sharing to control supply chain operations during COVID-19 pandemic outbreak under a circular economy context	Singh et al. (2019b)
3	A smart and automation technologies have ensured long-term performance during the pandemic of the manufacturing industry	(Chen and Lin 2020)	Cleaner production practices are undeniable to reduce the manufacturing industry operations burden on the world ecological system	(Dong et al. 2019)
4	(El Baz and Ruel 2020) has introduced the comprehensive conceptual research model to control supply chain disruption during COVID-19 in industry 4.0	(El Baz and Ruel 2020)	Gupta et al. (2020) filed the list of essential barriers and overcoming strategies that hinder sustainable supply chain operations in the Indian manufacturing industry under the circular economy context	Gupta et al. (2020)
5	Similarly, Ivanov (2020a) found that the COVID-19 pandemic negatively impacted supply chain performance, but adopting innovativeness technologies can reduce supply chain disruption	Ivanov (2020a)	(Minunno et al. 2020) found that adopting circular economy practices such as recycling, reusing and redesigning for end-of-life products reduced the greenhouse emission by 88% and was beneficial for environmental indicators	(Minunno et al. 2020)
6	Prior literature stated that digital technologies positively enhanced sustainable firm performance in the era industry 4.0	(Li et al. 2020)	(Tiong et al. 2021) believed that cleaner operations positively contributed towards green recovery in the hotel industry during COVID-19 pandemic outbreak	(Tiong et al. 2021)
7	In the same direction, earlier literature found intelligent and autonomous technologies significantly contributed to green product innovation and manufacturing industry performance	Makris (2021)	(Wang and Yang 2021) stated that product redesign and green innovation significantly positively impacted sustainable firm performance and reduced the burden of the Chinese manufacturing firms on the world ecological system	(Wang and Yang 2021)
8	Robotic and intelligent technology has positively reduced the severity of pandemics and controlled virus transmission during the production processes of the manufacturing industry	(Wang and Wang 2021)	(Karmaker et al. 2021) identified and mitigated the significant drivers to a sustainable supply chain in the Bangladeshi manufacturing industry during a pandemic outbreak in the circular economy	(Karmaker et al. 2021)
9	Prior literature confirmed that artificial intelligence significantly reduced SC risks and played an essential role in managing the supply of agricultural goods during lockdown situations during pandemic outbreaks	(Nayal et al. 2021)	COVID-19 pandemic has exposed the manufacturing and supply chain firms; thus, earlier literature has found redesigned supply chains by developing digitalization, localization, and agility and linked them with blockchain circular economy practices	(Nandi et al. 2021)
10	In the same direction, explored how deep learning techniques, artificial intelligence, and machine learning can perform their role in forecasting future disasters in light of COVID-19 pandemic	(Shastry and Sanjay 2021)	(Edwin Cheng et al. 2021) Confirmed that circular economy practices significantly influenced BDA capabilities and sustainable supply chain performance in the Hong Kong manufacturing industry	(Edwin Cheng et al. 2021)

Table 2 Demographical details

Particulars	Description	Employees		Academia	
		Numbers	Percentage	Number	Percentage
Gender	Male	76	55.88%	48	61.54%
	Female	60	44.12%	30	38.46%
Total		136	100%	78	100%
Age	20–29 years	24	17.65%	05	6.41%
	30–39 years	58	42.65%	35	44.87%
	40–49 years	35	25.73%	24	30.77%
	Above 50 years	19	13.97%	14	17.95%
Total		136	100%	78	100%
Education	High school and below	08	5.88%	0	0
	Undergraduate	73	53.68%	0	0
	Postgraduate	55	40.44%	78	100%
Total		136	100%	78	100%
Management levels	Top level management or Professor	14	10.29%	13	16.67%
	Middle-level management or Assistant professor	54	39.71%	40	51.28%
	Lower-level management or Lecturer	68	50.00%	25	32.05%
Total		136	100%	78	100%
Job experience	Less than 5 years	37	27.21%	16	20.51%
	6–9 years	58	42.65%	30	38.46%
	10–14 years	27	19.85%	19	24.36%
	Above 15 years	14	10.29%	13	16.67%
Total		136	100%	78	100%

results of green practices, SC crisis mitigation strategies, and smart technologies.

In this study, to identify and verify the moderation effect of organizational commitment, MODPROBE macro was proposed to apply in Statistical Package for the Social Sciences (SPSS) according to the guidelines of (Hayes and Matthes 2009). Commonly, MODPROBE macro is used to verify the moderation effect of factors in a structural model. Five-thousand bootstrap resamples were utilized to generate the statistical output in MODPROBE. In the next step, the authors examined H5a, H5b, and H5c, considering Hayes and Matthes (2009) recommendations for verifying organizational commitment moderating role in a model. Similarly, in Table 8 (moderation effect), model 1 and model 2 represent control variables and direct relationships, respectively. Although, model 3* (H5a, H5b, H5c) proposes the moderating role of organizational commitment between green practices, SC crisis mitigation strategies, smart technologies, and SSCP. Our study results verified that organizational commitment positively moderating between green practices and SSCP H5a ($\beta = 0.648$; $p \leq 0.001$); organizational commitment is positively moderating between SC crisis mitigation strategies and SSCP ($\beta = 0.465$; $p \leq 0.001$) and finally, organizational commitment is also positively moderating between smart technologies and SSCP ($\beta = 0.664$; $p \leq 0.001$). For more details, it can be found in the moderation effect Table 8.

Table 3 Data collection details

Provinces	Numbers	Cities	Numbers
Islamabad	15	Islamabad	15
		Punjab	88
Sindh	36	Faisalabad	18
		Lahore	15
		Multan	10
		D.G.Khan	08
		Gujranwala	11
		Sialkot	05
		Rawalpindi	07
		Bahawalpur	06
		Sargodha	03
		Sahiwal	05
		Karachi	25
		Sukkur	09
Khyber Pakhtunkhwa	30	Hyderabad	02
		Peshawar	12
		Swat	08
		Mardan	06
Balochistan	45	Abbottabad	04
		Quetta	10
		Gwadar	20
		Khuzdar	06
		Turbat	07
		Makran	02
Total	214	Total	214

Table 4 Instrument reliability and validity

Factors	Items	Factor loading ranges	Cronbach's Alpha	AVE	CR
COVID-19 pandemic	4	0.678–0.885	0.88	0.674	0.834
COVID-19P1		0.725			
COVID-19P2		0.678			
COVID-19P3		0.840			
COVID-19P4		0.885			
Green practices	6	0.740–0.890	0.90	0.638	0.860
GP1		0.740			
GP2		0.768			
GP3		0.856			
GP4		0.779			
GP5		0.801			
GP6		0.890			
SC crisis mitigation strategies	5	0.583–0.817	0.82	0.569	0.749
SCCMS1		0.682			
SCCMS2		0.705			
SCCMS3		0.590			
SCCMS4		0.583			
SCCMS5		0.817			
Smart technologies	6	0.709–0.945	0.95	0.695	0.875
ST1		0.823			
ST2		0.755			
ST3		0.880			
ST4		0.709			
ST5		0.902			
ST6		0.945			
Organizational commitment	4	0.664–0.822	0.86	0.558	0.768
OC1		0.664			
OC2		0.785			
OC3		0.822			
OC4		0.754			
Sustainable supply chain performance	7	0.765–0.948	0.93	0.687	0.906
SFP1		0.789			
SFP2		0.804			
SFP3		0.909			
SFP4		0.765			
SFP5		0.948			
SFP6		0.920			
SFP7		0.886			

5 Discussion

An outbreak of COVID-19 is proved as an unprecedented event in human history that is life-threatening to people and affects the world supply chain system. The lockdown situation is a unique challenge for supply chain managers and decision-makers, guaranteeing sustainability in supply chain operations during a pandemic demands changes in existing SC operations. To resolve this issue, barriers and drivers related to adopting green practices, SC crisis

mitigation strategies, and smart technologies, which might have a significant positive effect on SSCP during this pandemic, should be undoubtedly identified and verified. Therefore, this study evaluated the relationship between the COVID-19 pandemic and SSCP through the mediation role of green practices, SC crisis mitigation strategies, smart technologies, and moderation effect of organizational commitment. The current study has presented a new conceptual framework with different direct and mediation moderation hypotheses between the COVID-19 pandemic and SSCP.

Table 5 Discriminant validity analysis

Factors	COVID-19	GP	SC-CMS	ST	OC	SSCP	Mean	S.D
COVID-19	-						3.65	0.634
GP	0.516**	-					1.98	0.426
SC-CMS	0.386*	0.256**	-				2.54	0.338
ST	0.485**	0.509**	0.488**	-			4.56	0.765
OC	0.287**	-0.425	-0.228	0.386**	-		1.70	0.743
SSCP	0.568**	0.490**	0.561**	0.358***	0.465**	-	5.89	0.873

GP Green practices, OC organizational commitment, SC-CMS SC crisis mitigation strategies, ST smart technologies

*P (P < 0.05); **P (P < 0.01); ***P (P < 0.001)

Sustainable supply chain performance required various kinds of resources, processes, and operational excellence during pandemic disruption situations in the Pakistani context. As mentioned by Ivanov et al. (2021), the supply chain operations of food and beverages, apparel, IT, agricultural, electronics industries are directly and significantly affected by COVID-19. Thus, adopting green practices, smart technologies, and implementation of supply chain crisis mitigation strategies are ideal concepts that require specific adoption by supply chain manufacturing firms without disrupting their supplies during a lockdown.

The results of this study have been divided into three types of hypotheses, such as (i) direct relationship, (ii) mediation effect, and (iii) moderation effect in five types of hypotheses. The direct results have summarized three hypotheses (H1, H2a, H2b, H2c and H3a, H3b, H3c). The results direct of the study in (H2a, H2b, H2c) indicated that COVID-19 seems to positively influence the adoption of green practices and smart technologies and directly affect SC crisis mitigation strategies in the Pakistani pandemic context. In this current situation, it is essential to understand how the adoption of green practices, smart technologies, and successful implementation of SC crisis mitigation strategies might be helping businesses in making money in pandemic disruption; however, our study results are supported by an earlier study by El Baz and Ruel (2020) his empirical study results confirmed that COVID-19 pandemic disruption directly related with supply chain risk management strategies (SCRMS), besides, also verified the mediating role of SCRMS between COVID-19 pandemic disruption and supply chain resilience and robustness in French manufacturing firms. H1 is describing that SSCP was negatively affected by the COVID-19 pandemic, which proved that supply chain

and manufacturing survival could be increase by the adoption of green practices and smart technologies, which is confirmed by Nasiri et al. (2020) demonstrated that the adoption of smart technologies might increase the relationship performance. Finally, (H2c and H3a, H3b, H3c) represents that SSCP significantly positively influenced green practices, SC crisis mitigation strategies, smart technologies. While empirical results of this study suggested that those firms negate new technologies' importance, green practices and not properly implemented crisis mitigation strategies failed to perform their business activities during the pandemic. The importance of smart technologies and crisis mitigation strategies supports earlier results in the literature. The greater adoption of smart technologies leads to higher firm performance during a crisis (Kummitha 2020). The successful formation and implementation of crisis mitigation positively impact firm survival (Quigley et al. 2020).

In this research, mediation results were summarized in hypotheses (H4a, H4b, H4c). The mediation effect of green practices, SC crisis mitigation strategies, and smart technologies was checked and verified through SEM that confirmed that green practices, SC crisis mitigation strategies, smart technologies positively mediate the relationship between COVID-19 pandemic and SSCP. The supply chain and manufacturing industry need to understand how green practices, SC crisis mitigation strategies, and smart technologies mediate the positive relationship between the study's dependent and independent factors. As many businesses adopt them, their chances of survival will increase during this situation in the Pakistani context; otherwise, vice versa. Our study findings confirmed that green practices and smart technologies mediating the strong relationship between COVID-19 pandemic and SSCP than

Table 6 Model fitness results

Fit induces	NNFI	NFI	CFI	GFI	AGFI	TLI	CMIN/DF	RMSEA	SRMR
Criteria	≥0.90	≥0.90	≥0.90	≥0.90	≥0.90	≥0.90	≤3	≤0.08	≤0.08
Measurement model	0.921	0.910	0.914	0.908	0.932	0.942	1.932	0.038	0.028
Structural model	0.932	0.924	0.937	0.913	0.946	0.950	1.254	0.039	0.025

Table 7 Mediation regression analysis

Variables	Green practices		SC crisis mitigation strategies		Smart technologies		Sustainable supply chain performance					
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11	
COVID-19 pandemic	-	0.560*** (0.236)	-	0.446*** (0.178)	-	0.605*** (0.285)	-	-0.235 (0.182)	-	-	-	-
Green innovation	-	-	-	-	-	-	-	0.356** (0.160)	0.354** (0.139)	-	-	-
SC crisis mitigation strategies	-	-	-	-	-	-	-	0.239* (0.089)	-	0.468*** (0.245)	-	-
Smart technologies	-	-	-	-	-	-	-	0.521*** (0.258)	-	-	-	0.638*** (0.320)
Gender	0.049 (0.034)	0.058 (0.021)	0.068 (0.034)	0.017 (0.085)	0.078 (0.043)	0.056 (0.024)	0.040 (0.076)	0.088 (0.023)	0.061 (0.065)	0.067 (0.043)	0.085 (0.052)	0.086 (0.044)
Age	0.043 (0.017)	0.026 (0.053)	0.025 (0.052)	0.086 (0.042)	0.059 (0.029)	0.056 (0.030)	0.075 (0.035)	0.034 (0.017)	0.068 (0.037)	0.055 (0.083)	0.086 (0.044)	0.054 (0.029)
Education	0.056 (0.023)	0.034 (0.004)	0.028 (0.087)	0.066 (0.040)	0.087 (0.059)	0.030 (0.009)	0.044 (0.029)	0.068 (0.045)	0.090 (0.032)	0.069 (0.036)	0.087 (0.041)	0.054 (0.029)
Position	0.064 (0.033)	0.017 (0.012)	0.039 (0.028)	0.076 (0.039)	0.055 (0.073)	0.058 (0.005)	0.078 (0.017)	0.076 (0.026)	0.054 (0.025)	0.070 (0.004)	0.087 (0.041)	0.054 (0.029)
Experience	0.085 (0.038)	0.076 (0.047)	0.023 (0.003)	0.077 (0.044)	0.046 (0.027)	0.089 (0.034)	0.068 (0.027)	0.032 (0.054)	0.082 (0.036)	0.067 (0.007)	0.023 (0.651)	0.023 (0.651)
Firm size	0.061 (0.026)	0.060 (0.033)	0.037 (0.025)	0.088 (0.045)	0.056 (0.018)	0.080 (0.029)	0.090 (0.055)	0.028 (0.015)	0.070 (0.023)	0.046 (0.067)	0.078 (0.037)	0.078 (0.037)
Constant	5.13*** (0.452)	3.65*** (0.366)	1.68** (0.287)	2.88** (0.199)	1.96*** (0.254)	5.09** (0.516)	3.26*** (0.390)	1.11*** (0.106)	3.76*** (0.298)	2.98** (0.284)	2.98** (0.284)	5.23*** (0.790)
R ²	0.474	0.565	0.678	0.530	0.634	0.459	0.656	0.589	0.385	0.453	0.654	0.654
Adjusted R ²	0.472	0.543	0.676	0.525	0.630	0.450	0.568	0.578	0.380	0.342	0.650	0.650
F	178.98***	265.66***	198.49	114.90***	245.78***	109.90***	19.45*	219.37***	169.98	108.34**	226.13***	226.13***

*P (p ≤ 0.05), **P (p ≤ 0.01); ***P (p ≤ 0.001)

Table 8 Moderation regression analysis

Variables	Sustainable supply chain performance		
	Model 1	Model 2	Model 3
Green practices	-	0.654*** (0.325)	-
SC crisis mitigation strategies	-	0.543*** (0.243)	-
Smart technologies	-	0.589*** (0.334)	-
GP*OC	-	-	0.648*** (0.098)
SC-CMS*OC	-	-	0.465*** (0.231)
ST*OC	-	-	0.664*** (0.187)
Gender	0.079 (0.031)	0.065 (0.034)	0.020 (0.087)
Age	0.046 (0.024)	0.048 (0.023)	0.067 (0.018)
Education	0.088 0.044	0.034 (0.018)	0.089 (0.057)
Position	0.053 (0.030)	0.088 (0.032)	0.025 (0.008)
Experience	0.078 (0.045)	0.076 (0.009)	0.058 (0.034)
Firm size	0.043 (0.061)	0.032 (0.004)	0.045 (0.023)
Constant	4.58*** (0.365)	5.48*** (0.543)	6.54*** (0.632)
R ²	0.586	0.465	0.648
Adjusted R ²	0.543	0.0460	0.646
F	18.25***	15.76***	16.46***

*P ($p \leq 0.05$); **P ($p \leq 0.01$); ***P ($p \leq 0.001$)

SC crisis mitigation strategies. In this way, our empirical results built the depth association between COVID-19 pandemic and sustainable supply chain performance through mediating role of green practices by extending comparable model results of AIZgool et al. (2021), which has conducted in Bahrain food supply chain industry and verified the positive mediating role green supply chain practices between COVID-19 and firm performance. Abbas (2021) confirmed that successful formation and adoption of crisis management strategies minimized the rapid spread of coronavirus to decrease the burden of COVID-19 patients on the Pakistani healthcare sector. Finally, COVID-19 pandemic and smart technologies enhance sustainable supply chain performance, supporting earlier research results (Nasiri et al. 2020). Our study results and conceptual model provide empirical evidence that adopting green practices inappropriate supply chain infrastructure using smart technologies might acquire a competitive advantage

among Pakistani supply chain and manufacturing firms. Moreover, our results proved that the COVID-19 pandemic is a critical driver for adopting green practices, smart technologies, and the formation and implementation of SC crisis mitigation strategies to enhance the sustainable supply chain performance in a crisis.

Finally, the moderation effect of organizational commitment is summarized in hypotheses (H5a, H5b, and H5c), organizational commitment moderates the relationship among green practices, SC crisis mitigation strategies, smart technologies, and SSCP. This study's empirical results reveal that the formal moderation relationship proved that supply chain and manufacturing firms with a higher level of organizational commitment might increase SSCP during a pandemic situation in the Pakistani context. A similar track Athar (2020) found that organizational commitment significantly impacted green practices during the COVID-19 pandemic outbreak. Sustainable supply chain performance can be attained during pandemic disruption when organizations show their commitment to adopting green practices, smart technologies, and implementing crisis mitigation strategies.

Based on this study results and the discussed results in the section mentioned above, it was found that this study has unique findings compared to prior published research in literature. Although, COVID-19 has drastic effects on the supply chains of different industries in different countries. However, it is not necessary that results derived in this study could be generalized to all developing countries. Despite the scarcity of studies in the related area, this study is different by providing unique results.

6 Conclusion

Finally, it is concluded that green practices, smart technologies and the formation and implementation of SC crisis mitigation strategies are undeniably important for SSCP during the COVID-19 pandemic. Similarly, organizational commitment positively moderates the relationship between green practices, SC crisis mitigation strategies, smart technologies, and SSCP. This study has introduced the empirical conceptual model to sustainable supply chain performance during a pandemic disruption in the Pakistani context. Although green practices, SC crisis mitigation strategies and smart technologies play a fundamental role in SSCP. This study finding confirmed that the COVID-19 pandemic is more strongly correlated with green practices and smart technologies than SC crisis mitigation strategies. However, smart technologies and green practices strongly impacted SSCP as compared to SC crisis mitigation strategies. However, green practices, SC crisis mitigation strategies and smart technologies mediation effect was verified by applying the PROCESS macro test

in SEM. The study results revealed that green practices and smart technologies mediate the more powerful relationship between COVID-19 pandemic and SSCP than SC crisis mitigation strategies. Moreover, the researcher verified the moderation effect of organizational commitment between green practices, SC crisis mitigation strategies, smart technologies and SSCP. Study moderating results confirmed that organizational moderates a strong relationship between green practices and smart technologies compared to SC crisis mitigation strategies.

6.1 Theoretical and practical implications

COVID-19 pandemic effect can be minimized by adopting green practices, supply chain crisis mitigation strategies, and smart technologies. Moreover, adopting green practices can also produce positive results in terms of SSCP and global supply chain performance, especially in the pandemic era. Similarly, the formation and application of SC crisis mitigation strategies also can positively contribute toward global supply chain performance and SSCP. However, to handle the COVID-19 impacts on SSCP and global supply chain performance, implementing smart technologies in sustainable supply chain operation can generate better results for manufacturing firms' performance in Pakistani. Therefore, it is necessary to explore all these risk prevention strategies (green practices, SC crisis mitigation strategies and smart technologies) in the Pakistani manufacturing and supply industry context.

- Our empirical results recommend that big data analytics' entry empowered the businesses to utilize a large amount of data in a refined manner. An effective and efficient application of big data analytics might help green practices operations and supply chain function of manufacturing firms and support the sustainable supply chain performance during COVID-19 pandemic disruption.
- This study's conceptual model might help supply chain and logistics managers guide them on dealing with COVID-19 disruption in supply chain operations while surviving in crisis and enhancing and sustaining profitability during a pandemic. This will also help remove the complexities that COVID-19 creates in supply chain and logistics operations, such as the unavailability of suppliers.
- The spread of the COVID-19 virus is emotionally challenging governments, organizations, and people because of changing lifestyles in unprecedented ways. This research empirical result reveals that human beings' long-run survival and organizations have depended upon viable supply chain operations. The current research has given insights to supply chain and manufacturing firms and local government to develop new strategies such as smart lockdown strategies according to the spread of cor-

onavirus to tackle the economic crisis as it will become a practical post-COVID-19 pandemic situation.

- Information technology (IT) based well-structured framework should introduce supply chain & logistics and manufacturing firms in their supply chain operations for credible supplies managing during lockdown situations. The IT-based system will facilitate the supply chain managers to control their supplies inefficiently way and capacity enhancement.
- Our study finding suggests that pairing of humans and workers might open the door to numerous opportunities in logistics and supply chain and manufacturing firms to improve their efficiency and productivity.
- An investment in smart technologies and big data analytics adoption by manufacturing and supply chain firms not only ensured their survival during the COVID-19 pandemic disruption situation but increase and maintain sustainable supply chain performance.
- The government should offer financial incentives such as tax relaxation and interest-free loans or low-interest loans to purchase or import new smart technologies and blockchain technologies in the logistics and supply chain industry.
- It is not enough to convert the systems into digitalization. Still, government and organizations should arrange technosavvy skills programs to enhance the technical skills of their workforce to smoothly operate the digital systems.
- The supply chain managers should invest in green practices, smart technologies that may significantly affect supplier relationships and supply chain performance.
- In formulating comprehensive supply chain crisis mitigation strategies, the logistics and supply chain firms should involve the supply chain and logistics professionals, professors, and supervisors.

6.2 Limitations and future research directions

This research has some limitations that can make this topic more attractive and encourage more publications. Firstly, this study has utilized cross-sectional data. Secondly, this study's results have been obtained from a sample size from the Pakistan supply chain and manufacturing industry. Evaluating them based on this small managerial perception might produce biased and lack of generalizability in study results. It is soon recommended that this research be conducted in different countries targeting different departments and industries. Thirdly, this study's conceptual framework can be supported by relevant theories. In the future, the researcher can expand the scope of this topic by utilizing the results of this research as a foundation to introduce complex hypothetical models to testify and verify the relationship between the COVID-19 pandemic and SSCP through mediating and moderating factors. The concept of SSCP can also be divided in

to trio-sustainability idea. It will provide a refined view of COVID-19 impact on a firm's economic, social, and environmental performance. Furthermore, many factors related to this topic and relating to selected variables might be considered for further research. Lastly, this study's findings in the Pakistani supply chain and manufacturing industry context during pandemic outbreak might also be helpful for other developing countries' supply chain and manufacturing industry such (China, Bangladesh, India and Iran). Still, at this stage, it is uncertain either these study findings will fit in other developing countries' supply chain and manufacturing industry context.

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