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Abstract

Purpose – The purpose of this paper is to examine the role of digital supply chain (DSC) technologies in automotive supply chain resilience (SCR) practices to improve the supply chain performance (SC-Perf.) objectives of companies operating in the automotive industry. This study also compares the results of the associated SC-Perf objectives before and after the COVID-19 pandemic outbreak lockdown situation.

Design/methodology/approach – We undertook in-depth empirical research using a questionnaire survey to explore the performance of automotive supply chains. Our sample consisted of practitioners from supply chain entities such as automotive original equipment manufacturers (OEMs), Tier-1 component manufacturers, and lead logistics providers in Asia-Pacific (AP) emerging markets. Research questions, framework, and hypotheses were developed using the literature review.

Findings – The research outcome from analysis of the data we collected from an emerging market context, specifically the automotive sector, emphasizes the role of DSC technologies and encourages the firm's SCR practices which, in turn, supports the SC-Perf objectives. The DSC technologies competency moderates the SCR and SC-Perf objectives relation, and the moderation effect is higher for post-COVID-19 pandemic outbreak lockdown situation than at prior state.

Research limitations/implications – The scope of the study is restricted to the automotive firms in the AP region. The data were collected from a representative sample of the population through a questionnaire survey. The small size of the sample incurs a certain level of subjectivity.

Practical implications –This research provides practical insights for practitioners and academicians on DSC technologies' influence in SCR practices to improve the firm's SC-Perf. This research shares the literature insights on use of DSC technologies across the sector to allow the automotive firm to reassess the existing operational practices.

Originality/value – The paper adds insights on introducing or implementing DSC technologies across AP automotive firms to increase the operations' performance by improving SCR practices and sustainability.

Keywords – Asia-Pacific, COVID-19, automotive, digital supply chain, supply chain resilience, supply chain performance, China, India, Thailand.

Paper type - Research paper

1. Introduction

Digitalization has touched almost every aspect of humankind across the globe, greatly impacting supply chain processes. The primary focus of firms is to retain and fortify their core proficiencies in a competitive market. In the area of the supply chain, which spans the end-to-end operations in most of the firms, digital technologies act as a core platform for conducting the business. These technologies allow collaboration among firms across supply chains to interact in the design, supply, production, and distribution of goods and services (Remko, 2020). While considering organizational change management of automobile supply chains, the digitalization aspect is often neglected or delayed (Büyüközkan and Göçer, 2018). Thus, the research objective is to examine the role of digital supply chain (DSC) technologies in automotive supply chain resilience (SCR) practices to improve the supply chain performance (SC-Perf.) of companies operating in the automotive industry. This study also compares the results of SC-Perf before and after the COVID-19 pandemic outbreak lockdown situation.

The use of DSC technologies across industries is trending upwards. In recent years, data usage has grown rapidly as a result of globalization and is further stimulated with the help of the Internet, networks, social media sites, and mobile devices (Liu *et al.,* 2016). Nowadays, digital business models are disruptive due to their complex framework that encompasses an engaged workforce, supplier collaboration, core business processes, assets and Internet of Things (IoT), and customer experience (SAP, 2015). Westerman *et al.* (2013) describe the significance of value creation through digitalization strategies, with 9% more revenue creation, 26% more impact on profitability, and 12% more market valuation. 5G technological advancement supports DSC and vehicle-to-everything technologies. These technologies enable supply chain communication across stakeholders using the IoT, vehicle-to-vehicle communications, traffic systems, and related infrastructure (e.g., toll booths) to generate awareness around the environment (Vaish and Matthews, 2020). To address increasing dynamics in the business environment, supply chains need to be aligned with changing consumer preferences to meet the new age of volatility and complexity (Christopher and Holweg, 2017; Turner *et al.,* 2018). This enables firms to make sustainability provisions in their individual products and logistics services (Dubey *et al.,* 2017). Craighead *et al.* (2007) define supply chain disruption as an event that disrupts the flow of goods and services in a supply chain. To overcome the supply chain disruption, resilience allows firms to deliver their products and services to the customer in a continuous manner. SCR is defined at the firm level as the ability to foresee, respond and overcome any SC disruptions (Pettit *et al.,* 2013). Back in 2011, the Japan earthquake and Thailand flood natural disasters impacted global business and generated major risks for companies around the world as they did not have supply chain visibility in the face of such devastating situations. These disasters caused substantial economic damage globally (Haraguchi and Lall, 2015).

Similarly, the port explosions at Beijing's maritime gateway affected most of the global companies, particularly the automobile sector which took the hardest hit (Millar, 2015). Such supply chain disruption risks cause a ripple effect and performance degradation for firms in terms of revenue, service level, and productivity decrease (Dolgui *et al.,* 2020). The recent coronavirus (COVID-19) pandemic has significantly disrupted supply chain and production disruption across all sectors and affected trade within and across countries. Ivanov (2020) identifies the components of risk in supply chain disruptions that are caused due to pandemic or epidemic outbreaks: (i) presence of long-standing disruption and its impulsive scaling; (ii) concurrent disruption spread in the supply chain (i.e. the ripple effect) and epidemic outbreak propagation in the population (i.e. pandemic propagation); and (iii) concurrent disruptions in demand, supply, and logistics infrastructure. Thus, to overcome such disruptions, firms need to build their SCR capabilities to improve SC-Perf objectives.

Lack of information across supply chain tiers results in significant disruption and delays to recover the operations capacity of business firms and to redress the poor decision making of such firms. Research shows how larger corporations managed their supply chain – mostly in siloes due to lack of information (Kilpatrick and Barter, 2020). Although data were available, data collection and integration for effective decision making resulted in a mammoth task across the supply chain. The lack of data integration prevented various industrial firms from being agile enough to swiftly react to *force majeure* situations. Hence firms need to improve their supply chain visibility for effective collaboration with suppliers to fulfill their requirements (Poberschnigg *et al.,* 2020; Zouari *et al.,* 2020). During times of business emergencies, supply chain visibility provides the parts availability and support status from various sources across the globe. Original equipment manufacturers (OEMs) then increase their investments in supply chain data visibility and analytics as this allows SCR which enhances the SC-Perf objectives in firms (Chowdhury *et al.*, 2019a). This is to boost the SC-Perf through uninterrupted supplies by assessing impact to make swift decisions on a real-time basis. These efforts increase the SCR for firms to ensure business continuity plans are in place through adjusting production schedules or switching to alternative suppliers. To improve and manage the SC-Perf during a pandemic outbreak or disruption event, it is necessary for firms to implement a digital platform from the information technology (IT) perspective to support the data integration and connectivity of the information.

In the automotive sector, DSC technologies are widely employed for effective communication across supply chain entities such as dealers, OEMs, suppliers, and service providers with the help of data. Operations digitalization in the areas of production, warehousing, and transport logistics deepens the digital transformation of SCM (Gautam *et al.,* 2017). Peters *et al.* (2016) describe the role of information and communication technology (ICT) in the digitalization of the automotive industry.

Not many of the studies discussed above dealt with the automotive sector. To address this gap, this research examines DSC technologies and develops an empirical and conceptual understanding of these technologies on automotive SCR practices to improve SC-Perf in emerging markets based in the Asia-Pacific region. India, China and Thailand markets are considered as emerging markets as the automotive sales demand is high in these markets. Instead of mentioning these markets individually, henceforth, the term 'emerging markets' is used throughout this paper. Currently, firms lack a framework for guiding them in the deployment of digitalization technologies for better integration across the supply chain to manage risks such as normal supply chain disruption or a pandemic outbreak situation. The research intends to offer clearer insights and a more integrated framework to understand the moderating effects of DSC technologies' competence on SCR and firms' SC-Perf objectives, focusing on those firms that currently practice one or more DSC technologies such as Big Data, Blockchain, Robotics Process Automation (RPA), 3D Printing (3DP), and Radio Frequency Identification (RFID) tags, among others.

Considering that the respondents from different automotive firms may have different understandings of these DSC technologies, this research investigates how the mentioned DSC technologies are expected to have different levels of impact on a firm's performance, and sometimes they may have no or limited impact on firm performance. Hence, the following research questions guiding this study indicate how automotive firms based in emerging markets effectively handle and manage the supply chain before, during or after a disruptive event occurs with the use of DSC technologies at the firm level. Responding to these research questions through an empirical study for emerging markets' automotive firms possibly will satisfy the research gap concerning academic references.

- How does the competence of DSC technologies influence automotive firms to practice their routine (day-to-day) operations?
- How does the use of DSC technologies affect the SCR practices to improve the firm's SC-Perf objectives?
- How does DSC technologies' competence impact the relationship between SCR practices and SC-Perf objectives?

The rest of the paper is structured as follows: Section 2 presents the literature review on DSC technologies, SCR practices, and SC-Perf objectives. Section 3 is devoted to research model and hypothesis development. Section 4 highlights the methodology which contains the data collection and questionnaire development. Findings and results based on quantitative analysis are presented in Section 5. Section 6 describes the research discussions and conclusion. Section 7 describes managerial implications and Section 8 indicates the research limitations and scope for future research.

2. Literature Review

2.1. Digital supply chain (DSC) technologies competency – Data performance, and quality

DSC is a smart, value-driven, efficient process to generate new forms of revenue and business value for organizations and to leverage new approaches with novel technological and analytical methods. DSC deals with how supply chain processes are managed with a wide variety of innovative technologies such as Augmented Reality (AR), Artificial Intelligence (AI), Blockchain Technology (BCT), Big Data and Analytics (BDA), Cloud Computing (CC), Robotics (R), Sensor Technology (ST), Omni Channel (OC), IoT, RFID, RPA, Self-Driving Vehicles (SDV), Unmanned Aerial Vehicle (UAV), Nanotechnology (N) and 3DP (Büyüközkan and Göçer, 2018; Hartley and Sawaya, 2019). Bhargava *et al.* (2013) state that DSC is composed of hardware, software, and communication network systems that support interactions among globally distributed organizations and arranges the activities of the partners in supply chains. It includes buying, making, storing, moving, and selling a product. Thus, DSC technologies have been used to modernize the business using digital tools and techniques to unleash innovation, speed up decision making, and improve efficiency.

To cope with the future of the workplace, firms are in the process of accelerating digitalization and automation towards core functional areas such as supply chain and manufacturing, among others as DSC technologies promote value chain analysis to consider and pre-empt unpredictable business disruption so that businesses can build competitive advantage (Linkov *et al.,* 2020). In general digitalization is considered as an opportunity for businesses to change their current business model to achieve revenue and value-added. Digitalization is also referred to as digital innovation and transformation (SAP, 2015). The scope for the research study considers DSC technologies such as BDA, RPA, IoT-enabled BCT, RFID, and 3DP. These technologies are considered based on the feedback from automotive OEMs' practitioners based in emerging markets.

BDA ensures the maturity of the analytics tools in providing in-depth analyses and it is considered another vital resource that drives data analytics competency in firms (Davenport, 2013). These technologies have high levels of ability which can carry out analyses regarding current and past events, predict future happenings, and issue the prescription to the firm on where it can take the best courses of actions (Aryal *et al.,* 2018; Carlos *et al.,* 2021; Ghasemaghaei *et al.,* 2017). Richey *et al.* (2016) describe the role of Big Data in supply chain management in terms of 5 Vs – velocity, veracity, value, volume, and variety – to process and utilize the data from the firms to derive the desired insights.

RPA is software that performs routine process tasks such as an automated email response based on simple rules. Supply chains have many repetitive tasks that can be automated with RPA in sourcing, operations, and logistics (Monahan, 2017) which in turn drives the process standardization, continuous improvement, and establishment of the digital workforce. Hartley and Sawaya (2019) describe RPA as a firm's quick-win tool for the digital transformation of supply chain business processes to manage repetitive and transactional tasks.

BCT is a nascent state defined as the digital distributed ledger technology (Cottrill, 2018). In recent days, BCT is being considered by many SCs around the globe to enhance trust and avoid scam. BCT is able to provide real-time insights and eliminate redundancies through sharing information to all parties through its integration with supply chain management (Calatayud *et al.,* 2019; Queiroz *et al.,* 2019; van Hoek, 2019). Also, by incorporating the IoT into the Blockchain, contractual fraud will be easily detected and prevented along with improved connectivity and visibility (Min, 2019). This technology is implemented in the finance and banking sector, and many other sectors (Kuhn *et al.,* 2021).

RFID technology supports and synchronizes the supply chain processes to improve the real-time visibility across warehouse and transportation systems. It can be applied at parts level, shipping container level, and finished vehicle level to ascertain the value stream and identify any bottlenecks. Musa and Dabo (2016) discuss the role of RFID technology and reveal that, despite technical and cost challenges at present, the high potential exists, and RFID technology is likely to grow into the future in supply chain management.

3DP technology, also known as additive manufacturing, involves layer-wise creation of objects by selectively adding material such as polymers, metals, or organic materials, among others (Delic *et al.,* 2019). It will allow firms to produce almost anything using a 3D printer. Although it is expensive, it has the potential to shrink and disrupt the existing supply chain and logistics. Mohr and Khan (2015) indicate how the areas of the supply chains are most likely to be disrupted by 3DP. A prototype for testing non-functional attributes and rare spare parts has been produced using this technology at a minimal scale.

Ghasemaghaei (2019) considers the following roles of measurement items for technology tools: to identify problems; evaluate different alternatives; offer real-time insights, information sharing, and retrieval capabilities; perform modeling and simulation; as well as the capability of the workforce or employees in the firm to use the critical DSC technologies (example: data analytics). Thus, the workforce with the right skills, knowledge, and experience is essential in integrating and analyzing data while using the analytics tools. Having a workforce with the desired capabilities is an important resource for firms to generate value from DSC technologies. This research study considers the automotive firms that perform analytics with high velocity and real-time tracking visibility measurement items to assess the firm's competency. This is in line with the above DSC technologies such as Big Data, RFID, and RPA in line with the literature reference. The breadth and depth of these competencies also determine the firm's present state to understand the knowledge, skill, and expertise present in the workforce.

To use DSC technologies effectively in the firms, data quality is recognized as a critical data competency resource which refers to the quality of the data that are being used in the assessment studies. Wang and Strong (1996) claim that data accuracy, reliability, relevancy in terms of representation, and data accessibility are key factors to improve the quality of the data. Also, according to Popovič *et al.* (2014), data quality influences the value that data analytics tools generate to obtain insights for decision making. Ghasemaghaei (2019) uses measurement items such as security, reliability, time, accuracy, relevancy, and appropriate level of details for the data quality construct for analytics study to improve the decision making. This research study considers the same measurement items to qualify DSC technologies to enhance the efficiency of automotive firms.

To enable DSC technologies competency, utilization of available data at the firm is essential. Data utilization is defined as a firm's ability to integrate data of high variety, velocity, veracity, value, and volume. The *velocity* of data refers to the speed in integrating and analyzing data, the *variety* of data refers to the analysis of different types of data, the *veracity* of data refers to the trustworthiness and reliability of the data, the *value* of data refers to the conversion of other insights into value-added assessment, and the *volume* of data refers to the integration of large amounts of data (Ghasemaghaei, 2018; Richey *et al.,* 2016). This research considers the measurement items for data utilization as part of DSC technologies competency as the processes of real value data, high volume data, and high variety data. Veracity is part of data quality and velocity is already covered under the data performance.

Refer to Table I, DSC technologies competency construct, and associated measurement items with the literature reference listed.

2.2. Digital supply chain (DSC) technologies use

Extensive usage of DSC technologies may support the dynamic capability (DC) needed to improve business performance in organizations (Hasegan *et al.,* 2018). The DC is viewed as a powerful tool and organizational ability to streamline resources and capabilities to bring rapid change in business environments (Teece, 2012). Teece *et al.* (1997) propose DC as the resource-based view (RBV) theory extension to elucidate firms' competitive advantage in volatile markets with dynamic and changing environments to make effective decisions. Also, as organizations move towards the digital transformation of supply chain processes, they face hurdles that occur when adopting new information technologies (e.g., user resistance) as well as new challenges from the fast pace of digital technology changes. In addition, digital transformations in organizations help them to overcome challenges faced such as lack of investment, lack of skills to evaluate and implement new technologies, resistance to change, and organization change management (Polites and Karahanna, 2012). Thus, top management commitment in firms to invest in DSC technologies to improve SCR is considered a measurement item in this research study (Sawyerr and Harrison, 2019). Developing from the technology acceptance model (TAM) framework, DSC technologies can predict the information acceptance and usage on the job for the firms. This research considers perceived usefulness and perceived ease of use as measurement items to assess the degree to which the practitioners believe that using a technology or a system would enhance their job performance and help them develop (Davis, 1989).

To lead the digital transition process, it is essential to record the purpose documenting and mapping of current business processes. Digital transition implementation can be led by those who understand technologies, possess the change management skills, and effectively intermediate between supply chain and information technology. Data analytics, one such digital transition process component of DSC technologies helps to predict the supply chain disruption using the machine learning application for an OEM with the help of historical data (Brintrup *et al.,* 2020). Ghasemaghaei (2019) assesses the data analytics usage with the help of duration, recurrence, and degree or range. To measure the usage of DSC technologies in the firms, similar measurement items are included in the research as follows: (i) how employees adopt or accept by gauging the duration of usage; (ii) how often or frequently technologies are used with compliance; and (iii) the extent of data shared across supply chain entities for day-to-day operations.

Refer to Table I, DSC technologies use construct, and associated measurement items with the literature reference listed.

2.3. Supply chain resilience practices

Ali *et al.'s* (2017) meta-study classifies the literature of SCR into three constructs. i) Phases: pre disruption, during disruption, and post disruption. ii) Strategies: proactive, concurrent, and reactive. iii) Capabilities which is the ability to: anticipate, adapt, respond, recover, and learn. SCR has attracted significant attention from both academics and practitioners due to increasing uncertainty resulting from rapid climate change, rapid urbanization, and political instability (Durugbo *et al.*, 2020). Kamalahmadi and Parast, (2016) in page 121, define SCR as

> *…the adaptive capability of a supply chain (SC) to reduce the probability of facing sudden disturbances, resist the spread of disturbances by maintaining control over structures and functions, and recover and respond by immediate and effective reactive plans to transcend the disturbance and restore the SC to a robust state of operations.*

Roundy *et al.* (2017) assert that resilience refers to a firm's ability to recover from shocks and adapt to disruptions. A resilient supply chain captures unanticipated business disruptions and reinstates the supply chain to a healthy state of operations that can result in competitive advantages (Ali *et al.,* 2017). A global resilient supply chain has the adaptive capability to manage disruptions by enabling the supply chain to bend rather than break which increases the sustainable competitive advantage of firms (Ambulkar *et al.,*2015).

Ruiz-Benítez *et al.* (2018) adapt resilient supply chain practices to study and measure the performance impact. In the context of measuring DSC technologies' influence in SCR practices to improve business performance, this research considers the six measurement items as follows:

Adopting the SCR practice to improve visibility, collaboration, coordination, and understanding with suppliers allows automotive OEMs and suppliers to state business processes and systems to anticipate, monitor, and respond against unexpected or disruptive events in a coordinated way (Chowdhury and Quaddus, 2015; Zouari *et al.,* 2020). DSC technologies support this practice extensively with historical data across supply chain entities. SCR practice to maintain the required capacity in productions, storage, handling, and transportation allows automotive supply chain partners to retain the desired capacities to manage the new business needs arising from the occurrence of supply chain disruption (Rajesh *et al.,* 2015). DSC technologies support this practice to predict the scenarios with the help of sales demand plans. The SCR practice of performing contingency planning allows desired measures aimed at identifying and treating a risky event before it affects the normalcy of the automotive firm's activities (Hohenstein *et al.,* 2015). DSC technologies' ability to perform what-if studies support this practice. To enforce security, these technologies allow automotive supply chain partners to prepare against attacks from disruption events (Tukamuhabwa *et al.,* 2015). DSC technologies support this practice by having robust data security with disaster recovery plans as part of business continuity requirements from organizations (Cheung *et al.,* 2021). Thus, developing a disaster recovery plan allows for putting in place the desired measures to recover the normalcy of the automotive firm and de-risk supply chain activity after an unexpected or disruptive event (Pettit *et al.,* 2013; Remko, 2020). DSC technologies lend support in developing the recovery plan considering security, cost, and time factors.

SCR practice of the use of control information systems enables automotive firms to detect, monitor, and respond to unexpected or disruptive events (Romano *et al.,* 2013). Information systems act as the foundation of DSC technologies to support this practice. To perform communication and information sharing with automotive supply chain partners allows information exchanges between supply chain entities to detect, monitor, and respond to unexpected or disruptive events (Colicchia *et al.,* 2019; Soni *et al.,* 2014). DSC technologies support the practice of information exchange or sharing across supply chain entities in a flawless manner. The SCR practice of developing a flexible supply base allows the creating of a preferred automotive supplier group to secure material procurement when a disruption event occurs (Govindan *et al.,* 2014). DSC technologies are capable of identifying such an alternate source base across the globe and are able to confirm the support in order to establish the agreements between automotive supply chain partners, which results in more jointly beneficial agreements with desired incentives and responsibilities across time. Both firms agree to improve their response over recovery capacity against disruption events (Tukamuhabwa *et al.,* 2015). DSC technologies support measuring the capacity shortfalls across time against demand. Thus, they generate real cost options which allow automotive OEMs to pay a proportion of costs derived from their supplier due to redundancy when a disruption event occurs (Guojun and Caihong, 2008; Remko, 2020). DSC technologies have the capacity to compute the financial details considering the quality and delivery performance with the help of historical data.

The SCR practice of alternative transportation routing allows automotive OEMs to plan to make and authorize suppliers to route the part deliveries on time after an unexpected event occurs (Govindan *et al.,* 2015). DSC technologies are capable of recommending an alternate mode of parts shipment. In addition, implementing visible transportation describes the automotive OEMs' ability to introduce an advanced tracking system that enables the real-time visibility of transported elements (Romano *et al.,* 2013). DSC technologies such as RFID as discussed in section 2.1. supports such practice.

Refer to Table I, DSC technology-enabled SCR construct and associated measurement items across firms with the literature reference listed.

2.4. Supply chain performance improvement

DSC technology such as BDA enables significant supply chain transformation in business firms to improve their performance (Fosso and Aktar, 2019). To assess the SC-Perf at the firm level, measures from use of DSC technologies as well as robust supply chain management resilience practices, and a mixture of business, economic and operational performance are employed to evaluate SC-Perf in the study using the performance measures established in the literature as follows:

Economic performance objectives such as *reduced cost* for material purchasing, transportation, energy consumption, and production are considered to evaluate SC-Perf using DSC technologies and resilience practices in automotive firms (Prajogo *et al.,* 2016).

Operational performance objectives such as *speed of delivery* to ensure timely delivery are considered to evaluate SC-Perf across automotive firms using DSC technologies. In the situation of a disruption or pandemic outbreak, DSC-enabled transportation ensures the swift recovery of material delivery (Prajogo *et al.,* 2016). The operational performance objective, *dependability of supply chain service,* is considered to evaluate the performance across automotive firms focusing particularly on the service rate in after-market situations using DSC technologies (Akkermans and Voss, 2013). Operational performance objectives such *as risk mitigation or reduction on supply chain and distribution* are considered to measure the performance using DSC technologies. The buying and selling firms' social relationship plays a vital role in mitigating risks in the end-to-end supply chain particularly during situations of disruption (Chowdhury *et al.,* 2019).

Business performance objectives such as *sustainable supply chain operations* (e.g., green supply chain practices) improve the eco-system partners and supply chain traceability for firms. With the help of DSC technologies, identifying optimized distribution networks and using green practices such as returnable packaging containers increase the performance. Traceability allows quicker recovery from the disruption to normalcy situations (Agyabeng-Mensah *et al.,* 2020; Cousins *et al.,* 2019).

The business performance objective, *end-customer satisfaction,* is included based on a firm's competitive advantage against market rivals and its flexibility in supply chain operations to provide after-sales service considered to measure SC-Perf. Competitive advantage against market rivals is the outcome of supply chain transformation and resource efficiency using DSC technologies and its influence over resilience practices in automotive firms (Kalaitzi *et al.,* 2019). Similarly, flexibility is the automotive firms' ability to operate in a volatile and uncertain environment. By adapting DSC technologies and robust resilience practices in supply chain management, flexibility measurement items can gain strategic advantages (Tiwari *et al.,* 2015). Thus, end-customer satisfaction is considered to measure the automotive firms' supply chain management competency in using DSC technologies and resilient best practices. Also, end-customer satisfaction significantly improves firm performance and shareholder value (Ellinger *et al.,* 2012).

Refer to Table I, use of DSC technology and resilience practices that enabled SC-Perf construct and associated measurement items across automotive firms with the literature reference listed.

Table I. Literature Reference and Descriptive Statistics

3. Research model and hypotheses development.

Figure 1. Conceptual framework with hypotheses relations.

Based on the literature review from section 2, the research model formed includes four relevant constructs and 29 measurement items. While considering a holistic view of strategic, tactical, and operational tasks together to ensure key decisions to improve the SC-Perf, this research considers the firm level to understand the role of DSC technologies and involvement. It explores how the firms' data quality enables competency development for firms and how DSC technologies influences SCR practices and SC-Perf objectives. It also assesses how a firm's DSC technologies moderates the relationship between resilience practices of supply chain and SC-Perf objectives, particularly in the context of supply chain disruption situation as shown in the above Figure 1. The survey was conducted before the COVID-19 situation in December 2019 and then the same was conducted after March 2020. The responses were collected and analyzed for two different periods.

3.1. Effects of DSC technologies competency and DSC technologies use.

The DSC technologies competency employed 11 measurement items based on the quality of the data used in DSC technologies, the data characteristics in DSC technologies which can be potentially used for the organizational process to make effective decisions, and the availability of DSC technologies in the organization. Ivanov *et al.* (2019) describe that an increase in data quality of DSC tools such as RFID, Blockchain, and sensors allows for the digitalization of track and trace technologies supply chain application. Data quality also allows the firm to reduce the information disruption risks, thus improving the parts supplies as the coordination occurs on a real-time basis across entities. Hence, the data quality could help firms to rely on DSC technologies competency while making effective decisions in the event of a disruption. The DSC technologies competency approach is to manage and analyze the data volume, variety, velocity, and veracity to generate business intelligence and analytics value creation for firms in line with Industry 4.0; hence, these measurement items were added (Bordeleau *et al.,* 2020). Ghasemaghaei (2019) indicates that a firm's data analytics competency can have an important role in improving the firm's decision-making quality through data analytics usage and knowledge sharing in the firm. Data analytics is one of the DSC tools; therefore, the DSC technologies competency builds trust and confidence to allow firms to use or practice the DSC technologies effectively in the event of a disruption to engage in swift decision making.

In line with the literature review, not all DSC technologies are widely used across automotive firms. To measure the usage or practice of one DSC technology, or more than one, in the firms, six measurement items based on organizational top management's commitment to invest in these technologies (Teece, 2012), perceived usefulness and ease of use (Davis, 1989), adapting over a shorter span of time, and using them to a broader extent on a shared basis across supply chain entities with data privacy and compliance (Ghasemaghaei, 2019).

Thus, we posit the first research hypothesis:

H1: DSC technologies competency will lead to DSC technologies use and practice.

3.2. Effects of DSC technologies use and SCR practice and SC-Perf objectives

Büyüközkan and Göçer (2018) propose 11 key DSC features which bring distinct advantages for the firm as follows: speed, flexibility, global connectivity, real-time inventory, intelligence, transparency, cost-effectiveness, scalability, innovation, proactivity, and eco-friendliness. Practicing BCT drives cost-effectiveness through reduction of the transaction costs and eliminating third-party involvement. RFID enables innovation and visibility across the supply chain which brings more transparency and helps to know the real-time inventory of parts or products for firms to take intelligent or effective decisions in challenging times. DSC technologies allow improved connectivity among supply chain partners to work on the integration of digital and physical worlds. Hence, DSC technologies practice by firms results in the improvement of SC-Perf objectives both in normal and disruption conditions. Thus, we posit the second research hypothesis:

H2: DSC technologies will support supply chain performance objectives.

Resilience is the ability to sustain and restore the supply chain functionality using adaptation and recovery plans. Ambulker *et al.* (2015) empirically examine the firms' resilience to supply chain disruption. Chowdhury and Quaddus (2015) develop an approach to determine efficient resilient strategies to overcome the dark effects of the supply chain disruption. SCR used six measurement items considering that DSC technologies influenced resilience practices: these are visibility improvement, handle and manage production capacity, develop recovery or alternate plans, perform communication and information sharing, develop alternate cost options, and parts track and trace during transportation (Ruiz-Benítez *et al.,* 2018). Ivanov *et al.* (2019) investigate the influence of digitalization in the supply chain considering the firms' resilience. Hence, the DSC technologies practice or use influences the resilience practices in a firm's supply chain operations. Thus, we posit the third research hypothesis:

H3: DSC technologies use will encourage the firm's supply chain resilience practices.

3.3. Effects of supply chain resilience practice and supply chain performance objectives.

Pettit *et al.* (2019) describe the evolution of resilience in supply chain management. The effect of resilience on SC-Perf depends on future business vulnerabilities which results in the enhancement of technology costs. Remko (2020) suggests a pathway to develop a more resilient supply chain in the industry to improve the firm's performance post-COVID-19. Particularly in a time of crisis, businesses may not invest in such technologies as there is no guarantee of payback. According to Um and Han

(2020), supply chains with high resilience can handle supply chain risks effectively. It has been evident from the recent COVID-19 situation around the globe that the food and essential product supply chains have built resilience within their supply chains quicker than any other supply chains due to collaborative effort. A similar message has been highlighted by several other researchers in the context of various supply chains (Agarwal and Seth, 2021; Sarkis, 2020; Sibanda and Ramanathan, 2019). Overall performance of supply chains is also enhanced through collaborative operations and transparent information which will help build a high level of resilience across the supply chains (Ramanathan *et al.,* 2014). Based on the above discussions, we posit our next research hypotheses for pre-COVID-19 and post-COVID-19 situations:

H4: The stronger the supply chain resilience practices, the higher the supply chain performance.

> H4a: Supply chain resilience practice positively relates to supply chain performance (pre-COVID-19 pandemic outbreak lockdown situation).
>
> H4b: Supply chain resilience practice positively relates to supply chain performance (post-COVID-19 pandemic outbreak lockdown situation).

According to Zouari *et al.* (2020), the digitalization of the supply chain does contribute to the resilience. Conversely, though, Singh and Singh (2019) describe the development of business risk resilience against supply chain disruption events by developing Big Data analytics capabilities. Ju *et al.* (2020) show the moderating role of digital technology in the context of relationships among integration quality, value co-creation, and resilience in the logistics service supply chain. Hence, to measure the SC-Perf objectives enabled by DSC technologies influenced by SCR, six measurement items have been drawn from the literature such as reduced cost, speed of delivery (Prajogo *et al.,* 2016), dependability of firm's service (Akkermans and Voss, 2013), reducing risks in supply chains/distribution (Chowdhury *et al.,* 2019), operations sustainability (Cousins *et al.,* 2019), and end-customer satisfaction (Ellinger *et al.,* 2012). These six attributes may contribute differently based on their level of operations; however, the nature of every supply chain will indicate the level of requirement of the DSC technologies to increase the performance and, accordingly, the objective will be set locally. Based on the above discussions, we posit the following hypothesis derived to assess the relationship of SCR and SC-Perf objectives influenced by DSC technologies:

H5: DSC technologies competency moderates between supply chain resilience (SCR) on supply chain performance objectives such that the effect is stronger with higher competency.

Ali *et al.'s* (2017) paper on SCR highlighted the comparison of the disruption significance in before, during, and after phases. Anderson *et al.* (2020) reveal how business is adapting to COVID-19. Nandi *et al.* (2020) adapt theoretical approaches to assess the firm's responses to supply chain disruptions during COVID-19 to improve their resources and capabilities such as localization, agility, and digitization by applying Blockchain technologies. Queiroz *et al*. (2019) highlight that digital technologies such as Blockchain with supply chain integration have the potential to disrupt the traditional healthcare, transportation, and retail industries. Sarkis (2020) finds that sustainability and resilience are complements that require joint investigation post-COVID-19 scenario. Ivanov (2021) reveals the lean resilience framework using active usage of resilience assets for post-COVID-19 supply chain management. Agarwal and Seth (2021) analyze SCR barriers and their inter-connectivity in an Indian automotive company prior to the pandemic situation. Um and Han (2020) find that SCR capability plays a mediating role between supply chain risks and resilience. In line with the above literature, this current study attempts to reveal pre- and post-COVID-19 impact on SCR practices with respect to SC-Perf, and the moderation effect of DSC technologies on both SCR and SC-Perf. This study considers the pre-COVID-19 pandemic outbreak lockdown situation where the respondents may have based their response on the case of similar disruptions such as strikes and natural calamities. The survey was conducted in India, China and Thailand where natural calamities are quite common, and the people encounter various type of disruptions time and time again. In this research, the post-COVID-19 pandemic outbreak lockdown situation (lifting of lockdown and reduction in reported COVID cases) is measured to understand respondents' expectations about DSC technologies as it is part of the 'during' and 'after' phases of disruption. In the post-COVID-19 phase, respondents may require the right resilience ecosystem enabled with DSC technologies for swift business recovery. Hence, DSC technologies competency-influenced resilience practices were measured before and after the lockdown date declared by the respective government agencies using the following hypotheses:

H5a: DSC technologies competency moderates the relationship between supply chain resilience (SCR) on supply chain performance objectives such that the effect is stronger with higher competency (pre-COVID-19 pandemic outbreak lockdown situation).

H5b: DSC technologies competency moderates the relationship between supply chain resilience (SCR) on supply chain performance objectives such that the effect is stronger with higher competency (post-COVID-19 pandemic outbreak lockdown situation).

4. Research methodology

In recent years, significant growth has been found in automotive production from emerging markets as the passenger and commercial vehicles supply to meet domestic and export sales demand. To meet the demand within available production capacity, automotive firms are compelled to focus on end-to-end supply chain management activities to optimize the cost and order to delivery (OTD) lead-time. Thus, swifter recovery of end-to-end supply chain post-pandemic outbreaks is necessary to mitigate any major business impact. This study investigates the relationship among DSC technologies, SCR, and SC-Perf across automotive supply chain entities such as OEMs, component suppliers, and lead logistics service providers (LLSPs). Emerging markets' automotive supply chain management professionals are sampled to gain their perceptions on the DSC technologies application to improve their firms' SC-Perf and role of DSC technologies to improve SCR in supply chain disruption or pandemic outbreaks. In this research, the data were collected through a survey approach called the *total design method* (Dillman, 1978), and the research constructs are evaluated using multiple item measurement (Gerbing and Anderson, 1988).

4.1. Data collection

Automotive supply chain professional details were collected from the confederation of the Indian Industry (CII), the China Association of Automobile Manufacturers (CAAM), and the Thai Automotive Industry Association (TAIA). The database included a list of 675 potential participants, most of the OEMs, suppliers, and LLSPs living in emerging markets working as supply chain and logistics management professionals who have extensive experience in automotive supply chain planning, inbound logistics, in-plant logistics, and outbound logistics domains. These participants were familiar with supply chain technology applied in their respective domains.

A questionnaire was developed using the survey scale development recommendations (Churchill, 1979). Based on the database, the survey was launched using a Google form and invites were sent to the 675 participants using the purposive sample method (Teddlie and Yu, 2007). The data collection period was between December 2019 and May 2020, both before and after the COVID-19 epidemic outbreak lockdown declared by the government in the respective location (India, China, and Thailand) for automotive production. In China, the national lockdown was declared on 23 January 2020 in Wuhan, Hubei province; in India, the lockdown was declared on 25 March 2020, and in Thailand, a state of emergency was declared on 26 March 2020. The pre-COVID-19 data collection period is considered as December 2019 to January 2020 for China-based firms, and from December 2019 until the end of February 2020 for India- and Thailand-based firms. Similarly, post-COVID-19 data collection started from February 2020 to May 2020 for China-based firms, and March 2020 to May 2020 for India- and Thailand-based firms. Including 10 pilot responses, the returned questionnaire survey is 313, which gives a response rate of about 46%. Based on the survey date stamp in comparison with lockdown or state of emergency declaration from the respective locations, the surveys returned before and after lockdown dates are 162 and 151, respectively.

4.2. Questionnaire design

The survey questionnaire comprises two sections. The first section evaluates the demographics of the participants such as gender, age, firm location, firm age, firm size, length of work experience, annual revenue, and supply chain entity. The last section contains all the scales measuring the constructs proposed as per the research model in section 3. In total, 50 items measuring four constructs were identified and seven-point Likert-type scales ranging from strongly disagree (1) to strongly agree (7) were used. The research instrument was first developed in English and then translated into Chinese to communicate with China's automotive firms. The Chinese translation was introduced to ensure clarity, readability, and language equality (Brislin, 1986). The translation was initiated with a Chinese native senior supply chain manager specialized in the area of the automotive field, followed by another academic member of Chinese origin, who specialized in the area of management studies.

Both English and Chinese versions were then reviewed, and necessary minor changes were made to ensure face validity. The final English version of the questionnaire was then uploaded online using Google drive. The online version was then checked to overcome any operational errors. The final Chinese version of the questionnaire was emailed to all the participants who were asked to update and return a scanned copy in case they had any difficulty completing the questionnaire using the online English version. Before the formal launch of the survey, 10 respondents from the database, comprising four from India and three each from China and Thailand, participated in the pilot test. Telephonic discussion was conducted with respondents to assess the survey design, wording, and flow content. Respondents gave positive verbal feedback regarding the same and the relevance of the questionnaire considering the supply chain disruption measures they have undertaken.

5. Findings and results

The demographic data of the sample shown in Table II highlights nearly equal responses from males (51%) and females (49%). Most are between 31 and 50 years old (76%). Respondents who are specialized in automotive procurement, supply chain management and automotive logistics who are based in China and Thailand share account for 41% each, and Indian respondents account for the remaining 18%. All the survey respondents have been working across automotive supply chain entities – most are component suppliers (60%). Respondent work experience for more than five years is about 88%, and 95% of their firms are aged over five years which are key indicators for both respondents' and firm's adaptability for

DSC transformation. Furthermore, 60% of the firms based in emerging markets employ more than 500 staff and associates, while 72% of the participating respondents' firm's annual revenue is less than $US500 million, which indicates the firm's capability to invest in digital technologies.

Based on the survey date in consideration of COVID-19 lock-down declared by each country's government, 51% of respondents completed the survey before lockdown and 49% of the respondents completed the survey after lockdown. This indicator helps to assess the change in perceptions of respondents pre- and post-COVID-19 lock-down situations from emerging markets' automotive firms.

Table II: Demographic Data

To determine the correlation among the measurement items in the data set, an exploratory factor analysis (EFA) statistical approach was employed using SPSS 21.0. Data appropriateness was checked through KMO statistics (0.957) and Bartlett's test of sphericity was shown as significant ($p < 0.001$). It was noted that about 83% of variance was explained by four factors. Due to higher cross-loadings, measurement items under DSC technologies competency such as decision-making capabilities using DSC technologies with the help of real-time data, volumes of data, variety of data, and higher extent of the usage of DSC technologies were removed. Deleting these measurement items will not change the construct as the model follows reflective measurement (Bollen and Lennox, 1991). All measurement items with their descriptive statistics are provided in Table I. Cronbach's Alpha indicated equal to or above 0.944 against all four constructs.

Post-EFA, reliability and validity of the constructs were evaluated using confirmatory factor analysis (CFA). In CFA, the goodness of fit indicators were used such as chi-square divided by degree of freedom (Chi Sq. /df), comparative fit index (CFI), and root mean square error of approximation index (RMSEA) to evaluate the measurement model using AMOS 26.0 (Anderson and Gerbing, 1988). Table III shows the CFA results such as factor loadings range, composite reliability (CR), average variance extracted (AVE), maximum shared variance (MSV), and average shared variance (ASV) against each construct. In addition, model fit measures which confirm the reliability were applied; ChiSq/df = 3.43 (<5), CFI = 0.956, and RMSEA = 0.08 (Hu and Bentler, 1999). Although RMSEA values closer to zero represent a good fit, considering that the comparative fit index (CFI) is 0.956 (greater than >=0.9 cut-off for a good fit), the resulting RMSEA score of 0.08 (against the cut-off for a good fit < 0.08) may be accepted.

Table III. CFA summary statistics

All factor loadings were higher than 0.50 and significant at $p < 0.001$ indicating high convergence (Hair *et al.,* 2006). Convergent validity was also supported in an examination of the composite reliabilities as CR values were greater than 0.7 (Hair *et al.,* 2006) against each construct. The AVE for each construct was greater than 0.5, indicating support for convergent validity. Also, MSV and ASV are less than AVE, which confirms the discriminant validity against each construct. Thus, all the constructs satisfy the tests of reliability and validity.

Before the structural model test, non-response bias was tested by random comparison of the first 20 responses and 20 responses a month later for the SCR and SC-Perf constructs (Armstrong and Overton, 1977). No significant differences were found in the assessment. Common method bias was checked through two methods. First, Harman's single factor test was used. In the study, the largest variance explained by any single factor was 31.74%. Second, the latent factor test was applied (Podsakoff *et al.,* 2003). In this test, no loss in the significance of the factor loadings was found by introducing a latent factor in the measurement model. Thus, these two tests imply that common method bias is minimized. Dependent variables of DSC technologies use and SCR practices act as independent variables to measure the overall SC-Perf objectives for the firm; hence structural equation modeling (SEM) is used in this research as a statistical analysis technique in comparison with other tools such as regression. Also, SEM provides a way to test the specified set of relationships among observed and latent variables as a whole and allows theory testing (de Carvalho and Chima, 2014). SEM was used to test the conceptual framework hypothesized relationships as shown in Figure 1. The structural model test resulted in the following SEM indices to prove the adequacy of the model. The results shown in these indices are chi-square divided by degree of freedom (Chi Sq/df =3.706), the Bentler comparison fit index (CFI = 0.951), and the root mean square error of approximation (RMSEA = 0.08).

At the $p < 0.001$ level, regression standardized weights were significant for the path from data quality to competency development within (i) DSC technologies competency construct, (ii) DSC technologies competency to DSC technologies use, (iii) DSC technologies use to SC-Perf objectives, (iv) DSC technologies use to SCR, and (v) SCR to SC-Perf objectives. Table IV summarizes the hypotheses with dependent and predictor variable relations, path weights, and p-values for the constructs.

Table IV. Path weights of the structural model

Table IV infers that H1, H3, and H4 are statistically highly significant ($p < 0.001$) with path weights of 0.683, 0.713, and 0.717, respectively. H2 reflects the path weight of 0.008 with no insignificant p-value ($p > 0.05$). The path weights for hypotheses H4a and H4b reflect 0.694 and 0.734 respectively, with high statistical significance ($p<0.001$).

To test the moderation effect of DSC technologies competency over SCR and SC-Perf objectives' relations (hypothesis H5), the interaction method (Cohen *et al.,* 2003) was used. A cross-product term of DSC technologies competency with SCR was created (moderator A) with standardized values as variables using SPSS 21.0. Then using AMOS 26.0, variables such as SCR, DSC technologies competency, and moderator A were considered in assessing the effect for supply chain performance (SC-Perf) objectives by computing standardized regression estimates with significance.

Data analysis was conducted to measure the moderation impact on SCR and SC-Perf objective relationships in line with the hypothesized relationship H5. H5a and H5b infer the pre- and post-COVID-19 pandemic outbreak lock-down response and the moderating effect variations of DSC competencies measured over the SCR and SC-Perf relations. Table V summarizes the effects of the moderation using the regression estimates and their corresponding significance over SC-Perf.

Table V. Moderation effects – Estimates and significance

The Table V shows that H5, H5a, and H5b are highly significant statistically ($p < 0.001$) with positive regression estimates of 0.188, 0.172, and 0.194, respectively. This implies that DSC technologies competency does moderate the SCR and SC-Perf relations. Also, the moderation effect has increased post-COVID-19 lockdown situation in comparison with the situation pre-COVID-19.

6. Research discussion and conclusions

This research emphasizes the importance of DSC technologies, particularly during the current pandemic outbreak situation. When human interaction is difficult, technologies can play a greater role in improving SC-Perf. Also, this research closes the gap identified by Pettit *et al.* (2019) on the impact of resilience on performance exclusively for the emerging markets' automotive sector. Normally, resilience enhancement such as introducing advanced DSC technologies requires investment, and it is difficult to monetize the payback. Considering the vitality of automotive sector growth in the emerging market economy, this perception-based study compares the relationship of SCR and SC-Perf objectives during the normal supply chain disruption caused due to earthquakes, floods and strikes, among other events, and a pandemic outbreak situation (COVID-19). The current situation also acted as a proof of concept to increase the usage of digital technologies to allow their workforce to work from home virtually for non-place dependent tasks during the lockdown period. These tasks for the continuation of the business are (i) design and development, (ii) sales and operations planning, (iii) procurement and supply chain, and (iv) finance and accounting functions.

DSC technologies competency influences automotive firms to use DSC technologies effectively in their day-to-day operations. The mean value of DSC technologies measurement items is over 5.0 – Table I highlights the data quality importance to develop the DSC technologies competency in automotive firms. The role of data quality in supply chain visibility provides insights on a real-time basis related to supply chain ordering, physical movement of materials, and supplier information. It enables the supply chain planning function by using DSC technologies such as data analytics to extend to all entities such as OEMs, component suppliers, LLSPs, and carriers to perform time-sensitive decisions and reduce errors to boost performance. Research also confirms that apart from data quality, firms need to build more capabilities to respond to velocity, volume, and variety (Ghasemaghaei, 2019). For example, in the event of a supply chain disruption, the automotive firm could sense the supply interruption and invoke a business continuity plan to switch to alternative suppliers or adjust production schedules to meet the customer demands.

Empirical research outcomes as per Table IV highlights the higher path weight for H1 which is 0.683 with higher significance ($p<0.001$). DSC technologies such as BDA and BCT interfere with multiple areas of the logistics and supply chain industry. Automotive logistics, particularly in the transportation business, is flawed by paperwork involving a greater number of stakeholders such as customs, warehousing, and distribution. In the traditional supply chain process, the operation is sequential and complex which requires waiting time at each stage, and also increases the total turnaround time. Considering smart contracts used in BCT, contract management across supply chain partners including payments is taken care of easily. BCT promotes transparency and supply chain efficiency by logging transactions which in turn increases the visibility for firms to track their product precisely from its source to destination. This shows that using such supply chain technologies makes firms to achieve both perceived 'usefulness' and 'ease of use' with greater involvement from top management. Thus, the empirical research outcome confirms H1 from the theoretical framework that DSC technologies competency positively relates to DSC technologies practices implemented by the automotive firms (Ivanov *et al.*, 2019). Also, it answers the first research question in terms of how DSC technologies capability influences its use or practice in day-to-day operations in emerging markets' automotive firms.

DSC technologies empower the key business drivers such as demand planning, capacity assessment and utilization, and production and retailing optimization for automotive operations to adapt and respond quickly post-disruption. Consumer buying patterns shift due to economic uncertainty situations; for instance, new product technologies such as electric vehicles emerge to comply with the regulatory needs which cause demand stability concerns (Xiao *et al.,* 2019). DSC technologies' collaboration with business builds online retailing, inventory optimization, and supply chain flexibility and visibility to allow required controls for automotive firms to increase operational efficiency with less cost. End-to-end supply chain visibility in the automotive sector in the context of market position further enables supply chain planning improvement, strategic sourcing actions, parts tracking or finished vehicles' quality issues, and swifter responses to supply chain risks during pandemic outbreaks and other devastating events. These factors facilitate firms to enable SCR drivers to increase SC-Perf objectives. DSC technologies support data integration and connectivity to build and implement cloud-based digital platforms. They provide many benefits to automotive firms in terms of improving SC-Perf with the standardized approach as follows: (i) reduced data inaccuracies and associated error costs; (ii) effective inventory management of finished vehicles; (iii) work-in-progress assemblies and components; (iv) enhanced ability through scenario planning to meet the customer demand; (v) better tracking and transportation management; (vi) higher on-time and higher utilization of deliveries; (vii) flawless order delivery, and receipt; (viii) higher customer service levels; (ix) ability to anticipate and handle risks wisely; (x) manage vehicle recalls effectively on a needs basis according to severity level; (xi) fix root causes, and (xii) build an improved demand forecasting. These findings confirm that digital technologies allow information exchange within or across supply chain entities to play a dominant role in supply chain operations, similar to healthcare entities (Mandal, 2018).

In this research study, the use of DSC technologies relationship to increase a firm's SC-Perf objectives and improve SCR practices are shown as H2 and H3, respectively. In addition, the firm's practice to improve SCR practices increases the SC-Perf objectives shown as H4 which supports the literature findings (Remko, 2020) As per Table IV, standardized estimates for H2, H3, and H4 are 0.008, 0.713, and 0.717, respectively.

One of the research outcomes indicates that DSC technologies practice does not directly influence the SC-Perf as H2 shows lower path-weight (0.008) and is not statistically significant ($p > 0.05$). This finding contrasts with the literature outcome (Haddud and Khare, 2020). It implies that automotive firms based in emerging markets are yet to completely undergo DSC technologies transformation. This is possibly due to legacy systems used in the current IT infrastructure, proliferation of software systems used with the existing standards, data interface and exchange bottlenecks, higher investment costs of connectivity software assets and equipment, lack of in-house competencies, and cybersecurity risk issues. Also, it may be too early for the firms which realized the direct performance benefits to consider full implementation. Moreover, Table II shows that local component suppliers account for 60% of the survey respondents from emerging markets. It shows that auto suppliers possibly will be meeting the cost targets set by OEMs to stay competitive in business and improve the firm's performance by focusing on localization and productivity improvement rather than introducing digital technology needs. Thus, in the present situation, DSC technologies used by automotive firms do not relate positively with SC-Perf objectives.

Regarding the DSC technologies use on resilience practices in the supply chain, the H3 relation shows the path weight as 0.713 with statistically high significance ($p < 0.001$) as shown in Table IV. The perceptions of respondents confirm that the DSC technologies use positively relates to managing resilience practices. The present COVID-19 pandemic situation crisis may accelerate digital transformation across the supply chain to bring the manufacturing and logistics opportunities using DSC technologies as follows: (i) real-time visibility; (ii) connectivity using the IoT; (iii) digital contracts and freight booking; (iv) dynamic asset management through network planning tools; (v) contactless and paperless goods delivery processes; (vi) building RPA as part of the digital workforce; and (vii)automated handling and warehouse management. Hence, the automotive firms are implementing and using the DSC technologies benefits to deal with resilience practices.

DSC technologies that influenced SCR practices in automotive firms positively relate with SC-Perf objectives as per the H4 relation which shows the path weight as 0.717 with statistically highly significance ($p<0.001$) as shown in Table IV. It also indicates the importance of the automotive business-to-business (B2B) relationship to deal with disruption or pandemic outbreak situations to improve SC-Perf objectives using DSC technologies as DSC technologies support shared information across supply chain partners to enable effective decision making. In the pandemic outbreak situation, DSC technologies may improve innovation practices for quicker operations recovery across the automotive industry ecosystem which consists of OEMs, first- and second-tier component manufacturers, LLSPs that deal with multiple modes of transport operations such as air, sea, rail and road, leasing companies, energy suppliers, and IT infrastructure providers. Thus, in the emerging market automotive firms, DSC technologies influences are increasing in nature over SCR practices to improve SC-Perf objectives. To assess the relations before and after the COVID-19 lockdown situation, H4a and H4b were introduced as shown in Table IV. Path-weight details are shown as 0.694 and 0.734, and thus statistically highly significant ($p<0.001$). This implies that the path weight of H4b is greater than H4a (H4b > H4a), which means that DSC technologies that influenced resilience practices are higher in use. This answers the second research question.

This research also extends to examine the DSC technologies competency of the automotive firms as a moderating variable in the relationship between SCR practices and SC-Perf objectives to determine its standardized value. This is to understand the practitioner's perceptions when they interpret DSC technologies competency role although these technologies are not or are only partially used in the automotive firms. H5 shown in Table V indicates the regression standardized estimates shown for the moderator variable as 0.188 with high statistical significance ($p < 0.001$).

Based on the statistical outcome, it is evident that DSC technologies competency moderates the relationship between SCR and SC-Perf objectives with a positive effect. To assess the moderator variable (DSC technologies competency) relations with SCR and SC-Perf objectives, before and after the COVID-19 lockdown situation, H5a and H5b were introduced as shown in Table V. Standardized estimate details are shown as 0.172 and 0.194 with statistically high significance ($p<0.001$). This implies that the path weight of H5b is greater than H5a (H5b > H5a), which means that DSC technologies competency moderates higher in the post-COVID-19 situation in comparison with the pre-COVID-19 situation. Considering H5, H5a, and H5b result outcomes, DSC technologies competency acts as a moderator variable for emerging markets' automotive firms which answers the third research question.

In supply chain disruption or pandemic outbreak situations, business agility is critical for faster response to the market. DSC technologies from automotive firms allow consumers to track and trace their product in the OTD window time. An example of this is when consumers purchase any fast-moving consumer goods (FMCG) from Amazon or Alibaba websites. Hence, DSC technologies drive innovation for consumers. They can allow consumers to track and trace the OTD for product or service deliveries. Automotive firms may also explore the usage of AI to build end-to-end supply chain visibility, extract inference from generated data at each operational stage, and develop scenario planning using insights on a real-time basis from Big Data for making effective decisions. The ongoing situation of the COVID-19 pandemic outbreak carries more vulnerability challenges in the global automotive supply chain. Digital technologies allow the firm's transformation through the prediction of supply chain visibility for multiple tiers of the supply base with corresponding locations for effective decision making. Also, these technologies attempt to bring more transparency, high resilience over the supplier network and geography, and allow proactive and collaborative communication. To improve SC-Perf, this research suggests that automotive firms invest in digital technologies to get the right pay-off from pandemic outbreaks apart from regionalization or localization opportunities to minimize the supply chain disruption impact. In summary, COVID-19 revealed more vulnerabilities in the automotive supply chain, so adopting DSC technologies is one of the solutions for better agility and to minimize the business impact for effective supply chain recovery.

In comparing the technology acceptance model (TAM) with the research hypotheses outcomes, automotive firms in emerging markets were inclined to adopt DSC technologies based on both perceived usefulness and ease of use. This empirical study assessment from the emerging markets auto sector is a primary research contribution for academicians, researchers, and practitioners. Hypothesis 2 (H2) reflects that investing in such technologies will not directly result in the SC-Perf improvement. This is a clear gap that the research identified between the academic literature and emerging markets' firms' practices. Perhaps, the ongoing COVID-19 pandemic outbreak situation (or) other future disruptive events such as trade tension or *force majeure* may change the situation as DSC technologies contribute to improving SC-Perf beyond SCR aspects (Ivanov *et al.,* 2019; Remko, 2020; Zouari *et al.,* 2020).

7. Managerial implications

Research conclusions confirm that adapting the DSC technologies influenced resilience practices to improve the SC-Perf objectives during pandemic outbreak situations (ex. COVID-19) and other supply chain disruption events in the emerging markets' automotive sector. Automotive supply chain professionals have recognized that the DSC technologies competency and practices in firms as well as in their supplying firm allow operations to recover swiftly. The DSC technologies bring out business agility for quicker response to market when a pandemic situation occurs. Emerging markets' automotive firms procure components or raw materials from their supply chain partners based at domestic and overseas supply bases. To perform resilience practices in the supply chain, this research elaborates on the DSC technologies competency and firm's adaptability to use or practice this on a day-to-day basis while dealing with supply chain disruption. Hence, implementing and practicing DSC technologies across emerging markets' automotive firms facilitates data sharing, and enables buy, produce, and sell actions in a swift manner and to restore the situation to a normal state. The managerial implications for introducing and maintaining DSC technologies for automotive firms are as follows:

First, it is necessary to include the information technology (IT) team in strategizing DSC technologies need immediately after finalizing the business strategy. The IT team can support top management to identify the various DSC technologies options that are available on the market which suit the firm's goals and requirements. *Second*, DSC technologies improve SCR practices through increasing visibility, flexibility, agility, and collaboration. Building an integrated data ecosystem eliminates information silos and other duplication efforts. It produces a single source of truth based on the shared and integrated data that induce speed in making decisions to restart the business across the supply chain. *Last*, to resume the operations after supply chain disruption or pandemic outbreak situation, emerging markets' automotive firms may follow the return-to-work readiness checks with the help of DSC technologies with greater data quality. It allows firms to build stronger B2B relationships and supports firms to follow communication, cooperation, clarity of demand forecasting, inventory status, and other initiatives to boost the commitment and assurance with their supply chain partners.

The research findings highlight that DSC technologies generate value when the firm perceives their usefulness. It has been evident from the findings that the more DSC technologies are used, the higher the improvement in SCR practices during supply chain disruptions. Also, the firm's ability to improve with DSC technologies helps them to recover quickly from disruptions and improves the business performance. The findings also indicated the moderating effect of DSC technologies competency on SCR practices and SC-Perf objectives over the long term in dealing with the COVID-19 pandemic outbreak event for the emerging markets' automotive sector. DSC technologies contribute to the success of supply chain visibility through synchronizing and data connectivity – the lack of the same will result in delay in resuming operations, customer complaints, lack of revenue from product shortages, higher inventory and freight costs, delayed cash flow, and decrease of productivity. Hence, to stay competitive, automotive firms need to prepare for broader supply chain visibility and data-sharing across entities.

In the COVID-19 pandemic outbreak situation, it is obvious that DSC technologies might support supply chain risk mitigation actions such as (i) extending the supply chain visibility focus beyond Tier-1 supplier risk, (ii) building strong scheduling flexibility by prioritizing high margin product shortages, (iii) developing transparency with carriers to secure the transportation capacity, (iv) exploring the alternate source of parts supply, and (v) prescribing the analytics solutions to assess the post-COVID-19 impact associated with social, economic and natural reasons for firms to make timely decisions. It is necessary for firms to create an enterprise team to manage the adoption and institutionalization of DSC technologies and corresponding business process updates. Alternatively, firms can obtain support from service providers who already have the technical capabilities and business know-how on supply chain connectivity.

8. Limitations and scope for future research

The study has limitations since it is specific to emerging markets' automotive sector and perception-based research approach applied in the midst the COVID-19 pandemic outbreak situation. Market-wise individual assessment is limited due to the lower sample size from three different markets in two different periods. The research outcome cannot be generalized across other nations or other industrial sectors. Before applying it to other nations and industries, it needs to be further tested and expanded. However, it will be useful to the supply chain professionals from other nations and industries to learn and adapt the relevant practices on DSC technologies. The adaption and learning will be useful in the concurrent and post- disruptions phases, as it will increase the speed of response to implement SCR practices to achieve long-term SC-Perf objectives.

The research contributions from this study open further research opportunities. In the automotive sector, disruptive supply chain and logistics technologies such as using the UAV or drones for transporting small packages, which transforms the delivery process, may be explored. Conducting this research marketwise in emerging markets may give more insights considering OEMs and domestic component manufacturers. Also, studying the DSC technologies' influence on the overseas supply base may help further in the experimental aspects of the discussion. It is suggested that future researchers explore the DSC technologies followed in other industries (pharmaceuticals, refinery, electronics, aviation, etc.) within India, China, and Thailand markets. Further research could also compare the influence of DSC technologies on resilience practices in supply chain management across international automotive markets to make the right investment decisions.

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Table I. Literature Reference and Descriptive Statistics

Construct Name	Measurement items	Mean	Std. Deviation	Corrected item total correlation	Cronbach Alpha
DSC Technologies competency	In my organization, we use one or more DSC technologies {such as Big Data, Blockchain, Internet of Things (IoT), Robotics Process Automation (RPA), 3D Printing(3DP), RFID Tags, ...} that…				
	perform analytics with high velocity (Velocity). [Richey *et al.*,2016]	5.270	1.304	0.761	0.972
	perform real time tracking of parts or finished vehicles or shipping containers from their origins (track and trace). [Musa and Dabo (2016)]	5.360	1.304	0.716	
	In my organization quality of data used in DSC technology.				
	is secure. [Ghasemaghaei. M (2019)]	5.220	1.291	0.899	
	is reliable (Veracity). [Ghasemaghaei. M (2019)]	5.250	1.313	0.891	
	is relevant to task on hand. [Ghasemaghaei. M (2019)]	5.270	1.308	0.879	
	is timely. [Ghasemaghaei. M (2019)]	5.320	1.281	0.870	
	is accurate. [Ghasemaghaei. M (2019)]	5.300	1.286	0.867	
	has an appropriate level of details? [Ghasemaghaei. M (2019)]	5.280	1.294	0.876	
	To make decisions, DSC technologies utilized in my organization processes				
	real-time data. [Ghasemaghaei. M (2019)]	5.120	1.275	0.845	
	high volumes of data (Volumes). [Ghasemaghaei. M (2019)]	5.170	1.265	0.846	
	different types of data (Variety). [Ghasemaghaei. M (2018)]	5.170	1.256	0.850	
DSC Technologies Use	In my organization top management is committed on investing the DSC technologies. [Polites and Karahanna (2012); Teece (2012)]	5.310	1.188	0.961	0.966
	In my organization DSC technologies perceived usefulness. [Davis (1989)]	5.300	1.188	0.960	
	In my organization employees adapt the DSC technologies in a shorter span of time. [Ghasemaghaei. M (2019)]	5.370	1.197	0.951	
	In my organization DSC technologies perceived ease to use. [Davis (1989)]	5.370	1.208	0.931	
	In my organization, DSC technologies are used more often with data privacy and protection compliance across supply chain entities. [Ghasemaghaei. M (2019)]	5.250	1.248	0.808	
	In my organization, DSC technologies are used higher extent to enable shared understanding of the data flows across supply chain entities. [Ghasemaghaei. M (2019)]	5.150	1.203	0.745	

Construct Name	Measurement items	Mean	Std. Deviation	Corrected item total correlation	Cronbach Alpha
Supply Chain Resilience	In my organization DSC technologies build across supply chain entities (Supplier, LLP, OEM, Dealer) to.				
	improve visibility, collaboration, coordination and understanding. [Chowdhury and Quaddusa, 2015; Ruiz-Benítez *et al.,* 2018; Zouari *et al.,* 2020]	5.400	1.120	0.836	0.944
	maintain capacity in production, storage, handling and transportation. [Rajesh *et al.,* 2015; Ruiz-Benítez *et al.,* 2018]	5.230	1.201	0.791	
	develop disaster recovery plan. [Pettit *et al.,* 2013; Remko, 2020; Ruiz-Benítez *et al.,* 2018]	5.200	1.244	0.886	
	perform communication and information sharing. [Colicchia *et al.* 2019; Soni *et al.,* 2014; Ruiz-Benítez *et al.,* 2018]	5.480	1.174	0.861	
	generate real cost options. [Guojun and Caihong, 2008; Remko, 2020; Ruiz-Benítez *et al.,* 2018]	5.170	1.217	0.933	
	track using visible transportation. [Romano *et al.,* 2013; Ruiz-Benítez *et al.,* 2018]	5.190	1.267	0.807	
Supply chain performance	In my organization robust SCM resilience improves supply chain performance at firm level objectives as follows.				
	Reduced cost. [Prajogo *et al.,* 2016]	5.270	1.281	0.869	0.971
	Speed of delivery. [Prajogo *et al.,* 2016]	5.620	1.263	0.943	
	Dependability of our service (service rate). [Akkermans and Voss, 2013]	5.520	1.241	0.956	
	Risk reduction on distribution. [Chowdhury *et al.,* 2019]	5.680	1.199	0.876	
	Sustainability of operations [Cousins *et al.,* 2019]	5.420	1.272	0.947	
	End customer satisfaction [Ellinger *et al.,* 2012]	5.590	1.310	0.899	

Sample Size (N) = 313

Table II. Demographic Data

Survey Questions	Division / Range	No. of respondents	% of Response
Gender	Female	151	48.24%
	Male	162	51.76%
Age (in years)	20-30	66	21.09%
	31-50	240	76.68%
	> 50	7	2.24%
Firm Location	India	56	17.89%
	China	129	41.21%
	Thailand	128	40.89%
Supply chain entity	Supplier	188	60.06%
	LLSP	20	6.39%
	OEM	105	33.55%
Work Experience (in years)	< 5	38	12.14%
	5-10	121	38.66%
	11-15	82	26.20%
	> 15	72	23.00%
Firm age (In Years)	< 5	18	5.75%
	5-25	184	58.79%
	26-50	83	26.52%
	>50	28	8.95%
Firm size (in numbers)	<500	125	39.94%
	501-1000	52	16.61%
	1001-5000	65	20.77%
	>5000	71	22.68%
Annual Revenue (In US$ Million)	1 - 500	226	72.20%
	501 - 1000	30	9.58%
	>1000	57	18.21%
Survey date in relation with lockdown	Before	162	51.76%
	On or After	151	48.24%

Table III. CFA summary statistics

Construct	Range of factor loadings	Composite reliability	Average variance extracted	Maximum shared variance	Average shared variance
DSC Competency	0.601 - 0.997	0.972	0.819	0.541	0.449
DSC Usage	0.770 - 0.999	0.976	0.893	0.508	0.414
Supply chain resilience	0.816 - 0.900	0.944	0.738	0.541	0.523
Supply chain performance	0.845 - 0.972	0.972	0.853	0.521	0.377

Model fit index: Chi.Sq/df = 3.433; CFI = 0.956, and RMSEA = 0.08

Table IV. Path weights of structural model

Hypotheses	Dependent variable		Predictor variable	Path Weights	p-value
H1	DSC Usage	<---	DSC Competency	0.683	***
H2	Supply-chain performance objectives	<---	DSC Usage	0.008	0.894
H3	Supply-chain resilience practices	<---	DSC Usage	0.713	***
H4	Supply-chain performance objectives	<---	Supply-chain resilience practices	0.717	***
H4a	Supply-chain performance objectives	<---	Supply-chain resilience practices (pre COVID-19 lock-down)	0.694	***
H4b	Supply-chain performance objectives	<---	Supply-chain resilience practices (post COVID-19 lock-down)	0.734	***

Model fit index: Chi.Sq/df = 3.706; CFI = 0.951, and RMSEA = 0.08

Table V. Moderation effects – Estimates and significance

Hypotheses	Dependent variable		Moderating effect	Estimates	p-value
H5	Supply-chain performance objectives	<--	Moderator A: SCR x DSC Competency	0.188	***
H5a	Supply-chain performance objectives	<--	Moderator A: SCR x DSC Competency (Pre COVID-19 lock-down)	0.172	***
H5b	Supply-chain performance objectives	<--	Moderator A: SCR x DSC Competency (Post COVID-19 lock-down)	0.194	***

Figure 1: Conceptual framework with hypotheses relations