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Research Article

Strategic Integration of Big Data Analytics and Business Intelligence for Enhancing Supply Chain Resilience in SMEs

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ABSTRACT

This study examines the impact of Big Data Analytics (BDA) capabilities on supply chain resilience and the role of Business Intelligence capabilities as a mediator, especially in small and medium-sized enterprises (SMEs). The cross-sectional method through survey responses was adopted for hypothesis testing. In all, 153 responses were obtained and analyzed using the approach based on partial least squares with SmartPLS3. The results indicated that capabilities in BDA significantly contributed to the anticipation, response, and recovery dimensions of supply chain resilience. Further, it was realized that BI capabilities mediated the process of change of information into actionable insights that enhance agility and reactivity. This mediation effect is especially beneficial for SMEs, as it amplifies the impact of BDA by effective data utilization. The findings further depict that BDA technology integration with strong BI capabilities enhances decision-making, risk management, and operational efficiency to drive supply chain resilience plus competitiveness..

Keywords: Big Data Analytics Capability; Business Intelligence; Supply Chain Resilience; SMEs; Supply Chain Management; Data Utilization; Partial Least Squares.

1 INTRODUCTION

The most important issue for supply chain resilience has come to the fore in the modern business environment, characterized by increasing global interconnectedness and rapid disruptions (Sabahi and Parast, 2020). If anything these disruptions created due to, for example, geopolitical frictions, natural disasters, or sudden shifts in the market have underlined one thing, it is the importance of a supply chain to rapidly foretell, adapt to and recover from a disruption to keep the wheels of operation moving and meet customer expectations (Kamalahmadi and Parast, 2016). The use of advanced technologies such as BDA capability and business intelligence holds out much promise for improving supply chain resilience in this context. Integration with BI opens as a transformative approach (Adama and Okeke, 2024). BDA capability empowers the firms to use the data collected in huge volumes across the supply chain in giving notice to risks on a real-time decision-making basis, providing predictive consumer behavioral insights. BDA capability enables an organization to capture and analyze superabundant volumes of data emanating from across the supply chain ecosystem. Using these techniques, that firm would have actionable visibility into patterns of demand, vulnerabilities of the supply chain, and risks that are coming up in real-time. With advanced analytics techniques such as machine learning algorithms and predictive modeling, Dubey et al. (2019) argue that firms can realize actionable visions into demand patterns, supply chain vulnerabilities, and emerging risks in real-time. This would enable decision-makers to be proactive in the identification of probable disruptions, stock inventory optimization, and devising agile responses for mitigation impacts on operations and customer service (Bharadiya, 2023).

BI serves as the perfect link to converting raw data into actionable intelligence obtained from BDA. Therefore, BI plays an active role in translating raw data into actionable intelligence. The capabilities of BI tools and technologies in data visualization, interactive dashboards, and comprehensive reporting ensure sound decisions to be taken at various levels of the organization promptly. Business Intelligence helps in improving supply chain resilience, including increased visibility in performance metrics, ease of scenario planning, and strategic re-adjustments based on up-to-the-minute market information and operational insights. In so doing, BI helps people make better choices about where to allocate resources and how to mitigate risks (Ibeh et al. 2024). The research, however, has not been appropriately conducted, and there is a clear lack of empirical evidence on the ground benefits of combining BDA capability with BI to improve supply chain resilience. It has been acknowledged within the literature but only at the surface level of their combined effects within the complex and constantly changing world supply chains. Namely, there is an incomplete sympathetic of how companies can truly and appropriately incorporate these competencies to construct resilient, adaptive supply chains that are well robust against all forms of vagaries and disruptions.

It is highly paramount that this hiatus be met through rigorous research in the field of supply chain management for knowledge and practice in reality. The results were informed that further investigation on the interactions of BDA capability and BI is necessary to build resilient supply chains from the strategic implications for the practice of building managerial and technological capabilities in organizations that seek to enhance their resilience towards such capabilities. This is needed to inform future innovations, policies, and strategies that will enhance supply chain resilience as well as sustainable growth and risk mitigation in the highly volatile global market. Therefore, the research question is as follows:

RQ. "How do BDA capability *and BI capabilities synergistically improve supply chain resilience in the context of global business operations?"*

This research question seeks to identify the combined impact of BDA capability and BI on supply chain resilience. Specifically, it tries to find out how such technologies may be integrated and employed to reduce and/or manage risks, improve decision-making and increase operational as well as organizational resilience in a global business environment..

2 THEORETICAL BACKGROUND AND DEVELOPMENT OF HYPOTHESES

2.1 BDA Capability

Big Data Analytics (BDA) is the ability of an organization to acquire, store, and process large sets of diversified data in the search for valuable insights. In other words, it is the ability to analyze large volumes of structured and unstructured data by data scientists through the use of sophisticated analytics tools and techniques that include machine-learning algorithms, predictive modeling, and real-time processing (Mikalef et al., 2020). Such big data analytics capabilities enable patterns, trends, and relationships to be identified in data at much greater volumes than traditional analytics could manage. The enhanced analytical capacity can go a great way in assisting firms in making informed decisions and further unraveling ways to advancement and innovation through betterment of operations (Dubey et al., 2019). An important element of BDA capability is the infrastructure and technological stack over which the entire data lifecycle, ranging from data capture to storage and processing, is realized. The volume and variety of data being generated are such that organizations require strong data management systems, scalable cloud computing resources, and powerful analytics platforms if they are to make the shift (Arowoogun et al., 2024). Also, the integration of heterogeneous databases to ensure the value of available data and the security of data increases the accuracies and reliability of analytics results. It is with this strong technological base that organizations will enhance their BDA capacities in obtaining the ability to process real-time data streams and conduct complex analysis with actionable insight to drive strategic decision-making (Xia et al., 2024).

Further than technology, great execution of BDA capacities requires an emphasis on human resources alongside a data-driven culture. An organization’s seat needs to be skilled professionals in data science and IT that consult in the creation and execution of increasingly complicated analytics solutions. Majorly cultivating a culture philosophy that laser-focuses on accepting data-driven choices and drives a program of continual learning and invention is essential to drawing on BDA’s potential (Jiang et al., 2024). Organizations investing in coaching and cross-functional collaboration and guaranteeing data literacy will be better prepared to leverage their away from technology-based pieces of BDA. They can gain a competitive advantage in the market by pre-researching trends, pre-conditioning against risks, and quickly adapting to changing circumstances, in a much more efficient and resilient business operation. (Bahrami et al., 2024).

2.2 Business Intelligence

BI is the set of tools, technologies, and processes by which an organization takes to gather, integrate, analyze, and display business data. The power to convert raw data into actionable insights that are of strategic and operational decisions makes a difference in efforts (Ibeh et al. 2024). Among commonly used BI tools are such products as data visualization software, interactive dashboards, and reporting tools, as well as data warehousing solutions, which are used to collect information from different sources and present it through a single view. Through this, BI assists in offering relevant business metrics and performance indicators at any time to be used in improving efficiency, competitiveness in organizations by monitoring operations, trend spotting, and decision-making (Adama and Okeke, 2024).

BI is very essential in the context of data visualization, where any intuition about the complex set of data would be graphically represented as charts, graphs, and maps for easy understanding. Hence, the quicker and confident decisions of the patterns and trends become possible from these visualization tools and, hence, the actionable insights that are so empowered. For instance, the members of the sales team might use BI dashboards to see performance against targets in real time, whereas the supply chain manager might look to see levels of inventory and times of delivery. Handling data with BI visualizations allows an easy way to articulate insight-driven decision-making across organizations through sharing discovering across departments (Adaga et al., 2024). Besides, effective BI equals good practice in data governance and data quality management to assure the trust and correctness of the derived insights. Data governance refers to a set of policies and rules around managing data, including controls over access to data, safety measures, and compliance with regulatory standards. High quality of data implies correctness, completeness, and conversancy of data being analyzed. Good Business Intelligence companies usually invest in data stewardship programs and data quality initiatives to keep up the integrity of their information assets. Taking such initiative towards ensuring data quality and governance opens up the opportunity for the decision-makers to rely upon the derived insights through business intelligence for making wise decisions thereby resulting in better strategic planning, improving operational efficiency and enhancing market position. (Maghsoudi and Nezafati, 2023).

2.3 Supply Chain Resilience

Interruptions in the supply chain are common and more than ever, challenging to deal with in the current volatile business landscape. According to Jüttner and Maklan (2011), a disruption is any type of internal or external threat that hampers the flow of products and services in a supply chain; it can be highly risky for maintaining operational continuity. Following a stream of increasingly severe disruptions, the importance of resilience in SCM can be referred to as critical (Sabahi & Parast, 2020).

Resilience, according to Atadoga (2014), from the viewpoint of an organization’s ability to involve and adapt to a change, is the intrinsic ability of any system, be it ecologic, social, economic, or technological, to absorb an imposed or accidental shock, concerning disruptions, while preserving essential functions and subsequently forming, or reformulating according to the developing condition for long-term sustainability and stability. This view has also been extended to supply chain management (SCM), where the term 'supply chain resilience' normally refers to the ability to recover and return to its normal opening period after disruption. Supply chain resilience is termed by Brandon-Jones et al. (2014) as the capability of the supply chain to get back on its routine business path in an effective manner after a disruptive event, reflecting its newfound importance among increasing worldwide instabilities.

Supply chain resilience combines anticipation, resilience, and recovery. Anticipation is defined as the ability to proactively plan and foresee risks, as well as develop appropriate mitigation measures. The definition of a more formal vocabulary subsequently becomes a possibility of applying the correct measures into any business or project. Through a tone that evokes feelings of closeness or understanding between writer and reader, the rewritten text may also feature the following:

The capability of proactive planning and fore sighting risks with the subsequent ability to apply the appropriate measures into any business or project.

2.4 The relationship between impact BDA capability on supply chain resilience

The resilience of the supply chain stands to be intimately instigated by the link between BDA capability and, further, sustains operational continuance and competiveness especially in the highly dynamic business landscape of today. An intrinsic BDA capability is defined in this respect as the facility within an organization for fetching, processing, and making sense of large datasets coming from varied sources to derive usable insights that would power the resilience of supply chains. It starts with the anticipation phase, wherein organizations could explore historic data, monitor real-time data streams, and speculate potential risks and disruptions. These may be patterns and trends provided by advanced predictive analytics under the application of machine learning techniques that give insights into potential risks such as supplier failures, market fluctuations, or transportation delays. BDA enables SMEs to optimize their inventory level, make more precise demand forecasting, and even construct different plans to guarantee a good running of at least one day.

During the resistance phase, BDA functionality helps a company maintain full business continuity within its supply chain. This encompasses real-time visibility of performance metrics with regard to tracking shipments and steering supplier relationships. Especially for SMEs, often operating under tighter resource constraints, having a clear and up-to-the-minute view of the supply chain is highly valued: "As a company, you can easily identify the bottlenecks and see the disruptions' effects. Then, based on that knowledge, you can make an informed decision on resource reallocation or even rerouting the shipment." Maintaining business operations during disruptions means that the SMEs can continue to respond to customers' needs and guarantee service delivery when everything else goes wrong. In the recovery and response phase, what really matters is the capability at BDA to bring everything back to normal business operations quickly and effectively. Describing its own post-event analysis, the capacity of BDA to enable businesses to understand the root causes, determine the extent of the damage, and decide the order in which recovery activities should take place is vital. Advanced analytics can provide an understanding of the most effective recovery strategies in the choice of initial suppliers contacted, prioritization of transportation routes, and effective communication with stakeholders. This very aspect, for SMEs, of being capable of quick recovery from a disruption is a key competitive and customer satisfaction differentiator. BDA supports the minimization of downtime risk for nondelayed quick recovery in returning back to normal to survive and sustain the business operations without further and longer adverse effects (Gupta et al., 2024). Findings reveal an affirmative contribution of BDA to enhancing supply chain resilience. Results reported in literature works, for instance Dubey et al. (2021), explaining how the ability to analyze data strengthens supply chain resilience through interaction with structural flexibility. Likewise, the work of Papadopoulos et al. (2017), who presents an analytical framework for assessing the resilience of supply chain networks from the BDA outlook. The other major factors that drive supply chain agility were, according to Mandal (2018), BDA expertise in business, technology management, and relationship management. These results can be more specifically useful to SMEs, which do not often have resources comparable to large corporations but can be at par in attaining similar levels of resilience and operational efficiency by using BDA.

In summary, the relationship between BDA capability and supply chain resilience is complexly causal and extremely beneficial especially to the SMEs. It is through BDA that operations in small enterprises begin to focus on risk anticipation continuity during disruptions and later fast and efficient recovery. The assimilation of BDA into the management of the supply chain will make SMEs better off in ensuring their resilience to competitive and competent navigation through the challenges of the contemporary business environment. Documentary evidence underpins the critical significance of BDA in building a resilient supply chain branding it as a strategic asset for businesses of all sizes. Therefore, we recommend:

Hypothesis 1 (H1). *BDA capabilities positively impact supply chain resilience.*

2.5 The relationship between impact BDA capability on BI

The relationship between BDA ability and BI is that of essence, where BDA lies as an underpinning capability that fortifies and boosts BI competencies. As described, BDA is actually defined as the ability to collect, process, and analyze large volumes of structured and unstructured data in creating actionable insights. While BI refers to the software, applications, and methodologies employed in the integration, storage, analysis, and visualization of corporate data (Qaffas et al., 2023). In other words, informed decision-making, strategic planning, and organizational business performance depend on critical synergy of these two capabilities. It is particularly important in an SME setting (Maroufkhani et al., 2023). Normally, SMEs have very limited resources, and markets are strongly aggressive; thus, this becomes a critical disadvantage wherein adequate use of available data works to their best benefit. BDA supports BI by ensuring a richer dataset in analyses. All these complicated analytical techniques like machine learning, predictive modeling, and real-time analysis uncover very deep insights for SMEs in forecasting accurately enhanced with the help of such insights. For instance, BDA can help SMEs recognize the emerging market trends, customer preferences, and operational inefficiencies, which are then visualized and reported via BI tools. Integration in this way will let SMEs proactively make decisions informed by allowing growth and competitiveness (Willetts and Atkins, 2024).

One of the major foci in their relationship is how the BDA improves the depth and quality of insights in BI. Consequently, insights created by an organization are very limited, primarily with traditional business intelligence and analytics with little data. BDA extracts value from volumes of up-to-the-minute data collected from diverse sources, including social media, IoT devices, and transactional archives. It allows organizations to make use of business-user-driven real-time insights and predictive analytics thus enabling more dynamic and responsive BI. For example, an SME in the retail industry can use BDA to analyze customer behavioral patterns and forecast inventory requirements to maintain optimal stock levels, as reported by Zamrudi and Saputri (2024). Enhanced analytical BI enables SMEs to enhance effectiveness in strategic planning and operations, which are critical for the success and development of SMEs. Moreover, BDA and BI jointly instill a culture of data-driven decision-making within SMEs by all levels of users. It equips BDA to deliver the necessary analytical might, wherein BI now provides intuitive data visualizations and reports that can be understood by anyone across departments. This democratization of data places in the hands of the teams empowering evidence-based decision making, improved cooperation, and sparking of innovation. For example, the marketing department would be able to develop campaigns based on real-time customer data, while the supply chain can become more agile and resilient by continuously pre-assessing risks of disruption in logistics. This way of using data in a holistic manner ensures that SMEs are agile and resilient in a fast-changing business environment.

The study underlines that the integration of BDA and BI capabilities is a perfect ingredient to boost business performance. Qaffaset al. (2023) strongly vindicate that BDA talent capabilities positively influence BI infrastructure for firms to do better in their financial and marketing performance. Wuet al. (2024) proves it in the case of the Chinese manufacturing sector— that is, the sensing, transforming, and driving BDA capabilities of BI that act as mediators in the relationship of the impact of BDA capabilities with radical innovation. It is noted by Ilmudeen (2021) that BDA capabilities significantly influence BI infrastructure, which further enhances operational and marketing performance. BI infrastructure partially mediates the relationship between BDA capabilities and operational routine, though it totally mediates regarding its effect on marketing performance.

That, therefore, is the relationship that exists between BDA capability and BI—an enthusiastically beneficial nexus, particularly in the context of SMEs. The scope, depth, and quality of insights in BI are perfected by BDA, permitting SMEs to base their proactive decision making on astute nurturing of growth and competitiveness. SMEs will, by all means, include BDA as an operation that assures them of a philosophy based on data, the optimization of operations, and assured agility in the face of market challenges. Research evidence endorses the fixed place of BDA in enhancing BI capabilities—it is a required strategic resource for SMEs on the journey to excellence in the contemporary business environment:

Hypothesis 2 (H2). *BDA capabilities positively impacts BI.*

2.6 The relationship between impact BI on supply chain resilience

BI is, however, a combination of technologies and application with methodologies aimed at gathering, integrating, analyzing, and presenting business data. Supply chain resilience, on the other hand, refers to the ability to predict, withstand, and recover from disruptions. The linkage between BI and supply chain resilience is, therefore, a critical advantage for SMEs in the highly volatile business landscape of today (Adama and Okeke, 2024). Given that SMEs frequently operate with limited resources and less room to maneuver with respect to managing operational risks, the integration of business intelligence into supply chain operations is essentially vital (Sabahi and Parast, 2020). These BI tools enable such businesses to pool and analyze data from information on market trends, supplier performance, or even the stock levels of goods. At SMEs, this approach helps identify guidance on how to spot risks early, like learning when a risk surfaces due to a supplier's tardiness, transportation problems, or a change in customers' demand, and take proactive steps to mitigate risks. For example, with the use of predictive analytics, disruption can be foreseen, and the inventory can be planned adequately in SMEs to continue the operation without the expensive interruptions (Raj et al., 2016).

As disruptions take place, it becomes a principal interest for SMEs with much less wide-ranging reserves compared to big corporations to hold their operational integrity. BI armors them with the locus of control in real-time visibility of their supply chain operations to promptly categorize and respond to issues as they occur. For example, a delay experienced by a principal supplier may be communicated by the BI tools to SMEs in time to source alternative suppliers or change production schedules (Zamrudi and Saputri, 2024). Increased visibility ensures that SMEs are able to continue service levels, meet the required customer expectations, and reduce the effects of the disruption in their operations. At the recovery stage, business intelligence steps in, revealing the best ways to recover effectively (Ragazou et al., 2023). After the event, BI tools support SMEs to identify the root cause and scope of the damage, and to rank their efforts in recovery and, hence, facilitate communication and coordination among supply chain members. This will in turn support the SMEs to recover more quickly and effectively with lesser productivity time and financial loss (Fitrianingrum et al. 2023).

BI has a strong supportive relationship with the level of supply chain resilience. The study results of Aunyawong et al. (2020) show that proper technologies and tools, well-defined processes are essential for implementing powerful BI product; however, this is not directly leading to the development of the same. Knowledge and information to become empowered through decision-making in the supply chain are also needed. Some cultural issues between and within organizations affect the development of the product of BI. According to the findings of Jafari et al. (2023), BI, integration, and agility are important for enhancing the performance of the supply chain, among which the first stroke happens to be BI. In fact, it is an added advantage of integrating and increasing the flexibility of the supply chain. Modgil et al. They identified five major areas in which Artificial Intelligence can enhance supply chain resilience: fostering visibility across the supply chain; last-mile optimization in delivery execution; personalization across stakeholders within the supply chain; disruption mitigation; and agile procurement process.

To sum up, the relationship between BI and supply chain resilience is complex and highly beneficial especially to SMEs. Business intelligence increases the capacity of SMEs to pre-empt risks, sustain operational integrity in the face of a disruption, and quickly and efficiently recover. As a result, SMEs will increasingly incorporate or enhance the role of business intelligence in the management of their supply chains to ensure ever-improving resiliency in the face of remaining competitive and navigating the vicissitudes of the contemporary business environment. The documented evidence has stressed the acute importance of BI in building a resilient supply chain, underlining its status as a strategic asset for all sizes of businesses..

Hypothesis 3 (H3). *BI positively impacts supply chain resilience.*

2.7 The Mediating Role of BI

The mediating role of BI capabilities in strengthening the influence of BDA on supply chain resilience, especially in the context of SMEs. With BDA adoption becoming common among organizations for the processing and analysis of large volumes of data, BI capabilities would serve as the important intervening variable converting analytical insights into actionable strategies, thus enhancing the supply chain resilience.

The BDA capabilities involve the handling and analysis of large volumes of structured as well as unstructured data to reveal hidden patterns, trends, and correlations that could be left unexplored by traditional data processing techniques. Yet, the direct results of BDA, though very powerful, require expert-level analysis to harness them effectively (Wang et al., 2016). This is where the BI capabilities play a role. SMEs either have no interest in investment in heavy IT infrastructure and software licensing costs or do not derive any value from such investments. Therefore, they prefer a cloud-based solution that has lesser TCO as compared to an on-premise deployment.

BI capabilities are also very significant for linking operations within the supply chain and making them agile. In the view of Jafari et al. (2023), it is this interaction among BI, integration, and agility that underlies good supply chain performance, with BI happening to be leading in effect. Thus, the BI systems can seamlessly gather information from any part of the supply chain from different sources in generating a holistic view of the entire ecosystem that makes up the supply chain. One important factor for the SMEs is to have a holistic view for real-time visibility and coordination of different functions within the supply chain. Improved integration will further imply more agility, enabling SMEs to respond fast and effectively to the varying market conditions, rapid demand changes, and supply chain disruptions. For example, if there is a business discovery that BDA capabilities expose to the supply chain risk facing the company, this information could be treated to all BI stakeholders so that timely and coordinated actions can be taken to minimize the impact.

In addition, BI capabilities support learning and sustained improvements—a long-term resilient supply chain. In many cases, BI platforms have extended capabilities to include features like predictive analytics and scenario modeling that enable an organization to mimic different strategies and foresee their possible outcomes. This is of value, with the SME functioning within highly dynamic markets where it has to change its strategies more frequently than not to remain competitive. Because it enables them to model many eventualities, and hence build up a contingency capable of standing a great deal of change (with rule restructuring), in a far quicker and more efficient manner than without the tool, BI capabilities allow SMEs to prepare robust change plans.

To sum up, the moderating role of BI capabilities is important in enhancing the positive effect of BDA capabilities on supply chain resilience. It is argued that BI capabilities convert complex analytical outputs into actionable insights, facilitate integration and agility, and support continuous improvement and organizational learning. Especially for SMEs, these capabilities are concerned with providing all that is necessary to navigate the complexity of modern supply chains—having the ability to recognize, respond, ensure operations, and guarantee a sound competitive edge. Supporting evidence is given in line with the necessary combination of BI with BDA to enhance decision support for supply chain resilience. Hence, the following hypotheses can be presented:

Hypothesis 4 (H4). *BI mediates the link between BDA capabilities on supply chain resilience.*

Table 1 highlights the contributions of previous research trainings and identifies the research gaps that the present study aims to address. In contrast, Figure 1 illustrates the research framework guiding this study.

Table 1 Comparison of contributions from prior research.

Author(s)	*BDA capabilities*	*Business intelligence*	*Supply chain resilience*
Mikalef et al. (2020)	✓		
Adama and Okeke (2024)		✓	
Sabahi and Parast (2020)			✓
Papadopoulos et al. (2017)	✓		✓
Mandal (2018)	✓		✓
Qaffas et al. (2023)	✓	✓	
Wu et al. (2024)	✓	✓	
Ilmudeen (2021)	✓	✓	
Aunyawong et al. (2020)		✓	✓
Jafari et al. (2023)		✓	✓
Modgil et al. (2022)		✓	✓
Present Study	✓	✓	✓

3 METHODOLOGY

3.1 Sample and data collection

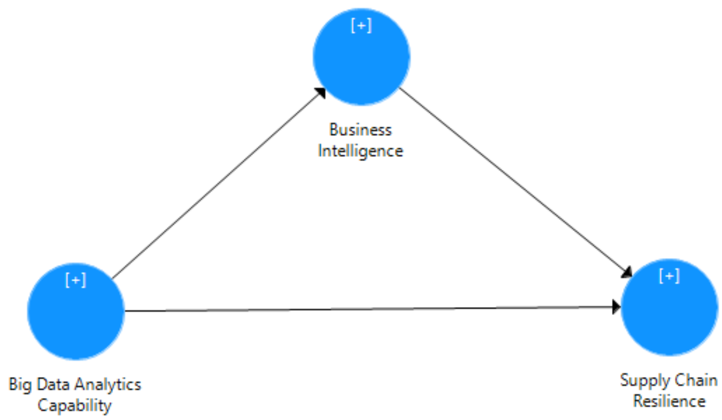
Based on the Ministry of Industry's website, 248 companies were selected for the study. Different industrial sectors were chosen to explore how BDA capabilities were being evolved across different domains (see Figure 1). This study uses the survey method in collecting information on the sample of companies to comprehend their characteristics and opinions, as noted by Gable (1994) for information gathering concerning population characteristics or opinions and by Flynn et al. (1990) for exploring conceptual models and theories.

Reliability is the extent to which the measurements of record data can be repeated in a consistent or repeatable manner that would show more or less the same results if applied under similar conditions and on several instances. Only through validity can accuracy and meaning be acquired in measurements, making sure that the study indeed, measures its intended factors and that the findings are actually related to the research problem or hypothesis. In the study, the questions of the questionnaire were translated into Farsi by a professional translator who also conducted in-depth interviews with ten senior managers in supply chain management (SCM) for this purpose. Four people reviewed the questionnaire to assess its content validity, a precondition test of which confirmed the applicability, and the measures of reliability. Description and examples from the startup helped all respondents understand to ensure accurate answers.

Survey-based research is defined as an approach to collecting data from a predetermined set of primary respondents to make available facts and information based on various interest areas. The technique involves obtaining quantitative data through the administration of structured questionnaires (Armstrong and Overton, 1977). The T-test is a statistical test that helps determine if there is any significant difference between the means of two given sets. It essentially helps in analyzing the respective average values of the groups to figure out if the observed differences are just likely due to chance (kim, 2015).

The survey is created with one defendant in mind, usually top executives with relevant educational background and work experience in business analytics, respondents include purchasing manager, supply chain analyst, supply chain consultant, E-commerce operations manager, Business Development Manager and IT Manager from the land location.

Figure 1 Research model.



A pilot study is an initial small-scale study designed to assess the practicability, time, cost, risk, and adverse events of a research project (Queiroz and Telles, 2018). In this research, the pilot study was done to test the reliability and validity of the questionnaire. The research ideas were concisely communicated to the respond- about the research to aid in understanding the concepts under research and to be specific in answering the questions in regard to Supply Chain Management.

Based on the following criteria, appropriate respondents were identified in conjunction with the human resources departments of each company. The questionnaires were then sent out and returned within a two-week period. Of the 189 questionnaires returned, the incomplete responses were discarded, leaving a total of 153 usable questionnaires (see Table 2).

The study instrument employed scales adopted from previous good quality studies to assure both face and content validity. The complete survey contained 24 items. A 4-item scale developed by Dubey et al. (2021) was used in the assessment of supply chain resilience. BDA capabilities were measured with a 10-item scale adapted from Corte-Real et al. (2020). BI was measured using a 10-item scale adapted from Lim et al. (2013). All constructs were measured reflectively. The survey items were worded on a 7-point Likert scale, ranging from strongly disagree to strongly agree.

4 DATA ANALYSIS AND RESULTS

Assessment of the study models was done using Smart PLS 3.0 based on partial least squares structural equation modeling (PLS-SEM). As per Dijkstra and Henseler (2015), PLS-SEM is an appropriate analytical technique particularly for testing very complex models when the sample sizes are small and for assessing the exogenous variables' predictive relevance. This technique is data-driven and handles both measurement and structural model considerations very well. The rule of thumb in PLS-SEM for sample size is generally agreed to be ten times the largest estimated path coefficient for making inferences about any one construct (to ensure that the sample size is adequate for the complexity of the model and the number of indicators used in the analysis,) as postulated by Hair et al. (2011). Consistent with this rule, the 153 valid responses collected within our study meet the requirement of an adequate sample size for the proposed model.

Table 2 Participant Demographics

Respondents (N= 153)	*Frequency (%)*
Job title type	
Purchasing Manager	15
Supply Chain Manager	20
Supply Chain Analyst	10
Supply Chain Consultant	10
E-commerce Operations Manager	15
Business Development Manager	10
IT manager	20
Industry type	
Food and Beverage	10
Retail	12
Healthcare	8
Hospitality and Tourism	7
Agriculture	6
Chemicals	9
Real Estate	5
Education and Training	7
Fashion and Apparel	10
Automotive Parts and Accessories	8
Printing and Publishing	6
IT	12
Number of employees	
0-50	20
51-100	15
101-500	25
501-1000	15
1001-10000	25

4.1 Measurement model

In PLS-SEM, the dimension model's value is usually evaluated by the investigation of both reliability and validity. Reliability was tested at the level of constructs and items using composite reliability (CR) and Cronbach's alpha (CA). According to Hair et al. (2016), values of CA and CR should lie ideally between 0.7 to 0.9 for good strong internal consistency. In the present study, all constructs had CA and CR above 0.7 being reported for good internal consistency of the measurement model (see Table 3).

Validity was tested using both convergent and discriminant validity tests following the recommendations of Hair et al. (2014). The confirmatory factor loadings should be tested to ensure that the AVE values are greater than 0.5 for all the constructs in the model for obtaining evidence in favor of convergent validity. This rule suggests that each of the constructs accounts for more than 50 percent of its variance in its dimensions, therefore asserting that each measured variable captures construct effectively. The appropriateness of AVE is meaningful to establish that the constructs are distinct and well defined with other constructs according to Hair et al. (2016). Discriminant validity was tested by three methods. First, the criterion suggested by Fornell and Larcker (1981), where the square root of AVE of each of the constructs is compared with the highest correlation between that construct and any other construct. Second, following the procedure undertaken by Farrell (2010) himself, it was ensured that each indicator's outer loading was greater than its cross-loadings on other constructs to prove discriminant validity. Lastly, heterotrait-monotrait (HTMT) correlation ratios were conducted following Henseler et al. (2015) to test discriminant validity; ideally below 0.85 these indicate clear differentiation between constructs.

The results of these tests, presented in Tables 3 and 4, were indicative of sufficient discriminant validity, since all HTMT ratios are below 0.85. In other words, these results mean that the measurement model is quite sound in recognizing different constructs accurately..

4.2 Common method bias (CMB)

CMB is likely to be especially problematic for those constructs measured with dependent measures when all data is collected from a single source. Rather than the constructs, the common method of measuring causes this bias, leading to usual overestimates of relationships among study variables (Podsakoff and Organ, 1986). CMB might be caused by factors such as social desirability or item homogeneity (Podsakoff et al., 2003). We have, by the same token, several ex post facto steps in our study to address and mitigate possible CMB influences. First, we performed the Harman one-factor test under the suggestion of Podsakoff and Organ (1986). The results of the test showed that the first factor extracted explained approximately 31.11% of the total variance, far below the stipulated 50% level, thereby ruling out CMB as a matter of concern. Moreover, we carried out a full collinearity assessment test and found all variance inflation factors (VIF) at less than 3.3 (Kock, 2015). Taken together, these results suggest that CMB does not seriously affect the validity of our model.

Table 3 Summary Measurement of Constructs

Constructs	*Item Code*	*Factor Loading*	*Composite Reliability (CR)*	*Average Variance Extracted (AVE)*
BDA capabilities	BDAC1	0.603	0.905	0.568
	BDAC2	0.431		
	BDAC3	0.709		
	BDAC4	0.720		
	BDAC5	0.648		
	BDAC6	0.790		
	BDAC7	0.759		
	BDAC8	0.793		
	BDAC9	0.786		
	BDAC10	0.710		
Business Intelligence	BI1	0.715	0.906	0.611
	BI2	0.599		
	BI3	0.720		
	BI4	0.662		
	BI5	0.537		
	BI6	0.799		
	BI7	0.763		
	BI8	0.743		
	BI9	0.734		
	BI10	0.705		
Supply Chain Resilience	SCR1	0.761	0.817	0.529
	SCR2	0.615		

	SCR3	0.811	
	SCR4	0.708	

Table 4 Inter-correlations among latent constructs

		(1)	(2)	(3)
(1)	BDA capabilities	0.703		
(2)	Business Intelligence	0.866	0.702	
(3)	Supply Chain Resilience	0.757	0.759	0.728

4.3 Structural model

The R^2 value is the statistical measure for the amount of variance in the dependent variable determined by the independent variables. That is to say, it is an indicator of how good the set of independent variables explain the dependent variable's variability. The value of R^2 ranges between 0 and 1, with values closer to 1 representing a larger proportion of explained variance, hence the model fits the data well. Values of 0.75, 0.50, and 0.25 for R^2 were denoted as substantial, moderate, and weak explanatory by Henseler et al. (2015), respectively. This can better be explained through Table 5 of our study, where the R^2 values concerning all dependent variables are appropriate. The value for the supply chain resilience stood at 0.62, meaning a moderate level of explanatory power.

Next, Stone–Geisser Q^2 probes the relevance of the endogenous constructs in PLS-SEM by considering how well the model is able to predict omitted data points in comparison to using the mean. It helps to ascertain how well the model is able to predict the endogenous constructs based on the exogenous constructs and their relationships. Table 5 indicates Q^2 values for all dependent constructs being greater than zero, reflecting good analytical importance. In the same way, we calculated the effect size of BDA capabilities with Cohen's (1988) f^2 measure. The resultant f^2 value turned out greater than the cut-off value of 0.02, which means it is a meaningful effect.

The goodness-of-fit (GOF) was computed for PLS-SEM to access the overall model fit. In this study, we calculated a GoF value for our model, which is equal to 0.50 with the equation given by Varian (1990). Specific GoF values for each dependent variable are provided in Table 5 to indicate overall model fitness..

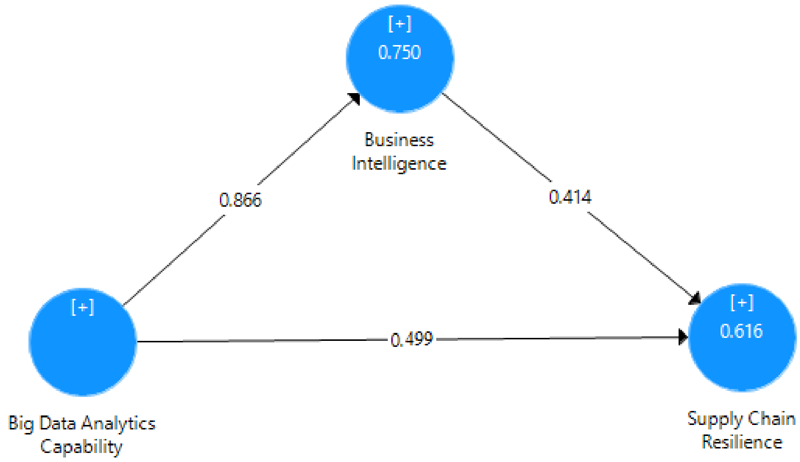
Table 5 Hypotheses Testing

No.	*Path*	*Path coefficient*	*Supported*	*R^2*	*Q^2*	*GoF*
H1	BDA → Supply chain resilience	0.499	Yes	0.62	0.31	0.39
H2	BDA → BI	0.866	Yes	0.75	0.34	0.42
H3	BI → Supply chain resilience	0.414	Yes			

The arithmetical outcomes supported the hypotheses:

H1 (BDA → Supply chain resilience), H2 (BDA → BI), and H3 (BI → Supply chain resilience). The path coefficients are accessible in Figure 2.

Figure 2 Structural model results



4.4 Mediation test

SEM-PLS was employed due to its greater statistical power compared to older methodologies (Matthews et al., 2018). The analysis began by first measuring the significance of the indirect effects and later proceeded to check the direct impact of BDA capabilities on supply chain resilience. The results for the mediation tests were obtained with the help of bootstrapping technique in SmartPLS3. Refer to Table 6.

The strength of the indirect effect, which is depicted in Table 6, justified the mediation analysis. The strength of the mediating effects of BI was calculated by Variance Accounted For (VAF = indirect effect / [direct effect + indirect effect]). Referring to Hair et al. (2013), VAF values over 0.2 stand for partial mediation, and over 0.8 stand for full mediation. The findings expose that BI is partially mediating the relationship between BDA capabilities and supply chain resilience. Hence, Hypothesis H4 is supported..

Table 6 Mediation Test Outcomes

No.	*Mediated path*	*Supported*	*Indirect effect*	*VAF*	*Conclusion*
H4	BDA capability → BI → supply chain resilience	Yes	0.358	0.418	Partial mediation

5 DISCUSSION

To address the research question based on the aforementioned gap, this study hypothesizes that there is an intervening mechanism of BI in the relationship between BDA capabilities and resilience in the supply chain. The results and path coefficients mediated through mediation analysis do shed a precise amount of light on the relationship dynamics that exist among these variables especially within the paradox of SMEs. In that the direct positive influence of capabilities in BDA on supply chain resilience was supported, it corresponded very well to previous works drawing up a spadework on the determinant role played by advanced analytics in improving supply chain performance. BDA enables real-time monitoring and predictive maintenance as well as strategic decision-making aspects significantly needed in the monitoring of the business environment for effectiveness in handling responses. The path coefficient value of 0.499 in the present study puts into context the importance of the capabilities of BDA in fostering a resilient supply chain-that is an immediately responsive kind of supply chain-to and eventual recovery from disruptions. Introducing BI as a mediating variable brings a nuanced distinction in understanding how further enhanced supply chain resilience is facilitated by capabilities in BDA. The indirect effect of .358 and a %^% of .418 qualifies as partial mediation. It reflects the notion that, although BDA capability has a direct impact on supply chain resilience, a big share of this influence passes through BI capability. Turning data-based insight into actionable intelligence turns up the volume initiated by BI in raw insight from B3A toward improved visibility, decision-making processes, and agility in the supply chain. Here, the strong mediation role of BI is advanced because it has the strength through the pooling of data from multi origins with advanced analytics and high-value strategic insights that are so critical for supply chain resilience. After all, it could be very transformative to BDA and BI capabilities for SMEs that usually work with scarce resources and have special idiosyncratic challenges in their supply chains. Thanks to BDA capabilities, now SMEs can access information previously beyond reach to help them become more capable of anticipating risks and better handling disruptions. This, therefore, underscores flexibility in the supply chain as a direct mediator toward building supply chain risk management. The results also bring out that there is more need to develop business intelligence application tools and training in SMEs. Thus, that in turn will drive effective usage of information in building a responsive supply chain. To the best of our knowledge, this paper contributes to addressing the deficiency in the literature about the interrelations among BDA, BI, and supply chain management. It further clarifies how BI acts in managing the relationship that exists between BDA capabilities and supply chain resilience, especially in the SME context. This study's partial mediation does indicate that other factors, while BI is very important as an intermediary, might enhance the level of supply chain resilience..

5.1 Implications for research

First, our study's results will have implications for future research in big data analytics, business intelligence, and supply chain resilience. First, given the partial mediating role of business intelligence, it inherently emphasizes the consideration of other mediating factors besides business intelligence that could drive the relation between big data analytics and supply chain resilience. This calls for investigation into more organizational, cultural, and environmental factors that could be facilitating the attribute of resilience into the supply chain. There is a need to test these factors across different industry contexts and geographical regions to have a more specific development of their impact. This study calls for several replicates because the development that business analytics and business intelligence capabilities have on supply chain resilience should be longitudinally researched in the future. The rapid changes in technology make it increasingly important to continue monitoring how advances in analytical and intelligent tools have effects on the dynamics of the supply chain. Moreover, scholars should use not only quantitative data but also a variety of methods that involve qualitative data to better understand the channels through which BDA and BI capabilities influence supply chain resilience. This might help uncover alternative perspectives in respect of the nuanced relationship and paint the big picture..

5.2 Implications for practice

The recommendations for practice emanating from this study are of special relevance to SMEs and their managers who seek to achieve greater supply chain resilience via a strategic deployment of BDA and BI capabilities. Especially for the SMEs, investments in sophisticated BI applications should be prioritized since such applications can convert large volumes of data into actionable insights, which can drastically improve decision-making processes as well as the general agility of the supply chain. SMEs have to infuse BDA with BI applications through strategic planning from a viewpoint of evolving a culture of analytics based on data to drive continuous learning and adaption to market changes.

Managers in SMEs should concentrate on constructing the prerequisite environment for supporting BDA and BI initiatives. This includes setting up training programs for upgrading the analytical skills of employees and providing knowledge about the tools of BI so that the workforce is adequately capable of holding on to the technologies. Besides, it is also the responsibility of the managers to facilitate cross-functional collaboration. This will help in a single stream of common understanding of how the insights driven by BI will be dispersed and used within the company, helping in effective supply chain management.

In practice, SMEs are more likely to take a proactive role in monitoring and evaluating their supply chain processes using BDA and BI output. With continuous assessment of these processes, managers would be in a position to identify early warning signs of vulnerability and mitigate them before they grow into major disruptions. Further, SMEs should enter into collaborations with technology vendors and consultants for updates on a real-time basis with the evolution of the technology in BDA and BI, so that the systems are up-to-date and capable of providing excellent quality of insights.

In a nutshell, the strategic implementation of BDA and BI capabilities gives an iron-clad framework to SMEs for boosting supply chain resilience. This capacity will be achieved through the fostering of a data-driven culture within organizations and employee training with the help of advanced analytics tools to foresee, as well as respond to, supply chain disruptions for being market smart..

5.3 Limitations and future directions

Since it was conducted in Iran, its results may not be easily generalizable to other countries due to Iran's unique conditions. To increase the generalizability of the results, further research should test the model on data from several countries. Fourth, because it was cross-sectional, the data used in this study were cross-sectional. Hence longitudinal datasets should be used in further studies for exploring the same kind of topics for checking credibility and robustness of findings. The data for the study were collected through a single respondent per organization. It may have the possibility of CMB. To further strengthen this situation in the future research study, responses from more than one respondent in each organization should be elicited. Further, future research studies should investigate the effect of different organizational sizes and industries on the association among BDA capabilities, BI, and supply chain resilience. The investigation of such factors could offer a more granular view of the interaction between contexts and relationships. Besides, the interaction effects of BDA and BI with AI, blockchain, and the Internet of Things in enhancing supply chain resilience need to be further investigated through longitudinal case studies with a mixed-method approach. The focus of future research should be an issue related to approaches that adequately capture how resilience is developed over time for the dynamics of supply chains. These are specifically in terms of longitudinal case studies or mixed-method approaches. With these gaps in place, future research can expound on the current findings further, thus enriching the understanding of the role BDA and BI play in enhancing supply chain resilience under different circumstances and conditions. While this study has adopted the perspective of dynamic capabilities view, in future studies various other theoretical frameworks of reference could be used to take this research to another level of development and validation of the model and findings. It would be to better understand the context and the nature of the phenomenon under study..

6. CONCLUSION

Building on an investigation into the capabilities of business data analytics (BDA) to enhance supply chain resilience, this paper empirically tests the mediating role of business intelligence (BI) capabilities in small and medium-sized enterprises. The results show that BDA capabilities significantly increase supply chain resilience in their ability to enable firms to anticipate, respond to, and recover from a disruption. These include the use of real-time collection, processing, and analysis of large volumes of data that create important insights facilitating decision makers at all levels in the value chain. It was also established from the study that BI capabilities strongly and significantly reduce raw data for supply chain agility and responsiveness. This essentially means that, more especially for SMEs, the very large increases attendant to BDA capabilities can be harnessed if accompanied by increased insight uptake. The results answer our research question by confirming that BI capabilities meaningfully mediate the relationship between BDA capabilities and supply chain resilience. It therefore brings out the importance of building strong BI capabilities with BDA technologies. For SMEs and managers, the practical implications suggest that investment in BDA technologies and strong BI capability building need to be high on the agenda to enhance decision-making, risk management, and operational efficiency that finally leads to improving the systems' resilience and competitiveness in today's aggressive landscape..

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