Enhancing Supply Chain Agility and Performance through Big Data Analytics: The Role of Digitalization and Top Management Support

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Enhancing Supply Chain Agility and Performance through Big Data Analytics: The Role of Digitalization and Top Management Support

Mostafa Jafari, Peyman Akhavan, Amirhossein Akbari

Abstract

Purpose: This study aims to examine the relationships between big data analytics capabilities (BAC), supply chain digitalization (SCD), supply chain agility (SCA), and supply chain performance (SCP), while assessing the moderating role of top management support (TMS) in these relationships. It seeks to advance understanding of how digital transformation and leadership support enhance supply chain agility and performance outcomes.

Design/methodology/approach: This study applies regression modeling to survey data collected from manufacturing firms. The model examines the direct effects of BAC on SCA and SCP, while assessing the mediating role of SCA and the moderating influence of SCD and TMS. The analysis also explores how these relationships contribute to sustainable supply chain performance outcomes.

Findings: The results demonstrate that BAC positively influences SCA, which in turn enhances SCP. SCD amplifies the effect of BAC on SCA, while TMS significantly moderates the relationships between SCD and both BAC-SCA and SCA-SCP. These findings suggest that digital technologies and leadership support jointly drive supply chain agility and performance in dynamic business environments.

Originality/value: This study contributes to supply chain management literature by integrating BAC, SCD, and TMS into a comprehensive framework that elucidates their combined effects on agility and performance. It highlights the strategic importance of digital transformation and top management support in fostering agile and high-performing supply chains, offering actionable insights for managers and policymakers.

Keywords: Big Data Analytics Capabilities, Supply Chain Agility, Supply Chain Performance, Top Management Support, Supply Chain Digitalization.

Introduction

In today's hyperconnected global economy, supply chains face intense competitive pressure, geopolitical disruptions, shifting trade patterns, and rapid technological change. Firms must pursue not only operational efficiency but also agility and resilience to respond swiftly to disruptions, adapt to dynamic market conditions, and seize emerging opportunities (Singh and Modgil 2025). In this volatile environment, Supply Chain Agility (SCA), the ability to effectively respond to internal and external changes, has become a vital determinant of Supply Chain Performance (SCP) (Singh and Kumar 2025). SCA helps firms mitigate risks, sustain service levels under uncertainty, and transform supply chains from cost-driven systems into strategic enablers of competitive advantage (Jum'a, Zighan, and Alkalha 2025).

Amidst these challenges, Big Data Analytics Capabilities (BAC) have emerged as a critical strategic resource that allows firms to process vast, complex datasets to enable data-driven decision-making, predictive modeling, and proactive risk mitigation (Wang et al. 2025). Leveraging advanced analytical tools such as machine learning and artificial intelligence, BAC shift decision-making from reactive to predictive and prescriptive modes (Chen 2024). Beyond improving data visibility, BAC support dynamic capabilities that foster real-time responsiveness, innovation, and proactive problem-solving (Chaudhuri et al. 2024). By enabling rapid adjustments in inventory, logistics, or production in response to disruptions, BAC serve as a strategic enabler of agility across operational and strategic levels, enhancing cross-functional collaboration and end-to-end synchronization.

However, while BAC can improve SCA and SCP, the mechanisms through which these benefits are realized remain insufficiently explored. Their effectiveness depends on the firm's digital infrastructure, technological maturity, and leadership engagement. The mediating role of SCA is especially critical in preventing "data-rich but insight-poor" outcomes in turbulent and resource-constrained contexts such as Iran, where sanctions, infrastructural gaps, and global supply chain disconnections complicate the translation of data capabilities into performance gains.

The rise of Supply Chain Digitalization (SCD) further reshapes this relationship. By embedding technologies such as the Internet of Things (IoT), cloud computing, and AI into supply chain processes, SCD enhances information flow, automation, and interoperability, amplifying the agility benefits of BAC (Jum'a, Zighan, and Alkalha 2025). Through real-time data sharing and system integration, SCD accelerates decision-making and operational responsiveness, making it a critical moderating factor in the BAC–SCA–SCP linkage.

Yet, technological advancement alone is insufficient. The success of both BAC and SCD initiatives depends heavily on Top Management Support (TMS), the active involvement of senior leaders in championing digital transformation, allocating resources, and fostering a culture of agility and innovation (Wrede, Velamuri, and Dauth 2020). TMS shapes strategic priorities, mitigates resistance to change, and ensures technological initiatives align with organizational goals (Chatterjee, Chaudhuri, and Vrontis 2025). Moreover, TMS may strengthen the moderating role of SCD by ensuring that technological investments are strategically integrated with analytics and agility initiatives.

Despite the recognized importance of BAC, SCA, SCD, and TMS for SCP, prior research has seldom examined their combined effects within a single framework. Most studies have analyzed them in isolation, neglecting their synergistic interactions and the moderating role of leadership, particularly in emerging markets facing institutional voids and uncertainty. Addressing these gaps, this study develops and empirically tests an integrated model that explores the direct, mediating, and moderating relationships among BAC, SCA, SCP, SCD, and TMS. Focusing on Iran's advanced technology sector, an environment of digital transformation, market volatility, and institutional constraint, the research extends the Resource-Based View (RBV), Dynamic Capabilities View (DCV), and contingency theory by revealing how technological and managerial capabilities jointly drive agility and performance in complex, technology-driven supply chains.

The paper is structured as follows: Section 2 reviews the literature and identifies research gaps; Section 3 develops hypotheses; Section 4 outlines methodology and data collection; Section 5 presents findings; Section 6 discusses theoretical and practical implications; and Section 7 concludes with contributions, limitations, and future research directions.

Literature Review

The digital transformation of supply chains has been a central focus of contemporary operations and supply chain research, particularly regarding how firms leverage advanced data analytics and digital technologies to enhance agility and performance (Gopal et al. 2024). wo critical constructs, BAC and SCD, have emerged as foundational enablers of this transformation.

BAC is broadly defined as an organization's ability to collect, process, and analyze vast, diverse, and real-time datasets to generate actionable insights

(Mikalef et al. 2018). This capability goes beyond technical proficiency; it encompasses the integration of human, technological, and organizational dimensions, including analytical skills, governance mechanisms, and decision-making processes (Lin, Wu, and Luo 2025). Analytical capability thus becomes a strategic resource that supports predictive and prescriptive decision-making. Conversely, SCD represents the degree to which digital technologies, such as IoT, cloud computing, ERP, and automation, are embedded in supply chain processes, enabling transparency, integration, and responsiveness (Lu and Taghipour 2025).

Although both constructs contribute to digital transformation, prior studies have often treated BAC and SCD as interchangeable, leading to conceptual ambiguity (Papadopoulos et al. 2022). Recent literature, however, emphasizes a complementary relationship rather than equivalence between the two. BAC focuses on analytical interpretation, the *"why"* and *"what"* behind decision-making (Wamba et al. 2015) , while SCD focuses on the *"how"* and *"where"*, enabling digital connectivity and data flow (Ardito et al. 2019). This distinction implies that firms require both capabilities in tandem: analytics without digital integration limits operational execution, while digitalization without analytical insight leads to "data-rich but insight-poor" decision-making. A key analytical gap lies in understanding how these two capabilities interact dynamically to create supply chain agility and competitive advantage, especially in volatile environments.

One critical mechanism linking BAC and SCD to firm outcomes is SCA. SCA refers to a firm's ability to sense, respond, and adapt swiftly to changes and disruptions in the market or supply base (Cadden et al. 2022). Conceptually, SCA embodies the essence of the DCV, wherein firms continuously integrate, build, and reconfigure internal and external competences to address rapidly changing environments. The analytical insight here is that agility does not automatically result from digital investment; it emerges from a firm's ability to translate technological potential into operational flexibility.

Empirically, while studies have established that BAC and SCD can individually enhance performance (Le, Nhu, and Behl 2024), their joint effect through SCA remains underexplored. The literature still lacks clarity on whether SCA merely acts as an outcome of digital capability or serves as a mediating mechanism that operationalizes analytics and digitalization into tangible performance improvements (Turi et al. 2023). This gap is particularly critical in contexts where technological adoption is uneven or resource-constrained. Analytically, positioning SCA as a mediator allows scholars to identify *how* digital and analytical resources are transformed into performance outcomes, shifting the discussion from "capability possession" to "capability utilization."

In parallel, the role of TMS has gained increasing attention as a key enabler of digital transformation (Zhang et al. 2024). TMS shapes not only resource allocation but also organizational culture, learning orientation, and the willingness to embrace change (Shao 2019). However, much of the literature treats TMS descriptively, as a background factor or direct antecedent, without sufficiently theorizing its moderating or boundary-spanning function. From an analytical standpoint, TMS can be conceptualized as a strategic catalyst that conditions the effectiveness of technological and analytical capabilities. For instance, when leadership actively champions data-driven decision-making, allocates digital resources, and communicates a shared vision, the value of BAC and SCD is amplified (Wang et al. 2024).

Recent studies support this argument by showing that leadership commitment fosters organizational learning and cross-functional collaboration, two mechanisms essential for digital transformation success (Majhi, Snehvrat, and Chaudhary 2025). Moreover, effective

TMS enhances trust, communication, and transparency across departments (Valdes, Mckay, and Sanko 2021; Al-Husseini 2024; Lo, Tian, and Ng 2021), thereby creating a culture where technological experimentation and agility can flourish. Conversely, insufficient managerial engagement can lead to digital fragmentation, project delays, or resistance to analytics-driven change.

Thus, examining TMS as a moderating variable, rather than merely a direct antecedent, offers a deeper analytical understanding of how leadership intensity and commitment influence the translation of BAC and SCD into SCA and ultimately into SCP. By taking this perspective, the study moves beyond description to explore interaction effects and contingencies, enriching the explanatory power of the model.

Addressing Research Gaps

Despite growing interest in digital supply chain transformation, three analytical gaps persist:

1. Integration Gap: Prior studies have analyzed BAC, SCD, and TMS largely in isolation, failing to capture their interactive and synergistic effects. This limits theoretical advancement in understanding how firms orchestrate technological, analytical, and managerial capabilities for superior performance.
2. Mechanism Gap: There is limited empirical exploration of how BAC and SCD translate into performance outcomes through agility-driven pathways. Identifying SCA as a mediator enables a more process-oriented view of capability deployment.
3. Boundary Condition Gap: The moderating role of TMS remains insufficiently theorized, particularly in emerging market contexts where institutional voids, resource constraints, and high volatility make leadership influence even more critical.

To address these gaps, this study develops and empirically tests an integrated model examining the direct, mediating, and moderating effects among BAC, SCD, SCA, TMS, and SCP. The analytical contribution lies in explaining how and under what conditions digital and analytical capabilities drive performance, rather than merely whether they do. Furthermore, by situating the analysis in Iran's advanced technology sector, a context marked by sanctions, uncertainty, and digital constraints, the study contributes to the cross-contextual generalization of the RBV and DCV. This not only expands theoretical applicability to volatile and resource-scarce settings but also provides actionable insights for managers aiming to integrate analytics, digitalization, and leadership for sustained supply chain excellence.

Hypothesis Development

BAC and Its Impact on SCA

In today's volatile and competitive business environment, SCA is increasingly recognized as a key determinant of SCP and sustained competitive advantage. SCA reflects a supply chain's capacity to rapidly reconfigure processes and resources in response to market uncertainties (Patel and Sambasivan 2022). Achieving this agility hinges on real-time, high-quality information and advanced decision-making capabilities, which are core components of BAC.

BAC encompasses a firm's technological infrastructure, data processing competencies, and skilled personnel that enable it to extract actionable insights from large and complex datasets (Wamba et al. 2015). These capabilities support predictive analytics, real-time monitoring, and informed decision-making (Gopal et al. 2024), thereby enabling firms to anticipate disruptions, manage uncertainties, and optimize resource allocation, all of which are essential for SCA (Mandal 2019). The resource-based view (RBV) and dynamic capabilities view (DCV) offer strong theoretical grounding for this relationship. RBV posits that valuable, rare, inimitable, and non-substitutable resources provide competitive advantage (Barney 1991). BAC qualifies as such a resource due to its complex, firm-specific nature (Sabharwal and Miah 2021). Firms with superior BAC interpret and act on data more effectively, enabling proactive and flexible responses to disruptions. DCV complements this by framing BAC as a dynamic capability that strengthens sensing, seizing, and transformation processes (Dubey et al. 2019).

Empirical evidence corroborates these claims. (Dubey et al. 2019; Mandal 2019) show that strong BAC enhances agility through data-driven decision-making. (Mandal 2018) found that BAC improves supply chain ambidexterity and performance in dynamic contexts. BAC also promotes cross-organizational collaboration and real-time data sharing, critical for agile responses such as rerouting shipments or shifting suppliers. Also (Ma, Wang, and Feng 2025) validated BAC's role in boosting agility and sustainable supply chain outcomes.

Collectively, theory and evidence highlight BAC as a pivotal enabler of SCA, equipping firms to transform data into strategic insights, adapt to market dynamics, and mitigate risks effectively. Therefore, we suggest the following:

- ***Hypothesis* 1**: BAC positively influence the adoption of SCA in supply chain operations.

SCA and Its Impact on SCP

In an increasingly complex and volatile business environment, firms must strengthen supply chain operations to sustain competitiveness and operational excellence. SCP, measured through delivery reliability, flexibility, responsiveness, and cost-efficiency, reflects an organization's ability to meet customer expectations and adapt to dynamic conditions (Singh 2025). One of the strongest drivers of SCP is SCA, which enables firms to quickly sense and respond to disruptions and market fluctuations (Jum'a, Zighan, and Alkalha 2025). Accordingly, Hypothesis 2 proposes a positive relationship between SCA and SCP.

Grounded in the DCV, this linkage highlights how agility allows firms to reconfigure resources in response to turbulence, thereby sustaining performance (Malik, Hassan, and Tufail 2023). SCA manifests through practices such as rapid order fulfillment, flexible sourcing, and adaptive production scheduling. These capabilities enhance customer service, shorten lead times, and reduce costs, enabling firms to mitigate disruptions and achieve superior operational, financial, and customer outcomes (Hamidu, Boachie-Mensah, and Issau 2023). Empirical studies reinforce this view: (Franco, Guimaraes, and Rodrigues 2023) show that agile firms outperform less agile competitors on both cost and responsiveness, especially in volatile conditions. Thus, SCA strengthens alignment between supply chain strategies and market needs, driving superior SCP. Relatedly, (Ghaderi et al. 2024) illustrate how green SCA and resilience mediate the link between GSCM practices and SCP, while (Meng et al. 2023) demonstrate the mediating role of SCA in digital transformation.

Beyond its direct effect, SCA also mediates the relationship between BAC and SCP. Hypothesis 3 posits that while BAC provides unique resources (e.g., data processing and predictive analytics), performance outcomes depend on dynamic capabilities such as agility. BAC enables firms to generate actionable insights about customer behavior, market trends, and disruptions. Yet without agile sourcing, production, and decision-making processes, these insights may not translate into value. For example, predictive analytics might detect a supplier shortage, but only agile systems can effectively mitigate the disruption. Empirical research supports this mediating role. (Dubey et al. 2019) show that SCA significantly mediates the BAC–SCP relationship, while (Mandal 2018) finds that firms with both high BAC and SCA realize the greatest performance benefits. Taken together, these insights position SCA as both a direct enabler of SCP and a key conduit for converting big data capabilities into tangible operational outcomes. Finally, we suggest the following:

- ***Hypothesis* 2**: SCA positively influences the SCP in supply chain operations.
- ***Hypothesis* 3**: SCA positively mediates the relationship between BAC and SCP.

SCD and Its Impact on SCA and SCP

In the evolving landscape of supply chain management, digital transformation has become a cornerstone of competitive advantage (Ghobakhloo et al. 2025). SCD has revolutionized efficiency, responsiveness, and data-driven decision-making (Işık, Yan, and Ongan 2025). By strengthening information flow and visibility, SCD enhances adaptability to dynamic markets and enables firms to leverage BAC for operational agility and performance gains. Technologies such as IoT, blockchain, cloud computing, and AI have made SCD a critical enabler of supply chain capabilities (Kim, Rhee, and Park 2024).

SCD also plays a moderating role by amplifying the benefits of analytics and agility. Specifically, Hypothesis 4 posits that SCD positively moderates the relationship between BAC and SCA. While BAC provides predictive and prescriptive insights into trends, risks, and customer needs, its effectiveness depends on the digital maturity of the supply chain (Mandal 2018). SCD provides the technological backbone for real-time data sharing, automation, and connectivity, enabling BAC outputs to be rapidly operationalized. In less digitalized systems, analytics face bottlenecks, whereas SCD amplifies agility gains by facilitating swift decision-making, resource reallocation, and seamless integration across supply chain processes.

Building on this reasoning, Hypothesis 5 proposes that SCD also moderates the relationship between SCA and SCP (Jum'a, Zighan, and Alkalha 2025). Although agility inherently enhances performance through responsiveness, flexibility, and customer satisfaction (Stank et al. 2022), its impact is magnified by digital integration. SCD facilitates real-time monitoring, automated workflows, and predictive maintenance, enabling agile processes to be executed with speed and accuracy (Hijjawi et al. 2023). For instance, adaptive production scheduling informed by agile practices can be instantly implemented across global facilities, reducing lead times and optimizing inventory. Furthermore, SCD enhances customer visibility and demand sensing, allowing firms to align agility with market needs more precisely, improving fulfillment rates, cost efficiency, and satisfaction (Agrawal and Narain 2023). In contrast, low digitalization may limit agility's benefits, leading to delays and inefficiencies. Empirical findings reinforce this view: (Jum'a, Zighan, and Alkalha 2025) showed that SCD strengthens agility's impact on delivery and satisfaction, while (Zhao, Hong, and Lau 2023) highlighted digitalization's role in tighter supplier and customer integration.

Overall, SCD not only enhances BAC and SCA but also ensures their effective translation into superior supply chain performance. Accordingly, we propose:

- ***Hypothesis* 4**: SCD positively moderates the relationship between BAC and SCA.
- ***Hypothesis* 5**: SCD positively moderates the relationship between SCA and SCP.

TMS and Its Impact on SCD

In today's digital era, supply chains are increasingly interconnected, dynamic, and complex, requiring organizations to continuously adapt to technological advancements and volatile markets. Within this context, TMS has emerged as a pivotal enabler of digital transformation and operational agility (Zhang et al. 2024). TMS reflects the extent to which senior leadership champions technology adoption, fosters an innovation-driven culture, and strategically allocates resources to digital initiatives (Chatterjee, Chaudhuri, and Vrontis 2025). Its role is particularly critical in SCD, which integrates technologies such as IoT, blockchain, cloud computing, and big data analytics into supply chain operations (Zhang, Xu, and Ma 2023). These technologies demand not only financial investment but also strategic vision and cross-functional coordination.

Hypothesis 6 posits that TMS moderates the impact of SCD on the relationship between BAC and SCA. While SCD provides the infrastructure for real-time data sharing and collaboration (Zhao, Hong, and Lau 2023), the extent to which these investments enhance agility depends heavily on top management's commitment. Beyond resource allocation, leaders establish governance mechanisms, drive cultural change, and overcome organizational resistance (Huo, Wang, and Zhang 2021). The synergy between SCD and TMS ensures that insights derived from BAC are aligned with strategic goals and swiftly translated into agile responses. Conversely, weak TMS often leads to underutilization of digital tools, limiting responsiveness. Empirical studies confirm this logic: (Wei et al. 2020) found that TMS amplifies the effects of digital technologies on supply chain responsiveness, while (Huo, Wang, and Zhang 2021) emphasize that without strong TMS, digital capabilities fail to deliver agility benefits.

Extending this reasoning, Hypothesis 7 suggests that TMS also moderates the effect of SCD on the relationship between SCA and SCP. While agility enhances performance through responsiveness, flexibility, and customer satisfaction, realizing these benefits requires both digital integration (Jum'a, Zighan, and Alkalha 2025) and strong leadership. In high-TMS contexts, leaders align digital initiatives with business strategies, promote collaboration, and allocate resources to sustain agile practices. This alignment ensures agility translates into reduced lead times, improved reliability, and superior customer service (Hijjawi et al. 2023). In contrast, weak TMS often results in fragmented digital initiatives, underfunding, or lack of buy-in, which undermines agility's impact. Empirical evidence supports this: (Atieh Ali et al. 2024) highlight that TMS enhances the effectiveness of digital investments by creating a supportive environment for agility.

Overall, TMS is essential for ensuring that the performance benefits of agility and digitalization are fully realized. The joint moderating effect of TMS and SCD reflects their complementary roles: while digitalization provides the technological infrastructure for real-time decision-making, top management ensures these technologies are strategically directed, embedded, and leveraged. Strong leadership also mitigates barriers such as resistance to change and siloed communication. Without sustained TMS, digital and analytic investments risk underperformance, limiting organizational responsiveness and competitive advantage.

Finally, based on these theoretical and empirical foundations, we propose the following hypotheses:

- ***Hypothesis* 6**: TMS moderates the effect of the SCD on the relation between BAC and SCA.
- ***Hypothesis* 7**: TMS moderates the effect of the SCD on the relation between SCA and SCP.

Fig 1 shows the research model.

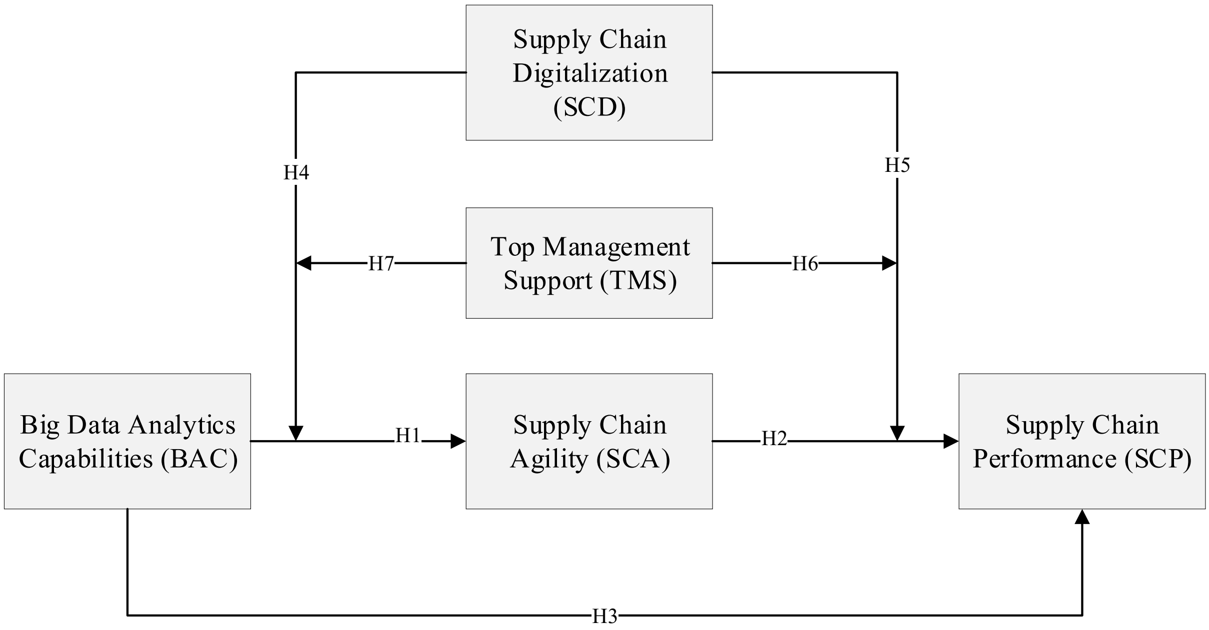

Fig 1. The research model

Methods and data

Sample and data collection

This study focused on firms in Iran's advanced technology sector, electronics, software, hardware, and network equipment, experiencing rapid digital transformation amid sanctions, market volatility, and supply chain disruptions. This high-turbulence, resource-constrained context provides an ideal setting to examine the interactions among BAC, SCA, SCD, TMS, and SCP, addressing empirical gaps and extending frameworks like the Resource-Based View, Dynamic Capabilities View, and Contingency Theory.

Out of 6,173 registered firms, a multi-stage screening identified 407 companies actively investing in BAC, SCD, and TMS to improve SCA and SCP. Verification via company records, industry reports, and professional networks ensured inclusion of firms with observable digital transformation initiatives. Structured questionnaires were distributed, with 197 firms participating and nominating 9–12 senior or mid-level managers, totaling 2,070 potential respondents.

The survey was divided into three sections, BAC (83 firms), SCA (71 firms), and SCD–TMS interaction on SCP (43 firms), to reduce respondent fatigue and focus on each construct. A total of 524 completed questionnaires were collected, yielding a 25.31% valid response rate, with many firms providing data across multiple sections, ensuring consistency and coverage.

Data were collected in three waves over three years to capture temporal dynamics and reduce bias. In Period 1, the first six months involved identifying firms, building trust, and securing participation, while the latter six months collected data from top managers on firm characteristics and employees on BAC and leadership practices. In Period 2, twelve months later, R&D and executive managers assessed improvisation capability, reflecting adaptability to unforeseen challenges. In Period 3, another twelve months later, R&D employees not previously involved reported radical and incremental innovation outcomes. This design ensured temporal separation between mediators and dependent variables, enhancing validity and minimizing respondent-related bias.

This longitudinal, multi-respondent design accounted for the temporal nature of digital transformation, recognizing that BAC and SCD effects on agility and performance require time to diffuse across processes, practices, and routines. Time lags between independent, mediating, and dependent variables enabled more accurate causal inference and minimized short-term confounding influences. Additionally, diversifying respondents across managerial levels and functional units controlled for single-source bias, enhanced construct validity, and provided richer, multi-perspective insights into how digital and analytical capabilities shape organizational agility and supply chain performance.

These design choices enhance internal validity, strengthen causal inferences, and provide a more realistic depiction of how BAC, SCA, SCD, and TMS interact to influence supply chain performance in a complex and resource-constrained environment such as Iran.

A pilot study, following best practices (Ismail, Kinchin, and Edwards 2018), ensured survey reliability and validity, with participants assured of confidentiality. Follow-up reminders encouraged participation. Non-response bias was assessed via t-tests comparing early and late responses across BAC, SCA, SCP, SCD, and TMS, revealing no significant differences. This rigorous process supported robust analysis of how digital transformation, analytics, and leadership influence supply chain agility and performance.

Measures

All constructs were measured on a seven-point Likert scale using validated items adapted for digital supply chain contexts. BAC captured real-time data management and analytics (Bhatti et al. 2024), SCA measured flexibility and responsiveness (Zhou et al. 2024), and SCP assessed operational and strategic performance. SCD reflected digital integration and visibility (Jum'a, Zighan, and Alkalha 2025), while TMS captured leadership, resources, and strategic vision (Chatterjee, Chaudhuri, and Vrontis 2025). Expert reviews and pilot testing ensured clarity and contextual relevance, providing reliable measurement of the interplay between digital capabilities, agility, performance, and TMS in supply chain transformation.

Control variables

Several control variables were included to account for factors influencing BAC, SCD, SCA, SCP, and TMS. Work experience and education level (Shao et al. 2023), geographic region and firm size (Singh et al. 2019). were controlled for digital competence and innovation. Firm age (Shao and Li 2022), and operational scope (Behl et al. 2024), were also considered, as they affect digitalization, agility adoption, and resource availability, ensuring that observed relationships reflect the effects of key digital and organizational capabilities rather than confounding influences.

Common method bias

To mitigate potential common method bias (CMB) from using the same respondents for BAC, SCD, SCA, SCP, and TMS, both procedural and statistical remedies were applied. Procedurally, varied question formats and psychological separation minimized social desirability and consistency biases (Podsakoff et al. 2003; Krishnan, Martin, and Noorderhaven 2006). Statistically, Harman's one-factor test showed the first factor explained only 15.22% of variance, and a single-factor CFA demonstrated poor fit, indicating that CMB is unlikely to affect the study's validity.

Results

This study investigated the effects of BAC, SCA, SCD, and TMS on SCP using hierarchical regression analysis on data from 524 organizations. Control variables, main predictors, mediators, and interaction terms were included incrementally to ensure robust testing of hypotheses.

Reliability, Validity, and Descriptive statistics and correlations

The reliability and validity of the measurement model were assessed using composite reliability (CR) and average variance extracted (AVE). The results indicate satisfactory internal consistency and convergent validity for all constructs. Specifically, BAC demonstrated a CR of 0.91 and an AVE of 0.67, SCA 0.83 and 0.63, SCD 0.81 and 0.61, TMS 0.92 and 0.66, and SCP 0.89 and 0.62. All values exceed the recommended thresholds of CR>0.70 and AVE>0.50, confirming the constructs' reliability and convergent validity.

Table 1 reports the means, standard deviations, and bivariate correlations. Descriptive statistics and bivariate correlations supported the hypothesized relationships. BAC (M=4.2, SD=1.1) demonstrated strong positive correlations with SCA (r=0.36, p<0.05) and SCD (r=0.42, p<0.05), indicating the pivotal role of data-driven capabilities in enhancing agility and digitalization. SCA (M=3.9, SD=0.8) and SCD (M=4.5, SD=0.9) were also positively correlated with TMS (r=0.31 and r=0.39, respectively; p<0.01), emphasizing leadership's influence on digital and agile transformations.

TMS (M=4.1, SD=0.9) was significantly correlated with SCP (r=0.37, p<0.05) and moderately with SCA (r=0.26, p<0.1), supporting the hypothesis that leadership commitment enhances performance outcomes. SCP (M=4.6, SD=1.1) showed positive associations with BAC (r=0.11, p<0.05), SCD (r=0.26, p<0.05), and SCA (r=0.29, p<0.05).

Control variables, including work experience (M=3.6 years) and organization size (M=86 employees), had weak correlations with main constructs (r<0.15), suggesting minimal confounding effects.

Table 1: Descriptive statistics and correlations.

	Variable	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11
1	BAC	4.2	1.1	1										
2	SCA	3.9	0.8	0.36**	1									
3	TMS	4.1	0.9	0.26*	0.31***	1								
4	SCD	4.5	0.9	0.42**	0.29***	0.39***	1							
5	SCP	4.6	1.1	0.11**	0.29**	0.37**	0.26**	1						
6	Work Experience	3.6	1.8	0.04	0.03	0.05	0.03	0.04	1					
7	Area	-	-	0.02	-0.02	-0.01	0.02	0.00	0.06	1				
8	Education	4.8	1.3	0.06	0.04	0.05	0.05	0.03	0.11*	0.06	1			
9	Age of Organization	13.7	5.9	0.02	0.01	0.03	0.04	0.01	0.08	0.06	0.07	1		
10	Scope	4.9	1.7	0.06	0.04	0.05	0.05	0.06	0.11	0.04	0.08	0.11	1	
11	Employee Number	86	26	0.05	0.06	0.03	0.05	0.06	0.13**	0.10	0.09	0.15*	0.09	1

*p<0.1, **p<0.05, ****p<0.01*

Multicollinearity Analyses

To ensure the reliability and validity of our regression results, we assessed multicollinearity among the independent variables and interaction terms by calculating the Variance Inflation Factor (VIF) values. The VIF values for the main predictors, BAC, SCD, SCA, and TMS, ranged from 1.12 to 1.48, indicating low multicollinearity. The interaction terms (BAC×SCD, BAC×TMS, SCD×TMS, and BAC×SCD×TMS) had VIF values between 1.30 and 1.75, well below the commonly accepted threshold of 5 (Hair et al. 2017). These results confirm that the predictors and interaction terms included in the regression models do not suffer from problematic multicollinearity, ensuring stable and interpretable parameter estimates.

Endogeneity Analyses

To address potential endogeneity in this cross-sectional study, diagnostic tests including the Durbin-Wu-Hausman (DWH) test were conducted for BAC, SCD, SCA, and TMS with respect to SCP. Instrumental variables, organizational tenure and industry-level digital maturity, significantly predicted the endogenous regressors (F-statistics>15, p<0.001). DWH results showed no significant differences between OLS and IV estimates: BAC (χ^2=1.87, p=0.17), SCD (χ^2=2.12, p=0.14), SCA (χ^2=1.45, p=0.23), and TMS (χ^2=1.32, p=0.25), indicating minimal endogeneity. Control function results confirmed this, suggesting that the observed relationships and moderation effects are robust and not biased by simultaneity or omitted variables.

Distinguishing BAC from SCD

The study highlights the distinction and complementarity between BAC and SCD. BAC focuses on data analytics capabilities for decision-making, while SCD emphasizes digital infrastructure and process integration. Hierarchical regression and confirmatory factor analyses (CFA) were performed to test the discriminant validity of BAC and SCD. The CFA results showed a good fit for the two-factor model (χ^2/df=2.1, CFI=0.95, RMSEA=0.045), significantly better than a single-factor model combining BAC and SCD (χ^2/df=5.8, CFI=0.72, RMSEA=0.11), confirming their distinctiveness. Hierarchical regression showed BAC significantly enhances SCA (β=0.34, p<0.001), and SCD positively moderates this relationship (interaction β=0.22, p<0.01), though SCD alone did not significantly affect SCA (β=0.16, p=0.12). Overall, BAC and SCD are distinct yet synergistic, jointly fostering supply chain agility and performance.

Regression Analysis and Hypothesis Testing

Table 2 reports regression analysis and PROCESS macro in SPSS, tested via bootstrapping with 10,000 samples. Regression enabled examination of direct, mediating, and moderating effects while controlling confounders (Aiken, West, and Reno 1991). Bootstrapping provided robust estimates for indirect effects and interactions, improving accuracy and reliability, consistent with best practices (Preacher and Hayes 2008).

Table 2. Regression result

Variables		SCA				SCP					
Model	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11
Control Variables											
Participants' Work Experience	0.03	0.03	0.02	0.02	0.02	0.03	0.02	0.03	0.02	0.03	0.02
Area	-0.01	-0.01	-0.01	-0.01	-0.01	0	-0.01	-0.01	0	-0.01	-0.01
Education	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.03
Age of Organization	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01
Scope	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.04
Employee Number	0.06	0.05	0.05	0.02	0.05	0.05	0.05	0.05	0.05	0.06	0.02
Independent Variables											
BAC		0.39**	0.36**	0.35**	0.34**	0.11**		0.10*	0.09*	0.10*	0.07*
SCA							0.29**	0.28*	0.23*		0.24**
SCD			0.16**		0.25**					0.21*	0.19**
TMS				0.21**	0.19**				0.26*	0.25*	0.24**
Interaction Terms											
Int1: BAC×SCA								0.25*			0.24**
Int2: BAC×SCD			0.28**		0.35**						0.29**
Int3: BAC×SCD× TMS				0.19**	0.17**						0.31**
Int4: SCA×SCD									0.19*		0.22*
Int5: SCA×SCD× TMS										0.18*	0.25*
Model Fit											
R^2	0.06	0.05	0.13	0.14	0.19	0.07	0.11	0.08	0.22	0.29	0.26
Adjusted R^2	0.02	0.06	0.12	0.14	0.15	0.04	0.03	0.14	0.21	0.22	0.38
ANOVA F	1.65	8.1**	6.9***	6.7**	8.4***	7.55*	7.8**	7.3***	7.4**	8.6***	8.9***

Standardized Beta Coefficients; **p<0.1, **p<0.05, **p<0.01*

Model 1 incorporated only control variables. These variables together accounted for just 4% of the variance in SCR (R^2=0.02), with none of the control variables showing statistical significance (all β<0.06, p>0.1). This finding is consistent with their low bivariate correlations with the main constructs and supports their role as non-confounding covariates in the analysis (Aiken, West, and Reno 1991).

Model 2 confirmed a significant positive effect of BAC on SCA (β=0.39, p<0.05), supporting H1. Firms with strong analytics capabilities can better manage disruptions and adapt to supply chain dynamics due to real-time data processing and decision-making insights. Model 3 showed that SCD significantly moderates the BAC–SCA relationship (β=0.28, p<0.05), validating H4. Digitally advanced firms more effectively translate analytics into agility due to technologies like IoT and cloud platforms enhancing real-time coordination. Model 4 added TMS as a moderator of the BAC–SCD–SCA relationship. The interaction ((BAC×SCD)×TMS) was significant (β=0.19, p<0.05), supporting H6. Strong leadership enhances the translation of analytics and digital infrastructure into agile practices through resource allocation and cultural alignment. Model 5 reaffirmed the dual moderating effects of SCD and TMS (β=0.19 and β=0.17, respectively; p<0.05), reinforcing H4 and H6. These enablers jointly amplify the impact of BAC on agility by fostering integration, speed, and responsiveness.

Model 6 revealed that BAC has a weak but significant direct impact on SCP (β=0.11, p<0.05), suggesting limited standalone influence. Model 7 confirmed that SCA strongly influences SCP (β=0.29, p<0.05), supporting H2. Agile supply chains perform better due to enhanced responsiveness and flexibility. Model 8 identified a partial mediating role of SCA between BAC and SCP (β=0.28, p<0.1), validating H3. BAC indirectly boosts performance via improved agility. Model 9 demonstrated that SCD strengthens the SCA–SCP relationship (β=0.19, p<0.1), supporting H5. Digital technologies help firms better leverage agility for performance. Model 10 showed that TMS further moderates the SCA–SCP relationship under digitalization (β=0.18, p<0.1), reinforcing H7. Leadership plays a key role in capitalizing on digital agility for performance gains.

Model 11, the full model (R^2=0.38), integrated all constructs and controls, confirming the central roles of BAC, SCA, SCD, and TMS in shaping SCP. The findings collectively demonstrate that digitalization and leadership significantly enhance the value of data analytics and agility in driving superior supply chain outcomes.

Moderation diagnostics and visualization Analyses

Johnson-Neyman analysis shows that BAC significantly improves SCA only when TMS exceeds 5.4, and SCA enhances SCP only when SCD is above 5.6, highlighting the threshold levels of leadership support and digital infrastructure needed for these effects to materialize.

Interaction Plots for Moderation Effects

Below are four figures visualizing the moderation effects tested in the regression models. Variables are standardized (mean=0, SD=1), and slopes are calculated using coefficients from the hierarchical regression table. High/low moderator values are set at ±1 SD.

Fig. 2 shows the moderating role of SCD and DT on the relationship between BAC and SCA. SCD amplifies the positive impact of BAC on SCA by enabling real-time data exchange, digital integration, and advanced analytics, which foster supply chain flexibility and adaptability. At the same time, SCD strengthens the effect of SCA on SCP by supporting real-time information sharing, seamless collaboration, and automated decision-making.

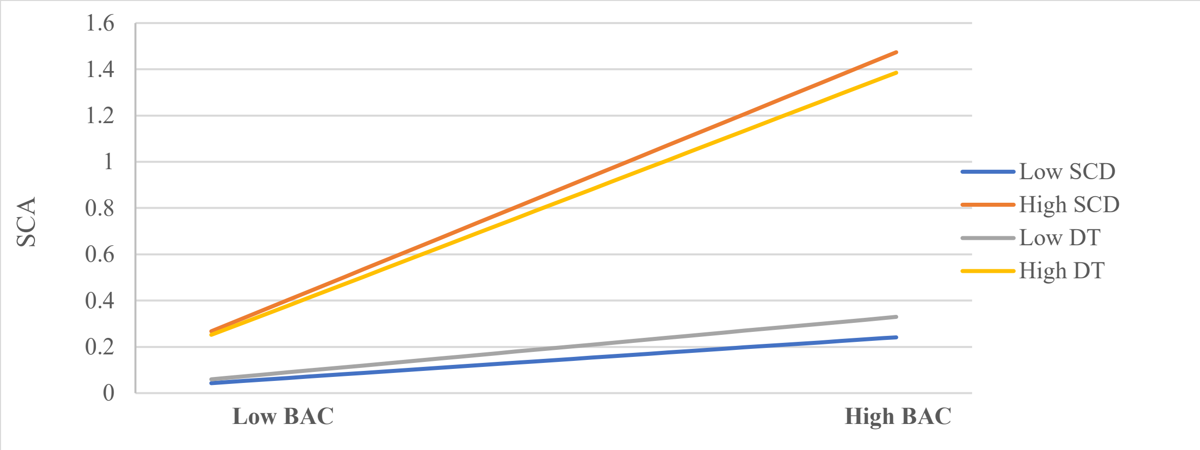

Figure 2: The Moderating Role of SCD and DT on the Relationship Between BAC and SCA

Fig. 3 indicate that TMS strengthens the moderating role of SCD in the relationship between BAC and SCA. By providing strategic direction, resources, and a supportive culture, TMS enables firms to integrate digitalization with BAC more effectively, leading to timely insights, stronger coordination, and greater responsiveness to dynamic market conditions.

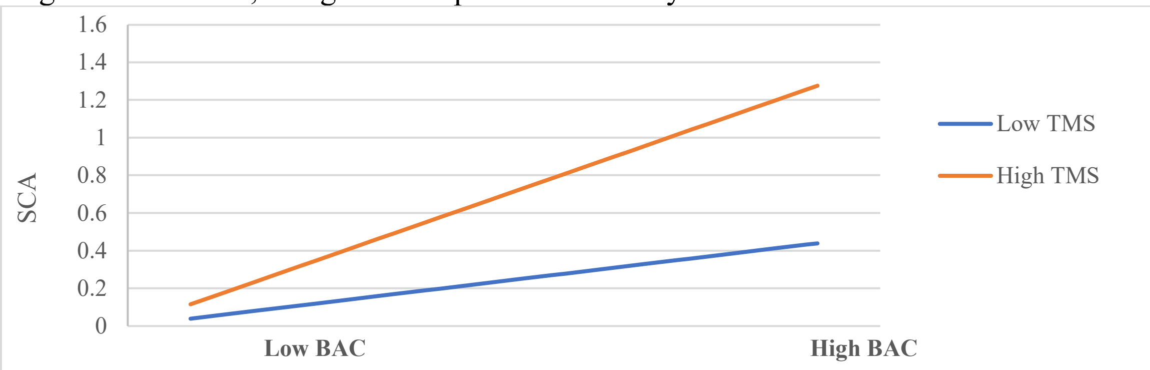

Figure 3: The Moderating Role of TMS on the Relationship Between SCD with BAC and SCA

Fig. 4 show that TMS positively moderates the effect of SCD on SCA and SCP. By providing strategic direction, resources, and a collaborative culture, TMS strengthens information sharing and coordination, enabling agile firms to better adapt to market fluctuations and achieve superior performance in dynamic environments.

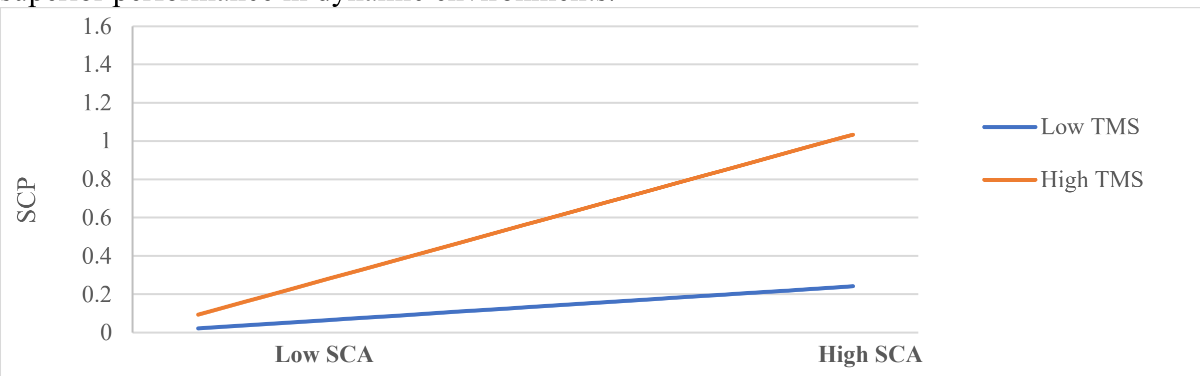

Figure 4: The Moderating Role of TMS on the Relationship Between SCD with SCA and SCP

Robustness Checks, Effect Size Analysis, and Diagnostic Tests

The robustness of the findings was confirmed through alternative regression models with varied controls and interaction terms. Across specifications, the key relationships remained significant and consistent. For example, BAC's effect on SCA ($\beta=0.28/0.26$, $p<0.01$) and TMS's moderating role ($\beta=0.15$, $p<0.05$) held steady, supporting the stability and generalizability of results.

Cohen's f^2 analysis showed meaningful effect sizes: BAC→SCA (f^2=0.07, medium), TMS moderating BAC–SCA (f^2=0.04, small–medium), SCA→SCP (f^2=0.09, medium), and TMS moderating SCA–SCP (f^2=0.03, small). These results indicate that predictors and moderators contribute substantially beyond statistical significance.

The Shapiro-Wilk test of residual normality yielded a non-significant result (W=0.97, p=0.12), supporting the normal distribution of residuals. Additionally, the Durbin-Watson statistic was 1.95, close to the ideal value of 2, indicating no autocorrelation in residuals.

Discussion of findings

This study explored the complex interplay among BAC, SCA, SCD, TMS, and SCP, providing preliminary insights into how these factors might collectively influence supply chain outcomes in digitally evolving environments.

The evidence indicates that BAC positively influence SCA, aligning with prior research suggesting that advanced analytics enhance situational awareness and enable timely, informed decisions to address disruptions and market shifts (Zheng et al. 2022). SCA serves as a partial mediator between BAC and SCP, functioning not merely as an outcome but as a transformation mechanism. It converts analytical insights into actionable strategies through rapid decision-making, flexible resource allocation, and adaptive coordination, effectively bridging the gap between data capabilities and performance (Alyahya et al. 2023). his dynamic capability is especially critical in contexts like Iran, where economic volatility, sanctions, limited global integration, and constrained access to raw materials heighten the importance of agility. Here, SCA is essential not only for competitive advantage but also for organizational resilience and survival, highlighting the strategic role of analytics-driven agility in challenging environments.

Second, SCD functions as both a contextual amplifier and a mediating mechanism. In turbulent environments like Iran, marked by sanctions, limited resources, and market volatility, SCD bridges BAC and SCA, channeling analytical insights into improved SCP. While BAC provides analytical depth, SCD delivers the technological infrastructure and connectivity necessary to operationalize insights and agile responses in real time. Positioning SCD as a mediator underscores its role as a critical enabler of agility and performance, complementing prior research on digitalization's positive effects on agility (Škare and Soriano 2021; Pfaff 2023) and performance outcomes (Hautala-Kankaanpää 2022).

Third, the moderating role of TMS appears to be relevant across multiple relationships, including BAC–SCA, SCD–SCA, and SCA–SCP. Strong TMS, manifested through strategic vision, resource commitment, and fostering an innovation-oriented culture, may enable firms to overcome organizational barriers, integrate digital initiatives with broader business goals, and potentially translate analytics and digitalization into agility and improved performance. In developing and unstable economies, particularly Iran, with limited access to advanced technologies and volatile markets, TMS may be especially critical in guiding resource allocation, supporting cross-functional collaboration, and sustaining digital and analytical initiatives. These findings serve as a complement to prior propositions (TMS on SCD (Shao et al. 2024), agility (Wrede, Velamuri, and Dauth 2020), performance (Men et al. 2023), and BAC (Shafique, Yeo, and Tan 2024)). As a novel insight and complementing previous findings, TMS can moderate the effect of digitalization on the relationship between BAC and SCA, as well as the role of digitalization in linking SCA to SCP, potentially enhancing both relationships.

This study proposes a framework distinguishing BAC and SCD, highlighting SCA as a mediating dynamic capability and suggesting TMS as an amplifying factor. In Iran's volatile, resource-constrained context, the findings advance theoretical understanding of digital supply chain management and offer preliminary guidance for managers seeking to improve resilience and performance in data-driven, digitally enabled supply networks.

Generalizability and Applicability of Findings

This study, set in Iran's advanced technology sector amid high uncertainty, provides insights into how BAC, SCA, SCD, and TMS interact to influence supply chain performance. While grounded in an emerging market context, the findings may also be relevant for developed economies undergoing digital transformation, offering guidance for strategic decision-making and digital supply chain management in complex and dynamic environments.

Theoretical Contributions

This study contributes both conceptually and empirically to supply chain management, digital transformation, and BAC research. It distinguishes BAC from SCD, showing that while BAC provides analytical depth for actionable insights, SCD enables the infrastructural and process-level integration needed to operationalize them. By combining both constructs, the study explains how their interplay influences SCA and SCP. It also highlights SCA as a partial mediator between BAC and SCP, clarifying how agility translates data-driven capabilities into performance gains, extending dynamic capability perspectives. Additionally, TMS is examined as an active moderator interacting with BAC and SCD to enhance agility and performance, revealing socio-technical boundary conditions where leadership, resources, and strategic alignment amplify digital capabilities. Together, these findings provide an integrated understanding of how analytics, digital infrastructure, organizational agility, and leadership jointly shape supply chain performance. Although based on Iran's advanced technology sector, the framework is adaptable to other volatile, technology-driven, and complex supply chain environments, extending its theoretical and practical relevance beyond the immediate study context.

Practical and Managerial Implications

This study provides actionable insights for enhancing supply chain performance (SCP) by integrating BAC, SCD, and SCA under strong TMS. Findings highlight the synergistic effects of analytics and digitalization, emphasizing that aligned investments in BAC and SCD enable faster, more accurate decision-making and greater adaptability. Prior research (Papadopoulos et al. 2022) often examined analytics or digitalization in isolation, this study underscores their complementary roles, particularly in resource-constrained and volatile contexts such as Iran. Here, macroeconomic instability, sanctions, financing challenges, and supply disruptions make uncoordinated investments ineffective. Coordinated development of BAC and SCD allows firms to maximize limited resources, enhance agility, and respond effectively to external shocks, addressing gaps in earlier frameworks and providing practical guidance for managers navigating uncertain and turbulent environments.

While TMS has been acknowledged as important in earlier works, it has often been treated as a background enabler (Chatterjee, Chaudhuri, and Vrontis 2022; Shao et al. 2024). Our study deepens this view by showing that TMS actively moderates key relationships between capabilities and agility, magnifying their impact on SCP. Leaders should not merely endorse initiatives but also commit resources, foster an innovation-oriented culture, and directly address organizational resistance to change. Without such active engagement, the performance gains from BAC and SCD remain limited.

This study reframes supply chain agility (SCA) as a transformation mechanism rather than merely an outcome (Patel and Sambasivan 2022; Naghshineh 2024). SCA converts digital and analytical capabilities into improved SCP. Practitioners can leverage this by developing adaptable workflows, cross-functional training, and real-time decision-support systems to bridge the capability-to-performance gap.

The interaction between SCD and TMS highlights that digital initiatives must align with broader strategic goals rather than function as isolated IT projects (Deepu and Ravi 2023; Wang et al. 2024). This extends prior literature by demonstrating that capability integration at both the technical and strategic levels is essential for enabling organization-wide agile decision-making. These findings also inform education and policy, suggesting curricula that prepare managers for technology-driven complexity and programs that strengthen digital infrastructure and leadership, particularly in emerging markets, to jointly enhance SCP.

The study provides a practical roadmap for resilience in volatile markets, emphasizing the concurrent development of BAC and SCD, strengthened agility, and aligned leadership. Moving beyond generic "invest in technology" advice, it advocates coordinated, interaction-based strategies to anticipate disruptions, seize opportunities, and sustain superior performance, offering actionable guidance for managers, educators, and policymakers.

Research Limitations and Future Directions

This study offers valuable insights but has several limitations that suggest directions for future research. It relies on perceptual survey data, which may introduce bias, highlighting the need for objective metrics or mixed-methods approaches combining surveys with interviews or case studies. While SCD and TMS were examined as moderators, other factors like firm digital maturity and innovation intensity could further clarify BAC–SCA–SCP relationships. TMS was treated unidimensional; future studies could explore strategic, structural, and cultural dimensions separately. Additionally, SCA may not capture all mediating pathways, so examining mechanisms like integration, collaboration, innovation, or risk management could provide a more comprehensive understanding of digital transformation in supply chains.

Conclusion

This study examines the interplay between BAC, SCD, SCA, and SCP, emphasizing TMS as a critical moderator. Findings indicate that organizations with robust digital capabilities and supportive leadership can better leverage analytics to enhance agility and performance. SCA acts as a dynamic capability and a key mediator, translating data-driven insights into effective supply chain actions and competitive advantage. The research highlights the synergy among BAC, SCD, and TMS, underscoring the importance of integrating advanced digital technologies, agile processes, and managerial support to build resilient, high-performing supply chains. While based on Iran's advanced technology sector, the findings are applicable to other emerging and volatile markets, offering theoretical insights and practical guidance for navigating digital transformation in complex supply chains.

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