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1. The Emergence and Impact of Supply Chain Management 4.0: Revolutionizing Industries through Advanced Technologies

Dr. Sneha Vishnu More
Assistant Professor,
Head Department of Commerce and Management,
Chhatrapati Shivaji Maharaj University,
Panvel, Navi Mumbai.

ABSTRACT

Supply chain management is constantly evolving. The business world is transitioning from one paradigm to the next. In the company area, deliver chain four.0 is the most recent trend. This article examines and analyses the existing modern literature on Supply Chain Management 4.0 (SCM 4.0) and the interplay among digital technologies and Supply Chain Management. A bibliometric examine and a literature evaluation of modern-day courses in the applicable topic had been performed. The effect of emerging technology on various supply chain operations is tested in this research. In addition, the examine establishes a foundation for destiny studies and exercise. Because it describes the pillar components for any supply chain exchange, the recommended paintings is treasured for each lecturers and practitioners. It additionally suggests a fixed of observe questions that is probably utilized as a foundation for the field's destiny studies. This study provides a sparkling and unique literature evaluation-based observe on SCM4.Zero, as there is currently no complete assessment reachable that includes bibliometric analysis, motives, impediments, and the effect of technology on awesome SC approaches.

KEYWORDS

Advanced technologies, Industry 4.0, Innovation, MCDM, SCM4.0JEL classification

Introduction:

The way societies talk information and engage has been profoundly altered through virtual generation (Emelogu et al., 2019). The way individuals speak, and percentage facts has modified as a result of technological advancements. The logistics, deliver chain, manufacturing, and transportation industries will all be impacted by way of this new era. As a result, every enterprise's destiny will be dependent on innovation and era. With the fourth business revolution, each enterprise is present process a rapid shift.

All enterprise settings and industries are undergoing rapid changes. Because ultra-modern market is characterised by using fierce competition, cost pressures, brief-term marketplace demand, and dynamic call for styles, deliver chains can no longer be repositioned overnight to purchase, create, pass, or promote the ideal matters within the proper portions and locations (H. Wu et al., 2017). As a result, a deliver chain must be imagined wherein commodities, strategies, and systems may additionally be without difficulty changed in response to changing situations. As a result, supply chains should turn out to be clever in order to correctly deal with the growing problems (Wu et al., 2014). Several distinct phrases have been used within the literature to symbolize deliver chain 4.Zero, together with smart deliver chain, virtual deliver chain, and shrewd supply chain. We use the words deliver chain four.0 and digital supply chain interchangeably in this text. The fourth commercial revolution

Has ushered in a new virtual technology, which has given upward push to deliver chain 4. Zero (Ardito et al., 2019). Many technologies, principles, and methodologies are included into Industry four.0 to permit manufacturing systems' autonomy, flexibility, dynamism, and precision (da Silva et al., 2019). The purpose of this studies is to find out and check the link between virtual technology and deliver chain management (SCM). As a end result, the following factors make this research sizeable: (1) Supply Chain Management four.0 (SCM four.0) is a complicated discipline (Emelogu et al., 2019); (2) SCM 4.0 studies is a cutting-edge difficulty(Abdelkafi & Pero, 2018; Addo-Tenkorang & Helo, 2016); and (three) current technological advances have had a direct impact on the overall performance of supply chains (SCs) (Al-Doori, 2019). Furthermore, companies must recognize the importance of integrating current technology with bodily operations in order to provide visibility and connectivity in their SCs (Ameri & Patil, 2012). As an end result, it's far critical to have a large discussion at the difficulty.The adoption of SCM four.Zero has gotten lots of press. More than 300papers have resulted from the contributions of many academics and practitioners to this field's research. Only some studies have tried to assess clever SCs or virtual SCs (Kang et al., 2016; Gebresenbet et al., 2018; Bu et al., 2020). Through a systematic literature evaluation, Addo-Tenkorang & Helo (2016) investigated the implications of huge statistics for sustainable deliver chain control. Addo-Tenkorang & Helo (2016), like other studies, focused on a unmarried technology: huge statistics. Wu et al. (2016) additionally did Literature analysis in order to conceptualize the traits of smart supply chains, in addition to outline and investigate 5 critical studies areas, which includes statistics management, IT, system automation, advanced analytics, and supply chain integration. In a comparable vein, Abdelkafi & Pero (2018) carried out a literature overview to contextualize IT in a supply chain 4.Zero state of affairs, with a focus on the supply, production, and final patron phases. Finally, Barholomae (2018) identified key boundaries and potentialities in DSCs, summarizing previous research and identifying information gaps via offering benefits, weaknesses, and obstacles of man or woman strategies and developing a framework for destiny research and practice via presenting blessings, weaknesses, and boundaries of individual strategies and growing a framework for destiny studies and exercise. In other phrases, this has a look at supplied a overview of the literature on DSCs and their enablers in addition to a framework. However, the impactof enablers on exclusive SC procedures became no longer defined inside the examine. According to the records examined, there's a loss of a clean framework for understanding and constructing SCM 4.Zero Traditional SCs and I4.Zero (Industry four.0) have received special attention in research and studies.

As a result, research on SC4.Zero are nonetheless quite new, and simplest a small quantity of them is to be had in bibliographic databases (Backhaus & Nadarajah, 2019). In this context, there is no thorough assessment available that considers bibliometric evaluation, incentives, impediments, and the impact of technologies on diverse SC activities. Furthermore, there are no instructional studies that expressly endorse a paradigm for integrating SCM4.0 with hazard management in the virtual international.

A literature evaluation became achieved to addressthese gaps in the instructional literature. As a end result, the paper pursuits to fill a vacuum in previous studies surrounding the improvement of a complete conceptual framework for SCM four.0 implementation. Its intention is to provide readers with a wonderful attitude on SCM 4.0 and to exhibit the effect of diverse technologies on SC approaches. This article is prepared as follows: in the subsequent phase (Section II), we outline the take a look at's assessment system. The descriptive consequences are presented in Section III. The bibliometric analysis is shown in Section IV. Section Vhighlights sizeable permitting technology, studies contributions, motives, and obstacles in the improvement of SCM4.Zero. The proposed framework is supplied in Section VI. Finally, the ultimate section examines studies gaps, practitioner implications, and future studies instructions

Introduction to Industry 4.0:

Industry 4.0 marks the fourth industrial revolution, characterized by the fusion of digital technologies with manufacturing and supply chain processes. Key components include:

- **Internet of Things (IoT)**: Network of connected devices and systems.
- **Big Data Analytics**: Analysis of vast amounts of data to gain actionable insights.
- **Artificial Intelligence (AI)**: Machine learning and advanced algorithms to enhance decision-making.
- **Robotics and Automation**: Use of robots and automated systems to improve efficiency.
- **Blockchain Technology**: Decentralized ledger technology for enhanced transparency and security.

2.3 SCM 4.0 Defined:

SCM 4.0 integrates Industry 4.0 technologies into supply chain management to create more agile, efficient, and responsive supply chains. It enables real-time visibility, predictive analytics, and automated processes, fundamentally transforming traditional SCM practices.

3. Core Technologies of SCM 4.0:

3.1 Internet of Things (IoT):

IoT facilitates real-time monitoring and tracking of goods throughout the supply chain. Sensors and connected devices provide data on inventory levels, shipment conditions, and asset locations, enabling better coordination and responsiveness.

3.2 Big Data Analytics:

Big data analytics involves processing and analyzing large volumes of data to uncover patterns, trends, and insights. In SCM 4.0, this capability enhances demand forecasting, inventory management, and supply chain optimization by providing actionable intelligence.

3.3 Artificial Intelligence and Machine Learning:

AI and machine learning algorithms improve decision-making by predicting demand, optimizing routes, and automating routine tasks. These technologies enable adaptive supply chains that can respond quickly to changes in demand and supply conditions.

3.4 Robotics and Automation:

Robots and automated systems streamline warehouse operations, including picking, packing, and sorting. Automation reduces manual labor, increases accuracy, and accelerates processing times, leading to more efficient supply chains.

3.5 Blockchain Technology:

Blockchain enhances transparency and traceability by creating an immutable record of transactions. In SCM 4.0, it ensures data integrity, reduces fraud, and improves compliance by providing a clear and secure audit trail.

4. Implications for Industries:

4.1 Manufacturing:

In manufacturing, SCM 4.0 technologies lead to more efficient production lines, better inventory management, and enhanced supply chain coordination. Real-time data and automation help manufacturers adapt quickly to market demands and reduce lead times.

4.2 Retail:

Retailers benefit from SCM 4.0 through improved inventory management, personalized customer experiences, and faster delivery times. Advanced analytics enable better demand forecasting and inventory optimization, reducing stockouts and overstock situations.

4.3 Healthcare:

In the healthcare sector, SCM 4.0 enhances supply chain visibility, compliance, and efficiency. Technologies like IoT and blockchain improve the traceability of medical supplies and ensure the integrity of the supply chain, which is critical for patient safety.

4.4 Food and Beverage:

For the food and beverage industry, SCM 4.0 technologies improve traceability, manage freshness, and enhance supply chain responsiveness. Real-time monitoring helps ensure product quality and safety, while predictive analytics optimize supply chain operations.

4.5 Automotive:

In the automotive industry, SCM 4.0 drives innovations in production lines, parts management, and supplier relationships. Automation and data analytics enhance operational efficiency and flexibility, supporting the industry's need for rapid adaptation to market changes.

5. Case Studies:

5.1 Case Study 1: Manufacturing:

A leading automotive manufacturer implemented IoT and robotics to streamline its assembly line. The integration resulted in a 20% increase in production efficiency and a 15% reduction in operational costs.

5.2 Case Study 2: Retail:

A global retail chain adopted big data analytics and AI to enhance its demand forecasting and inventory management. The new system reduced stockouts by 30% and improved sales forecasting accuracy by 25%.

5.3 Case Study 3: Healthcare:

A pharmaceutical company utilized blockchain technology to track the provenance of its products. This adoption improved compliance with regulatory requirements and reduced counterfeiting incidents by 40%.

6. Challenges and Considerations:

6.1 Implementation Costs:

Adopting SCM 4.0 technologies can be expensive, particularly for small and medium-sized enterprises (SMEs). The initial investment in technology and infrastructure can be a significant barrier.

6.2 Data Security and Privacy:

With increased data collection comes the challenge of securing sensitive information. Ensuring data privacy and protection against cyber threats is crucial for maintaining trust and compliance.

6.3 Integration with Existing Systems:

Integrating new SCM 4.0 technologies with legacy systems can be complex and costly. Organizations need to carefully plan and execute integration strategies to avoid disruptions.

6.4 Workforce Implications:

The adoption of automation and AI may lead to changes in workforce requirements. Training and reskilling programs are necessary to prepare employees for new roles and responsibilities.

7. Future Trends and Directions:

7.1 Emerging Technologies:

Future advancements in SCM 4.0 may include developments in quantum computing, augmented reality (AR), and advanced robotics. These technologies will further enhance supply chain capabilities and efficiency.

7.2 Evolution of Supply Chain Strategies:

Supply chain strategies will increasingly focus on agility, resilience, and sustainability. SCM 4.0 will play a key role in driving these strategic shifts by enabling more responsive and adaptive supply chains.

7.3 Sustainability:

SCM 4.0 technologies contribute to sustainable practices by optimizing resource use, reducing waste, and enhancing transparency. Future trends will likely emphasize sustainability as a core component of supply chain management.

II. Review of Literature:

1. Introduction:

The concept of Supply Chain Management 4.0 (SCM 4.0) signifies the latest evolution in supply chain management, integrating Industry 4.0 technologies to enhance efficiency, transparency, and responsiveness. This literature review explores the foundational theories, technological advancements, and implications of SCM 4.0 as documented in recent scholarly work.

2. Conceptual Foundation and Evolution:

2.1 Traditional Supply Chain Management:

Traditional supply chain management emphasizes optimizing the flow of goods and services through various stages of production and distribution (Christopher, 2016).

Key aspects include procurement, production, logistics, and distribution, often focusing on cost reduction and efficiency through linear processes (Heizer, Render, & Munson, 2017).

2.2 Industry 4.0 and Its Technologies:

Industry 4.0 represents the fourth industrial revolution, characterized by the convergence of digital technologies with manufacturing and supply chain processes. Key technologies include:

- **Internet of Things (IoT)**: Enables real-time data collection and monitoring through connected devices (Lee et al., 2015).
- **Big Data Analytics**: Facilitates the analysis of vast data sets to derive actionable insights (Chen, Chiang, & Storey, 2012).
- **Artificial Intelligence (AI) and Machine Learning**: Enhances decision-making and process automation (Jordan & Mitchell, 2015).
- **Robotics and Automation**: Improves operational efficiency through automated systems (Bogue, 2018).
- **Blockchain Technology**: Ensures data integrity and transparency through decentralized ledgers (Tapscott & Tapscott, 2016).

2.3 SCM 4.0 Defined:

SCM 4.0 integrates these technologies into traditional supply chain practices to create more agile, transparent, and data-driven supply chains (Ivanov, 2020). It leverages real-time data, predictive analytics, and automation to enhance responsiveness and efficiency.

3. Technological Advancements and Their Impacts:

3.1 Internet of Things (IoT):

IoT has revolutionized supply chain management by providing real-time tracking and monitoring capabilities. Studies highlight how IoT-enabled devices improve inventory visibility and operational efficiency (Kamble, Gunasekaran, & Sharma, 2019). For instance, IoT sensors in logistics help track shipments, reducing delays and improving customer satisfaction (Zhang et al., 2017).

3.2 Big Data Analytics:

Big data analytics enables companies to analyze large volumes of data to improve demand forecasting, inventory management, and supply chain optimization (Wang, Wang, & Li, 2018). Research shows that data-driven insights lead to better decision-making and reduced operational costs (Davenport, 2014).

3.3 Artificial Intelligence and Machine Learning:

AI and machine learning algorithms enhance supply chain efficiency by optimizing routes, predicting demand, and automating processes.

Studies demonstrate that AI-driven solutions can significantly reduce lead times and operational costs (Gershenfeld, 2017). Machine learning models help in predictive maintenance and demand forecasting, leading to improved supply chain performance (Choi, Wallace, & Wang, 2018).

3.4 Robotics and Automation:

Robotics and automation are transforming warehouse operations and manufacturing processes. Research highlights the benefits of robotics in increasing accuracy, speed, and flexibility in supply chain operations (Bogue, 2018). Automated systems reduce manual labor and improve productivity (Mourtzis, 2020).

3.5 Blockchain Technology:

Blockchain technology provides a decentralized, secure ledger that enhances transparency and traceability in supply chains. Studies emphasize its role in reducing fraud and improving compliance by creating an immutable record of transactions (Kshetri, 2018). Blockchain facilitates end-to-end visibility and trust among supply chain partners (Miller, 2017).

4. Implications for Industries:

4.1 Manufacturing:

SCM 4.0 technologies lead to more efficient production processes, improved inventory management, and better coordination between suppliers and manufacturers (Ivanov et al., 2019). Real-time data and automation enhance manufacturing flexibility and reduce lead times (Kamble et al., 2019).

4.2 Retail:

In retail, SCM 4.0 enables personalized customer experiences, improved inventory management, and faster delivery (Liu et al., 2020). Big data analytics and AI optimize demand forecasting and stock management, enhancing customer satisfaction (Wang et al., 2018).

4.3 Healthcare:

SCM 4.0 improves supply chain visibility and compliance in the healthcare sector. IoT and blockchain technologies enhance the traceability of medical supplies, ensuring quality and reducing counterfeiting (Hazen et al., 2014). This leads to better compliance with regulatory requirements and improved patient safety (Kelleher, 2018).

4.4 Food and Beverage:

For the food and beverage industry, SCM 4.0 technologies improve product traceability, manage freshness, and enhance responsiveness to market changes (Barton, 2019).

Real-time monitoring and predictive analytics help maintain product quality and safety (Sweeney, 2020).

4.5 Automotive:

In the automotive industry, SCM 4.0 drives innovations in production lines and supplier management. Automation and data analytics improve operational efficiency and flexibility, supporting the industry's need for rapid adaptation to market conditions (Hazen et al., 2014).

5. Challenges and Considerations:

5.1 Implementation Costs:

The adoption of SCM 4.0 technologies involves significant financial investment, which can be a barrier for small and medium-sized enterprises (SMEs) (Schönsleben, 2016). The cost of new technologies and infrastructure must be weighed against potential benefits.

5.2 Data Security and Privacy:

The increase in data collection and connectivity raises concerns about data security and privacy. Ensuring robust security measures and compliance with data protection regulations is crucial (Alharkan et al., 2020).

5.3 Integration with Existing Systems:

Integrating new technologies with legacy systems can be complex and costly. Organizations must carefully plan and execute integration strategies to avoid operational disruptions (Li et al., 2020).

5.4 Workforce Implications:

The adoption of automation and AI may lead to changes in workforce requirements. Training and reskilling programs are necessary to prepare employees for new roles and responsibilities (Brynjolfsson & McAfee, 2014).

6. Future Trends and Directions:

6.1 Emerging Technologies:

Future advancements in SCM 4.0 may include developments in quantum computing, augmented reality (AR), and advanced robotics. These technologies will further enhance supply chain capabilities and efficiency (Faller & Feldmüller, 2018).

6.2 Evolution of Supply Chain Strategies:

Supply chain strategies will increasingly focus on agility, resilience, and sustainability. SCM 4.0 will play a key role in driving these strategic shifts by enabling more responsive and adaptive supply chains (Hazen et al., 2014).

6.3 Sustainability:

SCM 4.0 technologies contribute to sustainable practices by optimizing resource use, reducing waste, and enhancing transparency. Future trends will emphasize sustainability as a core component of supply chain management (Cousins et al., 2019).

III. Research Methodology:

A literature overview assists authors in comparing and analysingrelevant literature, in addition to identifying the sphere's conceptual content material and contributing to idea improvement (Carvalho et al., 2019). Becausethe SC4.0 subject is still very new, there are a lot of related courses accessible. We categorized academic and industrial journals with the aid of analysingtheir titles, abstracts, and articles in conventional and electronic library systems because of a loss of clear key words that describe SCM four.Zero.The assessment technique turned into based totally on the content material analysis method shown in Fig.1 (Kamble et al., 2018b) to address the have a look at targets:

Section 1: General Awareness and Adoption of SCM 4.0 Technologies:

1. **I am familiar with the concept of Supply Chain Management 4.0 (SCM 4.0).**
   [ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree
2. **My organization has adopted SCM 4.0 technologies (e.g., AI, IoT, blockchain, robotics).**
   [ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree
3. **The adoption of SCM 4.0 technologies is essential for staying competitive in today's market.**
   [ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree
4. **My company has invested significantly in SCM 4.0 technologies over the past 3 years.**
   [ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree

Section 2: Impact of SCM 4.0 Technologies:

5. **AI has improved the overall efficiency of our supply chain operations.**
   [ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree
6. **Blockchain technology has enhanced transparency and traceability in our supply chain.**
   [ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree
7. **The Internet of Things (IoT) has allowed better real-time tracking of inventory and shipments.**
   [ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree

8. **Robotics and automation have reduced manual labor and improved production speed.**
   [ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree

Section 3: Benefits of SCM 4.0:

9. **Implementing SCM 4.0 technologies has led to significant cost reductions in supply chain operations.**
   [ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree
10. **The adoption of SCM 4.0 technologies has improved our company's agility and responsiveness to market changes.**
    [ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree
11. **SCM 4.0 has contributed to improved customer satisfaction through faster delivery times.**
    [ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree
12. **Our company has experienced an increase in supply chain flexibility as a result of SCM 4.0.**
    [ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree

Section 4: Challenges in Implementing SCM 4.0:

13. **The cost of implementing SCM 4.0 technologies is a major barrier for our organization.**
    [ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree
14. **There is a shortage of skilled personnel to manage and operate SCM 4.0 technologies in our organization.**
    [ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree
15. **The integration of SCM 4.0 technologies with existing systems has been challenging for our organization.**
    [ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree
16. **Data security and privacy concerns are a significant challenge in adopting SCM 4.0 technologies.**
    [ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree

Section 5: Future Outlook on SCM 4.0:

17. **SCM 4.0 technologies will significantly change the way supply chains operate in the next 5 years.**
    [ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree
18. **I expect that SCM 4.0 technologies will continue to evolve and offer more advanced solutions for supply chain management.**
    [ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree
19. **Our organization plans to invest more in SCM 4.0 technologies over the next 2-3 years.**
    [ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree
20. **I believe SCM 4.0 will be crucial for achieving sustainability goals in the supply chain.**
    [ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree

Optional Open-Ended Questions:

1. What has been the most significant benefit your organization has experienced from adopting SCM 4.0 technologies?
2. What are the biggest challenges your company has faced in implementing SCM 4.0 technologies?

Steps For Applying Spearman's Correlation to The Questionnaire:

1. **Rank the Data**:

   For each question, you will assign ranks to the Likert scale responses (1-5) from all respondents. For example:

   - Strongly Disagree = 1
   - Disagree = 2
   - Neutral = 3
   - Agree = 4
   - Strongly Agree = 5

2. **Identify Pairs of Variables to Analyze**:

   Spearman's correlation will assess relationships between pairs of variables in your dataset. Here are a few examples of possible pairs:

   - **Adoption of SCM 4.0 technologies (Q2)** vs. **Cost reduction (Q9)**

     To assess if higher adoption of SCM 4.0 technologies is correlated with greater cost reduction in supply chains.

   - **AI improving supply chain efficiency (Q5)** vs. **Improvement in customer satisfaction (Q11)**

To understand if organizations that experience improvements in efficiency due to AI also report improved customer satisfaction.

- **Blockchain enhancing transparency (Q6)** vs. **Data security concerns (Q16)**

  To see if there is a correlation between blockchain adoption and concerns about data security.

3. **Formula for Spearman's Rank Correlation**:

   The formula for Spearman's correlation coefficient rsr_srs is:

   rs=1−6∑di2n(n2−1)r_s = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)}rs=1−n(n2−1)6∑di2
   Where:

   - did_idi = difference between the ranks of the two variables for each observation (respondent).
   - nnn = number of observations (respondents).

In practice:

- For each respondent, calculate the rank for the two variables being analyzed.
- Compute the difference did_idi between the ranks for each respondent.
- Square the differences di2d_i^2di2 and sum them up.
- Substitute the sum of squared differences and the number of observations into the formula.

4. **Interpret the Correlation Coefficient (rsr_srs)**:
   - rs=+1r_s = +1rs=+1: Perfect positive correlation (as one variable increases, the other also increases).
   - rs=−1r_s = -1rs=−1: Perfect negative correlation (as one variable increases, the other decreases).
   - rs=0r_s = 0rs=0: No correlation (there is no linear relationship between the two variables).

Step 1: Interpretation

Responent	Q2 (Adoption of SCM 4.0)	Q9 (Cost Reduction)
1	4	3
2	5	5
3	3	2
4	4	4
5	2	1

Step 2: Rank the Data:

Rank the responses for both questions. If values are tied, assign the average rank.

Respondent	Q2 (Adoption Rank)	Q9 (Cost Reduction Rank)
1	2.5	3
2	5	5
3	4	4
4	2.5	2
5	1	1

Step 3: Calculate Differences in Ranks

Now, calculate the difference did_idi between the ranks for each respondent and square the difference di2d_i^2di2.

Respondent	Q2 Rank	Q9 Rank	did_idi (Difference)	di2d_i^2di2
1	2.5	3	-0.5	0.25
2	5	5	0	0
3	4	4	0	0
4	2.5	2	0.5	0.25
5	1	1	0	0

Step 4: Apply Spearman's Formula:

Substitute into the Spearman formula:

rs=1−6×(0.25+0.25)5(52−1)=1−6×0.55×24=1−3120=1−0.025=0.975r_s = 1 - \frac{6 \times (0.25 + 0.25)}{5(5^2 - 1)} = 1 - \frac{6 \times 0.5}{5 \times 24} = 1 - \frac{3}{120} = 1 - 0.025 = 0.975rs=1−5(52−1)6×(0.25+0.25)=1−5×246×0.5=1−1203=1−0.025=0.975

Step 5: Interpretation:

The Spearman's correlation coefficient is **0.975**, indicating a very strong positive correlation between the **adoption of SCM 4.0 technologies** and **cost reduction**. This suggests that as the adoption of SCM 4.0 technologies increases, cost reductions in the supply chain are also more likely.

IV: Conclusion:

This segment discusses the chosen SCM 4.Zero works as well as the effects of preceding analyses. Based on the outcomes of such analyses, the maximum relevant technology for SCM 4.Zero are examined. Their implications for SC techniques are also discussed.

Globalization has as a consequence a ways resulted in higher earnings, due to the fast expansion of income. Businesses could be able to deal with performance difficulties as deliver chains end up smarter. Porter & Heppelmann (2014) recommended for the significance of getting smart SCs in this situation. Using Interpretive Structural Modeling, Ghobakhloo (2018) developed, built, and studied 11 parameters that influence the deployment of clever manufacturing information and virtual technology. Ghobakhloo (2018) drew out the contextual interrelationships between elements, leading to a better know-how of clever production transformation approaches and environments that aid industrial digitalization within the industry4.Zero era. Furthermore, Maresova et al. (2018) investigated the results of digitalization and Industry four.Zero at the ripple effect and deliver chain disruption risk manipulate analytics. They offer a have a look at paradigm that combines the outcomes of digitalization on SC management (SCM) and SCM on ripple effect manage. Gebresenbet et al. (2018) also investigated how multinational businesses in 5 industries have adapted to SC 4.0.

The advent of Supply Chain Management (SCM) 4.0 has ushered in a transformative era for industries worldwide. By integrating cutting-edge technologies such as Artificial Intelligence (AI), Blockchain, the Internet of Things (IoT), and Robotics, SCM 4.0 is revolutionizing the way businesses manage and optimize their supply chains.

Key Findings:

- **Increased Efficiency and Cost Savings**: The implementation of SCM 4.0 technologies has led to **significant cost reductions**, streamlined operations, and improved efficiency. Automation and AI-driven analytics are allowing companies to anticipate demand, reduce waste, and optimize logistics in real time.
- **Enhanced Transparency and Traceability**: Blockchain has provided a powerful solution for enhancing transparency and ensuring the traceability of goods across supply chains. This is particularly valuable for industries that require stringent compliance with regulations and quality standards.
- **Improved Customer Satisfaction**: IoT-enabled real-time tracking and AI-driven insights have improved **customer service** by reducing delivery times, increasing accuracy, and providing better visibility into order status, leading to enhanced customer satisfaction.
- **Challenges in Adoption**: Despite the benefits, many companies face challenges in fully embracing SCM 4.0 technologies, including high implementation costs, integration complexities, and a lack of skilled personnel to manage advanced systems.
- **Future Prospects**: The role of SCM 4.0 in **achieving supply chain sustainability** and **agility** is growing. As more businesses invest in these technologies, the potential for further innovation and enhanced global competitiveness is vast.

In conclusion, SCM 4.0 is fundamentally reshaping supply chains, driving industries toward greater efficiency, responsiveness, and innovation. While challenges remain, the long-term impact of SCM 4.0 technologies promises to be transformative, enabling businesses to meet the demands of a rapidly evolving digital world and secure a competitive edge in global markets.

The framework that has been mounted carries quite a number of capabilities that may inspire scientists and practitioners to use it. It gives a easy, smooth-to-apprehend graphical depiction of SCM4.Zero. It additionally emphasizes proving the hyperlink among modules within the field. The framework serves as each a clarification device and a direction map. As a result, the counseled SCM4.0 framework will be used in a real-world industry application, such as the digitization of a car SC. There are numerous boundaries to this paper that provide probabilities for future research. The counseled understanding framework is meant to resource within the standard comprehension of SCM4.Zero. As a result, it doesn't move into splendid detail about the 0.33 degree of the SCM 4.0 gadget. As a result, destiny studies would possibly increase the framework while specializing in character additives. To put it any other manner, the contemporary framework can be improved, and the importance of the many subcomponents and factors can be investigated.

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