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Integrating Supply Chain Partners through Implementing Industry 4.0 Technologies to Enhance Competitiveness

Choudhury Abul Anam Rashed*, Mst. Nasima Bagum, Md. Mehedi Hasan Kibria, Rafid Ahmed Chowdhury, Md. Ariful Islam

Department of Industrial and Production Engineering, Shahjalal University of Science and Technology, Sylhet, Bangladesh.

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Abstract

Manufacturing companies must embrace state-of-the-art technologies to keep up with the rapid advancements in technology and innovation. This study examines how integrating supply chain partners in implementing technologies like I4.0 can improve Competitiveness. The research employed a survey-based approach, utilizing a well-constructed semi-structured questionnaire. One hundred and twenty-five responses were obtained from Bangladesh's Readymade Garments Sector. Based on previous literature and the responses from the respondents, a conceptual model was formulated, which generated six hypotheses. The model and the hypotheses are tested and validated through Structural Equation Modeling. Smart PLS 4.0 was employed for data analysis. The study's findings support all the proposed hypotheses, confirming the validity of the developed model. The effective and efficient implementation of cutting-edge technologies through linking with the supply network partners would build Competitiveness.

Keywords: Industry 4.0 technology; Supply Chain Partners; Competitiveness; Conceptual Framework..

1. Introduction

Industry 4.0 is described as creating Cyber-Physical Systems (CPS) that relies on the fusion of diverse data and expertise. In essence, it can be characterized as a collaborative manufacturing approach that combines adaptability, optimization, and a focus on services. This approach is closely associated with algorithms, Big datasets, and advanced know-hows e.g. Industrial Automation, Internet of Substances/Things (IoT), Cloud Computing, Cybersecutrity and smart Robots [1].

Collaboration and cooperation between suppliers, producers, and customers are necessary for Industry 4.0 adoption. It takes more than just implementing new technologies to implement Industry 4.0 successfully; it also requires a vital shift in how businesses interact with their stakeholders. Companies adopting Industry 4.0 must be prepared to collaborate closely with their suppliers and customers to benefit from this digital change fully. Benitez et al .[2] explored the dynamics of Industry 4.0 technology provisions and the impact of supply chain partners on supporting technology providers. The study investigated how supply chain partners influence the implementation, adoption, and success of I4.0 technologies, highlighting the importance of collaboration and partnerships in leveraging such technologies effectively.

Industry 4.0 adoption depends heavily on suppliers. They are in charge of supplying the necessary components and raw materials for the production process. Suppliers may boost productivity, reduce lead times, and raise product quality by implementing modernized knowhow. For example, they may use smart sensors to monitor the raw materials' quality and notify the makers of variations. This proactive strategy can aid in reducing waste, preventing defects, and improving customer satisfaction. Industry 4.0 is greatly influenced by supply chain members' alliance and fairness [3].

RQ 1: How the involving supplier affects in the implementation of I4.0 technologies?

Manufacturers predominantly spearhead the adoption of Industry 4.0. Innovative manufacturing stands as a pivotal facet of the forefront expertise associated with Industry 4.0 [4]. Leveraging innovative technology, data analytics, and the Internet of Things (IoT), they can enhance production processes, reduce costs, and amplify productivity. For instance, predictive maintenance systems enable manufacturers to monitor equipment performance and anticipate maintenance needs, thereby curtailing maintenance expenses, averting unplanned downtime, and elevating overall equipment effectiveness (OEE). Embedded within the realm of cutting-edge technology, the cultivation of streamlined and digitally-enabled production systems emerges as a pragmatic business strategy, vital for ensuring corporate sustainability and viability [5]. To expedite the integration of novel technologies, manufacturers must grasp the decision-making dynamics of their clientele [6]. Moreover, employing data analytics

* Corresponding author e-mail: rashed-ipe@sust.edu.

enables manufacturers to glean insights into consumer preferences and market trends, facilitating the refinement and execution of their marketing and product development endeavors.

RQ 2: What are the roles of the manufacturer in the successful implementation of I4.0 technologies?

Another key participant in the adoption of Industry 4.0 is the consumer. With increasing frequency, consumers are demanding personalized goods and services tailored to their specific needs and preferences. Companies that offer customized services and products are poised to gain a competitive edge in the market [7]. Leveraging Industry 4.0 technologies, businesses can gather and analyze customer preferences to gain deeper insights into their behavior. For instance, IoT-enabled devices can be utilized by companies to collect data on how customers interact with their products and services. This information serves as a valuable guide for product development and marketing strategies, enabling the creation of more specialized goods and services that effectively meet customer needs.

RQ 3: How the incorporation of the customer would affect the implementing of I4.0 knowhow?

The engagement of suppliers, manufacturers, and customers in embracing Industry 4.0 has the potential to bolster an organization's Competitiveness. Enhanced production quality and flexibility positively influence the performance of suppliers of modern technologies [8]. Improved communication infrastructure within the supply chain fosters closer connections between consumers and the production process [9]. Through the implementation of updated knowledge [10, 11], companies can augment productivity, reduce costs, and enhance efficiency, ultimately leading to shorter time-to-market, higher-quality products, and increased consumer satisfaction [12]. The strategic significance of I4.0 adoption for modern supply chains offering insights into how organizations can leverage technology to build resilience and improve performance in an increasingly complex and uncertain business environment is depicted in [13]. Furthermore, businesses offering personalized goods and services are likely to gain a competitive edge. Thus, the integration of Industry 4.0 technology can assist companies in maintaining their market position and outperforming their rivals.

RQ 4: What are the relation between implementing I4.0 knowledge and Competitiveness of the organization?

1.1. *Objectives of the Study*

The research objective is to explore the effect of integrating the Supply chain partners (such as the supplier, buyer, and manufacturer) in implementing Industry 4.0 technologies to enhance Competitiveness.

2. Literature Review

Industry 4.0 denotes to the 4th industrial revolution, which involves the incorporation of cutting-edge tools like IoT, data analytics, and artificial into industrialized operations. This integration promises to revolutionize how products are designed, manufactured, and distributed. Implementing cutting edge tools demands alliance between suppliers, manufacturers, and customers. In this literature review, the role of these three stakeholders in implementing Industry 4.0 are reviewed, and how their involvement can lead to increased company competitiveness.

Tarigan et al. [14] investigated the impact of internal integration, supply chain partnership, supply chain agility, and supply chain resilience on sustainable advantage. It employed empirical research methods to analyze how these factors contribute to sustainability within supply chains and ultimately lead to a competitive advantage for organizations. Strategic significance of supply chain integration and resilience in improving supply chain performance is presented in [15]. For the supply chain to perform more efficiently, suppliers must be involved in applying Industry 4.0. According to earlier inquiries, coordination is essential in traditional and decentralized supply chains [16]. However, the conventional supply chain model's sustainability has given rise to doubts, necessitating a move toward Industry 4.0 practices. Salam [8] emphasizes how improved manufacturing quality and flexibility positively impact suppliers' performance. Even though they may not directly impact supplier performance, elements like delivery time and cost reduction are still essential. Government policies and supply chain collaboration have also been recognized as critical factors in successfully adopting I4.0 practices [3]. According to Eslami et al. [17], applying modernized technologies strengthens the influence of supply network agility on financial enactment. Although these technologies do not moderate the association between supply chain integration and agility, their assimilation improves the performance of the chain.

Additionally, Mason et al. [18] emphasize that collaboration and knowledge sharing within and across organizations are essential in optimizing supply chain operations. The characteristics, challenges, and opportunities associated with fostering sustainability between two entities (dyads) within supply chain are studied in [19]. Twenty of Industry 4.0's most important applications were outlined by Javaid et al. [10], who highlighted the technology's potential to improve sustainability by using resources more efficiently. These results imply that suppliers must modify their procedures and products to satisfy Industry 4.0 requirements, helping businesses achieve sustainability objectives. TRONNEBATI and JAWAB [20] identifies common themes, challenges, and best practices in green and sustainable supply chain management by synthesizing the findings from multiple studies.

Manufacturer involvement in implementing Industry 4.0 is crucial because they take on a leading role in comprehending and utilizing potential value-added solutions. Instead of fully appreciating the opportunities it presents for creating customer-centric value-added solutions, managers frequently believe that Industry 4.0 will improve process monitoring [21]. By employing machine learning models, the cyber-physical systems (CPS) framework enables automated and proactive quality monitoring, enhancing the reliability and performance of CPS across various applications and industries [22]. However, Frank et al. [4] claim that updated know how includes the systemic implementation of advanced know-how, such as Smart Engineering, that enable manufacturers to optimize operations and establish competitive advantages. Nayernia et al. [23] identify research streams emphasizing the importance of addressing customer needs and achieving radical improvements in business models to achieve successful implementation. Continuous improvement, lean management, and top management leadership all support this customer-centered strategy, according to Pozzi et al. [12]. These findings highlight manufacturers' crucial role in embracing Industry 4.0's transformative potential and matching it to customer needs while highlighting the necessity of ongoing development and strong leadership to ensure its successful implementation.

Customers must be involved in Industry 4.0 implementation for companies to understand their changing needs and preferences [9]. Customer satisfaction increases, and manufacturers can tailor their products and services due to improved supply chain communication systems that bring consumers closer to the production process. Sepasgozar [6] emphasizes the active role of vendors in comprehending customer decision-making processes to boost technology adoption rates. Customer adoption patterns offer insightful Information that can help new businesses and slow adopters implement their strategies. In their framework, Ciano et al. [24] highlight the significance of customer relationships in implementing Industry 4.0. Companies can improve their Competitiveness and customer relationships by utilizing technologies like customer segmentation, digital transformation, and rapid prototyping. Saniuk et al. [7] Industry 4.0 on environmentally friendly consumption. These results underline the importance of creating Industry 4.0 ideas that align with consumer behavior and sustainability goals.

The successful execution of cutting-edge technologies and realizing their probable benefits depend on the involvement of suppliers, manufacturers, and consumers. Manufacturers face several difficulties, including a shortage of innovative tools, financing, administration visualization, and expert labor [25]. Similar knowledge gaps and communication problems prevent SMEs in developing nations from adopting intelligent manufacturing and digitization [26]. Stakeholder collaboration and knowledge sharing are essential for implementation success [18, 27]. Jraisat et al. [28] emphasized that no single actor within a value chain can achieve sustainability goals in isolation; collaboration and partnerships among various stakeholders are crucial. How I4.0 concepts such as IoT, AI, and big data are reshaping supply chain integration practices and design strategies are presented in [29, 30]. Order fulfillment and transport logistics are two areas specifically affected by Industry 4.0 that could see improvement in efficiency [31]. Big Data has been shown to contribute positively to competitive advantages, but caution should be exercised when investing in advanced robots to prevent detrimental effects on sales growth [32]. For implementation to be successful, challenges like cost, employee attitudes, a lack of knowledge, and resistance to change must be overcome [33, 34]. Schmidt et al. [35] et al. demonstrated the integration of I4.0 technologies within supply chain operations and its impact on buyer-supplier relationships. The paper provided a comprehensive review of the evolution of these relationships in the context of I4.0, examining how advancements such as automation, data exchange and IoT are reshaping collaboration, communication and interdependence between buyers and suppliers. It is crucial to collaborate, share knowledge, and address challenges to maximize the advantages of Industry 4.0 for suppliers, manufacturers, and customers.

Lean methodologies and continuous improvement techniques, on the other hand, can reduce these challenges and speed up implementation [36, 37]. Organizations must address these drivers and obstacles to ensure successful performance and increased Competitiveness. Fruitful adoption of modern innovations and overall company competitiveness have been credited to lean practices. How various forms of flexibility in manufacturing processes, such as capacity, technology, or product flexibility, impact operational efficiency, responsiveness, and ultimately, the Competitiveness of the system was shown in [38]. Leadership, commitment, employee involvement, cultural alignment, and effective communication are critical for establishing a synergistic relationship between lean manufacturing and Total Quality Management (TQM) to enhance operational performance [39]. Implementing lean production techniques can improve productivity in manufacturing contexts [40]. It examined various aspects such as waste reduction, process optimization, and workforce involvement. Díaz-Reza et al. [41] identified specific pathways through which Lean practices contribute to social sustainability, such as improved employee well-being, enhanced community relations, and increased stakeholder engagement. Lean critical success factors (CSFs) are recognized by Qureshi et al. [42] as having advantageous effects on adopting Industry 4.0 and encouraging increment of efficiency, a decrease of waste, competitive lead, and ecological manufacturing systems. Lean manufacturing principles can also be effectively applied to healthcare settings, specifically within emergency departments, to enhance efficiency and effectiveness in patient care delivery [43]. Nayernia et al. [23] also identify research streams that concentrate on enhancing supply chain management, human resources, and lean tools in the business context.

Employee-aided and IT-assisted know-how, administration, and L4.0-linked factors were recognized as crucial achievement dynamics for I4.0 implementation, resulting in productivity gains, waste minimization, competitive edge, and long-term industrialized structures [42]. It became apparent that technological aptitude and strategic adaptability were crucial for successfully implementing I4.0 [44]. I4.0 readiness is positively impacted by total quality management, digital transformation, and radio frequency identification [45]. Understanding the socio-technical requirements for applying modernized know-hows, including effective communication and organizational change management [46]. The adoption of updated technologies is positively influenced by long-term, in-operation, and green prospects [47].

While manufacturing companies in developing countries, particularly in the South-East Asian territory, put forth significant efforts, bigger companies typically spend more in adopting updated expertise [48]. Digital readiness levels vary between companies, with larger companies typically better prepared than smaller ones. Some of the technologies anticipated to have a substantial influence are expected to receive less investment [49]. Digital technologies are prioritized according to the size and resources of the manufacturing company, with smaller manufacturers concentrating on those that directly impact productivity, quality, and safety and larger manufacturers prioritizing enterprise support operations technologies [50]. Smaller manufacturers can gradually digitize particular areas of operations in alignment with their core strategies, transitioning to a lean-digitized manufacturing system. Organizational integration and digitization of value chains are needed for an effective I4.0 transition [5]. Although micro-enterprises are reluctant to invest in Industry 4.0 components, investments in Czech engineering companies are primarily focused on apparatuses and techniques confirming data safety, automation of scientific apparatus and procedures, mass customization, cloud-based computing, and sensor integration [51].

Implementing Industry 4.0 has been shown to have a wide range of benefits and boosts industry competitiveness. The application of updated technologies positively affected ergonomics, efficiency, and process standardization, which increased Competitiveness, according to Ciccarelli et al. [52]. Australian manufacturers' use of updated knowhows to systematize capturing, analyzing and integrating the data has increased their Competitiveness [18]. Data analytics, the IoT, and smart factories illustrate 4^{th} revolutionary technologies that improve sustainable business performance, particularly for SMEs [53]. The potential of 4IR to employ lean principles, improve resource utilization, and lowering waste was highlighted by Sanders et al. [54]. 4IR adoption has improved productivity, consistency, and operational costs in the food manufacturing sector [11]. Additionally, it has been discovered that combining 4IR employment with lean principles improves financial and operational performance [55]. Companies can effectively leverage Industry 4.0 and boost their Competitiveness by integrating new technologies with lean principles like continuous improvement, supply chain engagement, market-oriented, and consumer center [37].

Effective implementation of 4IR for maintaining company competitiveness necessitates active engagement and collaboration among suppliers, manufacturers, and customers. This collaborative effort enhances the application process through coordinated efforts, resulting in quality improvements, enhanced flexibility, and seamless technology integration provided by suppliers and manufacturers. Customers play a pivotal role in value creation and elevating customer experiences. Successful implementation would be facilitated by strategic decision-making, a deep understanding of customer decision-making processes, and adopting lean practices. However, challenges such as costs, employee attitudes, and resistance to change must be addressed. Collaboration, knowledge sharing, training, and skill development are imperative to ensure successful implementation while leveraging data analytics and data-driven decision-making, further empowering businesses to gain a competitive edge.

3. Methodology

The study is performed grounded on a questionnaire-based survey. The questionnaire was developed and finalized based on a broad literature assessment and conversation with the relevant specialists from academics and practitioners. The export-oriented Ready Made Garments (RMG) sector cluster was selected as the respondents. About Four hundred factories were approached, and One hundred twenty-five responded. As per the 95% confidence interval the sample size is Three Hundred and Eighty Five. Further analysis was performed based on the online and offline responses from the studied factories. The respondents involved in the research are the respective organizations' strategic decision-making levels and the demographic details of the respondents are shown in Table 1. Based on their answers, the developed conceptual model was tested and validated. The paths of the model that represents the hypotheses were tested. The collected data were tested through the PLS-SEM model. PLS-SEM method is used in recent days because it allows for estimating intricate models containing numerous constructs, indicator variables, and structural paths without necessitating assumptions about data distribution [56]. Moreover, PLS-SEM stands out as a causal-predictive approach in structural equation modeling, prioritizing prediction in statistical model estimation and emphasizing causal explanations in their designed structures. The hypotheses were tested through IBM SPSS 25 Version. Microsoft Excel was also used. The data gathered are interpreted, and a conclusion is drawn based on the analysis.

Table 1. Demographic details of the respondents

Serial No.	No. of Respondents	Concerned Department	Position of the Concerned Personnel	Duration of Service (years)
1	15	Quality Control & Management	QC Manager	
2	13	Sales & Marketing	Sales & Marketing Manager	
3	11	Procurement and Supply Chain	GM/AGM	
4	26	Engineering (Industrial)	Incharge	
5	23	Production	AGM or GM	
6	3	New Product & Service Development	Head	
7	3	Business Strategy	Director	15 to 20
8	3	Research & Development	Director	
9	4	Cost and Management	CEO	
10	3	Production	GM/AGM	
11	8	Business and Planning	Director/Manager	
12	8	Centralized Planning	Planning Head	
13	5	Computations and Software Solution Provider	CTO	
Total	125			

4. Conceptual Model

A conceptual framework was developed to testify to the interrelationship between the Supply network, particularly manufacturer, supplier, and buyer, with the putting into practice 4IR knowledge. Gold et al. [57] outlined directions for developing a conceptual model that integrates various factors such as organizational culture, technology infrastructure, and human resources to enhance knowledge management practices. The developed model in the current research needs to testify whether the involvement of the supplier and buyer with the manufacturer in the design and development phase of the garments product aid in implementing Industry 4.0. Moreover, implementing cutting-edge technology and innovation management affects the Competitiveness of the manufacturing firm. The framework is represented in Figure 1.

Six hypotheses have been developed based on the paths of the conceptual model, as shown in Figure 1. Figure 1 shows that the involvement of the supplier and manufacturer are independent variables. In contrast, the manufacturer's involvement and implementation of I4.0 technology are mediating variables, and the improvement of Competitiveness is the dependent variable. Sparrowe and Mayer [58] represented how to establish and validate the hypotheses concerning the relationship between dependent and independent variables.

Hypothesis 1

Dawson and Mukoyama [59] discovered the relationship between customer involvement in 4IR implementation and its influence on commercial enactment. The authors conducted a quantitative analysis and found that higher levels of customer involvement positively influence business performance, including customer satisfaction, product quality, and overall business success. The study suggests involving customers in implementing Industry 4.0 technologies can significantly benefit organizations. Vanhala and Ritala [60] investigated the engagement of customers from I4.0 perspective. The study synthesized existing research on customer involvement and identified various mechanisms and strategies for engaging customers in Industry 4.0 initiatives. The findings highlighted the importance of customer co-creation, collaborative innovation, and digital platforms for enhancing customer engagement from the perspective of I4.0. Wu and Yang [61] examined the role of customer involvement in 4IR on product and service quality. The authors conducted survey-based research and found a affirmative connection between customer involvement in 4IR initiatives and product/service quality. The findings suggest that when customers actively participate in implementing cutting edge knowhows, it can results in improvement of the quality of the products or services, resulting in enhanced customer satisfaction and business performance.

H1: Involvement of customers enriches the putting into practice 4IR knowhows.

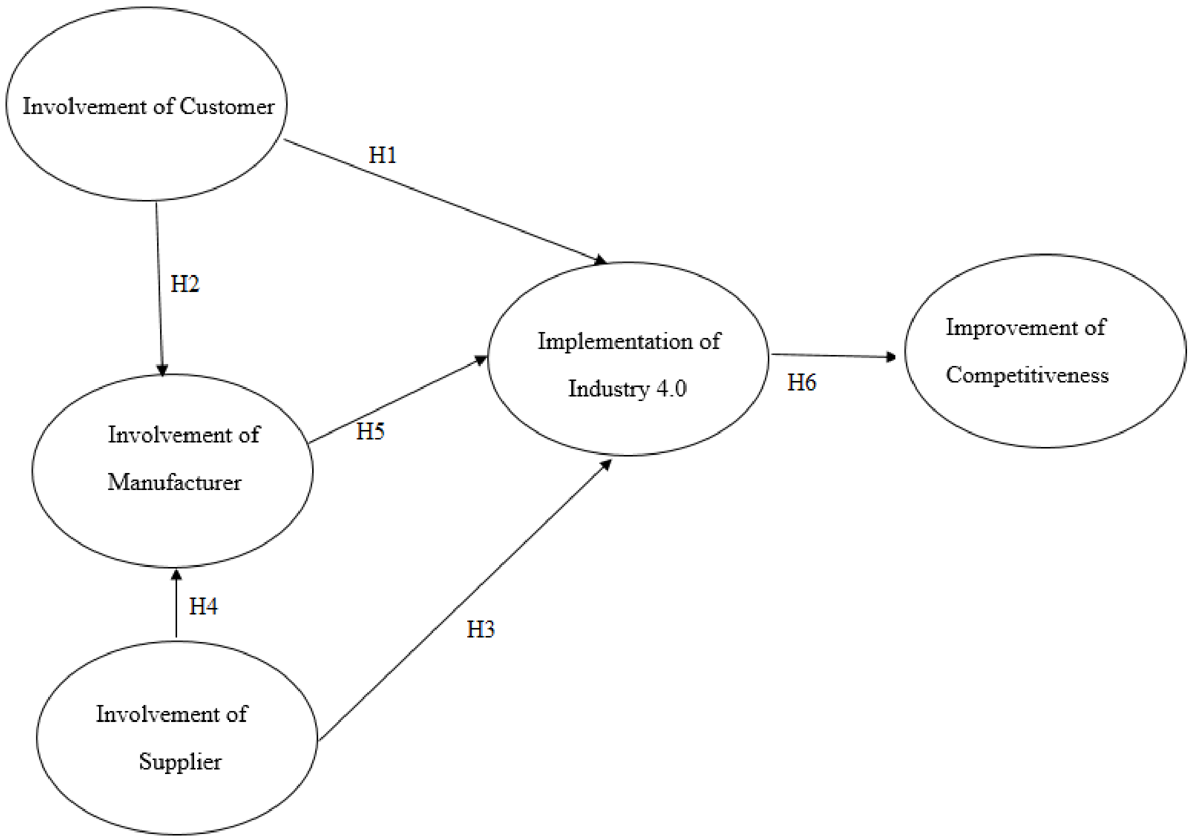

Figure 1. Conceptual Framework

Hypothesis 2

Proper Information and knowledge sharing create a trust-based relationship between the manufacturer and buyer [62]. The study explained the importance of the buyer-manufacturer relationship from the perspective of manufacturing firms' performance. Utilizing a Vendor Managed Inventory (VMI) model, designed to address the complexities of inventory management, particularly for impulse purchase items, enhances supply chain effectiveness by reducing stockouts and maximizing profitability for suppliers and buyers [63]. Information sharing between buyers and manufacturers positively impacts supply chain responsiveness. Open and transparent information exchange facilitates faster decision-making, enables proactive adjustments to changing market conditions, and enhances overall supply chain agility [64, 65]. The hybrid decision-making framework in [66] combines mathematical modeling, optimization techniques, and simulation methods to address the challenges inherent in managing such systems effectively. The buyer's involvement in the early design and development phase would improve the producer's performance.

H2: The involvement of the buyer encourages the producer.

Hypothesis 3

Mertens et al. [67] explored the challenges and complexities of supplier involvement in 4IR. They emphasized the need for effective dealer network management, including supplier selection, collaboration, and coordination, to successfully navigate the complexities of implementing modernized knowhows. Kagermann et al. [68] showed that 4IR implementation needs strong collaboration and integration among various stakeholders, including suppliers. Effective supplier involvement facilitates the seamless integration of digital technologies and processes, improving efficiency and productivity. Toffel and Schussler [69] presented the role of suppliers in fostering circular economy practices in the framework of 4IR. It highlights the significance of supplier involvement in developing innovative solutions for waste reduction, resource efficiency, and sustainable supply chain management in the era of updated technologies. Srai et al. [70] highlighted the necessity of supplier integration in Industry 4.0 initiatives, emphasizing that close collaboration with suppliers enables access to their expertise, resources, and innovative capabilities. This collaboration enhances supply chain visibility, agility, and responsiveness, improving operational performance. Stock and Seliger [71] advised that supplier involvement in I4.0 implementation fosters knowledge sharing and co-creation, enabling innovative solutions and technologies. This collaborative approach enhances the adaptability of an organization to respond to the market shifts, improve product quality, and optimize processes, ultimately leading to better overall performance. Hoberg and Thonemann [72] explored the digital capabilities of suppliers, such as real-time data sharing, predictive analytics, and collaborative platforms, and how this adaptability affects the supply chain resilience in the face of disruptions and uncertainties.

H3: Integration of suppliers with the manufacturing organization enhances putiing into practice the updated knowhows.

Hypothesis 4

The impact of supply network integration and supplier-manufacturer linkage on firm performance was studied [73]. The authors argued that a strong connection between suppliers and manufacturers improves operational performance. Considering contingency factors, Liu et al. [74] explored the effects of buyer-supplier links on the performance of the manufacturing firm. The study found that a higher level of linkage between buyers and suppliers positively affects manufacturing firms' performance. Link between supplier-manufacturer integration and operational measures in supply network coordination was explained in [75]. The findings indicate that the assimilation of suppliers and manufacturers has a positive influence on firm performance, and this connection is facilitated by the synchronization of the supply network. Sabahi and Shahraki [76] examined the influence of incorporation of suppliers and manufacturers on operational measures and investigated the intermediary function of supplier involvement and supplier capabilities. The results indicate that supplier-manufacturer integration has an affirmative impact on operational performance. Liu and Choi [77] investigated the influence of supplier integration on firm performance, considering the mediating part of the complexity of supply chain. The study revealed that supplier integration has a positive impact on companies performance, and this linkage is dependent on the degree of supply chain complexity.

H4: There is a positive linkage between supplier and manufacturer.

Hypothesis 5

Porter and Heppelmann [78] discussed how smart, connected products drive transformation in various industries. They emphasized the role of manufacturers in integrating digital technologies into their products and operations to deliver value-added services and gain a competitive advantage. It builds some insights into the opportunities and challenges manufacturers face within the framework of 4IR. Kagermann et al. [68] emphasized the need for close collaboration between manufacturers, suppliers, and customers and highlighted the importance of standardization, security, and the development of skilled labor. The report provides a comprehensive framework for manufacturers to understand the critical components and steps in implementing I4.0. Hermann et al. [79] identified key principles of design for implementing modern technologies scenarios. The authors proposed six philosophies: interconnectivity, digitization, decentralization, concurrent proficiency, service alignment, and modularity. Manufacturers can use these principles to design and implement Industry 4.0 solutions. Schumacher et al. [80] proposed a readiness and maturity framework designed for assessing the manufacturing companies in implementing I4.0. The framework is consisted of four levels: the initial level, followed by the aware, prepared, and intelligent levels. Manufacturers can employ this model for the evaluation of their current state and identify improvement areas to adopt Industry 4.0 technologies effectively. Shao et al. [81] discovered the role of manufacturers in implementing 4IR knowhows, highlighting the importance of technology adoption, connectivity, data-driven decision-making, supply chain integration, and workforce transformation. It emphasized the need for manufacturers to embrace advanced technologies and collaborate with partners to gain victory in the era of 4IR.

H5: Manufacturers' involvement boosts the implementation of 4IR knowhows.

Hypothesis 6

Stock and Seliger [71] emphasized that successfully implementing 4IR knowledges in manufacturing can give economic Competitiveness and environmental sustainability. By leveraging the opportunities presented by Industry 4.0, manufacturers can achieve greater resource efficiency, product customization, and collaboration, leading to a more sustainable and competitive manufacturing sector. Lee and Bagheri [82] highlighted the significance of addressing the challenges associated with IoT implementation in manufacturing. They suggested the need for collaboration among industry stakeholders, research organizations, and policymakers to entirely harness the prospective of IoT in transforming engineering processes and operations. A comprehensive overview of the critical issues, potential applications, and benefits of incorporating IoT technology in the manufacturing industry, highlighting its transformative potential for improving operational efficiency and Competitiveness, is provided in the article. Romero and Vernadat [83] presented a comprehensive review of enterprise interoperability from the point of view of 4IR, highlighting the challenges, frameworks, and emerging technologies crucial in achieving seamless integration and collaboration among different enterprises and systems. The insights provided in the paper would be helpful for industry practitioners in their efforts to achieve interoperability from the perspective of modern technologies.

H6: The successful implementation of modernized knowhows is interlinked with enhanced Competitiveness of manufacturing firms.

5. Analysis and Results

5.1. Estimate of the Model

To use Structural Equation Modeling (SEM), it is necessary to establish a connection between measurement items or gauges and their corresponding underlying variables in the measurement model.

To evaluate a reflective measurement model, the following four steps are followed:

1. Assessing the intensity of the connection between the indicators and its respective constructs.
2. Examining the consistency of the developed framework internally.
3. Evaluating the extent to which different indicators converge to measure the same construct.
4. Determining if the indicators demonstrate distinctiveness from other constructs.

It is recommended to have indicator loadings above 0.70, indicating that more than 50% of the gauge's variation is described by the underlying construct, thus ensuring acceptable item reliability. However, outer loadings above 0.65 are also allowable [84, 85]. In Table 2, entire indicator loadings are exceeding 0.7, representing a strong association between the indicators and their latent variables, thus confirming their suitability as indicators.

The interdependence among the pointers is assessed using the Variance Inflation Factor (VIF). Ideally, VIF values should be lower than five [67]. In Table 2, all the VIF values are below 5.

Table 2. Outer loading of the indicators.

Factors	C	CI	IoI 4.0	MI	SI	VIF
C 1	1.000					1.000
CI -2		0.771				2.141
CI -3		0.888				4.191
CI -4		0.847				2.901
CI -5		0.863				3.729
CI -6		0.903				4.115
CI -7		0.918				4.316
IoI 4 -1			1.000			1.000
MI-1				0.821		3.764
MI-10				0.711		2.181
MI-11				0.807		3.789
MI-12				0.796		4.036
MI-13				0.749		2.247
MI-14				0.793		3.166
MI-2				0.786		3.417
MI-3				0.818		3.951
MI-4				0.769		3.199
MI-5				0.820		3.965
MI-6				0.832		4.952
MI-7				0.834		3.748
MI-8				0.794		4.247
MI-9				0.814		3.889
SI-1					1.000	1.000

**C= Competitiveness, CI = Customer Involvement, IoI = Implementation of Industry 4.0, MI= Manufacturer Involvement, SI= Supplier Involvement.

5.2. Reliability and Validity

To fully examine the structural framework, it is crucial to establish the dependability and credibility of the dormant variables. Cronbach's alpha, which is a commonly used extent for assessing a scale's internal consistency and reliability. It assigns a level within 0 to 1, with larger data points that represents stronger inner dependability among the scale items. Generally, a Cronbach's α of 0.7 or above is satisfactory, while values above 0.8 indicate high reliability [86].

Composite reliability is another measure of scale reliability, which is determined by the standardized loadings of the items on the latent construct. Like Cronbach's α, composite reliability values from 0 to 1, with upper data points suggesting better dependability. Hence, alpha and composite consistency are two procedures used to calculate internal dependency and reliability, with specific thresholds indicating the degree of consistency [85]. Composite reliability values of both constructs reached higher than the required inception of 0.70, as mentioned by [86]. When the AVE value reaches or surpasses 0.50, the items come together to assess the fundamental concept and confirm their reliability [87]. In Table 3, all the variable's AVE values are above 0.5. As per the standard set by Fornell and Larcker [87], discriminant rationality is recognized when the √AVE for a notion go above the correlation value of others. Table 3 displays the square root of AVE values for the constructs, all greater than their correlations with other constructs. Therefore, based on this analysis, it can be decided that discriminant validity is proven.

5.3. Heterotrait-Monotrait (HTMT) Ratio

The HTMT (Heterotrait-Monotrait) ratio represents Discriminant Validity. As per the guideline provided by Kline [88], a recommended threshold for the HTMT ratio is 0.85 or lower. From Tabke 4 it can be seen that the HTMT ratio for each constructs ranges within acceptable value.

5.4. Justification of structural model

Validation of the structural framework is the critical segment of Structural Equation Modeling (SEM) process. It ensures the validity, reliability, and informativeness of the analysis results while also determining the magnitude and orientation of the connections between the constructs in the model. Several assessment criteria can be utilized to evaluate the structural model in SEM. These criteria contain:

1. Multicollinearity- Assessing multicollinearity (among predictor variables) often using measures such as VIF to make sure no excessive interdependency among predictors, shown in Table 6.
2. R^2 Values: Scrutinizing the values of R^2 (for dependent variables) point out the percentage of variance explained by the model. Higher R^2 values suggest more substantial predictive power. The R square values are shown in Table 5.
3. Cross-Validated Redundancy (Q^2) Values: Evaluating Q^2 values (a measure of the predictive relevance of endogenous variables) to assess the degree to which the model's predictions are accurate, and the values are shown in Table 5.
4. The importance and value of path coefficients: Analyzing the importance and value of path coefficients to understand the strength and the relationships between hypotheses. The β value indicating the path co-efficient is shown in Table 6.
5. Bootstrap Confidence Intervals: Calculating bootstrap confidence intervals for path coefficients to estimate the correctness and reliability of the estimated relationships [89]. The values of confidence intervals are presented by Table 6.

Table 3. Reliability and Validity analysis among the latent variables.

Latent Variable	CA	CR	AVE	Fornell-Larcker Criterion				
				1	2	3	4	5
1. Competitiveness	1.000	1.000	1.000	**1.000**				
2. Customer Involvement	0.933	0.947	0.751	0.381	**0.866**			
3. Implementation of Industry 4.0	1.000	1.000	1.000	0.622	0.384	**1.000**		
4. Manufacturer Involvement	0.956	0.96	0.635	0.344	0.51	0.409	**0.797**	
5. Supplier Involvement	1.000	1.000	1.000	0.593	0.209	0.658	0.291	**1.000**

**CA = Cronbach's alpha, CR = Composite reliability, AVE = Average Variance Extracted. The diagonal elements in the Fornell-Larcker criterion (bolded) are √AVE. The off-diagonal elements represent the correlation.

Table 4. HTMT values for the latent variables.

Latent Variable	C	CI	IOI 4.0	MI	Q^2
Competitiveness					1.000
Customer Involvement	0.395				0.642
Implementation of Industry 4.0	0.622	0.397			1.000
Manufacturer Involvement	0.35	0.528	0.414		0.577
Supplier Involvement	0.593	0.218	0.658	0.293	1.000

**C= Competitiveness, CI = Customer Inovolvement, IoI = Implemetation of Industry 4.0, MI= Manufacturer Involvement, SI= Supplier Involvement.

Table 5. R^2 values of the dependent variables.

	R^2	Adjusted R^2	Q^2
Competitiveness	0.386	0.381	0.378
Implementation of Industry 4.0	0.511	0.499	0.487
Manufacturer Involvement	0.295	0.284	0.183

Table 6. Hypothesis testing result

Hypothesis		β	STDEV	T Statistics	P Values	VIF	Bias corrected Confidence Interval	
							2.50%	97.50%
H1	CI-> IoI- 4.0	0.190	0.079	2.406	0.016	1.359	0.025	0.335
H2	CI -> MI	0.470	0.080	5.901	0.000	1.046	0.278	0.603
H3	SI -> IoI- 4.0	0.577	0.051	11.352	0.000	1.098	0.468	0.666
H4	SI -> MI	0.192	0.076	2.538	0.011	1.046	0.040	0.338
H5	MI -> IoI- 4.0	0.145	0.061	2.354	0.019	1.419	0.017	0.259
H6	IoI- 4.0 -> Co	0.622	0.051	12.129	0.000	1.000	0.511	0.714

**C= Competitiveness, CI = Customer Involvement, IoI = Implementation of Industry 4.0, MI= Manufacturer Involvement, SI= Supplier Involvement.

H1: Involvement of customers enriches the employment of modernized technologies.

Hypothesis 1 examines how the involvement of customers aids in implementing 4IR knowhows. The H1 is supported as (β = 0.190, t = 2.406, p = 0.016).

H2: The involvement of the buyer encourages the manufacturer.

Hypothesis 2 tries to establish the relationship between the manufacturer and the buyer. As (β = 0.470, t = 5.901, p = 0.000), H2 is supported.

H3: Integration of suppliers with the manufacturing organization enhancesimplementing I4.0 Technologies.

H3 highlights the impact of suppliers' involvement in implementing cutting-edge technology. H3 is supported as (β = 0.577, t = 11.352, p = 0.000).

H4: There is a positive linkage between supplier and manufacturer.

Hypothesis 4 links the supplier with the manufacturer. It is also accepted as (β = 0.192, t = 2.538, p = 0.011).

H5: Manufacturers' involvement boosts implementing the 4IR technologies.

The hypothesis presents the involvement of manufacturers in implementing Industry 4.0 technology. As (β = 0.145, t = 2.354, p = 0.019), hypothesis 5 is also supported.

H6: The successful execution of cutting-edge knowhows is positively interlinked with enhanced Competitiveness of manufacturing firms.

Hypothesis 6 represents the effect of implementing cutting-edge technologies on the Competitiveness of the manufacturing firm. It is also established as (β = 0.622, t = 12.129, p= 0.000).

The summary of the developed model is shown in Figures 2 and 3.

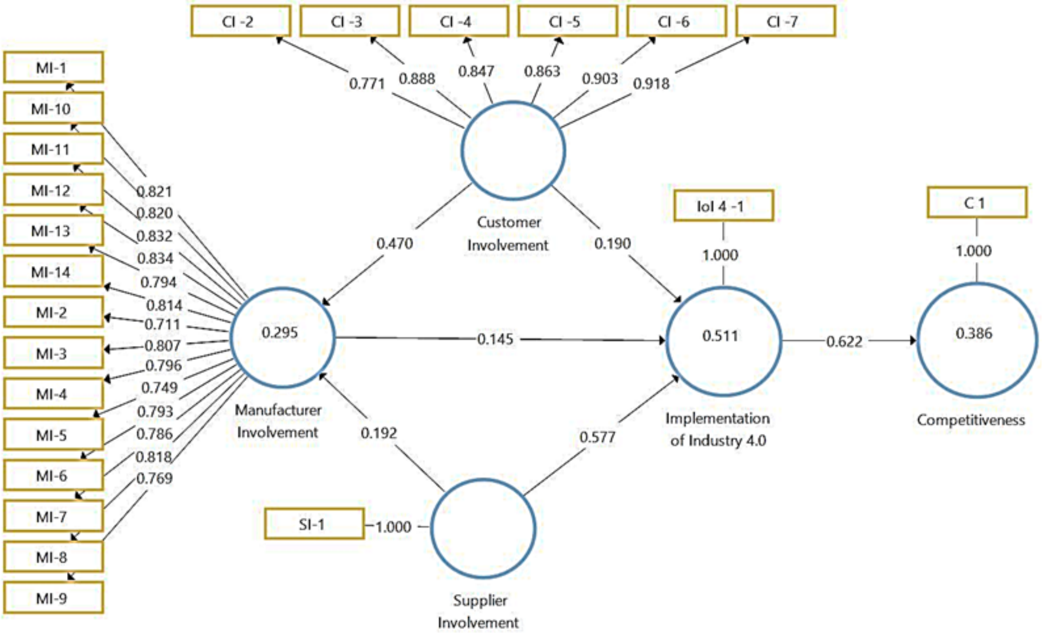

Figure 2. PLS-SEM with path co-efficients of Implementing Industry 4.0 and its links

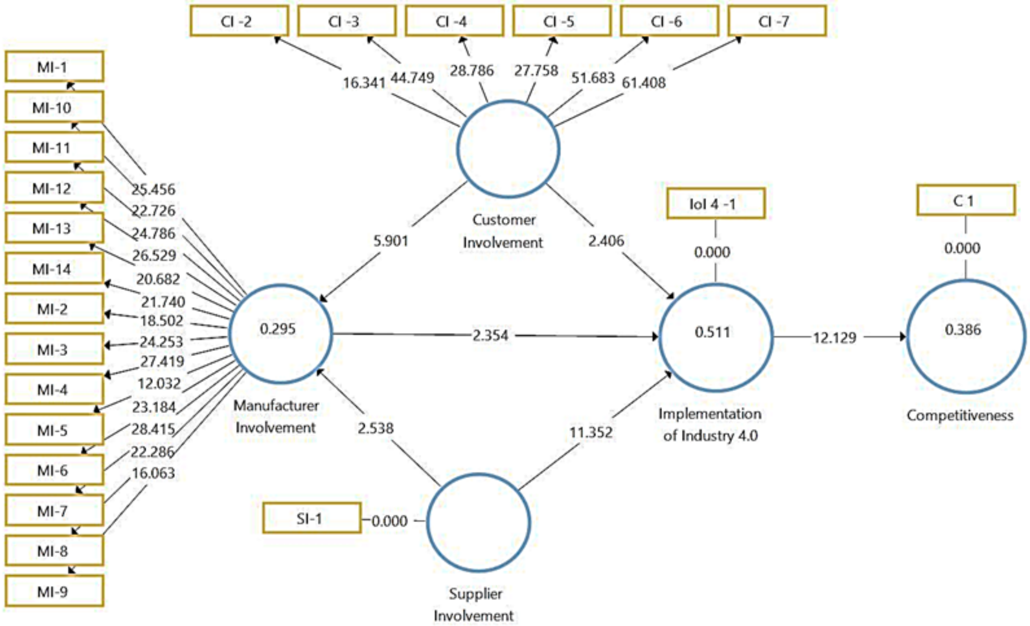

Figure 3. PLS-SEM with T-values for the conceptual model.

6. Discussion

The objective of the paper is to construct a conceptual model for the implementation of Industry 4.0 technology in Manufacturing. The target is to link the supplier and buyer with the manufacturer and observe the influence of implementing cutting-edge technologies. The paths of the developed model signify the hypotheses. The collected data was analyzed by Smart PLS 4.0, which was selected due to its suitability for analyzing a small number of cases, specifically 125 in this study. The choice of SmartPLS 4.0 over other software was motivated by the simplicity of the model examined in this research.

Additionally, the Disjoint two-step Method [90] was employed to validate the second-order construct in the model, as it is commonly utilized in studies involving reflective formative models. The alternative approach yielded a comparable outcome, further supporting the decision to use this approach. Six hypotheses were developed, and all the hypotheses were accepted.

The first and second hypotheses link the buyer/customer with the manufacturer and its role in implementing I4.0 technologies. The developed hypotheses agreed with [6]. Sepasgzar [6] demonstrated the use of digital technology in the context of I4.0 implementation. As the hypothesis 1 and 3 deals with the involvement of supplier and buyer in the implementation process of I4.0 knowhow, the more the incorporation of digital sharing i.e. the information sharing the better the process of implementation. For customer involvement, seven questions were designed. Later one question was omitted as the T values and path coefficients were not in the reasonable range. At the same time, the third and fourth hypotheses relate the supplier to the manufacturer and its role in implementing cutting-edge technologies. The above hypotheses are well supported. It is evident from the point of view that if proper information is shared, conforming to the interconnectivity, it will aid in linking the supply network for applying 4IR knowledges [3, 91]. The author [80] in their earlier work demonstrated the effect of incorporation of supplier and customer in the implementation of 4IR through information sharing and interconnectivity.

The fifth hypothesis is to find the interconnectivity between the manufacturer's involvement in implementing I4.0. It is also supported. For the manufacturing firm, the I4.0 components like IoT, Cloud computing, simulation, and artificial intelligence needs to be set for the real-time monitoring and control system as presented in [37]. Involvement of supply chain partners influences the implementation of I4.0 technologies as is supported by Benitez et al. [2]. They [2] showed that SMEs, with the help of supply chain partners like suppliers, competitors, R&D centers, and customers, can offer effective Industry 4.0 solutions that boost customer loyalty, drive innovation, and even reduce costs through collaboration, while inbound open innovation in the supply chain fuels further technology development.

The sixth hypothesis links the IoI 4.0 with improving the firms' Competitiveness. As stated by the respondents, the IoI 4.0 technologies are like core competence for companies. It provides the company an added advantage, as it is stated by [18]. The importance of adopting I 4.0 within contemporary supply chains is also highlighted in [13], providing guidance on how companies can utilize technology to enhance resilience and enhance performance amid growing complexity and uncertainty in the business landscape.

Form practical implications, the study result will aid the practitioners to impose light on the adoption of 4IR technologies while incorporating their supply network. The development of the conceptual model relates the successful implementation of 4IR technologies with its supply network components to gain higher Competitiveness. From the study, it is evident that linking with supply partners in the process of designing and developing aids in improving Competitiveness through the application of cutting edge technologies.

7. Conclusion

The paper's main target is to link the supply network partners for the implementation of cutting-edge knowledges and its effects on the manufacturing firm's Competitiveness. From the attained results, it can be decided that

- Linking suppliers and buyers with the manufacturer aids in the implementation of I4.0, which improves the manufacturer's Competitiveness.
- A conceptual framework is designed and validated. All the six developed hypotheses are tested and found acceptable.

Though the research results are based on a small cluster of export-oriented RMG factories, linking the supply chain partners enhances the implementation of I4.0 technologies and thus improves the findings, will aid the policymakers to link their supply networks through I4.0 technologies for the improvement of Competitiveness through efficient and effective management of the cutting-edge knowhows.

Contributor Roles Taxonomy (CRediT)

The first author is involved with conceptualization, funding acquisition, project administration, supervision, and writing. The second author is concerned with data curation, formal analysis, and software. The third author is involved with investigation, methodology, and visualization. The fourth author is responsible for writing the initial research and data analysis. The last author is accountable for resources and validation.

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