The Impact of Industrial Internet of Things on Customer Experience in Business-to-Business Relationships

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ABSTRACT,
The digital transformation has significantly impacted businesses' operations, particularly in the Business-to-Business (B2B) sector. This study explores the interplay between Industrial Internet of Things (IIoT) and the B2B customer experience in the manufacturing industry. Despite the recognized potential of IIoT, its impact on customer experience remains a nascent field of study. This study addresses this gap by analyzing a single case study using a qualitative approach, engaging in semi-structured interviews with a semiconductor company known for advanced manufacturing techniques. The goal is to provide the internal perspective of IIoT's impact, using secondary data to contextualize insights from primary data collection. Through triangulation, the study ensures a comprehensive, credible, and reliable set of findings. This study demonstrates that IIoT technologies not only improve the B2B customer experience but contribute to significant internal business value, highlighting the strategic importance of IIoT technologies in refining customer experiences and fostering long-term, mutually beneficial business relationships in the manufacturing sector.

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Industrial Internet of Things (IIoT), B2B Customer Experience, Manufacturing sector, Semiconductor industry

1. INTRODUCTION

In the past decades, digital transformation has redefined business norms and operations. With the technological shift, businesses continuously seek innovations to stay competitive (Verhoef et al., 2021), refine operational efficiencies, and strengthen customer interactions. With the rise in tech advancements, various digital tools have emerged. From the capabilities of artificial intelligence to the protective aspects of blockchain, the Internet of Things (IoT) notably stands out, showing significant promise in altering how businesses operate and engage with one another. This is especially evident in the business-to-business (B2B) landscape. As B2B entities aim for operational excellence and lasting partner relationships, weaving IoT into their customer journey unveils unique prospects, although with its complexities.

According to the theory of Moore's law, the number of transistors on a microchip approximately doubles every two years, so the world can expect computing power to exponentially increase its speed and capacity. When devices become more powerful, they can host complex IoT applications. In addition, with the learning curve concept from Wright's law, when the total volume of items produced doubles, the cost will fall by a consistent percentage and improve the quality; this implies that when IoT becomes more widespread, production increases, and the related costs will drop, making it more accessible and affordable for all different sizes of businesses.

Furthermore, based on the theories mentioned above, a dynamic environment can be expected with the predictions, especially in the manufacturing industry and shaping the Fourth Industrial Revolution (Schwab, 2016). The introduction of Industry 4.0 has led to an expansion in IoT investments, as Industry 4.0 heavily depends on the component. However, most companies have made limited progress due to the various challenges in implementing Industry 4.0 (Tuominen et al., 2022). Although IoT's impact on B2B operations is evident, the interplay between IoT and the B2B customer journey remains a relatively nascent field of study (Chui et al., 2021).

According to Lemon & Verhoef (2016), to deliver a customer experience nowadays, building seamless customer journeys and fostering customer-centric ecosystems is crucial. Academic studies have focused on recognizing the links between customer experience, customer satisfaction, and long-term relationships (Palmer, 2010). However, most of the attention has focused on B2C, and relatively few on B2B (Zolkiewski et al., 2017). B2C and B2B markets in customer journeys have many similarities but are more complicated in the B2B (Sahhar et al., 2021). They require multiple players with different roles and objectives at different stages of the procurement process; service offerings are often considered more complex and difficult to standardize than service offerings in B2C markets; regular and various modes of interaction are needed between service providers and clients (Sahhar et al., 2021). B2B service involves a large number of interpersonal interactions, and client encounters are part of broader efforts to build and support long-term connections (Zolkiewski et al., 2017).

However, the journey of customer experience has been transformed dramatically with the new advanced technologies and the expanding ecosystem of digital platforms. Nevertheless, businesses can utilize IoT to gain insight into customer behavior and preferences to provide customized experiences and meet their expectations. Manyika et al. (2015) research shows that B2B applications will likely capture 70 percent of IoT value in the coming decade. Much literature widely recognizes the potential benefits, while most of the data generated by IoT are not used; Mckinsey (2015) gives an example of a firm operating 3000 industrial applications with sensors, but only one percent of the data is utilized because it is used for detection and control only. Furthermore, Sestino et al. (2020) identify the progress and adoption rates vary across regions, sectors, sizes of businesses, and the outbreak of IoT and Big Data has resulted in mass disorganized knowledge. Overall, it led to a theoretical gap regarding the adoption and use of IoT (Sestino et al., 2020).

Given this background, this research aims to conduct a case study to provide a contemporary insight into how IIoT enhances B2B customer experience/value in the manufacturing sector—first, reviewing relevant literature on IoT/IIoT, exploring the complexity and shift of B2B customer experience, providing strategic attributes that drive B2B customer satisfaction, and the role of IIoT. Later on, following an embedded case study to identify essential factors, processes, and relationships to provide a holistic description within a real-life context. The primary data is collected through semi-structured interviews within the selected case study— an international company in the manufacturing sector, which is identified for its advanced state of IIoT adoption according to the Industry 4.0 Maturity Index (Schuh et al., 2020). Additionally, multiple sources such as the firm website, annual reports, and relevant journals will be used as secondary data to conceptualize the empirical data and develop a holistic description.

The following research questions guide this study:

In what ways do IIoT technologies impact the B2B customer experience in the manufacturing sector? What specific outcomes are achieved through the integration of IIoT technologies?

2. THEORETICAL BACKGROUND

The following section will discuss the research's relevance and significance, forming the foundation for the empirical study. It is divided into 4 subsections.

2.1 The Emergence of Industrial IoT

Before the term IoT became widely recognized, the technological landscape was already shifting towards an interconnected society. Embedded systems are foundational in this evolution (Ibarra-Esquer et al., 2017). With its specialized computing systems integrated into various devices, this technology sets the initial stage for intelligent devices. In addition, the development of RFID (Radio-Frequency Identification) technology, which Allows objects to be tagged and tracked via radio waves, is an early sign of turning ordinary objects into "smart" entities. The systems have contributed to M2M (machine-to-machine) communication, allowing devices to exchange data automatically (Ibarra-Esquer et al., 2017). Until the integration of computing processes into daily objects, which can reflect on this IoT-driven generation.

According to Vailshery (2023), in the past five years, the number of IoT-connected devices worldwide has increased from 8.6 to 15.1 billion, mainly from the customer market. In 2020, the customer segment made up 60 percent of the market. The key drivers that accelerate the adoption of IoT can be attributed to the advance of microelectronics, sensors, and wireless communications, allowing powerful computing devices with affordable costs to be seamlessly incorporated into ordinary objects. Moreover, the introduction of the fifth generation of mobile technology (5G) has tremendously increased the transmission speed, improved capacity, and enhanced connection stability. It has also brought radical changes in the industrial sector, such as M2M interactions and the increasing relevance of edge computing (Liu et al., 2020; Ren et al., 2019). The invention brings new capabilities and opportunities to industrial manufacturing and logistics (Parcu et al., 2022).

The technology transformation, especially in information technology, has shifted the industrial production and development market towards globalization and replaced the traditional production method. According to Hozdić (2015), the new structure and production system have improved the networking of autonomous and self-optimization in the supply chain. The innovation helps the industry to reduce a significant amount of costs in production, shorten the production cycle, and enhance product quality, which establishes a new expectation from customers (Agrawal et al., 2020).

Hence, during the Covid-19, the trend of globalization has led to high uncertainties and risks in the supply chain, such as sudden materials shortages along with steep drops in demand and worker unavailability, which hindered delivery and played a part in the worldwide shortage of food, fuel, power, and medication (Duffett & Wakeham, 2022). Nevertheless, the pandemic has catalyzed rapid digital transformation, such as remote working, e-commerce, and data analytics (Umair et al., 2021). At the same time, the global crisis has shifted the priorities and budgets of governments, organizations, and individuals to focus on digital readiness and resilience, effectively addressing some of the barriers that previously held back IoT adoption in many industries (Umair et al., 2021).

Due to the Covid restrictions, such as lockdown, quarantine, and social distancing, force a radical rethinking in the business model (OECD, 2021), raising the need for resilience and agility in mitigating uncertainties. The McKinsey survey found that around 90 percent of manufacturing and supply chain firms plan to invest in advanced technologies for digitization (Agrawal et al., 2020). However, the implementation of IIoT is more concentrated in large enterprises than SMEs. Many firms often face three barriers: internal skill gap, financing gap, and infrastructure gap, leading to a widening digital divide between firm sizes, regions, or sectors (OECD, 2021).

Apart from the firm size, in terms of economic development, the most significant barriers to IIoT implementation differ between developed and developing economies. Raj et al. (2020) research shows that in developing economies, the main challenges are the lack of standards, regulations, and forms of certification. In contrast, the most significant barrier in developed economies is the low maturity level of the desired technology. The dominant factor in both economies is the lack of a digital strategy alongside resource scarcity.

2.2 B2B Customer Experience

The challenges and barriers also extend to the B2B customer journey, which has been recognized as complex and dynamic (Zolkiewski et al. (2017). Similar to technological unevenness, the B2B customer journey is not limited to a single event or moment but an ongoing process that involves multiple touchpoints, interactions, and emotional exchanges before, during, and after a purchase (Rusthollkarhu et al., 2022). However, the experiences are subjective and can be very different, which makes it challenging to generalize (Lemon & Verhoef, 2016).

B2B contexts involve rational and economically driven decision-making processes (Hadjikhani & LaPlaca, 2013). However, Witell et al. (2020) argue that interactions between employees within B2B contexts can lead to experiences that correspond to those of customers in B2C settings. These experiences can encompass cognitive, emotional, behavioral, sensory, and social components influenced by interactions with physical equipment, software, and services and with other employees (Witell et al., 2020). These interactions can occur among individuals at different hierarchical levels or within functional units, with individual and collective experiences affecting each other. In other words, the experience comes from direct and indirect contact between suppliers, clients, end users, and diverse front-office and back-office actors, making it challenging to understand the customer experience (Zolkiewski et al., 2017). Therefore, the importance of various components of the customer experience is likely to vary across individuals and functional units.

The contemporary B2B customer journeys have significantly grown the reliance on digital touchpoints in varying degrees of interaction, such as via search engines, company websites, digital service platforms, or social media (Lundin & Kindström, 2023). Moreover, the interactions can occur digitally, and the existing touchpoints can be mediated through digital technologies (Larivière et al., 2017). In addition to the concept of touchpoints, the outcome and experience of a customer journey depend on the different roles that actors can play in a touchpoint (Lundin & Kindström, 2023). As the set of interactions that allow a customer to connect with a supplier, touchpoints are inevitably customer-oriented. However, customers and suppliers may be involved to varying degrees, so they play a more active or passive role (Witell et al., 2020). Digital technologies present new opportunities for clients to be more active, and such active, engaged clients are often more willing to share resources in co-creative works (Larivière et al., 2017).

2.3 Customer Experience Management

The research from the World Economic Forum (2015) shows that in recent years, a paradigm shift has urged these manufacturers to extend their focus downstream, which marks a significant turn toward customer-centricity. They are increasingly looking to add value by aligning their offerings and operations with customer needs, expectations, and experiences. This customer-centric strategy aims to uncover new opportunities, and this concept corresponds with a broader shift in the B2B landscape that emphasizes co-creation (Sarker, 2012).

However, the traditional customer experience metrics, which mainly rely on absolute performance indicators, may not be sufficient to capture the new B2B landscape. Zolkiewski et al. (2017) indicate that these approaches often fail to capture all the interactions, and not all the touchpoints are accessed by the actors. In addition, those touchpoints should not be viewed equally. Zolkiewski et al. (2017) suggest changing how B2B customer experience should be measured and managed to address the issue. Instead of focusing on input-output metrics, which tend to be short-term and limited in scope, the emphasis should be based on outcomes-based measures and closely aligned with the broader objectives of the clients, aiming to foster a partnership-style relationship that is sustainable over the long term.

This is not just a tactical change but a transformation in business strategy. It contributed to the emergence of what is now known as the 'Outcome Economy' from the World Economic Forum (2015); in this business landscape, competitive advantage derives from a company's ability to deliver quantifiable, relevant outcomes at specific times and locations, aligning with customer preferences. This new metric framework offers a more holistic view of customer satisfaction tailored to the complicated and unique demands of the B2B environment (Zolkiewski et al., 2017).

Tuominen et al. (2022) argue that focusing solely on identifying and satisfying customer needs may not be enough; instead, firms should also pay attention to the culture, values, and activities that enable them to build long-lasting customer relationships, especially in highly competitive international markets. Mittal & Sridhar (2020) identify eight strategic areas in B2B literature that capture around 70 to 80 percent of customer value elements in a customer satisfaction context which include product/service quality, pricing, sales, project management, safety, communication, corporate social responsibility, and ongoing service or support. Mittal et al. (2021) study categorizes pricing and project management as satisfaction maintaining, safety and sales processes as satisfaction enhancing, and quality, CSR, communication, service and support as satisfaction balancing; the role of attributes can vary across different industries and customer groups, while the research shows ongoing service and support, project management, and the sales process account for around 70% of the variance in overall satisfaction (Mittal et al., 2021). Furthermore, it highlights that the attribute level is an asymmetry linked to overall satisfaction, in which dissatisfaction is more consequential than satisfaction (Mittal et al., 2021).

2.4 The Case Study of IIoT

IIoT technology is believed to be an influential tool for executing these strategic areas. It enhances each of the eight strategic areas identified for customer satisfaction and links these improvements directly to tangible economic outcomes (Javaid et al., 2021). However, due to the implementation barrier, many firms cannot fully utilize the technologies.

Despite the various challenges, Chui et al. (2021) study shows that the potential of B2B solutions in the IoT market is expected to capture around 65% of the total value by 2030. In economic terms, it would be around 3.4 trillion to 8.1 trillion dollars, in which factory setting accounts for the most prominent potential economic value.

Focusing on a market-leading manufacturer as a case study can provide a detailed description of IIoT's impact in real life and how it plays a critical role in achieving strategic objectives and delivering tangible economic benefits.

The selected focal firm is referred to as IndustryCorp in this paper. The firm has more than 50,000 employees, with over 10 billion dollar turnover annually. It is a large international company that serves the global market in the semiconductor industry. However, due to the highly complex manufacturing process, it is crucial to understand the role of IIoT across various departments in the firm, as well as its interplay with suppliers and customers.

IndustryCorp is an ideal case for this research due to its scale, complexity, and extensive use of advanced technologies. Given its leadership in the semiconductor industry, understanding its IIoT approach can provide valuable insights. The key research questions that guide this study are:

How does IIoT contribute to achieving the strategic objectives?

What are the tangible economic benefits gained through the implementation of IIoT?

The scope of this case study will encompass multiple departments with IndustryCorp to provide a holistic view of IIoT's role in the firm's operations.

3. METHODOLOGY

3.1 Research Design

The present study follows a qualitative research methodology, using an embedded case study design to understand the dynamics and contextual implications; in contrast to quantitative methods that often reduce phenomena to numerical data, qualitative research highlights the richness of human experiences, perceptions, and interpretations.

Initially, an exploratory phase is guided by a theoretical background. The purpose of the phase is to find out "what is happening," "seek new insights," and "assess phenomena in a new light" (Saunders et al., 2009, as cited in Makri & Neely, 2021), which aims to explore how advanced technologies shift B2B customer value, experiences, journey, strategy, and measurement. Later on, an instrumental case study is used to provide insight about the specific subject within a bounded system, and help advance understanding of factors, processes, and relationships (Creswell, 2012). This method is preferred when the researcher has little control over events and when the focus is on contemporary phenomena within some real-life context (Yin, 2009).

In alignment with the study's aim to explore and understand the complexities of IIoT in B2B contexts, this research follows an abductive approach, which is particularly beneficial in this study as it allows for a flexible, iterative interplay between existing theories and emerging empirical data, to discover meaningful underlying patterns that make it possible to integrate surface and deep structures (Graneheim et al., 2017). In addition, it does not obligate to build and justify theory by analyzing the case study and empirical data but to adapt the research focus in response to unexpected findings, enabling the refinement of existing theories or identifying changed circumstances, additional dimensions, or misguided preconceptions (Tavory & Timmermans, 2014).

The empirical data is collected through an embedded single case study by interviewing relevant roles of workers in an organization, where multiple sources of evidence are used to develop a holistic description. The research uses a single case over multiple cases because of the uneven adoption of IIoT between firms, regions, and industries. So, selecting a firm that meets all the conditions is critical for the research. Furthermore, conducting a qualitative case study helped dig deep into respondents' thoughts to understand how the value co-creation process took place.

3.2 Data Collection

The data for this research was collected from multiple sources, utilizing a triangulation approach to enhance the depth and validity of the findings (Creswell, 2012). This study uses an embedded single case study design, conducting semi-structured interviews and reviewing relevant documents to corroborate evidence from different individuals. Triangulating these data sources provides a richer and more comprehensive understanding of the phenomenon under analysis, and also increases credibility, dependability, and confirmability of this study (Kekeya, 2021).

This research uses a single case over multiple cases due to the uneven adoption of IIoT across various firms, regions, and industries. This inconsistency in IIoT can significantly influence the study findings' generalizability and transferability if multiple cases are considered. Therefore, a single firm illustrating advanced and mature use of IIoT technologies was selected as the unit of analysis. This design facilitated a more profound, contextualized exploration and understanding of the

IIoT's impact. In addition, focusing on a single case allowed for a more concentrated and in-depth analysis, which is crucial when dealing with complex, multifaceted phenomena like the IIoT and B2B customer experiences.

The primary data in this research is collected through a semi-structured interview (see Appendix 1) with 9 participants. The data collection adhered to ethical guidelines, including obtaining informed consent from each respondent before the interview. All interviews were conducted and recorded online using Google Meet as the communication platform. The interview durations are from 30 to 80 minutes, and the respondents' information (see Appendix 3). During and after the interviews, additional annotations are added to a dedicated case study database, including raw data, preliminary analysis, and explanations. This approach aims to increase the reliability of the study by recording the data in an unprocessed form and simultaneously collecting and analyzing the data during the abduction process (Yin, 2009).

In addition to primary data gathered through interviews, the research uses secondary data sources from the firm website, the annual reports, and relevant journals. The secondary data is instrumental in validating and contextualizing the insights gained from primary data collection.

3.2.1 Case selection

The case selection process is based on two considerations: the study's primary purpose and theoretical background. The chosen company is required to meet specific criteria to be able to align with the research objectives:

- Actively Involved in B2B Market: The selected firm must operate primarily within a Business-to-Business (B2B) market context.
- Emphasis on Long-term Customer Relationships: The company should focus on maintaining and developing ongoing, long-term customer relationships.
- Industry 4.0 Implementation: The chosen firm should have implemented Industry 4.0 technologies and rank as mature based on the Industry 4.0 Maturity Index (Schuh et al., 2020).
- Sector Specificity: The company should operate within the manufacturing sector, as this sector is often the most impacted by and pioneering in using Industry 4.0 technologies.
- Data Availability: The company must make public annual reports or other forms of performance data that can be analyzed for the purposes of this research.

3.2.2 Sampling method

A purposive sampling strategy was used for this research to ensure the collection of relevant and insightful data. This approach involves identifying and selecting individuals or organizations knowledgeable or experienced with the research focus (Creswell & Creswell, 2017). Within the scope of this study, purposive sampling was critical for identifying participants within the selected case firm who either actively engage with IIoT technologies or are their customers/ suppliers, aiming to gain a more comprehensive view from the internal and external perspectives.

3.3 Data Analysis

The data gathered from the semi-structured interviews were transcribed by Amberscript platform. During and after the interviews, additional annotations are added to the case study database, including raw data, preliminary analysis, and explanations. This approach aims to increase the reliability of the study by recording the data in an unprocessed form, collecting and analyzing the data during the abduction process (Yin, 2009), and gaining holistic insights into the extent of IIoT influence on IndustryCorp's customers.

Thematic analysis was employed to analyze the data gathered from the semi-structured interviews. As a qualitative method, thematic analysis allows for identifying, analyzing, and reporting themes within the dataset (Braun & Clarke, 2006). The method helps capture and interpret the respondents' experiences and perspectives and identify critical themes derived from the data to answer the research questions.

4. RESULTS

This section clarifies the empirical findings gathered from semi-structured interviews and additional secondary data sources, all systematically arranged to address the research questions. The semiconductor industry is inherently cyclical, experiencing periodic fluctuations that respond to the constant demand for innovation in electronics from consumers, put relentless pressure on pricing and quality, and have intensified the focus on sustainability.

Maechler et al. (2016) show that the average customer satisfaction score in B2B companies was below 50 percent. In contrast, IndustryCorp has consistently outperformed this benchmark as a manufacturer that serves the world market with high levels of customer satisfaction. As evidenced by annual customer satisfaction surveys conducted by an independent third party, IndustryCorp has maintained a score of around 90 percent in the past seven years.

Although most respondents do not engage directly with B2B customers, their perspectives provide valuable insights. They offer an internal perspective on how IIoT implementations at different stages of the manufacturing process indirectly influence customer satisfaction and value.

This internal perspective gains additional weight when considering general customer satisfaction scores in the B2B sector. The result is shown under three themes: factory settings in IndustryCorp, customer relations, and supply chain.

4.1 IndustryCorp

The semiconductor manufacturing process is costly, complex, and time-consuming. To finalize their product, it will need to go through a thousand steps in the cleanrooms due to the sensitive processes and a highly controlled environment, with among the highest standards of any industry in which slight contamination can cause process defects, resulting in defective products.

4.1.1 Factory operational efficiency

Operational performance is crucial for retaining the trust and business of B2B customers. In the IndustryCorp case, they implemented various intelligent automation systems into their industrial equipment at different process stages. These include Accurate Fault Detection and Classification, Smart Advanced Equipment Control, and Intelligent Advanced Process Control systems.

First, the production equipment is integrated with process variation detection to identify and mitigate potential product defects proactively. This allows for self-diagnosis and automated corrective actions, minimizing process variability. Additionally, based on the deep learning model of AI, the auto-detect classification system significantly improves the accuracy of human eye judgment. These innovations significantly increase production capabilities and provide high-quality output for their B2B customers.

Second is the automated dispatching system. It integrates real-time machine status data with production priorities. This dynamic allocation enables IndustryCorp to precisely sequence the processing of multiple products across its range of equipment. Furthermore, with intelligent scheduling and work dispatch solutions that handle large-scale and highly complex process permutations, IndustryCorp leveraged AI algorithms. These can compute the optimal production schedule within minutes, handling nearly tens of millions of scheduling commands daily. These algorithms are part of the AI Process Control platform, with over 1,000 AI models deployed to compute the best parameters based on data quickly. Those approaches ensure that all product specifications meet customer requirements.

Third is the automated transportation and advanced material handling system. The technology shortens the overall production timeline and mitigates manual handling risks. It especially minimizes vibrations and potential contaminant exposure, which could adversely affect product quality. This system enhances efficiency and product quality.

However, the respondents mentioned that the degree of automation depends on the factories. From their experience, process engineers and operators no longer need to stay in the cleanrooms; they can monitor data, get information, adjust parameters, and add materials remotely. As process engineers, they now only need to stay approximately 10 hours in the cleanroom per month. The implementation has indeed reduced labor costs; before integrating the intelligent systems, the Man-to-Machine Ratio was 1:3, but now it is believed to be higher than 1:75. The ratio is defined as the total available workforce in a factory to the number of operational machines.

Also, according to the respondents, the automation system detects potential breakdown and sends an alarm to the workers but it still relies on manual ways to find the problems, and those machines require frequent maintenance and repair, which means the equipment engineers and machine vendors need to enter the factory regularly. However, there is a change worth mentioning: due to the required use of chemicals in their production line, the equipment needs to be washed frequently to maintain the yield and quality of the product. Previously, equipment components used to be carried by workers, but now they have adopted intelligent automated material handling systems that speed up the procedure and reduce the uncertainty of human error.

Despite the implementation, most operators and engineers working in the factory setting still adhere to a rotational shift work schedule, encompassing day shifts, night shifts, and overnight shifts, averaging 10-12 hours per day. In addition, to keep expensive and highly sensitive capital equipment running 24/7, engineers must monitor and adjust equipment or troubleshoot other potential problems that can impact the production line. Given the high stakes involved, in which potential losses range from millions to billions of dollars, the engineers and machine vendors remain on-call after regular working hours to address emergent situations. Speaking from the respondents' experience, it is not a rare case to receive such calls. So, even with the heavy focus on advanced systems, automation, and AI, humans remain an integral factor in maintaining the efficiency and reliability of the production line.

4.1.2 Eco-friendly production

The semiconductor manufacturing industry is responsible for one-third of global greenhouse gas emissions; with the growing demand for electronic products, the environmental footprint is expected to rise (Mehta & Prakash, 2023).

Given the substantial water and electricity consumption in IndustryCorp's manufacturing production, addressing environmental impact is one of the main focuses. Respondent 2 emphasized that the company has taken several approaches to mitigate the issue. The two cases below leverage IoT technology to minimize resource usage.

The first is the intelligent energy control system for factory machines, designed to optimize energy savings by automatically adjusting the energy consumption of production machines. This solution aims to achieve dynamic energy savings throughout the entire period. It is expected to save 82 million kWh of electricity and reduce 84,600 metric tons of carbon emissions annually.

They developed an advanced water valve system by analyzing energy consumption and operating parameters, automatically controlling hot water output for wafer carrier cleaning. This reduces half of the hot water supply during idle periods. This innovation can save 380,000 metric tons of pure water and 15.33 million kWh of electricity annually. To further optimize this, IndustryCorp collaborated with suppliers to design a closed-loop system that recycles all hot water during idle times, aiming for 100% recycling efficiency. Additionally, by the firm's estimation, this can reduce approximately 7,800 metric tons of carbon emissions per year.

The innovative advancements in algorithms, software, and hardware have optimized various systems, greatly reducing operational energy consumption. However, hardware manufacturing and infrastructure processes represent a significant part of the carbon emissions (Gupta et al., 2021). The manufacturing process involves hazardous chemicals, gasses, and raw materials, all contributing to the carbon footprint to different extents.

4.1.3 Safety

According to Mittal et al. (2021), safety refers to the assurance of product, customer, and employee well-being. This attribute is believed to be the most important in the manufacturing sector. It is noteworthy that approximately two million people die annually from work-related injuries and diseases, as estimated by WHO and ILO (2021).

Within this context, the role of automation solutions in cleanrooms (production lines) serves two purposes. First, it ensures product quality, as employees are a critical variable in maintaining the hygiene standards of cleanrooms and are the most common source of contamination. Second, it enhances worker safety and allows them to assist the production remotely. Working in cleanrooms requires workers to wear synthetic, non-breathable garments and masks, which can be uncomfortable and pose health risks over extended periods. This automation reduces the likelihood of product contamination while mitigating common cleanroom-related health issues for workers, such as skin problems. This approach improves both operational efficiency and the overall well-being of the workforce.

Furthermore, data highlight that IndustryCorp had an annual total of 44 cases of work-related injuries in the past year. The most severe cases were among the outsourced workers who did not follow standard procedures. Respondent 2 mentioned that the factory has recently used robots with AI image recognition functions as security patrols to determine whether the factory environment is safe. These robots also check if workers are wearing safety gear in compliance with regulations and provide timely warnings and reminders.

Further contributing to this safety approach, IndustryCorp developed an automated handling system to streamline transportation. By using conveyor belts, automated guided vehicles, and robots, the system has helped to reduce 95% of manual handling weight; each worker's carry workload can now be reduced by 1.8 tons. This system not only improves operational efficiency but also reduces workplace injuries.

4.2 Customer Relations

4.2.1 Cloud based co-innovation

IndustryCorp creates an Open Innovation Platform with their partners, which are all experts from different tech fields, operating as a comprehensive, collaborative forum bringing stakeholders across the semiconductor design chain. They provide their extensive intellectual properties portfolio with an advanced virtual design and Electronic Design Automation infrastructure, which lets all sizes of customers design in the cloud with their technical support. Given the complexities involved in the production and process flows, this streamlined setup empowers customers to co-create via a secure cloud-based platform. The platform aims to shorten customer design time and time to market in a cost-effective way, especially in this market environment where timing influences prices. By enabling real-time collaboration, it allows IndustryCorp to gain insights and respond to market changes quickly. It offers customers a seamless migration path without requiring significant engineering resource investment or longer design cycle time. This co-innovation can help the partnership to maintain a competitive edge in the market.

4.2.2 Transparent process

To enhance customer services, the firm provides an online platform for customers to place orders, monitor the production stages, and manage deliveries. The system allows customers to monitor their order status 24/7 and adjust it in time, reducing the time needed for back-and-forth communications. It provides transparent and real-time update information, eliminating delays due to time-zone differences and streamlining the overall process. The platform also records all log interactions, making historical data easily searchable to enhance communications.

This initiative effectively extends customer supply chain management by integrating advanced IT systems. These systems generate insights into customer orders and processes, which in turn helps in accurately estimating market demand.

Transparency and traceability are seen as essential in building B2B consumer loyalty and trust. IndustryCorp has implemented a sophisticated tracking system using 2D barcodes for each semiconductor package. This allows for detailed traceability down to the individual die level. The barcodes store information such as manufacturing history, material used, and production yields. This enhanced tracking helps quickly identify and resolve material or production issues, improving reliability and minimizing defects.

4.2.3 Remote inspections

Moreover, on-site inspections became challenging for many clients during the pandemic, as these were essential steps before mass production. To mitigate the impact on customers' production plans, IndustryCorp introduced virtual inspection technology. Utilizing augmented reality, clients can remotely view internal operations, achieving results comparable to traditional on-site visits. This innovation has effectively facilitated mass production schedules and accelerated product launches.

4.3 Supply Chain

4.3.1 Contract management

In supply chain optimization, IndustryCorp has introduced a digital contract management system to enhance sustainable practices and effectively shorten contract processing time. More than 2,500 customers and suppliers have completed signing the paperless contract, translating to approximately 75,000 sheets of A4 annually. The system has decreased 5.4 tons of carbon footprint and increased 97 percent of contract processing efficiency. Furthermore, it enables mobile management of contracts. Users can view contract details, receive periodic notifications for pending cases, and send reminders for contract reviews based on user-defined deadlines. The contract system is integrated with customer and supplier management systems. Once the non-disclosure agreement is signed, the new profile is automatically created in these systems, achieving integrated operation synergy.

4.3.2 Inventory resilience

The semiconductor ecosystem is a highly globalized and interconnected supply chain, with many companies specializing in different process stages (Ji et al., 2023). the supplier's role in IndustryCorp emerges as a critical variable with inherent risks. The firm has tightened the connection by developing an online platform, exchanging real-time inventory data with the suppliers, and enhancing the transparency of inbound supply chain inventories. This shared information infrastructure enables the identification of fluctuating demand patterns effectively. This approach improves network resilience, supply chain efficiency, and mitigates the risks associated with supply disruptions and surplus material accumulation.

4.3.3 Supplier accountability

Climate change is widespread and intensifying, which puts international corporations under increasing pressure to cut their carbon footprint to reach the agreement of net-zero greenhouse gas emissions by 2050. However, in most cases, their suppliers produce around 70 percent of the emission footprints, and most corporations know little about their non-tier one suppliers (World Economic Forum, 2022). In addition, the lack of standards and capabilities for collecting data and calculation complexities from suppliers leads to concerns about data credibility (Kaplan & Ramanna, 2022). To address this, IndustryCorp urges suppliers to adopt data-driven management of execution performance to provide quality and transparency of carbon emissions data and get audits by a third independent party to enhance accountability. The firm sets specific objectives for suppliers to focus on their energy efficiency, water conservation, and carbon reduction to create a more sustainable and accountable supply chain.

However, only half of the suppliers with high electricity consumption have achieved ISO 14064 certification for greenhouse gas emissions. These high-consumption suppliers are defined as local suppliers with operational facilities consuming over 5 million kWh annually.

Furthermore, from the respondent's experience, there is very little IIoT impact on their component cleaning suppliers. The cleaning of the manufacturing equipment parts has a significant impact on the product yield and quality. So even in this high-tech field, the components cleaning suppliers are relatively labor intensive with more exposure to the chemical and noise. The exposure to harsh chemicals used for washing or the particulate matter from sandblasting can be hazardous. Proper protective equipment, ventilation, and safety training are crucial to minimizing these risks; procedures like high-temperature diffusion could also be a source of thermal hazards.

5. DISCUSSION

The case study results show that the IIoT infrastructure has contributed to the customer value elements: product quality, pricing, sales, project management, safety, communication, corporate social responsibility, and ongoing service, in different degrees, which are identified by Mittal & Sridhar (2020) as the key attributes to the B2B customer satisfaction.

Mittal et al. (2021) indicate ongoing service and support, project management, and the sales process account for around 70% of the variance in overall satisfaction. Within this dynamic and complex customer journey and experience, IIoT emerges as an instrumental tool, as demonstrated by the findings of the IndustryCorp case study, which illustrates how integrating IIoT technologies can significantly enhance these attributes.

Furthermore, the implementation extends the number of customer digital touchpoints facilitated by the advanced technologies, making them more efficient, responsive, and customer-friendly. With the customer-centric strategy, the firm utilizes the data generated by IIoT to offer customized services and solutions, shifting to a co-creation that deepens customer engagement and builds a partnership-style relationship to aim for broader objectives with outcome-based measure approach, which aligns with Zolkiewski et al. (2017) B2B customer experience framework.

This digital framework seamlessly integrates business value and customer experience, creating a synergistic ecosystem where each element enhances the other, collaboratively forming a robust and cohesive network of interactions and value exchanges. This complex interplay builds long-term, robust, and resilient relationships. It solidifies the foundation for ongoing and mutually beneficial partnerships, establishing a resilient alliance between business operations and customer satisfaction initiatives, and uncovering the new opportunities in the co-creation B2B landscape as explored in the research by Sarker2012).

5.1 Business Value

IIoT technology has brought about notable operational efficiencies. In the case study, IndustryCorp's advanced technologies improved the Man-to-machine ratio from 1:3 to 1:75. The automated machines perform repetitive tasks with high precision and speed. In addition, it replaces some dangerous tasks carried out by humans and reduces 95 percent of workers' lifting workload. On the CSR aspects, it helps to optimize the energy saving from the production machines and enable 100 percent water recycling. The digital contact management system reduces 5.4 tons of carbon footprint and enhances contract processing efficiency by 97 percent. This operational optimization provides IndustryCorp with a considerable competitive advantage.

Additionally, due to the resource interdependence ecosystem, IIoT facilitates real-time data analysis, which informs strategic decision-making across the organization, making it easier for suppliers and customers to collaborate. This transparency speeds up decision-making and boosts efficiency across the network. By strengthening internal processes and fostering transparent relationships with suppliers and customers, IIoT technologies significantly enhance the robustness and resilience of IndustryCorp's value network. Effectively maintain their competitive advantage in the dynamic market.

5.2 Role in Customer Experience

The integration of IIoT has provided seamless customer journeys by replacing traditional interactions with digital touchpoints, enhancing the degree of transparency and traceability to customer experience. In the case study, IndustryCorp offers an online platform for customers to place orders and monitor the stages of production 24/7; it provides transparent and real-time updated information, eliminating delays in correspondence. In addition, through advanced tracking and 2D barcodes, which include manufacturing history, the material used, and production yields of each product package, to identify any production issues, improving reliability and minimizing defects. Furthermore, the remote inspections utilize augmented reality technology with results comparable to on-site inspections, effectively facilitating mass production schedules and shortening product launch time.

IndustryCorp's cloud-based co-innovation platform allows customers to use their extensive IPs portfolio with an advanced virtual design and Electronic Design Automation infrastructure on the cloud with their technical support. This co-innovation approach significantly reduces the customer's time and costs generally associated with the traditional design process. Also, it helps the partnership to maintain a competitive edge in the market.

6. LIMITATIONS AND FUTURE RESEARCH

6.1 Limitations

The small sample size was a limitation in the case study conducted for this research. Due to time and resource constraints, I could only collect data from a limited number of participants. This limited sample size may affect the generalizability of the findings and limit the ability to draw broad conclusions.

Furthermore, the single case study may be limited regarding the industry focus. The findings explored within the study's particular geographic area and industry may not completely apply to other settings. The potential variability in market dynamics, operational challenges, and strategic priorities characteristic of different sectors should be considered when generalizing the study's findings to other industries or regions. This limits the study's external validity and may limit the generalizability of the results.

6.2 Future Research

Future research could focus on the enhancement of transparency in supply chain footprints through IIoT technologies. With increasing emphasis on sustainability and corporate social responsibility, there is a growing need for firms to precisely monitor, report, and optimize their supply chain footprints. Additionally, exploring how IIoT can facilitate real-time tracking and reporting of various sustainability metrics across the supply chain, aiding firms in making more informed and responsible operational decisions. Research in this domain can also focus on developing standardized frameworks and protocols for supply chain footprint transparency enabled by IIoT, which could be crucial for fostering industry-wide best practices and accountability.

Future research could also explore IIoT technologies' impact on Small and Medium-sized Enterprises (SMEs). Since SMEs play a significant role in various economies, investigating how these entities leverage IIoT is crucial. Since SMEs often operate with limited resources, understanding the challenges and opportunities they face in implementing and benefiting from

IIoT technologies is essential. This exploration would offer valuable insights into how IIoT adoption within SMEs differs from large corporations and how these smaller entities can maximize their return on investment in IIoT.

7. CONCLUSION

The primary objective of this research was to examine the influence of the Industrial Internet of Things (IIoT) technologies on the Business-to-Business (B2B) customer experience within the manufacturing sector. The case study of IndustryCorp showed that IIoT technologies play a critical role in strengthening the customer journey and experience, with the extended digital touchpoints to optimize the customer experience attributes of the sale process, ongoing service and support, and project management, and refining the firm's internal processes. This strategic enhancement serves as a competitive tool by maintaining, balancing, and enhancing the customer satisfaction attributes at different extents. Moreover, the data-driven system strengthens the advanced technologies and facilitates a collaborative environment, building a co-creative ecosystem and deepening B2B customer engagements.

The case study results show that the IIoT infrastructure creates a business environment where customer experience and business value are integrally linked and mutually enhancing. This synergy establishes a resilient and responsive framework within the customer-centric approach. This dynamic and symbiotic relationship formulates a resilient and agile framework for executing customer-centric strategies effectively.

In conclusion, the findings validate the capability of IIoT technologies in enhancing B2B customer experiences in the manufacturing landscape. Highlights that companies should leverage these technologies not just as operational instruments but as strategic tools to foster and sustain long-term customer relationships and drive strategic business objectives.

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9. APPENDICES

9.1 Appendix 1

Semi-Structured Interview outline

Introduction:

- Introducing and explaining the purpose of the interview.
- Assure confidentiality and anonymity of responses.
- Obtain informed consent from the respondents.

Background and Role:

- Can you briefly describe your role and responsibilities at the firm?
- How long have you been working at the firm?
- What is your experience with IoT technologies in the context of B2B relationships?

interview questions:

- Can you provide examples of IoT technologies implemented or utilized within the firm operations or projects?
- What are the main objectives or benefits the firm expects to achieve through the advanced technologies?
- In your opinion, how does the integration of IoT technologies affect the overall customer experience in B2B relationships?
- Can you share any specific instances or examples where IIoT has improved or transformed B2B interactions?
- What aspects of customer experience have been positively influenced by IoT adoption, and why?
- Are there any insights that you can share on the progress of the advanced technologies changes over time?
- Is there any additional information that you think is important for this research and would like to share?

9.2 Appendix 2

Respondents Information

Organization	Role	Year of Experience
IndustryCorp	Supplier manager Ehs engineer Integration process engineer Process engineer RD software engineer	12 year 3 year 3 year 5 year 4 year
Key Supplier A Key Supplier B Supplier C	Process support engineer Application engineer Sale manager	4 year 6 year 15 year
Customer	RD software engineer	8 year