

Enhancing Supply Chain Visibility in the Fishing Industry: The Role of Emerging Technologies and Their Affordances

Maryam Mirzaei

Business School, Auckland University of Technology, New Zealand

Email: maryam.mirzaei@aut.ac.nz

Benjamin Dehe

Business School, Auckland University of Technology, New Zealand

Email: benjamin.dehe@aut.ac.nz

Kasuni Weerasinghe

Business School, Auckland University of Technology, New Zealand

Email: kasuni.weerasinghe@aut.ac.nz

Hari Srivastava

Business School, Auckland University of Technology, New Zealand

Email: hari.srivastava@aut.ac.nz

ABSTRACT

This study explores the role of emerging technologies in enhancing supply chain visibility (SCV) within New Zealand's fishing industry, a sector challenged by the perishable, temperature-sensitive nature of its products, subject to long supply routes, and strict regulatory standards. In this context, visibility within the supply chain transcends mere tracking; it encompasses real-time data access on product status, environmental conditions, and logistical status. Leveraging the technology affordance theory, the research examines how tools such as GPS trackers, RFID tags, and IoT devices influence decision-making and operational efficiency by offering actionable data insights. Through a qualitative case study, including interviews and workshops with industry experts, the article identifies key technological affordances: real-time tracking, proactive management, and data-driven decision-making. The theory of technology affordances provides insights into the interactions between technology and the socio-technical environment, highlighting the opportunities and challenges industry managers face. Our analysis reveals that while these technologies substantially improve monitoring and sustainability practices, their effectiveness is tempered by user knowledge, contextual conditions, and organizational collaboration. Moreover, the study highlights the complex interactions between technology, user expectations, and supply chain outcomes, emphasizing the need for integrated, user-centric platforms to maximize SCV benefits. This research contributes by providing a nuanced understanding of the factors linking SCV technologies, functionalities, and decisions through their adoption and impact. The mapping offers practical insights for supply chain managers to enhance transparency, resilience, and efficiency. Ultimately, the study encourages continued innovation in data-driven SCV solutions to address the unique challenges of perishable goods supply chains.

Keywords: *supply chain visibility, emerging technologies, perishable goods supply chains, affordances theory, data-driven*

1. INTRODUCTION

As industries worldwide seek to enhance efficiency, resilience, and sustainability, networks that are not only responsive but also adaptive to the opportunities and challenges presented by technological advancements have become a pivotal success factor. The evolution of global trade has led to extended and complex supply chains, increasing the likelihood of disruptions. Recent challenges, such as pandemics, sociopolitical unrest, and climate-related events, have further tested the ability of logistics and supply chain firms to harness the potential of their systems to maintain service levels and meet customer expectations. The situation becomes more complicated when perishable, temperature-sensitive, high value and high priority products are transported (Aung and Chang, 2014).

The fishing industry, vital for food security and economic livelihoods around the globe, is characterized by its dependency on timely and precise supply chain operations. The perishability of seafood products demands not only rapid transportation but also meticulous handling and storage conditions to preserve quality from ocean to plate (Kelling et al., 2023). The New Zealand fishing industry, in particular, is renowned for its high-quality products and stringent resource management, governed by a robust regulatory framework that upholds sustainability through strict licensing, catch monitoring, and compliance requirements. New Zealand industry stakeholders are actively investigating digital tracking and improved data management tools to enhance traceability and real-time monitoring of seafood products ('The Future of Commercial Fishing in Aotearoa New Zealand', 2021). Despite the country's strong "clean and green" reputation promoting sustainable practices, companies often grapple with reconciling environmental responsibility and financial viability—largely due to the substantial costs of compliance (Sajjad et al., 2020). These challenges underscore a significant disconnect between the potential benefits of

innovative tracking technologies and their practical implementation within the industry.

The global nature of the seafood trade introduces complexities such as fluctuating demand, variable regulations, and environmental concerns, which necessitate a higher degree of coordination and information sharing among stakeholders. Its geographic diversity—harvesting far from consumption markets and across multiple transit and regulatory zones—further complicates operations. Additionally, logistics firms must offer real-time situational awareness and accountability to all supply chain partners. A critical challenge in the fishing sector is the lack of visibility into real-time operations, which often leads to inefficient resource management and difficulty in monitoring compliance with sustainable practices. For example, lack of transparency in vessel tracking has been identified as a key enabler of illegal, unreported, and unregulated (IUU) fishing. Without visibility into where fishing activities occur, fisheries executives struggle to enforce regulations, combat overfishing, and ensure compliance (Orofino *et al.*, 2023). Various technological devices, such as GPS trackers, CCTV, dataloggers, sensors, and RFID tags, are used to share real-time information with partners across the fish supply chain. Barratt and Oke (2007) emphasized the importance of this information sharing for maintaining product quality and customer service levels. For instance, seafood mislabeling is another significant issue exacerbated by limited visibility. Studies show that seafood fraud, including species substitution, creates challenges in ensuring product authenticity and sustainability. This mislabeling not only deceives consumers but also obscures supply chain inefficiencies, making regulatory enforcement more difficult (Luque and Donlan, 2019). Additionally, there is a growing focus on incorporating advanced technologies into fish supply chain processes.

While existing literature highlights the potential benefits of advanced technologies in supply chains, including reduced costs and improved visibility, much of the research focuses on technical aspects (i.e. Karthiga *et al.*, 2023; Kilibarda and Pajić, 2022) or organizational challenges such as investment cost, data complexity and resistance to change (i.e. Ahmed *et al.*, 2021; Liao and Widowati, 2021). However, limited attention is given to how decision makers, across diverse supply chain actors, collaboratively incorporate these technologies, particularly in the fish industry—a sector marked by global trade complexities and strict sustainability demands (Mahadevan *et al.*, 2024). Therefore, we posit the following research question in this study: how are advanced technological tools incorporated into fish supply chain processes to improve supply chain visibility? In addressing this research question, the paper discusses the current landscape of tools and technologies dedicated to supply chain visibility, focusing on their alignment with decision-making processes in supply chain management. Furthermore, the study explores how the users perceive and engage with these tools, with a lens of technological affordances and how they shape organizational outcomes and influence technology adoption and effectiveness in enhancing supply chain transparency and efficiency.

Using the technology affordances theory, this research examines how decision-makers in the fishing industry

leverage technologies to improve their supply chain visibility. The theory of technology affordances provides insights into the interaction between technology and the socio-technical environment, highlighting the opportunities and challenges managers face. The affordance of a technology, which refers to actionable properties of technological phenomena, captures the dynamic nature of technology use, where perceived affordances evolve as managers interact with the devices, affecting their usage and outcomes (Thapa and Sein, 2018). This perspective is crucial for aligning technological affordances with organizational goals, ultimately leading to better decision-making and visibility in supply chains (Sodhi *et al.*, 2022; Kumar *et al.*, 2023).

The rest of the article is organized as follows: Section 2 presents a review of the literature on supply chain visibility, and the theoretical foundation of technology affordances. The research methodology is then presented in Section 3. Section 4 and 5 cover the findings and discussion, and Section 6 concludes with limitations and recommendations.

2. LITERATURE REVIEW

2.1 Supply Chain Visibility (SCV)

Supply chain visibility (SCV) has evolved from an asset to an essential requirement in today's complex, uncertain, and risk-filled economic environment. Freichel *et al.* (2022) define SCV as the ability of stakeholders to access accurate, timely information on goods flow, essential for informed decision-making, especially during crises. Effective SCV improves coordination and decision-making in industrial projects (Dharmapalan *et al.*, 2021) and enables organizations to quickly adapt, optimize operations, and manage risks (Freichel *et al.*, 2022). In this context, technology is crucial for enhancing supply chain transparency and efficiency through real-time data and improved operations. Businesses increasingly use sensors, trackers, RFID tags, and IoT applications to monitor and optimize supply chains. For instance, sensors track conditions like weight, temperature, and humidity to protect goods in transit (Karthiga *et al.*, 2023), while GPS trackers enable route optimization. RFID systems, which offer multi-level data identification, are gradually replacing traditional data collection (Kilibarda and Pajić, 2022). These technologies and their data are essential for advancing supply chain visibility.

The transformative role of data-driven visibility is central to promoting sustainable and efficient supply chains. By leveraging tracking and monitoring data provided by SCV, companies can also implement predictive maintenance (Yesodha *et al.*, 2023). IoT integration in supply chains enables continuous monitoring, reduces waste, and enhances performance (De Vass *et al.*, 2021). Best practices for implementing IoT involve using sensor-equipped devices, real-time data streams, and advanced analytics to gain visibility and control. These technologies support proactive decision-making and issue anticipation (Mohiuddin *et al.*, 2024). Energy-efficient devices enhance supply chain visibility and support sustainability by optimizing routes and inventory, thereby reducing the carbon footprint. (De Vass *et*

al., 2021). In maritime supply chains, digital tools further green logistics (Mohiuddin *et al.*, 2024), offering data-driven waste reduction and resource management (Venkataraman and Rajkumar, 2023). Real-time insights aid sustainable decision-making, meeting regulatory and consumer demands (Liao and Widowati, 2021). Notteboom *et al.* (2021) highlight that visibility of environmental metrics enables firms to improve sustainability and accountability.

The integration of digital technologies is also crucial for building resilient supply chains. Sharma and Khanna (2020) highlight the role of systems like Enterprise Resource Planning (ERP) and Advanced Planning Systems (APS) in enhancing visibility and coordination. They emphasize how the integration of IoT can improve real-time data collection, automate processes, and strengthen overall supply chain resilience, particularly during disruptions like the COVID-19 pandemic. Similarly, Çemberci *et al.* (2024) examine how digital technologies such as analytics and IoT can enhance supply chain transparency, leading to improved firm performance. They underscore the importance of these technologies in maintaining resilience and performance in uncertain environments, including during the COVID-19 crisis. Notteboom *et al.* (2021) further stress the significance of resilient systems supported by digital technologies like blockchain and IoT, particularly in managing global disruptions such as pandemics and financial crises. These technologies not only improve transparency but also ensure a robust response mechanism during crises. Overall, they fortify supply chains against disruptions and enable organizations to recover swiftly and effectively, maintaining a competitive advantage in turbulent environments.

For industries dealing with perishable goods, such as the fishing industry, leveraging these technologies to enhance transparency and efficiency is crucial. Emenike *et al.* (2016) highlight the need for more advanced models and sensors that can accurately monitor conditions within cold containers. Modern sensors and trackers now provide real-time data on location, temperature, and other critical factors, which are vital for maintaining the integrity of perishable goods. For example, RFID technology has been shown to improve temperature tracking in the pineapple supply chain (Amador *et al.*, 2009), and GPS-based smart locks in trucks have enhanced security and visibility (Verma, 2023). Additionally, RFID dataloggers have proven effective for quality control of fish during transportation (Trebar *et al.*, 2013). These technologies are vital for preserving the quality and safety of perishable goods, directly affecting consumer trust and market success.

However, despite the potential benefits of integrating advanced technologies into supply chains, there are several challenges. Key obstacles include the complexity and high costs of integration, managing vast amounts of data, and the need for effective change management and workforce development (Ahmed *et al.*, 2021; Karthiga *et al.*, 2023; Sallam *et al.*, 2023). Resistance to change is particularly prevalent in established industries, where firms may hesitate to adopt new technologies due to concerns about disrupting existing processes, costs, and uncertain returns on investment (Wisner and Spens, 2009). This challenge is compounded by the lack of standardization, leading to compatibility issues that hinder seamless technology integration across supply chains (Liao and Widowati, 2021).

The implementation complexity is further heightened by varying technological maturity across regions. Additionally, data security and privacy concerns arise as digital technologies become more integrated, necessitating robust data governance and compliance measures (Wisner and Spens, 2009; Liao and Widowati, 2021). Furthermore, the rapid pace of technological advancement can outstrip the available skills within organizations, leading to underutilization or incorrect application of these technologies (Liao and Widowati, 2021). Addressing these challenges requires a concerted effort from organizations to foster a culture of innovation, invest in training and development, and collaborate across the supply chain to develop standardized and evolving practices. This raises the question: *How can we better understand the role of users and decision-makers in this collaborative process?*

Enhancing collaboration across the supply chain is crucial for addressing some of the challenges discussed above. In complex markets, such as the Asia-Pacific region, Mahadevan *et al.* (2024) highlight that collaborative effectiveness—defined as the seamless cooperation between supply chain partners—directly affects supply chain resilience and efficiency. High levels of collaboration lead to synchronized operations, shared critical insights, and aligned strategies, enhancing the ability to respond swiftly to market changes or disruptions. However, achieving this level of collaboration requires overcoming barriers like diverse organizational cultures and management styles. As we delve deeper, it is essential to explore how these collaborative efforts influence user interactions with technology. What factors empower users to effectively engage with these technologies? How do these interactions shape supply chain efficiency? These questions pave the way for a deeper discussion on the underlying dynamics that drive successful technology integration and supply chain visibility.

2.2 Theoretical Framework: Affordance Theory

Originally developed by the psychologist Gibson in 1977, affordance theory provides a framework for understanding the interaction between agents and the environment surrounding them. According to Gibson's definition, affordances are intangible features that present potential actions within an environment, shaped by how well the environment's characteristics align with an individual's abilities. It is important to note that Gibson's definition recognizes that affordances are not just abstract but are uniquely anticipated by users and are acted on accordingly. Affordance theory has recently gained traction as a valuable framework for exploring how technology influences behaviors, decisions, and outcomes within complex socio-technical systems. The use of technology has two dimensions: intended use and situated use (Dulipovici and Robey, 2013). Intended use refers to the planned purpose of the technology, i.e., the features of technology as identified by the developers. On the other hand, situated use is the subjective understanding of the technology itself. This refers to how users of a given technology understand the purpose of the technology, leading to actual use. Understanding the situated use of technology, especially emerging technologies, is crucial to successful adoption. The notion of affordances fits well to explore situated use and allows understanding of the underlying perceptions and actions of

use for technology. Adopted from Gibson’s original theory into digital technology, scholars such as Norman (1988) and Gaver (1991), defined technology affordances as the perceived, actual, and actionable properties of digital technology, particularly those fundamental properties that determine how the technology could possibly be used. In a technological context, **affordances** are referred to as potential actions enabled by features of the technologies and perceived and actualized by the users based on their goals, experiences, and context. Using the affordances theory perspective, “technologies can be understood as artefacts which may be both shaped by and shaping of the practices humans use in interaction with, around and through them” (Hutchby, 2001, p. 444). It is important to note that affordances are not binary, but rather multifaceted, and act as a mediator between the technology and the outcomes of its use by a user in a particular context (Evans *et al.*, 2017). Figure 1 conceptualizes this understanding of affordance theory which will be used in the context of supply chain visibility of the fishing industry in New Zealand.

Understanding the affordances makes it invaluable for research related to the adoption, adaptation, and use of technologies within complex systems such as supply chains as it provides tools to explore understandings of users of technology and the reasons for such understandings and how they affect the outcomes. In supply chains and logistics, devices like GPS trackers or RFID tags create distinct opportunities for different users. In this context, the term “users” does not just mean operational staff but rather users within the broader context (for example, executives and managers who use data from the sensors for decision-making). By examining these technologies through the lens of affordance theory, we can uncover how they offer various possibilities for action and decision-making.

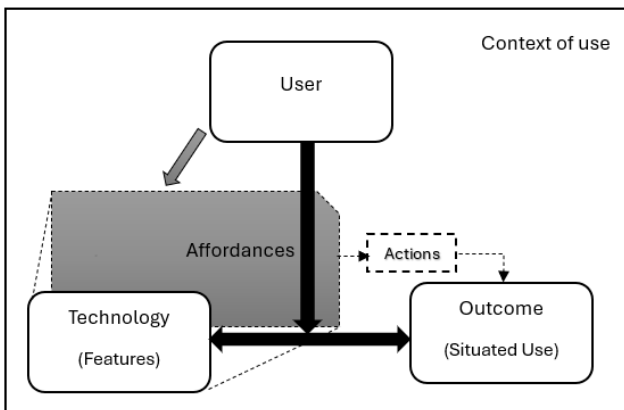


Figure 1 Conceptualization of affordances and their influence on technology use

The affordances provided by supply chain technologies directly affect the various **users** involved in these systems. These users, ranging from supply chain managers to logistics providers, benefit from the capabilities offered by devices such as GPS trackers and RFID tags. For example, Benbunan-Fich (2018) used the affordance lens to understand challenges with user experience, which are crucial for the effectiveness of devices in supply chains. Affordance theory offers a new lens through which to view these devices and their interactions with the goals and

capabilities of the actors in the supply chain. Pinkse and Bohnsack (2021) explain how affordance theory demonstrates the interaction between product features and behavior. Jahanbin *et al.* (2023) investigated blockchain technology and its affordances for supply chain operations. In their paper, supported by the "3TIC value-driver framework," they demonstrate how aligning blockchain features with organizational goals can benefit the users.

The **context** in which supply chain technologies are deployed also significantly influences their affordances, which in this case are the environmental, operational, and regulatory factors in the fishing industry. These affordances are constituted by the technical capacities of the devices and the social and organizational context in which they are used. In other words, affordances are material, culture, and socio-economics dependent (Glover, 2022). Mora *et al.* (2021) underline that the effectiveness of devices is conditioned by the socio-technical systems to which they belong, such as user relations and existing technological infrastructures. Kaaronen (2017) extends the affordance theory to environmental policy and found it can help identify leverage points in the human-environment system to promote self-reinforcing feedback loops of pro-environmental behavior.

The **outcome** of deploying supply chain visibility technologies is deeply influenced by the dynamic nature of affordances, which is the situated use of SCV technologies. Kumar *et al.* (2023) demonstrated how integrating blockchain with IoT results in positive outcomes, such as sustainable and secure supply chain operations, enabling more informed and effective decisions. Thapa and Sein (2018) emphasize that these outcomes evolve as users continuously interact with technology, which is crucial for understanding the shifting roles of devices within supply chain logistics. However, the outcome of technology deployment does not always meet expectations. Sodhi *et al.* (2022) explain that a disconnect often arises when the anticipated outcomes, based on perceived affordances, exceed the actual benefits realized by supply chain professionals. This mismatch can lead to phenomena like the Gartner Hype Cycle, where initial enthusiasm eventually leads to disillusionment. Recognizing this dynamic is crucial for aligning technological affordances with organizational goals, ultimately leading to better outcomes in decision-making and supply chain visibility.

Overall, the affordance theory offers a valuable framework for understanding the adoption and usage of technologies within supply chains. It deepens our understanding of the interactions between supply chain actors and the technologies they utilize, highlighting the critical role of decisions and perceptions in shaping these interactions. By emphasizing the need to align technological affordances with organizational goals, this research applies affordance theory as a lens to examine supply chain visibility (SCV).

3. METHODOLOGY

A social constructionist perspective (a subjective view of reality) was used in this research as the philosophical foundation to understand the world as being constructed through interactions and interpretations of everyday life (Morgan and Smircich, 1980). Based on a social

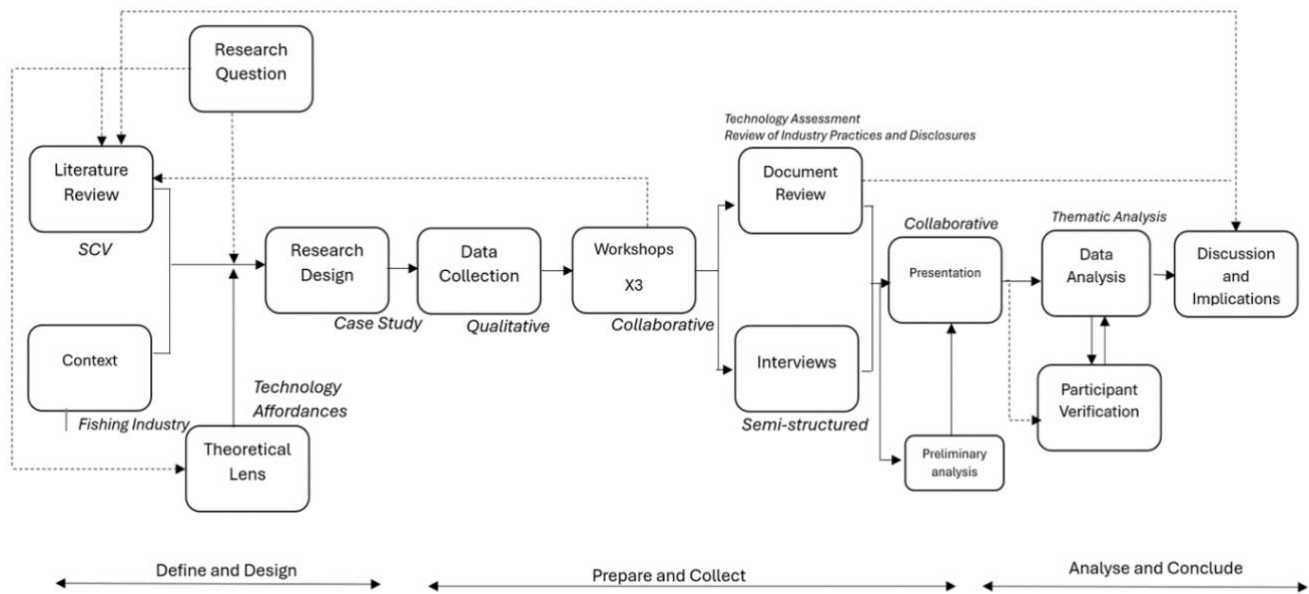


Figure 2 Research Process and Sequencing

constructionist view, social actors influence the shaping of social phenomena and their meanings (Bryman and Bell, 2015). This understanding aligns well with the understanding of affordances within research. Employing social constructionism suggests the need for an interpretative investigation to explore the affordances of technology for supply chain visibility. As such, a qualitative exploratory approach was used in this research.

To comprehensively understand the practical and technological aspects of supply chain visibility practices in the fishing industry, we employed a case study approach focusing on the New Zealand fishing industry (Yin, 2015). A single case is usually preferred when the research aims to get a deeper understanding of the dynamics of a phenomenon to make valid inferences (Eisenhardt, 1989; Kratochwill and Levin, 2015). To get an in-depth understanding of the case, qualitative data was collected via a series of workshops and interviews. Furthermore, detailed technological assessments were done as part of a comprehensive document review of industry practices and disclosures. The sequence of the research process is illustrated in Figure 2.

As presented in Figure 2, the research started with literature and context reviews. The understandings from these reviews then informed the research design along with the theoretical foundation (Technology Affordance Theory). Designed as an exploratory case study we aimed to understand how current SCV technologies influence decision-making processes and operational efficiency within the supply chain, particularly in the fishing industry. Qualitative data was collected in three different iterations, and an initial workshop with participants was conducted to obtain a better understanding of the research scope. Each workshop consisted of key industry participants and academic experts in supply chain management and technology (a total of 6 participants). The first 2 workshops (1.5 hours each) served as foundational sessions to explore key issues, refine our research focus, and develop relevant interview questions. The focus of the 3rd workshop (2 hours)

was to explore various devices and technologies, with a demonstration by the industry participants, and further observations by the researchers.

Following the workshops, semi-structured interviews and a document review consisting of a review of industry practices and disclosures as well as a detailed assessment of technologies in the context were conducted in parallel. We used purposeful sampling techniques to recruit participants with relevant knowledge and experience, ensuring a diverse range of insights. Our participants were selected from a fishing company, two logistics technology companies, a retail company, a marine logistics provider, a sustainable seafood company, and a security firm. The selected companies provided an integrated approach to using current technological devices to improve visibility. Within these organizations, we carefully chose individuals in decision-making roles who were familiar with the relevant technologies, ensuring that their insights were directly applicable to our research, and creating a rich case study of the NZ fishing industry. It is also important to note that while the total number of participants interviewed was 6 and interviews ranged from 45 to 60 minutes, 2 out of the 6 participants were interviewed more than once.

In the document review that took place in parallel, we conducted a detailed examination of organizational policies, guidelines, and other related documents from each company, as well as an analysis of publicly available industry disclosures and reports. In our comprehensive approach to uncovering the intricacies of supply chain visibility within the fishing industry, we extended our research beyond interviews to include detailed interactions with a variety of providers specializing in organization and supply chain monitoring technologies. This proactive engagement was instrumental in shedding light on the array of functionalities current devices offer, as well as the diverse types of data these innovative tools can capture. To achieve this, we meticulously combed through the websites of leading device manufacturers and technology solution providers, collecting

Table 1 Participant Details

Participant	Industry	Role	Duration
Participant 1	Marine Logistics	Regional Account Director	1 hour
Participant 2	Retail	Operations Manager	45 minutes
Participant 3	Logistics Technology	Head of Technology	3 interviews totaling 2 hours
Participant 4	Sustainable Seafood	Procurement Manager	1 hour
Participant 5	Logistics Technology	CEO	2 x 1-hour interviews
Participant 6	Security	Head of Security Risk Management	45 minutes

extensive information on their product offerings. This methodical web-based research was coupled with direct communications with these providers, allowing us to delve deeper into the technical specifications and operational capabilities of their devices. Our inquiries focused on a broad spectrum of technologies, ranging from simple temperature loggers to advanced Internet of Things (IoT) platforms that integrate multiple sensors and data streams into a cohesive monitoring solution. In a comprehensive table detailing 22 devices were documented identifying their product details, functionalities, design, built and applications. Features including tracking features, security and safety features, and power management were documented along with details of the physical design including configuration, sensors, compatibility, and network communication. This exercise helped us understand the nature of devices used in the fishing industry, also allowing us to map the device features later in the analysis (as seen in Figure 5)

This comprehensive assessment allowed us to explore the operational capabilities and technical specifications of these devices in depth and study the perceived and actual properties that determine how these technologies could be used. This triangulated approach allowed us to contextualize the interview data within broader industry practices and trends, providing a comprehensive understanding of supply chain visibility in the fishing industry.

After the interviews and document review were completed, a preliminary review of data was conducted to develop initial findings. This process enabled us to verify that we developed relevant findings before moving on further to the data analysis stage. Details of participants' interviews can be found in Table 1.

The interviews were aimed at understanding the practical challenges and specific requirements of data-driven decision-making in the fishing industry. General Inductive Thematic Analysis (Thomas, 2006) was used for mapping decision-making processes within the supply chain against the affordances provided by current technologies. A sample of our thematic analysis can be found in Table 2. An inductive approach was adopted because understanding affordances was exploratory in nature and there was a need to see what ideas emerged from the data (Bryman and Bell, 2015) to understand how participants experience and interpret the affordances of supply chain visibility technologies within the broader supply chain. The analysis process began with a thorough reading of interview transcripts, organizational documents, and industry disclosures to immerse ourselves in the data. Each transcript was then subjected to detailed line-by-line coding to identify significant statements and emerging themes. To ensure credibility, two researchers independently coded the data, followed by collaborative discussions among all four

researchers to refine and consolidate the themes. This approach provided rich insights into the perceived affordances of the technologies and their influence on decision-making, collaboration, and coordination across various levels of the supply chain, including interactions with suppliers, logistics providers, and other stakeholders.

Through this iterative process, we identified key themes related to the adoption, utilization, and impact of supply chain visibility technologies, focusing on the elements of agent, affordances, environment, and outcomes as outlined in affordance theory. We also explored the interrelationships between these elements. These themes were then mapped against broader supply chain practices and interactions, enabling a comprehensive analysis that captures the complex and interconnected nature of the supply chain.

To ensure the rigor and quality of the analysis, we adhered to the trustworthiness criteria outlined by Nowell *et al.* (2017). Credibility was achieved through rigorous coding, analysis, and interpretation processes, with researchers debriefing each other during coding and interviews. Strategies to ensure transferability included a detailed description of the context, transparent methodology, and a rich presentation of research findings, encouraging replication and validation in different contexts. Dependability was addressed through a logical, traceable, and well-documented research methodology, supporting the confirmability of our findings. Reflexivity was practiced by continuously evaluating our ideas, assumptions, and preconceptions to understand their impact on our decisions throughout the study (Nowell *et al.*, 2017). Lincoln *et al.* (1985) identified member checking as a method that enhances the rigor of qualitative research by improving the credibility of findings. Member checking is important to ensure “the participants' own meanings and perspectives are represented and not curtailed by the researchers' agenda and knowledge” (Tong *et al.*, 2007, p. 356). Thus, all participants were sent a summary of key findings via email and feedback was obtained and incorporated in the writing.

4. FINDINGS: TECHNOLOGICAL AFFORDANCES ON SCV IN THE CONTEXT OF THE FISHING INDUSTRY

The thematic analysis we conducted not only enhanced the understanding of data but also allowed us to align findings directly with the theoretical underpinnings of the study. The findings are discussed under the broader themes of affordances, users, context, and outcomes and later examined the relationships between the components to extend the understanding of the influence. Table 3 below gives an overview of the findings discussed.

Table 2 Sample Data Analysis

Sample data points and quotes	Code 1	Code 2	Final themes
<p>"Battery life is always something you got to consider. These devices consume battery power when they communicate with the central platform...but in environments like the middle of the ocean, where there's no cell tower, the device stores the data until it can reconnect" (P3)</p> <p>"For air freight, lithium battery is very difficult to get approved. Some airlines don't approve it because of the risk of fire. So we use another device without a lithium battery." (P1)</p>	Battery life, regulatory constraints, infrastructure challenges	Environmental & operational challenges	Contextual constraints on technology adoption
<p>"Companies often invest in smart data loggers but fail to utilize their full capabilities due to a lack of investment in the necessary infrastructure or personnel to analyze the data collected." (P4)</p> <p>"We're still almost getting dumb data from a smart device." (P6)</p> <p>"The complexity and variety of available devices can overwhelm businesses, making it difficult to choose the right technology for their needs. This situation is compounded by the lack of interoperability between different devices, which can lock companies into using specific vendors and limit their flexibility." (P4)</p>	Infrastructure gaps & misalignment of investment priorities Interoperability & tech vendor lock-in concerns	Organizational & strategic barriers to technology integration	
<p>"They love this device. They love their reporting and the visibility" (P1).</p> <p>"But not using it to its fullest and not appreciating the value that comes from that smart device." (P6).</p> <p>"...not using the technology correctly. And this is a human error. And these have to do with training." (P6)</p>	Successful adoption & utilisation Mixed adoption & under utilisation Training & human error	Perception of value User knowledge & engagement	User perception, knowledge, & engagement
<p>"But you need to attach this device in a way that the light sensor can detect the door open and close. If they put it on the roadway you understand that this device will never work correctly." (P6)</p>	Improper setup reduces effectiveness		
<p>"All this data will be stored in the database... customer has access to configure and monitor operations." (P6)</p> <p>"The device has a GPS and GSM module inside. So, GPS is to communicate with the satellites to get the latest position." (P6)</p> <p>"We don't wait until... We usually set it that once it reaches... then we get an alert so that you can then start to take some action." (P1)</p> <p>"It will automatically upload to the cloud which is good. You don't have to plug them in. So you don't lose the data." (P4)</p> <p>"We can monitor any anomalies... we place this asset tracker on the container or trailer ... light sensor will be activated if the door has been opened" (P6)</p> <p>"How about being proactive, ... and put them in overtime and get all of that rich data out and in map methods and be proactive instead of reactive." (P4)</p> <p>"We are using this device not just to track the temperature but to apply in real business ..., working together with customers to help them reduce ..." (P1)</p>	Enhanced visibility GPS tracking, automated alerts, anomaly detection Preventative decision-making	Real-time tracking & monitoring Proactive management & alerts	Technological affordances
<p>"We use a proximity alert that sends an SMS or WhatsApp message to the warehouse manager when a truck is within 10 kilometers of the pickup point. If the manager receives this personal message, they realize the importance and may prioritize the task accordingly." (P1)</p> <p>"So I saw already one of our countries that we sending from ...[client] is tracking the shipment and they can see when it lands in the airport. So within one minute they are sending an email to the customer to say cargo just landed...it's giving more real-time information to customers." (P1).</p> <p>"If we mapped and looked at the data...we'd suddenly find out...there's so much richness in the data that comes out of those things." (P4)</p> <p>"We are using this device not just to track the temperature but to apply it in real business circumstances, working together with customers to help them reduce costs, ...increase efficiency." (P1)</p> <p>"So we found that in one year we ... save 70 tons of CO2 emissions." (P1).</p>	Real-time updates, allowing businesses to enhance responsiveness to customers Optimise resources, reduce waste Minimise environmental impact	Improved customer service and operational efficiency Cost reduction & sustainability gains	Outcome - business and sustainability benefits
<p>"If the manager receives this personal message, they realize the importance and may prioritize the task accordingly." (P1)</p> <p>"If we mapped and looked at the data...we'd suddenly find out...there's so much richness in the data that comes out of those things." (P4)</p> <p>"No, I just saw many useful applications... Where they're using it in ... for some transport movements. We're learning from that." (P1)</p>	Real-time updates (outcome) modifies perceptions Recognition and realization of an affordance Learning and adapting	Fluidity of affordances, where outcomes are the result of continuous interaction between context, outcome and user Situated use shapes affordances	Interactions between components - feedback loops

Table 3 Overview of the findings.

Theme	Key Findings
Affordances	Real time tracking and monitoring is a key affordance of SCV technologies Alert systems enable proactive management by empowering users to make timely, informed decisions.
Users	Attitudes of users influence whether—and to what extent—individuals choose to engage with a given technology. Proper training and user’s adherence to correct setup procedures are vital for ensuring technology’s intended functionality.
Context	External factors influence technology affordances by impacting operational needs Regulatory frameworks, legal standards, and compliance requirements shapes technology affordances Nature of the product impacts the operational need and thereby influences technology affordances Infrastructure challenges within the context impacts technology affordances
Outcomes (Situating use)	SCV technologies provide affordances that enable organizations to enhance customer service, streamline operations, and achieve sustainability benefits.
Interactions Between Components	The user’s perception and selection of actions are influenced by the affordances presented by technology. The outcomes of using these technologies create a dynamic feedback loop that affects affordances by driving learning and adaptation, and alters the context, creating a cycle of interactions.

4.1 Affordances

The supply chain monitoring devices we examined offer a range of functionalities that enhance the visibility and integrity of products within the supply chain. These devices, including temperature sensors, GPS trackers, RFID tags, and IoT platforms, afford real-time location tracking, environmental condition monitoring (temperature and humidity), shock and vibration detection, and automated data logging. The affordances of advanced technologies, such as multi-sensor integration and cloud-based analytics, suggest a trend toward more holistic monitoring solutions that can better support proactive decision-making. This search was then complemented by a series of interviews where participants discussed the affordances they require from these devices. Next, we discuss some of the highlights.

4.1.1 Real-Time Tracking and Monitoring

One of the most critical affordances offered by supply chain technologies is real-time tracking and monitoring. This functionality enables users to maintain continuous visibility over their shipments, which is essential for making timely decisions. For example, a participant highlighted this affordance by stating, “We can monitor any anomalies... we place this asset tracker on the container or trailer door... light sensor will be activated if the door has been opened” (Participant 6). This real-time insight is crucial for ensuring shipment integrity and responding to potential issues as they arise.

Moreover, the integration of GPS and GSM modules in tracking devices provides another layer of affordance by allowing continuous communication with satellites, which is essential for obtaining the latest position of shipments. As one participant noted, “The device has a GPS and GSM module inside. So, GPS is to communicate with the satellites to get the latest position” (Participant 6). This capability is particularly valuable in industries that require precise location tracking. Another significant advantage is the ability to analyze data and generate automated reports in real time. This allows users to make informed decisions and respond quickly to changing conditions, enhancing operational efficiency and responsiveness. “All this data will be stored in the database... customer has access to configure and monitor operations” (Participant 6). Users can continuously

monitor operations without manual data collection, freeing up resources and improving decision-making processes.

4.1.2 Proactive Management and Alerts

The affordance of proactive management is evident in technologies that provide alerts based on predefined thresholds. This capability allows users to anticipate issues and take corrective actions before problems escalate. One participant illustrated this affordance by stating, “We don’t wait until... We usually set it that once it reaches... then we get an alert so that you can then start to take some action” (Participant 1). This proactive approach is essential for industries that require immediate responses, such as cold chain logistics, where maintaining temperature control is critical. The ability to analyze historical data and generate predictive insights is another aspect of proactive management. “How about being proactive, put them in and put them in overtime and get all of that rich data out and in map methods and be proactive instead of reactive” (Participant 4). By leveraging data analytics, users can identify patterns and trends that inform future actions, thus enhancing the overall efficiency and reliability of the supply chain.

4.2 Users

The attitudes, knowledge, and goals of users play a crucial role in their affordances of technologies. Managers often justify the use of devices by demonstrating their positive attitudes towards adopting these technologies and highlighting the value they bring. For instance, one manager noted, “They love this device. They love their reporting and the visibility” (Participant 1). This attitude directly influences whether and to what extent they choose to engage with technology. While this example demonstrates a high level of engagement, there are also instances where users’ expectations result in engaging less fully with technology. One participant highlighted this underutilization: “...but not using it to its fullest and not appreciating the value that comes from that smart device. We’re still almost getting dumb data from a smart device and not focusing on the problems we’re trying to solve or the issues this device could help us address” (Participant 6). This participant also discusses reservations which may stop them from using the device altogether: “Then start raising questions about

interoperability. So, if I'm a big multinational company, and I want to start using these devices to monitor my shipments, I don't want to tie myself to a particular vendor, because they will then be able to kind of hold me hostage in terms of price."

Users' knowledge and experience are also critical in their interaction with these devices. As noted by one participant: " ... *not using the technology correctly. And this is a human error. And these have to do with training. What I'm saying with that is we say to a person at the warehouse you need to attach this device to the container. But you need to attach this device in a way that the light sensor can detect the door open and close. If they put it on the roadway, you understand that this device will never work correctly.*" (Participant 6)

An intuitive and user-friendly interface can also significantly enhance the perceived affordances of a technology, encouraging broader adoption across the organization. For instance, one participant highlighted the simplicity of some devices by stating, "*But it's just a USB plugin. No smarts or that or anything, just records temperature*" (Participant 4). While this simplicity might limit functionality, it also makes the device accessible to a wider range of users. User-friendliness in technology often extends beyond just ease of use; it also encompasses convenience and data security, ensuring that users can interact with devices effortlessly while keeping their data safe and accessible. As highlighted by Participant 4: "*At the moment all of those smart ones will automatically upload to the cloud which is good. You don't have to plug them in. So, you don't lose the data*".

4.3 Context

The context plays a crucial role in shaping the affordances and effectiveness of the devices used; our findings identify important elements such as operational needs, regulatory frameworks, market conditions, and infrastructure challenges. **Operational needs** within supply chains are heavily influenced by contextual factors. For example, in environments where extended shipping cycles are common, both battery life and data capacity are critical for maintaining continuous monitoring and communication. These contextual factors directly determine the operational capabilities of a technology and shape its affordances for a particular context. As Participant 3 argued, "*Battery life is always something you got to consider. These devices consume battery power when they communicate with the central platform...but in environments like the middle of the ocean, where there's no cell tower, the device stores the data until it can reconnect.*" This underscores how battery life and data capacity are intertwined with the context, influencing the technology's ability to provide continuous and reliable affordances.

The **existing infrastructure** is another contextual aspect that plays a crucial role in how affordances are actualized. For instance, "*Companies often invest in smart data loggers but fail to utilize their full capabilities due to a lack of investment in the necessary infrastructure or personnel to analyze the data collected*" (Participant 4). This statement highlights that even when advanced technologies are adopted, the full potential of their affordances may not be realized if the surrounding environment—such as the

availability of trained personnel or adequate infrastructure—is not adequately developed. The affordance here is the ability to collect and analyze data; however, the context limits the actualization of this affordance, rendering the technology underutilized.

Additionally, **product perishability** is another crucial operational need, especially in industries like fishing, where maintaining cold chain integrity is essential. The highly perishable nature of products like fish necessitates specialized monitoring tools to ensure the safety and quality of goods throughout the supply chain. As Participant 4 emphasized, "*Why are we using them? And what are they going to deliver for us?... If that fish goes off, you could kill someone. You eat rotten fish, and you can get really bad problems, right? So, it's serious.*"

Compliance is not just about product integrity; it is also driven by **regulatory requirements**. These factors shape affordances, ensuring that technological solutions meet legal standards, especially in highly regulated sectors like fishing: "*We use the TV data logger, and the reason we use this, if you see [it] here, is the lithium battery. The reason for using this in ocean shipping is because ocean lead time is very long... For air freight, lithium battery is very difficult to get approved. Some airlines don't approve it because of the risk of fire. So, we use another device without a lithium battery.*" (Participant 1).

The **complexity of technology** ecosystems also affects affordances. "*The complexity and variety of available devices can overwhelm businesses, making it difficult to choose the right technology for their needs. This situation is compounded by the lack of interoperability between different devices, which can lock companies into using specific vendors and limit their flexibility*" (Participant 4). This quote illustrates how the affordance of flexibility is compromised by the complexity and lack of interoperability in technology choices. The overwhelming variety of devices and their incompatibility can lead to decisions that lock businesses into specific technologies, limiting their ability to adapt or scale their operations. Here, the context—marked by complexity and lack of interoperability—negatively affects the affordance of flexibility, demonstrating how environmental factors influence the effectiveness of technological affordances.

4.4 Outcome (Situated Use)

Our findings also demonstrate how the use of supply chain visibility technologies enables affordances that lead to positive outcomes. For instance, the regular use of tracking devices has afforded companies the ability to improve their responsiveness to issues in the supply chain. One participant noted, "*So, I saw already one of our countries that we [are] sending from ...[client] is tracking the shipment, and she can see when it lands in the airport. So, within one minute she's sending an email to the customer to say cargo just landed...it's giving more real-time information to customers*" (Participant 1).

Moreover, the affordance of data collection has been extended to facilitate collaboration and co-innovation. As Participant 1 also highlighted, "*We are using this device not just to track the temperature but to apply it in real business circumstances, working together with customers to help them reduce costs, reduce CO2 emissions, increase efficiency*".

This demonstrates how the technology’s affordance extends beyond monitoring, enabling companies to achieve broader business goals such as sustainability and cost reduction, thereby enhancing their overall value. The sustainability affordance of these technologies is particularly evident in their contribution to reducing CO2 emissions. “So, we found that in one year we could actually save 70 tons of CO2 emissions” (Participant 1).

These examples illustrate how the outcomes of deploying supply chain visibility technologies are closely tied to the affordances they offer, with the context of their use shaping the extent to which these affordances are realized. It is also important to consider broader aspects such as sustainability and innovation. The opportunity to design technologies with sustainable materials and consider their lifecycle from production to disposal is a future affordance that addresses environmental concerns. Moreover, there is a clear need for innovative solutions that integrate multiple functionalities into a cohesive platform, which can operate effectively in challenging environments like long ocean voyages. These considerations highlight the evolving nature of affordances as technologies and industry needs continue to develop.

4.5 Interactions Between Components

The elements discussed above do not operate in isolation; rather, they form a dynamic system where each influences and is influenced by the others. In this section, we examine how these interactions shape the overall process, leading to evolving perceptions, actions, and outcomes. Our findings discussed above demonstrate the intricate relationship between agents, affordances, context, and outcomes within supply chain monitoring systems. We have synthesized these insights into a conceptual model, depicted in the figure below, which visually represents the dynamic feedback loops and interactions that occur as agents engage with technological affordances within specific contexts.

In this model, the agent's perception and selection of actions are influenced by the affordances presented by the technology. These affordances, however, do not exist in isolation; they are modified or constrained by the context in which they operate. For instance, factors such as operational needs, regulatory requirements, and infrastructure capabilities play a significant role in shaping the effectiveness and realization of these affordances. As Participant 1 mentioned, “We use a proximity alert that sends an SMS or WhatsApp message to the warehouse manager when a truck is within 10 kilometers of the pickup point. If the manager receives this personal message, they realize the importance and may prioritize the task accordingly.” This illustrates how real-time data influences decision-making.

The outcomes of using these technologies, such as improved operational efficiency, responsiveness, and sustainability, create a feedback loop that leads to learning and adaptation. This process not only refines the agent's future perceptions and interactions with the technology but also has the potential to alter the context itself, creating a continuous cycle of improvement and adaptation. As highlighted by Participant 4, “if we mapped and looked at the data...we'd suddenly find out...there's so much richness in the data that comes out of those things.” This underscores how

ongoing use and data analysis from these devices lead to new insights, improving supply chain management.

By visualizing these interactions in the model presented in Figure 3, we emphasize how the deployment and effectiveness of supply chain monitoring technologies are deeply embedded in a dynamic system where agents, affordances, context, and outcomes continuously influence one another. Understanding this model can guide future efforts in optimizing the use and development of such technologies within the supply chain, ensuring that their full potential is realized in various contexts.

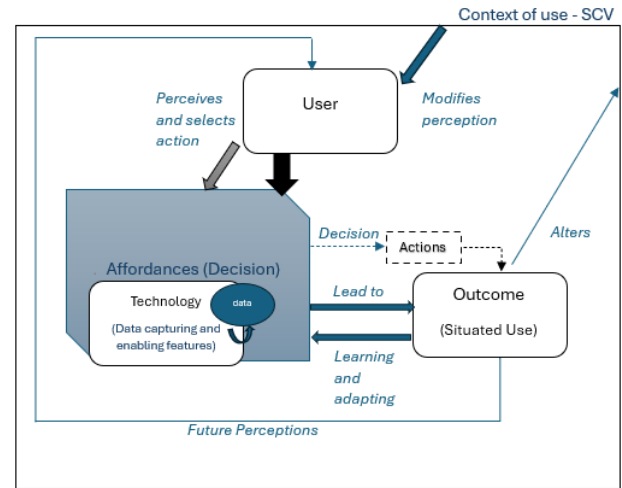


Figure 3 Affordances and its impact within the context of SCV

5. DISCUSSION

First, the findings indicate the effectiveness of supply chain technologies hinges not just on their technical capabilities but also on users and their context. Contexts play a critical role in enabling or limiting affordances. For instance, devices must function effectively in challenging environments, such as long ocean voyages, highlighting the need for more robust and versatile technologies. Additionally, energy-efficient devices are essential for sustained operation over extended periods. De Vass *et al.* (2021) emphasize that such devices not only enhance visibility but also contribute to sustainability by optimizing routes and inventory levels. Regulatory and compliance frameworks are also contextual constraints or enablers of technological affordances in the supply chain. According to Liao and Widowati (2021), aligning technology with regulatory requirements ensures legal compliance and enhances supply chain operations by promoting best practices and building stakeholder trust, especially in data security and privacy. Through affordance theory, regulatory frameworks within supply chains are crucial for enabling or constraining the technological actions organizations can actualize.

Second, our findings also indicate the effectiveness of supply chain technologies hinges not just on their technical capabilities but also on user perception and accessibility and the availability of comprehensive training programs. Participants in this research expressed a strong desire to make better use of their data, viewing it as a valuable opportunity, asserting that their organizations have a wealth of data with untapped potential for deeper analysis and

insights. Liao and Widowati (2021) pointed out that rapid technological advancements can outpace organizational skills, leading to underutilization or misapplication. Enhancing user interfaces and offering targeted training can significantly improve adoption and ensure optimal use of these tools. Karthiga *et al.* (2023) also highlight the importance of change management and workforce development for successful technology adoption. Enhancing user interfaces and providing targeted training can significantly improve adoption rates and ensure that personnel can utilize these tools optimally. Moreover, our findings confirm those of Mahadevan *et al.* (2024) by highlighting the importance of supply chain collaboration. We observe a feedback loop: collaboration is necessary for technology to deliver its intended affordances, and technology, in turn, fosters collaboration by enhancing communication. Thus, technology not only relies on collaboration but also facilitates it, making collaboration itself an affordance.

Building on our understanding of affordances and the extended conceptual framework, we explored the types of decisions made across the supply chain and the devices supporting them. By mapping situated use to device functionalities, we examined how technological features and outcomes are linked through decisions and data. The technology captures crucial data for decision-making, connecting user actions, affordances, and desired outcomes for supply chain visibility. This mapping highlighted both the alignment and gaps between decision-making needs and device functionalities. This mapping exercise shows that while there is a strong alignment in areas such as location tracking and temperature monitoring, significant gaps remain in security features and historical data analysis.

This device-decision map illustrates the connections between technological features and strategic decisions. By cataloguing device functionalities—such as GPS tracking, temperature and humidity sensors, and live fleet management systems—we were able to map how these features support various supply chain decisions. For example, the figure below (Figure 4) visualizes the interconnectedness of decisions and features, demonstrating how different combinations of these elements create new affordances. These combinations enable various decision-making capabilities, highlighting how certain features together offer unique opportunities for improving visibility in cold chain management. Temperature and humidity sensors are crucial for meeting food safety standards, but real-time data via Wi-Fi is essential for proactive quality control. While compliance can be achieved by reviewing sensor data after transport, live data enables immediate action if issues arise. Wi-Fi allows continuous monitoring of not just temperature and humidity, but also physical factors like shock and free-fall that can affect product quality. Live fleet management, integrating GPS/GNSS and sensor data, ensures timely responses to maintain product integrity, making live data critical when quick action is necessary.

The broader map (Figure 5) also links these features to specific devices, allowing users to identify technologies that best align with their decision-making needs. Additionally, this map can serve as a reverse guide for those who have already recognized a problem they are trying to solve. Users

can work backwards, identifying which devices offer the necessary data collection features to inform their decisions, making this device-decision map both a proactive planning tool and a problem-solving resource for the supply chain industry. We argue that this mapping forms the bulk of our practical contribution.

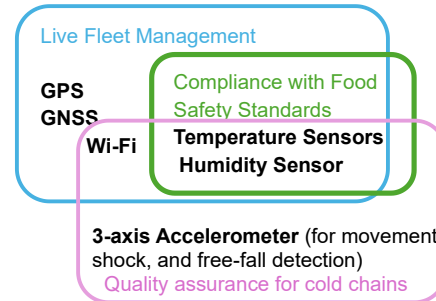


Figure 4 Example of decisions and features interconnectedness

Moreover, our mapping exercise reveals that technological solutions such as real-time location tracking and temperature monitoring are effectively enhancing supply chain visibility by directly addressing key operational challenges. This alignment explains the upward trend in adopting these technologies (Karthiga *et al.*, 2023), as sensors and RFID tags optimize supply chains by monitoring critical conditions like temperature and humidity, ensuring product quality. Similarly, Emenike *et al.* (2016) and Amador *et al.* (2009) emphasize the importance of real-time data for maintaining product quality, particularly in temperature-sensitive supply chains.

Despite these advancements, our findings underscore notable gaps in providing comprehensive solutions that enhance the overall supply chain visibility. While many devices offer valuable individual functionalities, a more integrated approach is necessary for predictive analytics and real-time decision support. Most existing technologies operate in silos, addressing specific needs, but the challenge lies in their integration. The lack of standardization leads to compatibility issues that hinder seamless technology integration across supply chains (Liao and Widowati, 2021). Karthiga *et al.* (2023) also point out the complexity and high costs of integration, managing vast amounts of data, and the need for effective change management and workforce development as key obstacles.

Our research indicates an increasing need for solutions that consolidate data from multiple sources into a unified platform, delivering actionable insights through advanced analytics to enhance supply chain visibility (SCV). This aligns with earlier studies emphasizing the need for integrated platforms to enhance efficiency and resilience (Sharma and Khanna, 2020; Kumar *et al.*, 2023). The trend is moving towards more intelligent, interconnected devices capable of providing a holistic view of the supply chain, encompassing security, environmental monitoring, and real-time visibility (De Vass *et al.*, 2021). Furthermore, Liao and Widowati (2021) suggest that integrating technologies into supply chain systems is crucial for meeting regulatory and consumer demands, presenting a strong case for platforms capable of effective integration.

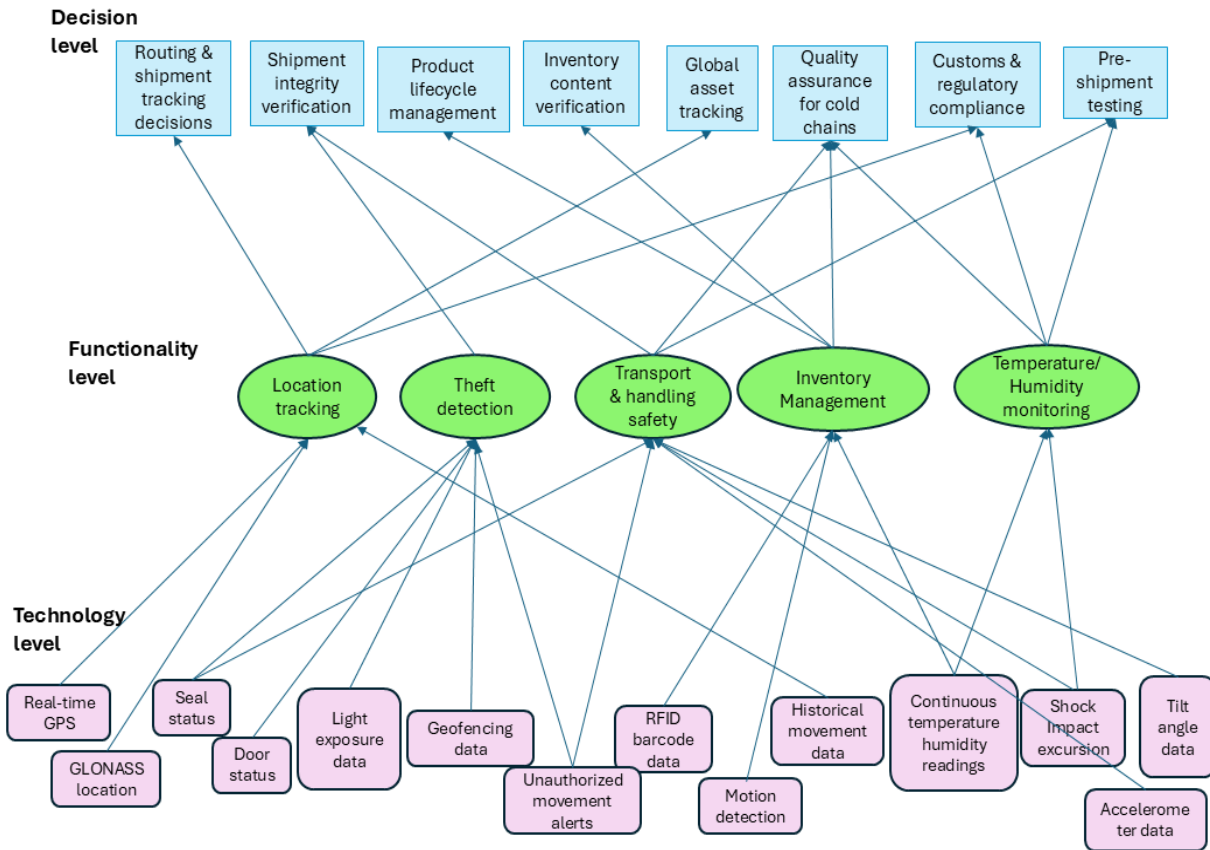


Figure 5 Technological mapping, from technology to decision-making

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While overcoming technological and operational challenges remains critical, these gaps present significant opportunities for innovation in device development aimed at improving supply chain visibility. Enhancing security features, historical data capturing, and environmental monitoring for regulatory compliance can significantly contribute to a more transparent supply chain. The future of supply chain management, especially in the fishing industry, lies in developing technologies that bridge these gaps, offering more sustainable, transparent, and efficient operations through enhanced supply chain visibility.

Based on this analysis, we propose three research propositions: (1) the effectiveness of technologies in enhancing SCV is contingent on the alignment between technological affordances and the specific operational context in which they are implemented, (2) higher user perception of usability, greater accessibility, and well-structured training programs significantly enhance the adoption and effectiveness of supply chain technologies, and (3) collaboration is identified as both a facilitator for realizing technological affordances and an affordance itself. This dual role underscores its critical importance in achieving comprehensive supply chain visibility.

6. CONCLUSION

This study examined the role of emerging SCV technologies in the fishing industry, focusing on how tools such as GPS trackers, IoT sensors, and RFID tags can enhance operational efficiency, sustainability, and

transparency in supply chains with complex, perishable goods. By applying affordance theory, we explored how decision-makers perceive and interact with SCV technologies.

Our study reveals that the effectiveness of advanced technologies in enhancing fish supply chain visibility hinges on technological affordances—the actionable possibilities these technologies offer within specific contexts. This research advances the field by applying affordance theory to supply chain visibility, highlighting the interplay between technological capabilities and user actualization. Our analysis suggests the need for unified, user-centered platforms that maximize technological affordances by aligning technical functionalities with user needs and contextual constraints. Building on our analysis, it becomes evident that collaboration is not merely a supporting factor but a fundamental affordance that shapes and is shaped by technological capabilities within the supply chain ecosystem.

Moreover, by applying the affordance theory, we uncovered a critical disconnect: users perceive they have vast amounts of untapped data, yet it remains unclear whether the right types of data are being captured to inform key decision-making. This issue makes it challenging for users to fully leverage existing technologies, as the data collected may not align with the strategic needs of supply chain visibility. By focusing on the interplay between technological capabilities and user actualization, future studies can drive the development of solutions that not only enhance supply chain visibility but also contribute to more sustainable, transparent, and efficient operations in the fishing industry and beyond.

We acknowledge that our study has some limitations that offer directions for future research. First, its focus on New Zealand's fishing industry may limit the generalizability of findings to other sectors or regions with different regulatory and logistical contexts. Second, the qualitative approach and limited sample size provide detailed insights but may not capture the full range of industry perspectives, making broader conclusions challenging. Furthermore, the study examines existing technologies like GPS, RFID, and IoT, which may not encompass the affordances of newer, rapidly evolving tools, such as blockchain or big data analytics. Finally, while socio-technical factors are acknowledged, the study does not extensively explore the influence of organizational culture on technology adoption. Examining these dynamics in future research would provide a more holistic view of supply chain visibility implementations.

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Dr Maryam Mirzaei is a Lecturer of Supply Chain Management at Auckland University of Technology (AUT), New Zealand. Her research explores the future of supply chains with a focus on emerging trends and transformative practices. Grounded in applied, industry-based solutions, she examines how digital transformation, Industry 4.0 technologies and sustainability can be integrated to solve real-world supply chain challenges. She has published in *Production Planning and Control* and a range of peer-reviewed journals, with continuing research that speaks to diverse scholarly and practical communities within the field.

Dr Benjamin Dehe is an Associate Professor of Supply Chain Management at Auckland University of Technology (AUT), New Zealand. His research focuses on operational excellence, supply chain innovation, and the exploration of digital transformation and Industry 4.0 technologies, with a particular emphasis on decision-making processes. Benjamin's work has been published in leading national and international journals, including *Production Planning and Control*, *International Journal of Operations and Production Management*, *Expert Systems with Applications*, and the *Journal of Business Research*.

Dr Kasuni Weerasinghe is a Senior Lecturer in Information Systems at Auckland University of Technology (AUT), New Zealand. She has a background in Information Systems and her research focuses on adoption of emerging technologies, socio-technical perspectives, social media and health information systems. Her work has appeared in numerous journals including the *Australasian Journal of Information Systems*, *Technology Forecasting and Social Change*, and *IEEE Access*. She co-hosted tracks, served as associate editor at several conferences including *Australasian Conference on Information Systems*, *Pacific Asia Conference on Information Systems* and *Hawaii International Conference on System Sciences*.

Dr Hari Srivastava is a senior lecturer at the Department of Management, Technology, and Organisation at Auckland University of Technology (AUT), New Zealand. His research focuses on supply chain sustainability, digital technologies in supply chain and logistics, and the circular economy. He holds a Ph.D. in supply chain sustainability from Auckland University of Technology.