NTU Management Review
Vol. 34 No. 3 Dec. 2024, 229-286
https://doi.org/10.6226/NTUMR.202412_34(3).0006

How ESL Devices Transform into Connected Label Solutions: A Perspective of Actor Interaction and Information Rebundling

從電子標籤轉型為連結式標籤服務方案：以行動者互動與資訊再組合的觀點探討

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Received 2022/11, Final revision received 2024/10

Abstract

Digital transformation has been recognized as the driving force in enhancing business operations and increasing revenue. Relevant studies have mostly focused on the implementation of specific technology and on the effects of that technology on individuals, organizations, and ecosystems. Prior studies fall short of examining the process of how a shift in a business model or a brand-new model can originate with the introduction of a simple device. The current study tries to elaborate on this process from the perspective of actor interactions and information density. Using secondary data from online sources regarding electronic shelf label (ESL)-enabled retail digital transformation, this study highlights actors interacting with other actors to provide some technological advancement. This case study focuses on actor-network interactions in ESL-enabled retail digital transformation. These interactions also trigger changes in information density and impact business operations. We propose three stages of digital transformation: digitization, unbundling and rebundling information, and information outsourcing for a business model shift. A well-designed system can turn a simple labeling device into a connected label solution through collaboration with other actors in the retail ecosystem. Our study provides contributions to understanding digital transformation from information density perspectives and how ecosystem actors co-create technology to leverage its functionalities.

【Keywords】digital transformation, electronic shelf label, information density, actor interaction, business model shift

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摘 要

數位轉型被視為提升營運與增加收益的驅動力。大多數研究聚焦於討論特定技術導入所帶來的個人、組織或者生態系統層級的影響，鮮少探討數位化設備的導入如何啟動商業模式轉型。本研究以行動者交互作用與訊息密度的角度闡述此商業模式轉型過程。透過網路二手資訊，爬梳由電子貨架標籤驅動的零售業數位轉型，並著重於採用行動者網路交互作用，探討各行動者間的互動如何帶動技術進步與零售產業的數位轉型；該交互作用亦使訊息密度產生變化並且對商業營運起了作用。本研究提出三個數位轉型階段：數位化、訊息解構與重組，以及商業模式轉型的外包訊息。本研究發現，在零售業生態系中，各行動者間緊密的互動作用打造了一個縝密的系統，使一個簡單的貨架標籤設備轉型成為全方位的零售解決方案，並以此提出理論發展及管理實務上之意涵。

【關鍵字】數位轉型、電子貨架標籤、資訊密度、行為者互動、商業模式轉型

1. Introduction

Digital transformation has been crucial for company and industry development in recent decades, involving actors or stakeholders who adopt a new technology and influence actors to change their behavior in adapting to advanced technology (Dąbrowska, Almpanopoulou, Brem, Chesbrough, Cucino, Di Minin, Giones, Hakala, Marullo, Mention, Mortara, Nørskov, Nylund, Oddo, Radziwon, and Ritala, 2022). According to Dąbrowska et al. (2022), digital transformation refers to a process of technology adoption with three stages: modernization, enterprise-wide transformation, and new business creation (Bonnet, 2022). The last stage might result in the creation of new enterprises and the discovery of new sources of wealth, whereas the first two stages focus on changing the firm's current operations. Although digital transformation requires several stages, we cannot neglect the role of technology adopters and features. Integrating new technologies and altering current behavior should undergo iterative and continual refinement, better suiting a particular environment or business.

Prior digital transformation research has focused on how technological characteristics help businesses and what major elements affect technology deployment (Kamble, Gunasekaran, Parekh, and Joshi, 2019; Pereira, Moura, Costa, Vieira, Landim, Bazaki, and Wanick, 2022). Technology deployment benefits companies variously by helping companies conduct business and connect to customers or partners through building dyadic communication (Bresciani, Ferraris, and Del Giudice, 2018; Scuotto, Arrigo, Candelo, and Nicotra, 2020), enhancing the development of new business distribution channels (Matarazzo, Penco, Profumo, and Quaglia, 2021; Windasari and Santoso, 2022), and reshaping value creation (Sjödin, Parida, and Visnjic, 2022).

The retail industry is highly active in hastening technology adoption to fulfill the fast-changing needs of customers. Retailers seize the opportunity and identify how technology can improve operational efficiency and customer experience. One emerging technology for retailers to reshape the existing retail business practices is electronic shelf labels (ESLs). Replacing paper labels on shelf edges, these small, battery-operated e-paper (Electronic Paper) displays offer product and pricing information. To connect with a central hub and create a network for dynamic price automation, ESLs utilize wireless technologies. Although an ESL is a tiny device, it can make shopping more engaging and interactive by

digitizing price and product information; digitization refers to converting information into digital format (Bloomberg, 2018).

During technology deployment, ESL technology is also evolving through the collaborative actions of various actors in the retail ecosystem, not only the retail supply chain network. Beyond digitization of the product price and information, ESL can also overcome certain operational barriers to the implementation of specific computing applications in real time. For instance, although merchants have used time-series data to predict product prices (Purohit, Panigrahi, Sethy, and Behera, 2021; Ren, Chan, and Siqin, 2020), they cannot adjust prices more quickly due to the time that in-store staff members must spend on updating on-shelf price tags. In contrast, ESLs allow retailers to change product prices and update price information on shelves in real time. Retailers have thus learned that ESL should be neither overlooked nor undervalued, offering them certain advantages in leveraging and reshaping existing business practices. In the early phases of implementation, ESL can help reduce costs and boost store operation efficiency. By inviting players from other industries to participate in cooperative actions, ESL implementation actively encourages retailers to enhance features and functions while maximizing their current benefits. ESL shifts a hardware solution into a "connected labeling" one.

The evolution of ESL during the digital transformation motivates the present authors to understand comprehensively how digital transformation can align with this technical evolution. Technology can change through iterative and continual refinement, molding it to a particular environment or business and altering related business models. Extant research has revealed that the installation of ESL can increase gross margins (Stamatopoulos, Bassamboo, and Moreno, 2021) and customer well-being (Ovani and Windasari, 2022). Besides, prior research on digital transformation has identified certain benefits (Ferreira, Moreira, Pereira, and Durão, 2020; Hokkanen, Walker, and Donnelly, 2020; Pereira et al., 2022; Pereira and Frazzon, 2021), actors' roles (Alaassar, Mention, and Aas, 2020; Audrin, 2020), and factors in digital transformation (Matarazzo et al., 2021; Solberg, Traavik, and Wong, 2020). However, these studies fall short of how digital transformation can align with the technical evolution of devices, particularly through actor-network interaction.

By answering the following research question, our study aims to fill this research gap: how do retailers conduct collaborative actions with other actors in the ecosystem to

advance the technology and turn it from a device into a solution?

The evolution of the ESL device creates a unique outcome. ESL shifts from a piece of hardware into a solution that may change the retail ecosystem by offering new services or products. Retailers anticipate ESLs to improve client experiences and bridge the gap between online and offline settings. Digitization of price and product information can then expand to become more fluid, allowing flexibility for information flow across different platforms, not only on shelves. Theoretically, we can see this phenomenon in terms of product and price information dematerialization, where dematerialization can be conceptualized as the capacity to decouple the informational components of assets or resources from physical environment (Lycett, 2013).

Specifically, dematerialization means lessening our reliance on physical resources. For instance, Spotify can dematerialize our music consumption into a digital format, reducing reliance on physical compact discs. Digital dematerialization can also help reduce the use and investment of specific production resources. ESL can dematerialize the product information and prices from the physical information on the shelf into a digital format. It can influence the liquidity of the information, which is easily manipulated and moved around different kinds of platforms. With information becoming more liquid, offline and online channels become closer; ESLs enable retailers to better manage omnichannel strategies and change the existing business landscape (Normann, 2001). Retailers can promote products through reconfiguration and the entire value-creation process to optimize its elements for relevant actors, asset availability, and asset costs, rather than just the physical object. In other words, retailers can change the business landscape through a connected labeling solution.

The liquification of the information occurs not only in a specific layer in the ecosystem. Dąbrowska et al. (2022) conceptualizes that four layers in the ecosystem can be affected by such digital transformation and change existing behavior: individuals (Micro Level), organizations (Meso Level), ecosystem (Macro Level), and society (Meta Level). This conceptualization aligns with network embeddedness theory (Granovetter, 1985), positing that the outcome of socio-economic activity affects the actor itself and the overall network in which the actor resides. Supporting this theoretical background, the socio-technical activity of technology adoption in digital transformation should be able to affect not only individual actors, but also all networks at different levels (Breslin,

2011; Cennamo, Dagnino, Di Minin, and Lanzolla, 2020; Dąbrowska et al., 2022; Ekbia, Mattioli, Kouper, Arave, Ghazinejad, Bowman, Suri, Tsou, Weingart, and Sugimoto, 2015).

These insights lead us to conclude that the information's liquification will impact ecosystems and organizations of all scales, not only at the level of a single client. Nonetheless, past studies have significantly neglected the dematerialization and liquification of the information at the various levels. As a result, we extend our research, aiming to answer our second research question: how does digital transformation facilitate the dematerialization of information, leading to a business model shift in operations?

ESL is a critical object in the dematerialization process of product information, which separates the information from the physical environment to the virtual environment. To answer aforementioned two research questions, the current study employs actor-network theory (ANT) (Callon, 1999, 2007). Here, an actor denotes an individual or organization carrying out and acting with certain tools or technological devices. Social actors in the digital transformation are distributed at different levels, following the ecosystem hierarchy at the micro, meso, and macro levels. At the micro level, actors can be identified as individual customers or employees. A group of individual customers and employees form an interaction network at the meso level and generate an organization, while at the macro level, different industries connect to share resources. Using the ANT theoretical perspective, the current study can clearly illustrate how social and technical systems interact during digital transformation. Explaining the digital transformation process from an ANT perspective is appropriate, since digital transformation is also a socio-technical system for adopting technology (Nadkarni and Prügl, 2021), which creates an interaction network between social actors and technological artifacts. Additionally, studying ESL as a key artifact in a social context, we also need to clarify the definition of the technological artifact. A technological artifact can be defined as a specific machine, technique, gadget, appliance, or device that appears in our daily lives.

Finally, to understand this relationship and experience, ANT offers a rich set of concepts to help researchers determine technology utilization in a social context with network elements such as humans, technological artifacts, organizations, and institutions (Callon, 1999, 2007). In understanding the mechanism of ESL evolution and its impact on dematerialization, the current study focuses on ESL as a focal point to explain the

relationships and interactions among actors in the network during digital transformation.

This paper is divided into five main sections. Section 1 provides background information. Section 2 provides a clear understanding of digital transformation by elaborating on the different levels of ecosystem digital transformation mentioned and discussed in prior studies. Section 3 offers the methodology, explaining our exploratory case study of ESL retail transformation using secondary data from internet sources, followed by our coding scheme. Lastly, we elaborate on our findings, discuss the result based on theoretical key literature, and provide the contribution of theoretical and management practices.

2. Literature Review

2.1 ESL and Its Advantages

As illustrated in Figure 1, an ESL device is a device retailers use to display product price information on shelves. More exactly, an e-paper shown on the screen of a digital shelf label system uses a local network to display or update product pricing. Even better, companies can update the system remotely and alter product prices concurrently across all stores. The low power consumption lowers the operational and maintenance costs of ESL. We then explain why ESL is an important focal point for digital transformation and why this technology deserves any attention in the case of retail digital transformation as follows.

First, ESL can open opportunities previously barred, for example, by operation efficiency. For instance, although AI has been applied in retail to forecast prices, the calculation does not suddenly affect prices shown on the shelves in real time. In the past, changing prices required in-store employees to manually change pricing by removing old price tags and placing new ones on the shelves. Such store operations require much in-store staff, increasing operational costs. However, by implementing ESL, retailers can update prices faster and more efficiently. ESL can leverage the use of AI to forecast prices and enable real-time dynamic pricing.

Second, ESL can uniquely enhance customer wellbeing by improving the customer experience (Ovani and Windasari, 2022) through enhancements in a display called Enhanced Display for Grocery Environment (EDGE) (Walton, 2019). ESL can integrate

back-end and front-end systems with fewer defects, for instance, an integration between an enterprise resource planning (ERP) system, warehouse system, and on-shelf system through communication technologies (Hanshow Technology Co., Ltd., 2022a). ESL can be categorized as a front-end interface for customers to gain rich product information, not limited to the product price. Related benefits signal a change in the business landscape, where ESL implementation results in the liquification of information (Normann, 2001)

Figure 1 ESL, Lower One, Attached to the Front Edge of Retail Shelves

Note: Source: e-Ink.

The connectivity between back-end and front-end systems also helps retailers connect multiple channels to close the gap between online and offline environments, enhancing the omnichannel strategy by dematerializing the information mechanisms. Gao and Su (2017) highlight three information mechanisms in the omnichannel in delivering information to the customers: the physical showroom**,** which allows customers to enjoy an in-store experience when visiting the store; the virtual showroom, which gives customers online access to an inadequate signal to their valuations; and the availability information**,** which offers real-time information about whether the store has products in stock. Nevertheless, each mechanism can either positively or negatively impact customer experiences. More exactly, the different information mechanisms of these three tools might influence availability risk, product value uncertainty, and store patronage. For instance, the physical showroom mechanism can expose customers to a higher availability risk and discourage store patronage; the virtual showroom can increase online returns and hurt profits if many customers migrate from offline to online environments. Therefore, an omnichannel retail

strategy requires more emphasis on the implementation of information management and mechanisms.

2.2 Stages of Digital Transformation

Digital transformation is difficult and in a given case it is likely to fail. It needs an iterative process to transform existing business practices through the adoption and implementation of digital technologies (Dąbrowska et al., 2022). Bonnet (2022) identifies three stages of digital transformation: modernization, enterprise-wide transformation, and new business creation. In the first stage, digital transformation involves digitizing existing processes and functions. By connecting products with digital technology, companies should re-engineer the core process, supported by digital technology features (Yoo, Boland, Lyytinen, and Majchrzak, 2012). Digital technologies should be able to be reprogrammed and reconfigured according to the needs of companies and industries.

Once digital technologies are connected to the system, companies face the dual world of offline and online communities. This process is defined as an enterprise-wide transformation (Bonnet, 2022). Companies create possibilities to capture complex cross-value chains enabled by certain efforts. In addition, companies heighten their engagement with digital transformation by creating and implementing various technological interfaces to develop, deliver, and capture more excellent value (Sjödin et al., 2022). For example, the recent development of omnichannel retail offers customers different touchpoints by which to capture more dynamic value within the retail industry (Piotrowicz and Cuthbertson, 2014).

Digital technology investments can open new opportunities to create new revenue streams and optimize existing business processes due to their generative capabilities (Iansiti and Lakhani, 2020; Sjödin et al., 2022). This opportunity arises from increased opportunities for new revenue streams, identified as new digital transformation business creation stages. The transition into new revenue streams should align with the organization's existing processes, structures, and capabilities. Digital technologies can revolutionize how an ecosystem governs innovation to co-create value by rethinking and creating a new boundary to promote combinatorial innovation (Leone, Schiavone, Appio, and Chiao, 2021; Thomas and Tee, 2022). Digital technologies are a platform interface that can connect and integrate diverse groups of actors to co-create and redefine value

propositions in the ecosystem.

2.3 Multi-Level Effect of Digital Transformation: Individual Actor to Ecosystem

As a structuring element for all business models, the ecosystem connects different firms and organizations through an interdependent network to acknowledge value propositions (Adner, 2017; Jacobides, Cennamo, and Gawer, 2018). Structurally, a view of the ecosystem also emphasizes a breakdown of industry boundaries to include an array of interdependent actors. The multiple dependencies of actors in an ecosystem are rooted at the micro level, where actors interact with focal objects (Alexander, Jaakkola, and Hollebeek, 2018), but are also embedded at higher levels. They create network embeddedness that can serve as a more proximate and accessible stimulus for ecosystem research.

In the initial formulation, this notion of embeddedness emerged after Granovetter (1985) observes how economic activity would reside in the network. Then, a robust effect of economic activity in the context of an interfirm network is revealed. An interfirm network captures the contingent aspect of an economic actor's operations while being embedded in a larger social framework. Alternatively, it refers to the contextualization of economic activity in ongoing patterns of social interaction. More specifically, the structure of the more extensive network of relationships in which the actor is embedded influences economic actions and results in addition to an actor's particular relationships with other actors (such as a more extensive network). Economic behaviors are woven into the network of relationships that serve as a proxy for economic activities.

One of the characteristics of network embeddedness is the quality of relationships among organizations and the architecture of network ties, called "structural embeddedness" (Choi and Kim, 2008). It is primarily concerned with how the quality and network design of material and information-trade linkages influence economic activities (Choi and Kim, 2008; Granovetter, 1985). In the context of the interdependency of ecosystem actors, actor relationships can arrange relationship networks, providing unique access to diverse resources, including knowledge, expertise, and technologies (Vargo and Akaka, 2012; Vargo, Akaka, and Vaughan, 2017). Structurally, the ecosystem can provide a valuable impression of how socio-technical activities might influence diverse actors in multi-level dependencies.

Digital transformation as a socio-technical activity transcends organizational

boundaries (Nadkarni and Prügl, 2021), providing positive and negative influences beyond organizations and affecting individuals, such as employees and individual customers (Dąbrowska et al., 2022; Dattée, Alexy, and Autio, 2018). However, prior studies have mainly focused on digital transformation's impact on a silo approach, as shown in Table 1 (see section 3.1). It is essential to understand how different levels of analysis of digital transformation can be affected, including individuals and other organizations in the interconnected network (Dąbrowska et al., 2022).

Digital transformation refers to socio-economic changes from a multi-level perspective: individuals, organizations, ecosystems, and societies through adopting and utilizing digital technology (Dąbrowska et al., 2022). This definition highlights elements critical to digital transformation: socio-economic changes to explain the nature of digital transformation's influences and a multi-level perspective to analyze the affected levels, with digital technology as the vehicle of change. In this study, we want to understand the impacts of adopting a specific digital technology in a particular ecosystem, the retail.

2.4 Retail Ecosystem and Digital Transformation Effects in Multi-Level Perspectives

In a retail ecosystem, actors exchange information and resources that can affect experience significantly by altering value and wellbeing within the ecosystem (Gardiazabal and Bianchi, 2021). A retail ecosystem can be conceptualized as a group of actors interacting and sharing resources within a retail industry through an omnichannel interface (Böttcher, Rickling, Gmelch, Weking, and Krcmar, 2021; Gardiazabal and Bianchi, 2021). A retail ecosystem has traditionally been represented as a low-technology ecosystem requiring digital advancements to offer new service offerings and to enhance the customer experience (Hilken, Heller, Chylinski, Keeling, Mahr, and de Ruyter, 2018; Palmié, Miehé, Oghazi, Parida, and Wincent, 2022).

The retail ecosystem has been studied for many decades in the case of digital transformation because many technologies can be applied and developed to ease customers' purchasing transactions. For instance, technology development can cause the disruption of the retail ecosystem. The development of e-commerce as a technology platform can also collect some external complementarities (Bärsch, Bollweg, Lackes, Siepermann, Weber, and Wulfhorst, 2019; Reinartz, Wiegand, and Imschloss, 2019) to satisfy buyers and offer more options compared with traditional stores (e.g., mom-and-

pop shops). Disruptions due to technology adoption in the retail ecosystem have been highlighted and can benefit self-renewal activities to restructure retailers (Böttcher et al., 2021; Palmié et al., 2022).

Recent technological development has accelerated changes and created disruptions in the retail ecosystem. In this section, we identify several prior studies within the last five years on which particular levels the digital transformation has influenced and what consequences have appeared on this level, as shown in Figure 2. More elaborately, digital technologies—such as artificial intelligence, big data analytics, digital platforms, self-service kiosks, service robots, virtual reality, and augmented reality—have been transforming the retail ecosystem for a decade. According to our findings from the previous literature, digital transformation in the retail industry can affect individual customers at the micro level, retail organizations at the meso level, and the retail ecosystem at the macro level. Individually, digital transformation enhances customer experiences by creating and enabling an interdependent relationship between humans and technology (Grewal, Kroschke, Mende, Roggeveen, and Scott, 2020; Hoyer, Kroschke, Schmitt, Kraumme, and Shankar, 2020). Digital technology offered through an omnichannel strategy in retail can increase customer engagement by addressing customer behavior, perceptions, and emotions (Dąbrowska et al., 2022; Hilken et al., 2018; Meyer, Helmholz, and Robra-Bissantz, 2018). Hence, in this situation, digital transformation affects actor engagement at the micro level (Alexander et al., 2018).

Organizationally, retailers can use digital transformation to gain more revenue through different profit foci and create more resilient organizations in crisis and uncertain conditions (Mujianto, Hartoyo, Nurmalina, and Yusuf, 2022; Papanagnou, Seiler, Spanaki, Papadopoulos, and Bourlakis, 2022). Digital transformation also provides a new business process in retail by facilitating some changes in the working procedures. With these promising indicators, retailers' staff can work more efficiently and help retailers reshape their existing structure into a more flexible one (Fletcher and Griffiths, 2020; Krymov, Kolgan, Suvorova, and Martynenko, 2019). This efficient working procedure can help provide a more convenient and faster customer shopping experience across different digital platforms (Bärsch et al., 2019; Fletcher and Griffiths, 2020; Ishfaq, Davis-Sramek, and Gibson, 2022).

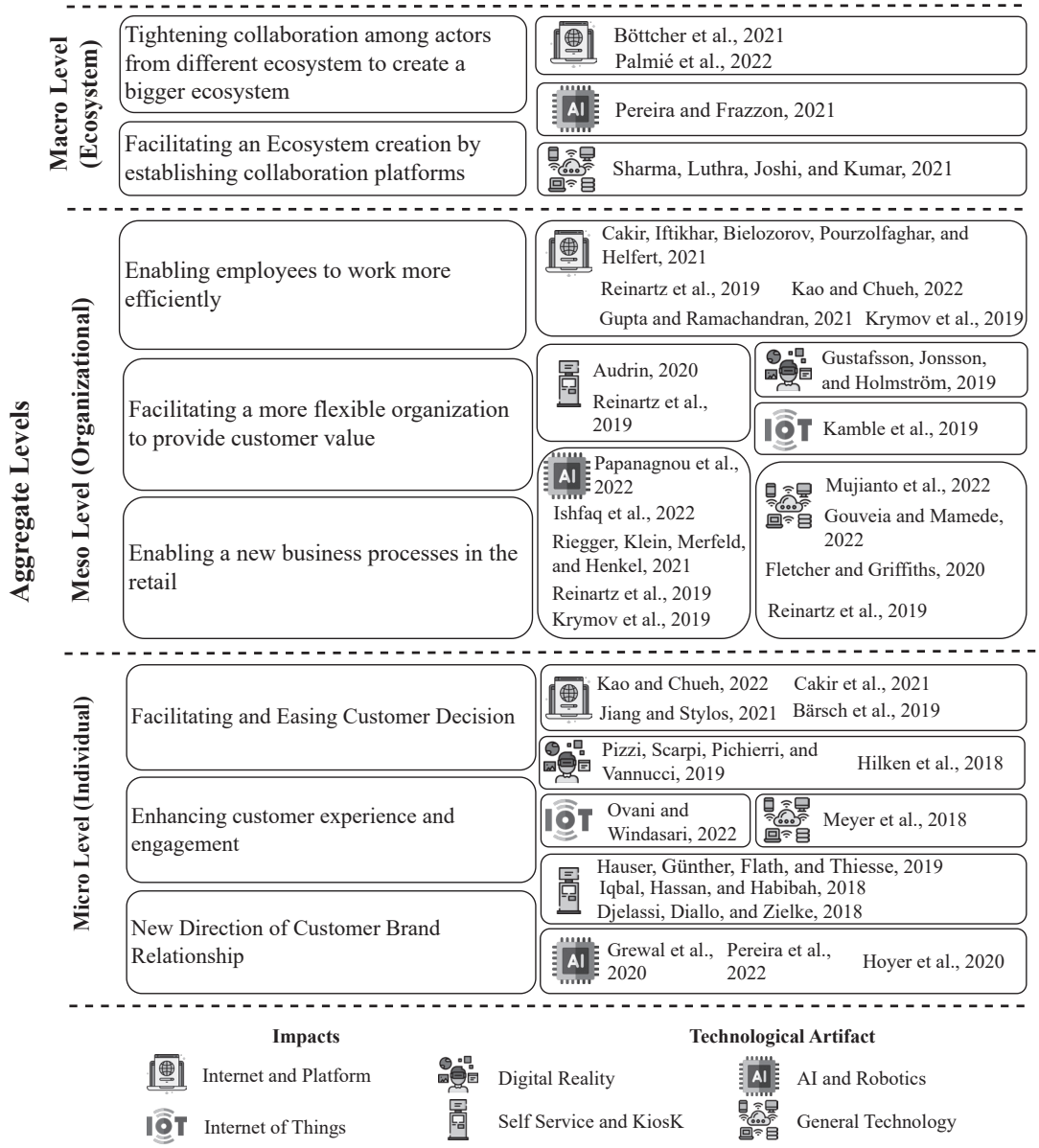

Figure 2 Prior Literature on the Retail Digital Transformation

On the other hand, retailers can also collaborate and gather with different actors and strengthen connectivity in the network (Böttcher et al., 2021). Retail digital transformation impacts the existing supply chain structures and integrates responsiveness into the new

value chain and interfirm relationships. Relatedly, digital innovation is enabled by the inter-organizational level at the meso-level of actor ecosystem engagement (Alexander et al., 2018). Further, digital transformation can also increase interactions among actors at the macro level by creating different types of collaborative action to form value chains or enhance existing ones in the ecosystem (Böttcher et al., 2021). These collective actions can invite different kinds of actors to join the ecosystem to increase the capacity and capabilities within the ecosystem, constituting a meta-ecosystem (Palmié et al., 2022).

2.5. Information Density: Dematerialization and Liquification

Density means the degree to which such mobilization of resources for a time/space/actor unit can occur. The density opportunity is primarily driven by new technology, which provides a breakthrough in the opportunity to restructure or reconfigure activity sets (Normann, 2001). The restructuring can generate two major implications in the process, namely shattering and re-linking a similar process, as mentioned by Normann (2001):

> *The density opportunity is driven primarily by new technology and, to a great extent, by our imagination and mindsets … Such restructuring implies two basic processes. The first is achieved by shattering activity sets and assets that used to be closely linked to each other, and the second comes from being able to re-link activities and assets that used to be impossible, difficult, very time-consuming, or too expensive to put together … The first thing in this set of driving forces, thus, is related to the ability to "break up" or "unbundle," and the second to the ability to "link" and "put together" or to re-bundle.*

Shattering a set of activities can provide a mechanism to separate the information from the physical world, a process known as dematerialization (Normann, 2001). As Lycett (2013) notes, "Dematerialization highlights the ability to separate the informational aspects of an asset/resource and its use in context from the physical world". The separation of information from the physical world requires a technological infrastructure to help place information in free-flowing real time. For instance, Lycett (2013) explains this dematerialization process in the disc rental model for the distribution of video content. The disc rental business model already provides data on the subscriber queue. From the subscriber's perspective, the queue can provide data on how the resources of the disc

rental go and clearly show a present value-in-use. However, online streaming or video-on-demand platforms have removed this queue, having dematerialized the structured and standardized metadata of the disc rental. IT infrastructure have changed and dematerialized this information. Mechanisms like this one can be dematerialized by technological infrastructure.

Once information is dematerialized from the physical world, it can easily be manipulated and moved around. The dematerialization creates liquid information that can be easily bundled and unbundled (Lycett, 2013; Normann, 2001), since IT infrastructure can liberate us from time (when things can be done), place (where things can be done), actors (who can do what), and configurations (with whom it can be done). As an outcome for the value co-creation process of this dematerialization process, information density comprises a (re)combination outcome mobilized for a specific time and place.

Unbundling and re-bundling information can appear in the online streaming business model. The liquefaction of subscriber information can provide a flexible choice to watch their favorite movies easily without any constraints. Further, it can also offer a dynamic recommendation system for subscribers to watch similar movies due to the liquefication of the subscribers' information. It can help explain the content to promote trust, rating, ranking, and review. Streaming services can rebundle this process by providing a similar recommendation system to other subscribers. Customers can be involved in the co-creation process in this resource integration as the outcome of the dematerialization process, including bundling and re-bundling activities.

3. Research Methodology

3.1 Data Collection and Analysis

We conduct an observatory case study with ESL as a key actor in retail digital transformation (Eisenhardt, 1989) by collecting internet data to answer our research questions. Internet data sources can be categorized as secondary data, which can be undertaken if the interview and direct observation are not possible. Secondary data sources can help scholars reduce the distance between the researcher and the original data context (Romano, Donovan, Chen, and Nunamaker, 2003). In addition, employing and utilizing substantial data sources can provide essential stakeholder perspectives, which might be

necessary to sensitize particular initiatives to respond to environmental changes (Hargadon and Douglas, 2001). We argue further that digital transformation is a multi-faceted environmental change, thus requiring key stakeholders' perspectives to help authors answer the research questions. Hence, an observation case study can help explain certain skewed views among essential stakeholders, collect them, and collate them (Silverman, 2021). This research analyzes how ESL, as a digital technology adopted by retailers, can enable digital transformation. In addition, we investigate how this technology can provide an underlying mechanism to close the gap between online and offline touchpoints in retail for the omnichannel mechanism.

Second, our data sources are from massive and publicly available data sources using the English language, such as online news, corporate blogs, press releases, and online interview videos (see Table 2). We also have some exclusion criteria to help researchers sort out some irrelevant and uncredible articles, such as: (1) the news or articles are not from a news company with an excellent international reputation, such as the BBC, Forbes, or The Times; (2) there is not enough proof of this information on the company's official website; and (3) the articles do not relate to our research questions and objectives. All three authors engage in the preliminary sorting process and thoroughly determine the inclusion of our data sources. With such a careful and thorough research methodology, we believe the current study result can help illustrate the actual case.

Third, our data sources derive mainly from various internet sources from January 1, 2017, to September 30, 2022. This period is essential to understand the digital retail transformation, as retailers have introduced hybrid e-commerce shopping experiences to the market, known as the "New Retail" concept. With this new shopping experience, customers can freely access products online or offline, experiencing omnichannel shopping in the retail store (Deloitte Touche Tohmatsu Limited, 2018, 2020). Omnichannel starts with the emerging use of digital touchpoints in retail stores, where customers can interact with the same retailers through different channels and encounter price discrepancies (Deloitte Touche Tohmatsu Limited, 2018). As illustrated in Figure 2, different types of technology have been involved in this reshaping retail experience with three major changes: (1) optimizing the existing retail business; (2) expanding the existing retail business; and (3) inventing new products and technologies for (new) customers (Deloitte Touche Tohmatsu Limited, 2020). ESL is expected to bring these three significant retail

changes due to implementing and utilizing this device to enable digital transformation.

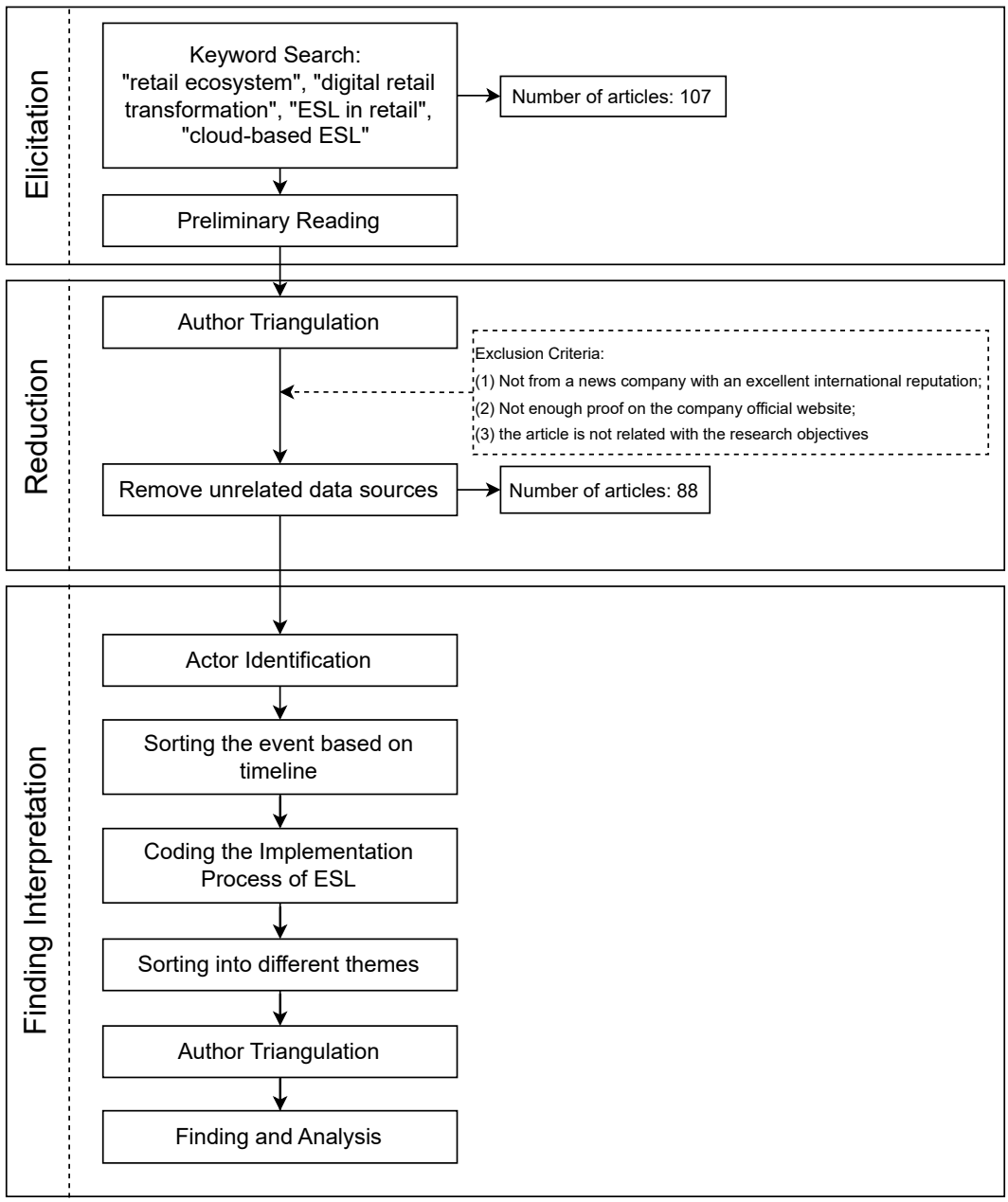

Figure 3 Research Methodology

Figure 3 shows the research methodology for this study. The data collection process

contains three steps: elicitation, reduction, and finding interpretations. First, we collect data from a comprehensive industry review of retail digital transformation trends. We search through the Internet by using keywords: “retail ecosystem,” “digital retail transformation,” “ESL in retail,” and “cloud-based ESL.” In addition, we set the region/country option to “all” to provide a comprehensive worldwide trend of this ESL technology implementation. By conducting an extensive industry review of the ESL and retail industry, we understand the industry context, such as technology, customer needs, value chain, and key actors in developing and deploying ESL technology. To begin our data analysis, we identify and categorize different actors according to each role, with a specific definition. Table 1 categorizes the actors.

Table 1 shows our category for each actor involved in the ESL-driven digital retail transformation. We classify them according to their roles during the implementation and development of ESL for the retail ecosystem. Since it is possible to place technological artifacts within this socio-technical interaction, we also identify those involved in digital transformation.

Following actor identification, authors sort events based on the timeline and code them to gain a greater understanding of each happening. Then, each author reads the data sources and meets regularly with the others for author triangulation. We remove 19 unrelated articles from our data sources, since they provide no relevant information about ESL. Our final dataset comprises 88 rich articles offering insight into how ESL can enable digital transformation in the retail ecosystem and the consequences at the organizational and ecosystem levels. Our dataset can be considered a transparent representation of how corporate operations and decision-making processes are created. We analyze our dataset by applying a coding process, identifying actors and mechanisms for this digital transformation, and ordering findings according to the timeline. Figure 4 presents our coding scheme.

Lastly, we did another triangulation of our findings to confirm the reliability of the results for this study.

Table 1 Categorization of the Actor

Actor	Description	Actors Example	Sample of Sentences
Retailers	A person or business that sells goods to the public in relatively small quantities for use or consumption rather than for resale.	Carrefour Alibaba Auchan Ahold Delhaize Super U Store Walmart	Retailers like Walmart are adopting ESL to electronically display the pricing of products (Bukhari, 2019).
ESL Technology Supplier	A company or collective companies that offer and deploy ESL systems to retailers.	Bison Pricer Hanshow SOLUM	Pricer announces that the retail group Carrefour has chosen Pricer as preferred supplier for new ESL (Pricer AB, 2020). Installations and upgrading of stores that are already equipped with Pricer's ESL (Pricer AB, 2020). Alibaba has chosen SOLUM as its ESL provider for its 65 stores located in major cities across China (Solum Co., Ltd., 2024a).
ESL System Integrators	A company or collective companies that specialize in adding some subsystems and features to enhance ESL features and functionalities.		
Digital Service Providers	A company of collective company that provides online computing services during innovating ESL features and functionalities.	Microsoft Vantiq Software Vendor Platform Provider AI Company	As Hanshow continues to expand its digital offerings to retailers, a new collaboration with Microsoft for its recently announced Microsoft Cloud for Retail (Hanshow Technology Co., Ltd., 2022b). An AI algorithm developed by Albert Heijn considers various factors to calculate the best price (Koninklijke Ahold Delhaize N.V., 2019a).
Technology Complementors	A company or collective of companies aside from ESL technology suppliers, digital service providers, and ESL system integrators that provides some technological components to enhance ESL systems.	Payment Application Provider Weather Beaurue AI-Camera Provider	Application can be added with color price tags and promotions on electronic shelf labels (Dalian Sertag Technology Co., Ltd., 2022). With the introduction of specialized AI, the need has arisen for connected cameras and sensors that are designed explicitly for store environments to enable a wide range of use cases (Pricer AB, 2020).
Technology Artifact: ESL	A device retailers use to display product price information on shelves.	ESL Hardware ESL Connected Label Solution	Pricer announces that the retail group Carrefour has chosen Pricer as preferred supplier for new ESL (Pricer AB, 2020). Installations and upgrading of stores that are already equipped with Pricer's ESL (Pricer AB, 2020). With reliable and robust wireless communication components, ESL solutions dramatically reduce labor costs and error rates compared to manually updated labels (Wireless Future, 2022). Establishing a true, global ESL standard gives retailers the freedom and confidence to source ESL components from multiple vendors, knowing each will work with the others (Bluetooth SIG, Inc., 2024). The ESL are controlled using wireless technology and android application (Bison Schweiz AG, 2021).
Technology Artifact: Cloud Services	Applications and IT infrastructure resources that exist on the internet.	Microsoft Azure	As Hanshow continues to expand its digital offerings to retailers, a new collaboration with Microsoft for its recently announced Microsoft Cloud for Retail (Hanshow Technology Co., Ltd., 2022b).
Technology Artifact: Internet Platform	Any particular websites that facilitate a service or interaction between customers and companies.	Payment Platform E-Commerce Platform	When customers point their smartphones at the ESL, it sends product information such as price, ingredients etc. to an app or web URL. Customers then decide whether they want to purchase the item or not. If they do, they can use this as a mobile checkout (Kuhlow, 2019).
Technology Artifact: Artificial Intelligence	A computer or machine that can perform some cognitive functions usually associated with the human mind.	AI-Camera Provider	With the introduction of specialized AI, the need has arisen for connected cameras and sensors that are designed explicitly for store environments to enable a wide range of use cases, providing real-time alerts to store manager using Pricer ShelfVision (JRTech Solutions, 2021).
Technology Artifact: Other Technology	Technology aside from cloud services, internet platforms, and artificial intelligence that can be integrated and deployed in the ESL system.	Price Crawler API	Again, partnering with price comparison sites makes life easier for both parties and gives businesses access to the app channels as well (Akrin, 2021).

Table 2 Summary of Internet Data Sources

Data Sources	Description	Number of Data	Topic Covered
Corporate official blog and press release	The official announced information about retail digital transformation, including new technology, solutions, and partnerships.	38	E-paper technology, Actor interactions, Technology and corporate development, Technology features
Online news publications	Authoritative news sources such as BBC, The New York Times, Forbes, Reuters, Bloomberg, etc., which talk about new retail and feature interviews of studied companies' executives. Retail industry news websites including Futureshelf, National Retail Federation, and Europe Supermarket Magazine.	23	Technology applications, History of ESL development, Technology development
Online Videos	Technology introductions from digital technology and system integrator companies. Interviews of studied companies' executives talking about new retail technology, solutions, ambitions, and trends.	15	ESL Technology, Technology application, Actor interactions for technology development, ESL features
Consultant Report	Research and insights reports published by authoritative and famous consultant companies such as Deloitte, PwC, and Accenture. The overview of the retail industry and retail ecosystem, including market trends, contexts, strategies, main actors, etc.	12	Ecosystem and actor interactions, Technology application, ESL technology, Industry value chain, Technology features

Examples (From Data Sources)	First Order Category	Second Order Category	Aggregate Dimensions
Hanshow, a Microsoft global ISV, was announced as an official partner in the new Microsoft Cloud for Retail network, allowing Microsoft cloud technology to support Hanshow's retail solutions, opening a vast new range of digitalization opportunities that make retail more efficient, engaging, and sustainable (Hanshow Technology Co., Ltd., 2022b)	Official Partner	(AI1) Collaborative Actions	Actor Interactions (AI)
Hanshow Works with Intel and Microsoft to Accelerate Smart Retail Innovation (Hanshow Technology Co., Ltd., 2022c)	Working Together		
The ESL system that the French grocery store Migros Etrembières had in place was reaching end of life. After an evaluation, the Pricer system with the cloud solution Pricer Plaza was chosen (Pricer AB, 2022)	Technology Implementation		
Hanshow, a Microsoft global ISV, was announced as an official partner in the new Microsoft Cloud for Retail network, allowing Microsoft cloud technology to support Hanshow's retail solutions, opening a vast new range of digitalization opportunities that make retail more efficient, engaging, and sustainable (Hanshow Technology Co., Ltd., 2022b)	Resource Sharing		
Pricer ShelfVision is a wireless camera designed for integration (. ...) Using image processing and AI the system (Federal Communications Commision, 2021)	AI Camera and ESL	(AI2) Technology Artifact Connectivity	
AI and IOT are transforming business models by helping companies move from simply making products and services (Hanshow Technology Co., Ltd., 2022c)	AI and IoT Interaction		
Hanshow's intelligence-enabled platforms and systems deliver customer-centric insights, helping retailers streamline operations and providing various solutions to support optimal pricing strategies to offer consumers a more personalized experience (Hanshow Technology Co., Ltd., 2022b)	Price and Product Changes Automatically	(ID1) Digitization	Information Density (ID)
ESL Makes the switch to digital price tags is not as complex as you might think (OpticonWorld, 2020)	Digital Price Tags		
Electronic Shelf Labels (ESLs) are digital product labels or tags that display digital price, inventory and product name. This is done by synchronizing a Point of Sale (POS) register's product information wirelessly in real time (OpticonWorld, 2020).	Digital Product Labels or Tags		
Hanshow's intelligence-enabled platforms and systems deliver customer-centric insights, helping retailers streamline operations and providing various solutions to support optimal pricing strategies to offer consumers a more personalized experience (Hanshow Technology Co., Ltd., 2022b)	Present Product and Pricing Information	(ID2) Dematerialization	
SOLUM are much more than just electronic price displaying tags, since (...) dynamic pricing, which means that automatic price changes can be triggered in real time (Solum Co., Ltd., 2024a)	Digital Price		
ESL users use label management systems to enter the data they want their ESLs to display. They are usually installed in desktop and laptop computers under businesses using ESL (Solum Co., Ltd., 2024b)	Entering Data to Digital System		
An algorithm developed by Albert Heijn takes into account various factors to calculate the best price (. ...) include location, bonus offers, weather conditions, historical sales performance and in-store stock (Pricer AB, 2019)	Adding Information to Price	(ID3) Rebundling Information	
Here are two examples of dynamic pricing. On Black Friday, Amazon changes its prices of highly competitive items (. ...) matches the doorbuster pricing of store-based retailers. A more sophisticated example: consumers buy more salads when it's over 80 degrees outside. A retailer or restaurant could easily capitalize on the trend by dynamic pricing (. ...) once the temperature hits that point (Baird, 2017)	Additional Information Price Changes		
As your customers don't have physical access to your products like they would in a retail outlet, this product information (. ...) But it's not just about syndicating product information across your online channels, though. (Inriver, 2022)	Split Information	(ID4) Unbundling Information	
Hanshow provided a stack recognition solution based on AI cameras that took high-frequency images of fresh food stacks to upload information such as display area and location in real-time (Intel Corporation, 2024)	Upload Information	(ID5) Outsourcing Information	
The offering of the whole range of in-store communication will be enhanced and at the center of the company strategy. This will enable retailers to engage with shoppers, staff, and suppliers to enable store process efficiency and increase sales (Tech Company News, 2022)	Customers Engagement	(IE1) Customers Engagement and Experience	Impacts of ESL (IE)
The offering of the whole range of in-store communication will be enhanced and at the center of the company strategy. This will enable retailers to engage with shoppers, staff, and suppliers to enable store process efficiency and increase sales (Tech Company News, 2022)	Real-time in-store communication		
Electronic Shelf Labels (ESLs) are digital product labels or tags that display digital price, inventory and product name. This is done by synchronizing a Point of Sale (POS) register's product information wirelessly in real time (OpticonWorld, 2020).	Product and Pricing real time display	(IE2) Better Store Operation Management	
The offering of the whole range of in-store communication will be enhanced and at the center of the company strategy. This will enable retailers to engage with shoppers, staff, and suppliers to enable store process efficiency and increase sales (Tech Company News, 2022)	Store management efficiency		
start by finding your significant competitors and tracking their price changes (Tech Company News, 2022)	Price Changes	(IE3) Dynamic Pricing	
In this environment, retailers have become increasingly challenged to find the optimal price for their products. One way to overcome this challenge is with dynamic pricing, a technology-based strategy that allows businesses to set flexible prices based on current market demand, competitor prices and other external factors (Tanir, 2023)	Technology-based Flexible Price based on market demand, competitor prices, and others		
Retailers are (...) experience omnichannel's complexities, but customers as well. As customer experience is (...) , retailers must ensure (. ...) From brick-and-mortar to e-commerce, there must be a seamless connection (smooth transition of customers between these channels) (Solum Co., Ltd., 2021)	Omnichannel Strategy	(IE4) Omnichannel Strategy	
"Through the extensive application of AI, retail can become smart, providing better operational excellence, intelligent supply chain, and stronger business intelligence. We are committed to collaborating with the industry and with our partners, such as Intel and Hanshow to advance AI-driven innovation and build an active ecosystem to support the next generation of smart retail." (Hanshow Technology Co., Ltd., 2022d)	Intelligent Supply Chain with an active retail ecosystem	(IE5) Tightening the Value Chain Ecosystem	
a higher value can be brought by AI-technology applications focusing on retail data insights, supply chain optimization, and related fields (Hanshow Technology Co., Ltd., 2022d)	Supply Chain Optimization through interoperability data		
With IoT's effectiveness in reducing inventory and supply chain management errors, improving retail operations efficiency, and reducing labor costs, it is no wonder up to 80% of these early adopters report improvements in efficiency and increase in profitability (Solum Co., Ltd., 2020)	Increase Supply Chain Network Efficiency		

Figure 4 Open Coding Scheme

4. Findings: Stages of ESL Retail Digital Transformation

Digital transformation in the retail ecosystem focuses on certain benefits at different levels, such as the individual (Meyer et al., 2018), organizational (Reinartz et al., 2019), and ecosystemic (Palmié et al., 2022). The outcome of the digital transformation is promising, and retailers can benefit by adopting emerging technology. Retailers should be able to follow the iterative processes for introducing digital technologies into bricks-and-mortar business. Jeniffer Guan, Hanshow Vice President for Strategy and Partnership, has said that ESL retail transformation happens gradually and continuously:

> *It is true that the retailers who were quicker to adapt new technologies outperformed their peers. For our solutions, we address a number of challenges for customers from a different angle for traditional retailers to save costs and increase efficiencies during difficult times. Efficiency enhancements, such as staffing surges during peak hours, labor costs, space constraints and better productivity management for hundreds of stores across regions, were important for these established retailers. (Zhu, 2021)*

The current study follows (Bonnet, 2022) in capturing ESL-enabled retail digital transformation in three stages: modernization, enterprise-wide transformation, and new business creation. However, Bonnet (2022) overlooks how actors interact in digital transformation and the information mechanism as a consequence of technology's implementation. Digital technology triggers the dematerialization of information and will influence its effect on retailers. Therefore, we extend the conceptualization of digital transformation stages by undertaking and identifying the interaction of the actors and the impact of digital transformation on information density. We argue that digital technology changes information density, with dematerialization mechanisms triggered by devices and affected by technology features. Understanding the information density process will be beneficial to extend digital transformation. Figure 5 explains the three stages of how retailers adopt and adapt ESL in their operations.

4.1 Stage 1: Modernization

This stage describes the early stage of ESL adoption by retailers and technology suppliers to replace paper-based, on-the-shelf labels with electronic ones. ESL technology

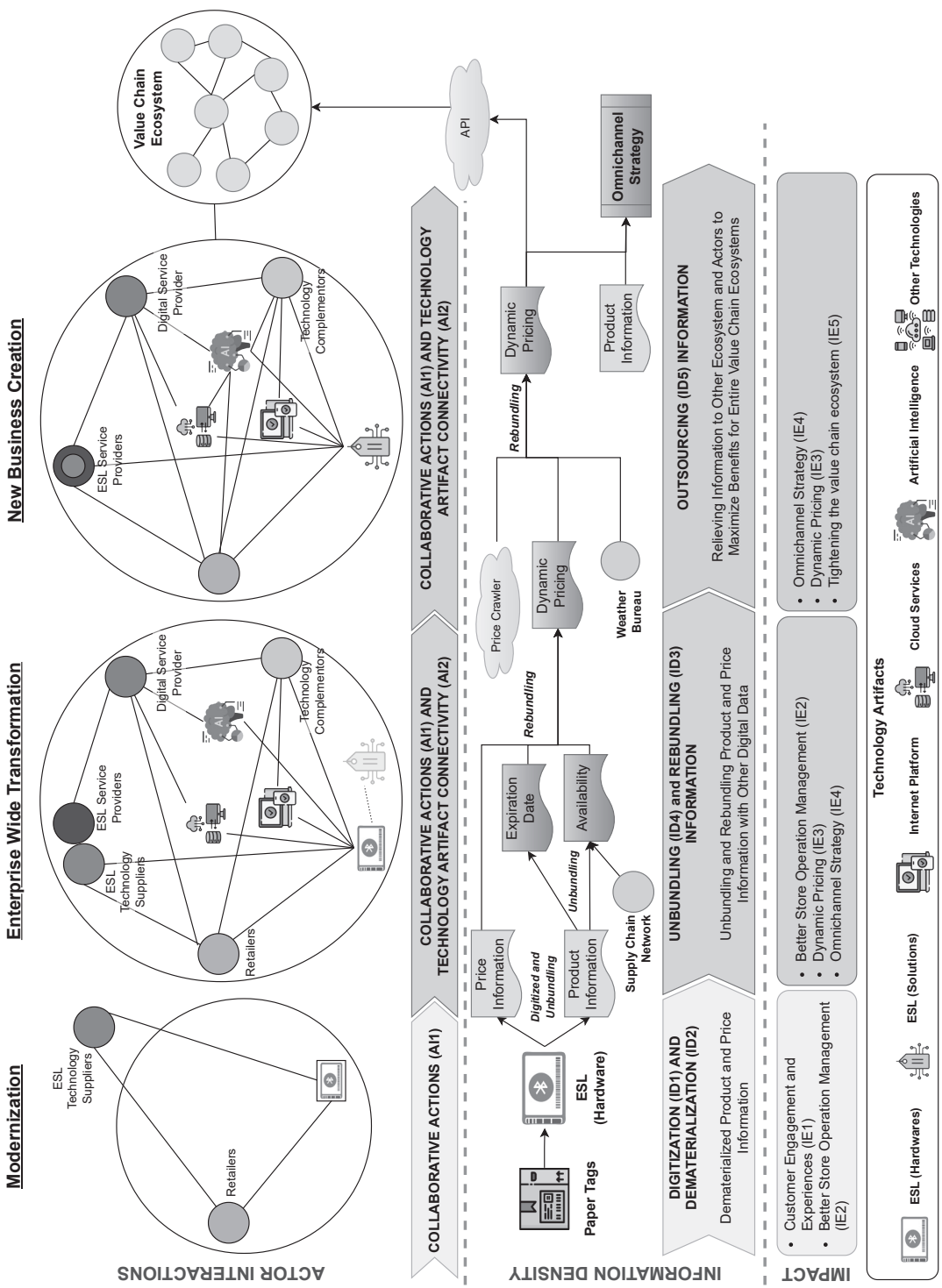

Figure 5 Actor-Network Interactions on ESL-enabled Retail Digital Transformation

Note: These interactions also trigger changes in information density and impact business operations.

suppliers implement ESL in retail. ESL technology suppliers do not involve the retail ecosystem further at this stage, since they only implement the ESL, as shown in Figure 5.

4.1.1 Actor Interactions

Modernization is the first step of digital transformation, involving switching from manual to digital operation (Bonnet, 2022). In the early development stage, retailers adopt ESL to change the existing procedure for price label changes. Before implementing ESL, staff have to spend more hours printing price tags, replacing the old paper price tags by sticking the new ones on shelves for each product and stock-keeping unit (SKU); changing price tags on shelves costs resources including time, money, and labor. The first generation of ESL has made this process become more efficient. ESL can provide real-time on-shelf information display and better control over product information management.

In this early stage, retailers work with ESL technology providers to offer technical support for adopting and implementing ESL for each physical shop. Suppliers of ESL technology provide retailers with ESL technology, including technology infrastructure, on-shelf devices, and handhelds for in-store employees. Businesses frequently worry about the operational value and return on investment when investing in new technologies. At this point, retailers have analyzed certain benefits and reactions from customers and employees due to the implementation and deployment of ESL as a new technology. ESL technology providers are not further involved as a third party, since they only implement and deploy ESL systems for retailers.

Retailers gain enormously from ESL, which also piques their interest in expanding its capabilities through joint innovation with other parties. ESL uptake, though, remains uneven at this point. Our research shows that while some retailers are still not interested in adopting ESL, others have begun to advance the usage of ESL for later applications. Nonetheless, ESL technology providers keep on developing new ESL features in response to store requests with the help of research and development.

Innovating ESL features extends the functionality of ESL, from price display to managing tools. ESL can help retailers manage inventory and alleviate rising operational costs. According to Auchan, France's second-largest retail group, this innovation can extend the retailers' benefits by offering real-time price management and information on the state of stocks (Wynne-Jones, 2017). This statement is supported by another French

retailer, Super U Store, as claimed by one of the store managers (Julien Morize):

> *There are mainly three new features that we use in store. The management data, before the morning, that allows us to see our stocks and all the internal data to prepare the orders. Secondly, the LED flashes, we scan a product and the ESL flashes. This can be useful for a new employee, for example, to find a product more easily. And the third point is internet shopping. We have the same LED display on the next three articles, this allows us to save time and increase productivity. (Hanshow Technology Co., Ltd., 2022e)*.

Moreover, American retailers who have already adopted ESL in their stores also acknowledge these features and benefits, as mentioned by Hanshow US Country Manager, April Cao: "*Now more American retailers have become aware of what electronic shelf labels offer beyond price displaying, especially in alleviating rising operational cost*" *(Hanshow Technology Co., Ltd., 2022f)*.

4.1.2 Information Density

The modernization stage leads to the digitization of product and price information, dematerializing information from paper-based to electronic-based tags. ESL enables the dematerialization of two pieces of information: price information from the physical (Paper) into digital (ESL) and product information from the physical (Packaging) into digital (ESL). Separating the information from the physical and virtual world is the most critical driver of ESL digital transformation, putting that information into a digital world. Once the information is placed in the virtual world, it is accessible to flow in real-time. Retailers benefit from this process, since they can easily update the product and price information, making store operations efficient. Moreover, customers can also have a more engaging shopping experience by reading real-time information with fewer human defects.

4.1.3 Impacts

ESL can improve customer experiences by giving consumers access to current prices and product information at this step. Real-time price and product information can be displayed with the aid of ESL, fostering stronger bonds between customers and retailers. Additionally, ESL can support shops in minimizing the pricing discrepancy

clients occasionally see while shopping. ESL can offer a more individualized purchasing experience, such as product recommendations and in-store shopping navigation, while maintaining pricing at a constant level.

Furthermore, ESL can enable the display of real-time price and product information, allowing retailers to expand their dynamic pricing strategies. Customers can also get more accurate product information and prices, leading to trust and loyalty. ESL can also enhance the customer experience by providing a more convenient shopping experience with fewer defects due to information inconsistency, as well as providing richer product information to help customers evaluate products comprehensively. ESL can enable retailers to adjust product prices to expand their dynamic pricing strategies based on real-time demand and supply trends.

ESL deployment also influences in-store staff efforts by enabling quicker price and product information updates, from manual to automatic. This automated process can speed up operations and reduce human error. To accept the shift in workflow from manual to automatic processes brought on by ESL technologies, employees must learn new skills and alter their cognitive and mental outlook. Retailers can benefit from automated procedures by maximizing human-technology cooperation in daily operations.

Enabling changes in employee working behavior, ESL can reduce human errors and save time. In-store operations become more efficient, and retailers can control operating costs. In addition, it can help retailers manage inventory more precisely. As explained by Rolf Vanden Eynde, a regional IT manager at Ahold-Delhaize, "*ESL improves pricing and promotion management and enhances the client's digital shopping experience. With this technology, costs go down and efficiency goes up*" *(Hanshow Technology Co., Ltd., 2022g)*.

In addition, ESL can optimize employees' working hours and reduce the human faults that sometimes occur while printing hundreds of thousands of shelf labels. The product label is updated through a centralized computer, allowing retail employees to take on higher-value missions, such as talking to customers and addressing complaints. Thus, ESL can optimize the store management process by providing richer information, including range changes and upcoming product delivery dates (Wynne-Jones, 2017).

4.2 Stage 2: Enterprise-Wide Transformation

This stage involves many actors with different skills and knowledge working in collaboration. Consequently, ESL starts evolving into a connected label solution, as shown by the different opacity levels of the ESL (please refer to Figure 5). In addition, there is a change in the role of ESL technology suppliers, who shift their business models into ESL system integrators. They not only supply hardware, but also contribute to an integrated ESL solution that encompasses also certain supporting third-party platforms and devices.

4.2.1 Actor Interactions

The earlier stage shows that ESL benefits retailers in managing product information through digitization. The advantage of implementing ESL is that it attracts other retailers to implement the same devices, catching up with the existing technological trend. ESL functionalities are escalated in collaboration among actors established in the earlier stage. The partnership goes beyond transactional relationships and is governed by rules and institutional arrangements to provide novel features for enhancing ESL capabilities and functionalities. ESL innovations should be able to fit with the existing retail business model. Hence, retailers offer some knowledge of retail business models and processes. At the same time, ESL technology suppliers provide ESL technical specifications. In the earlier stage, ESL is projected to transform from an electronic device into a connected labeling solution, helping retailers overcome existing omnichannel strategies with different information mechanisms. ESL can help strengthen connections between online and offline retail environments (Auchan Retail International S.A., 2019; Solum Co., Ltd., 2019).

Moreover, retailers and ESL technology suppliers in a collaborative network are insufficient to provide clear guidance on developing a connected labeling solution from ESL. They find challenges in facilitating the innovation of ESL. First, how can we advance connectivity between head office and branch integration to extend existing back-office and front-office integration? Furthermore, they also tried to explore how ESL can be integrated with other technologies, such as artificial intelligence and machine learning, to have a successful dynamic pricing strategy.

To answer the challenge of connecting ESL with other advanced technology, digital service providers offer a solution with their technical knowledge, technology infrastructure, third-party boundary resources (e.g., API), and web and mobile application platforms.

Third-party collaborations to develop and innovate ESL gain much attention from digital service providers. Other third-party complementors, such as the application developer community, also join the ecosystem to create some mobile and website applications. For instance, ESL system integrators provide access to the developer community to connect retailers with other third-party complementors in developing the platform.

Now equipped and integrated with digital platforms and other computing services, ESL has become more sophisticated. Consequently, its features can help enhance the customer in-store experience, as mentioned by Wouter Kolk, CEO of Adolf Delhaize Europe & Indonesia: "*The digital applications we will develop through this partnership will enhance the customer experience in our stores and allow us to operate more efficiently*" *(Koninklijke Ahold Delhaize N.V., 2019b)*.

ESL can collect individual organizations from various industries with different expertise to explore and extend joint-venture solutions for ESL. Innovation labs, established by other actors, provide a future application for ESL. In this case, the enterprise-wide transformation happens inside and outside the organizations. Inside the organizations, the interdependent relationship has transferred the knowledge and expertise of each actor to the new business, removing some barriers to this challenge. Outside the organization, the co-creation process could be seen as a step ahead in transforming retail ecosystems by connecting actors from new domains and enlarging the collaboration network in the retail ecosystem, including establishing innovation labs.

From the inside and outside, transforming retail ecosystems can handle dynamic pricing for ESL by considering product expiration dates or inventory levels. ESL is now integrated with mobile and web application platforms to enhance customer experiences. A physical store, a rich source of contacts and customer interactions, can be combined with other electronic commerce, providing a new customer behavior to connect online and offline. Showrooming and webrooming customer behavior emerge due to the integration between online and offline retail environments. Webrooming is the customer behavior practice of researching products online before purchasing them in a physical store. Oppositely, showrooming is the consumer behavior characterized by researching products offline before purchasing them in the online store (Mukherjee and Chatterjee, 2021; Verhoef, Kannan, and Inman, 2015). Integrating the online and offline (physical stores) requires retailers to restructure their business and organization and reshape the

current supply chain, warehouse operations, and shipping processes. Retailers need to have efficient and flexible retail operations, since connecting the online with the offline increases complexity and creates pressure on supply chain functions. ESL drives digital transformation by enlarging the retail ecosystem, attracting other actors to be involved, and unlocking a potential omnichannel strategy. However, this raises another question: How can ESL help restructure and reshape existing supply chain functions? It remains a new challenge for ESL innovations at this stage.

4.2.2 Information Density

In the first stage, ESL triggers the dematerialization of price and product information, converting them into a digital format and making the information free to flow. Retailers adopt a dynamic pricing strategy to maximize the benefits of digital forms of price information by considering product availability and expiration dates. This strategy can help retailers balance demand and supply and offer competitive prices to customers. However, to get product availability and expiration dates, retailers should be able to unbundle availability and expiration dates from the existing supply chain network, change them into a digital format, and share them through collaboration with existing supply chain networks. Information sharing through APIs can help fulfill the demand for specific information.

Moreover, the digitization of product information can also connect online and physical environments, facilitating the implementation of an omnichannel strategy that can abandon the distinction between the physical and digital worlds. Retailers should be able to unbundle some information from different actors to implement the omnichannel strategy. Information from supply chain networks should be able to drive the implementation of an omnichannel strategy.

Once the unbundling of the information from different enterprises has been confirmed, retailers should be able to rebundle the information. For instance, the dynamic price can be seen as a new direction for retailers to rebundle price information with product availability and expiration date, create new information density by manipulating it, and display it to customers in real time through ESL or online platforms. Retailers can also rebundle the product information with additional data to provide a more engaging customer experience. For instance, by rebundling product information with recipes, retailers can help customers

arrange their shopping lists and provide shopping recommendations in two channels by maximizing showrooming and webrooming.

4.2.3 Impacts

As explained in the previous stage, ESL can provide retailers with more efficient store management. The efficiency of store operations has been increased by offering best-in-class in-store applications through a strategic partnership among ecosystem actors. ESL enables collaborative innovations among different actors by sharing and integrating their resources and skills to co-create and co-innovate novel ESL solutions, projecting ESL as a connected labeling solution. As declared by Simon Jones, Chief Operation of Store Intelligence,

> *That was the benefit of going with Vantiq for us. We could focus our resources on what we do, not having to worry about how to build all of the other components that need to be made for a client's solution. (Vantiq Inc. and Jones, 2021)*

Implementing a dynamic pricing strategy requires collaboration from different actors. One of the examples from our data sources, Pricer, an ESL system integrator, connected with digital service providers to provide a back-end service for dynamic pricing calculations by integrating artificial intelligence and machine learning into the computing process. For instance, they calculate dynamic pricing according to the expiration date for time-sensitive products such as milk, meat, and seafood. ESL displays the updated product price, varying depending on the expiration date, from the dynamic pricing strategy. ESL can also help retailers launch promotions, making changing the product price easier without spending many resources.

ESL also integrates with certain web and mobile platforms to enhance the customer experience. Software solutions are as diverse, and some web or mobile applications can provide a novel customer experience and better store management efficiencies. Value-added features linked with different platforms can improve the customer experience. ESL can turn the functionality of shelves, which display price and product information, into a professional and interactive tool. Customers can get detailed product and price information, shop, and pay directly from their smartphones.

Integrating online and offline can also provide a new strategy for retailers to

optimize both channels. In the past, e-commerce web sales performance was too weak and inefficient, imposing availability risks which can hamper customer bonding and reduce customer retention. Implementing and adopting ESL changes a label-based price tag into an electronic one and can create a new opportunity to handle e-commerce web sales.

Meanwhile, Bison, an ESL technology supplier in Germany, partnered with the weather company to offer intelligent shelf labels and develop a system to inform customers about retail information based on the weather forecast. This system helps customers develop intelligent shopping behaviors. On the retailer side, this new system can help them control inventory levels more accurately and precisely. As we observe from the findings, we also find a shifting business model process at this stage. ESL technology suppliers become ESL system integrators, as they shift the business model from offering ESL hardware to ESL solutions.

In terms of the retail ecosystem, ESL can turn the traditional retail ecosystem around by attracting different actors to join and interact by sharing resources, knowledge, and skills. The collaboration drives the co-creation process through innovation, enhancing certain features and functionalities of ESL. In the past, retail ecosystems consisted of only actors involved in the retail supply chain network; the retail ecosystem becomes more diverse now through ESL-driven innovation, with actors in different industries.

4.3 Stage 3: New Business Creation

4.3.1 Actor Interactions

ESLs gradually become connected label solutions and the enablers and hubs of other retail digital services by optimizing retail operations, particularly connecting online and offline environments. The retail ecosystem emerges, triggering collaborations among its actors to become firmer and tighter in providing novel solutions for retailers. An omnichannel strategy becomes one potential solution for retailers, but this requires supply chains and daily operations to change concurrently. The development of the ESL as a connected labeling solution requires further advancement to make retail operations more efficient in supporting the omnichannel strategy. To achieve that goal, ESL continues to evolve through collaboration among actors in the network.

ESL has started to connect with the cloud to optimize on-premises databases, likely to connect local and global networks. Due to the development of ESL cloud-based solutions,

collaboration between ESL system integrators and digital service providers becomes tighter and more robust. As declared by Jeniffer Guan in 2021, vice president for strategy and partnership at Hanshow,

> *To realize cloud-based management on the scale of our customers' international operations, we partnered with Microsoft IoT technology to develop a SaaS solution that can handle this massive amount of integration. (Zhu, 2021)*

ESL triggers the development of software as a service (SaaS) at this stage through collaboration between ESL system integrators and digital service providers to help retailers cut the initial infrastructure investment fees. SaaS allows users to license software on a subscription basis and keep data on cloud storage. Blending ESL with cloud services also helps retailers manage the entire store chain and extend the supply chain network—for instance, ESLs can be responsible for tracing every product at every level at the store. Then, the connection between ESL and the logistic system can help in assessing the inventory level and provide some recommendations for restocking. To improve the capabilities of ESL, ESL technology suppliers embed geolocation information that can help locate particular items or products. Geolocation information can also help shoppers and employees find the location of specific products by providing a flashing light on the ESLs. Cloud-based ESL services can offer a viable and durable inventory tracking system by allowing users to update the status of every shipment as it progresses down the supply chain.

ESL is also integrated with an AI camera to detect the product identity and position of ESLs. Digital service providers, ESL system integrators, and ESL technology providers provide AI and machine learning to detect and identify ESLs within their field of view. Based on this capability, it can ensure product locations, detected holes (holes mean no product is found on the shelf), and missing product identification. This feature enables more efficient store management. Shopping platforms and ESL should be able to have data interchangeability that can ease the sharing of data. That is, they provide an API to share data among actors in the ecosystem. APIs enable ecosystem actors to rapidly and effectively implement more advanced technology to help retailers conduct more efficient operations and increase revenues.

We also find that the role of ESL system integrators has shifted from contributors to enablers of value for all new business creation. The evolution of this technology has

advanced from independent pieces of hardware to connected, layered labeling solutions, such as hardware, data, application, services, and other solutions. The collaboration and transformations among actors in the ecosystem evolve the organization's traditional processes, structures, and capabilities. It changes how actors work and collaborate in the ecosystem. It enables the retail ecosystem to co-evolve into a tech-savvy new retail ecosystem where data and analytics can accurately predict the operational performance of products or systems and enhance the customer experience. The feedback loops in the ecosystem are strengthened as more actors join in for value co-creation, resulting in a completely new retail ecosystem.

4.3.2 Information Density

Unbundling and rebundling product and price information can also aid in store operations. To achieve this benefit, retailers should be able to rebundle product information with geolocation information. Geolocation can help retailers have information about shelf arrangement and management. Further, to benefit from this automatic operation, retailers should be able to collaborate with other technology complementors to provide an AI camera. Implementing an AI camera can extend ESL utilization to understand the shelf arrangement and provide feedback when misarrangements happen. Furthermore, an AI camera can provide real-time automated inventory management and share information with supply networks through an API.

Meanwhile, product and price information becomes more complex through unbundling and rebundling the information from internal and external sources. Once this information becomes complex and the new density has been established, retailers should be able to specialize in the information through outsourcing or relieving other actors within the ecosystem. Information specialization through outsourcing can thus help retailers shift their existing business models. Retailers can connect marketing and sales departments with existing value chain networks using a single communication channel and bundling various customer touchpoints. Retailers can shift their business models by integrating information, touchpoints, and value chain networks within their structure and knowledge. The implementation of ESL triggers this integration by digitizing the information, unbundling and rebundling enterprise-wide information, and specializing in information outsourcing.

4.3.3 Impacts

As ESL usage grows, other digital retail technologies provide excellent prospects for efficiency gains. As an enabler for digital innovation, ESL provides a foundation allowing a variety of IoT devices, including shopping applications, smart trolleys, non-contact checkout kiosks, in-store marketing screens, robots for shelf monitoring, and AI cameras. These digital solutions offer numerous advantages, such as decreased operational expenses, improved shopping convenience, and a solid omnichannel strategy by creating a "click and collect" concept.

The ESL innovation involves many actors engaging in the co-creation of new digital solutions. ESL capabilities grow with more cloud-based service providers to replace the existing push update mechanism at this stage. More advanced ESL solutions can increase market demand for ESL implementation, expanding from only being based on one store to more cloud-based service providers to replace the existing push updates mechanism. The connectivity between retailers and their existing supply chain networks is also tightened by ESL, ensuring real-time inventory control management.

Blending ESL with AI can create more sophisticated dynamic pricing by adding indicators, such as weather data and competitors' prices. This advancement requires more data from other complementary sources. The Weather Bureau can provide an API to help retailers collect weather forecast data, while some independent software developers offer a price crawler to collect price data. AI-based dynamic pricing can also change how retailers decide on pricing strategies through intelligent pricing mechanisms. Simon Jones, COO of Store Intelligence, states that integrated and connected labeling solutions can deliver richer information to product shelves: "*I think we're laying the foundation with Vantiq to use newer technologies, faster chips within our ESLs, scaling up, being able to deliver more information onto tags*" *(Vantiq Inc. and Jones, 2021)*.

The installation of the ESL and the evolution of this device have changed the business models of retailers, enhanced by customers' new value creation. ESL enables retailers to adapt to a tech-savvy new retail ecosystem where data and analytics can accurately predict the operational performance of products or systems and enhance the customer experience. The feedback loops in the ecosystem become stronger as more actors join for value co-creation, resulting in entirely new retail ecosystems.

5. Discussions

According to our findings, we discover three primary stages of digital transformation, aligning with Bonnet (2022) three stages in digital transformation. However, Bonnet (2022) does not specify how the information is changing, and in the end, digital transformation can shift business models with advancing devices into solutions. To extend these three stages, we redefine them by considering information density, actor interaction, and the steps of digital transformation. Figure 6 shows those three stages and describes the development of the device into solutions. It also shows the underlying five layers forming solutions: hardware, data, applications, services, and solutions.

5.1 The Five Layers: From Hardware to Solutions

Before explaining the three stages, as well as how digital transformation can describe device evolution in the collaborative network, the authors want to disclose five layers that compose solutions, as we find in the ESL cases: hardware, data, applications, services, and solutions. “Hardware” here refers to tangible devices or systems that can contribute to the solutions. Hardware mainly becomes an interface to gain input or display output from the whole system. For example, connected labeling solutions include ESLs to display product and price information, as well as handhelds to help employees input information into the systems and display stored information.

Data are sent and received by hardware, then processed, organized, and structured to receive information based on different contexts. Hardware changes data and converts it into a digital format, free to flow through various platforms, such as web and mobile applications.

An application is in this context a piece of software developed specifically for use in a different scenario, such as a mobile or web shopping application for customers. According to our findings, price and product information are dematerialized and converted into a digital format. With a digital format, data can be transferred to different application platforms more easily. As the leading actor in the ecosystem, focal actors can connect various applications, enhancing interconnectivity and interoperability among those platform applications (Wulfert, Woroch, Strobel, Seufert, and Möller, 2022). The development of applications can rely on third-party ecosystem complementors to share their resources.

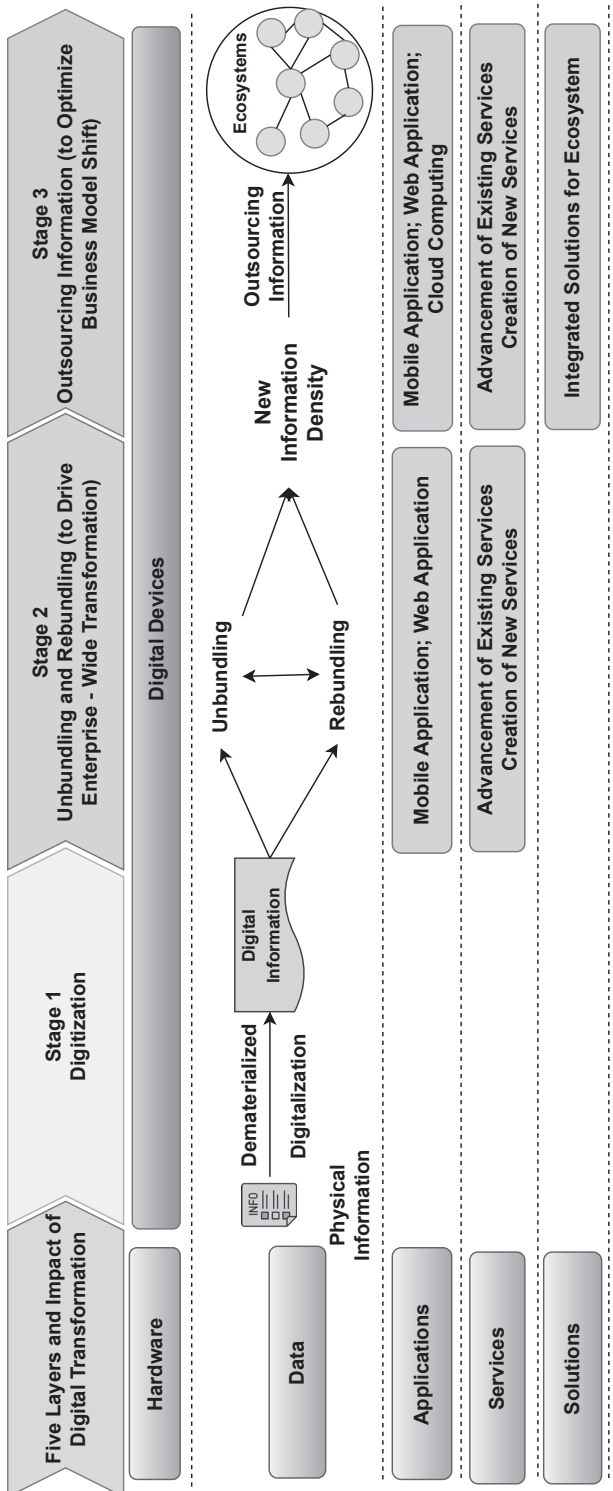

Figure 6 Three Stages of Proposed Digital Transformation

Notes: These stages are derived from Information-density Perspectives: (1) Digitization, (2) unbundling and rebundling (to drive enterprise-wide transformation), (3) outsourcing information (to optimize a business model shift).

Once data and information can be placed on the different applications, focal actors can develop services that can benefit specific individuals or collective users. For instance, retailers can continue to create applications for the front-end interface for customers and other retail ecosystem actors (Wulfert et al., 2022). Retailers, ESL system integrators, and digital service providers create applications to strengthen the bonds among them. Then, retailers can develop services, such as implementing an omnichannel strategy through an online-merge-offline (OMO) approach (for example, webrooming and showrooming) (Herrero-Crespo, Viejo-Fernández, Collado-Agudo, and Sanzo Pérez, 2022; Mukherjee and Chatterjee, 2021). This service can help enhance the customer shopping experience by reducing availability risks and product uncertainty (Cambra-Fierro, Gao, Melero-Polo, and Trifu, 2021; Gao and Su, 2017).

Lastly, once services are applied, focal actors can optimize collaboration with other value chain ecosystems to establish digital solutions, a computerized approach to addressing a specific problem. Digital solutions should be able to integrate and change existing activities (Pagani and Pardo, 2017). ESL can create connected labeling solutions that provide a much broader network to help transform the retail ecosystem through digital technology, from the physical and digital shops to its existing supply chain network. Those solutions should involve the four other layers.

5.2 Proposed Digital Transformation Stages from an Information Density Perspective and Its Impact on Business and Ecosystem

In an ecosystem, various actors are connected through an interdependent network to acknowledge value propositions (Adner, 2017; Jacobides et al., 2018). The ecosystem as a structure emphasizes the breakdown of industry boundaries to include an array of interdependent actors. The multi-dependency of actors interacts with focal objects, creating network embeddedness that can serve as a more proximate and accessible stimulus. Digital transformation occurs in an ecosystem that does not necessarily focus only on the adoption of emerging technology. Moreover, through collaborative actions, technology evolves to fit and enhance existing business models. Hence, technology is changing along with the journey of digital transformation.

As the adopter of the technology, the focal actor installs infrastructure and hardware to connect with digital technology. Adopting technology requires re-engineering as the

core process supported by digital technology features (Yoo et al., 2012). Consequently, it can provide benefits and change the behavior of particularly affected actors. The digital transformation and co-evolution of the device require changes in the information landscape, which can bring changes in the business landscape (Normann, 2001).

Meanwhile, collaborations exist among actors in the ecosystem to enhance the capabilities of the device. Co-creation between actors happens through resource integration, where shared resources can provide substantial contributions to achieve the desired end (Vargo and Akaka, 2012; Vargo et al., 2017). Actors coordinate resource exchange to shape the ecosystem's structure by forming relationships with other actors and determining the optimal value of resources in their respective contexts (Vargo, Maglio, and Akaka, 2008). Hence, resource integration can help form co-evolution and co-creation processes.

We extend Bonnet (2022) stages of digital transformation by including how the changes in the information density landscape happen in those three stages.

5.2.1 Digitization

Digitization is about adopting emerging technology and learning how digital technology can simplify and digitize existing operations. This stage should not be undervalued and derided, since this is the beginning of the digital transformation journey. Focal actors invest in technology infrastructure to adopt the technology. They buy some hardware to be integrated with their existing operations. At this initial stage, technology complementors can provide some reasonably quick returns and benefits to focal actors, fueling more complex digital enhancement. Complex digital enhancement requires collaborative actions among actors and creates stronger connectivity. Hence, complementors should be able to share their technical knowledge, while focal actors contribute to sharing their knowledge of existing business practices. When those two resources blend, technological advancement can fit the existing ecosystems.

Focal actors should also understand basic technological features and what information is affected and changed into digital format through dematerialization and digitization. Once the information becomes digital and free-to-flow, the next step is to form a new density through unbundling and rebundling other information. Further, focal actors should learn how digital information might help improve existing business practices.

Implementing technology and hardware can drive some advantages for workflow and customer satisfaction. Focal actors can improve workflow and customer advantage by optimizing the existing business operations and enhancing the customer experience. For instance, in the case of ESL, our findings show that installing ESL hardware can help customers find information and help retailers more effectively change on-shelf product labels. Installing a digital device can make existing information liquid through digitization and dematerialization. Consequently, it will benefit workflow and customers.

5.2.2 Unbundling and Rebundling to Drive Enterprise-Wide Transformation

Digital technology investments can open new opportunities to create new revenue streams and optimize existing business processes due to their generative capabilities (Iansiti and Lakhani, 2020; Sjödin et al., 2022). This opportunity arises from increased opportunities for new revenue streams, identified as new business creation stages of digital transformation. The transition into new revenue streams should align with the organization's existing processes, structures, and capabilities. As platform interfaces that can connect and integrate diverse groups of actors to co-create and redefine value propositions in the ecosystem, digital technologies can revolutionize how an ecosystem governs innovation to co-create value by rethinking and creating a new boundary to promote combinatorial innovation (Leone et al., 2021; Thomas and Tee, 2022).

At this stage, actors are trying to project future solutions that can be developed from the current device. With the collaborative inputs and actions of ecosystem actors, digital devices can connect with different kinds of applications. Collaborative actions and technology artifact connectivity are the main points in this stage. This process is facilitated through the liquification of the information. Once the information has changed into a digital format, it can be unbundled and rebundled with other information for strategic decisions. For instance, in our findings, some system integrators use AI applications to connect with ESL to enhance their dynamic pricing strategy. An AI application for dynamic pricing can rebundle product prices with product availability and expiration dates. At the same time, retailers can combat food waste through this AI-driven, dynamic pricing.

Moreover, connectivity across technology artifacts can provide interoperability capacity, leading to information exchange across different platforms and networks.

Through information exchange, focal actors can create or enhance new services. Unbundling and rebundling information through interoperability capacity can help redefine enterprise-wide transformation by capturing complex cross-value chains and offering refined and novel values (Piotrowicz and Cuthbertson, 2014; Sjödin et al., 2022). Our findings reveal the exact mechanism of this improvement.

When ESL can connect with other technology artifacts, such as AI and internet platforms, retailers can integrate ESL with web or mobile shopping applications for an omnichannel strategy. They can offer showrooming and webrooming services for customers. Hence, the devices have become solutions in this process by unbundling and rebundling the information. As an outcome, it can provide benefits, including workflow, customers, and strategic advantages. We highlight in our findings that ESL can help retailers improve store operation management (Workflow Advantage), deploy advanced dynamic pricing (Customer Advantage and Strategic Advantage), and follow an omnichannel strategy (Strategic Advantage).

5.2.3 Outsource Information to Optimize Business Model Shift

The interaction of actors in the ecosystem happens simultaneously with their engagement. Actor engagement in the ecosystem involves the interactive integration of the focal actors' resources (Storbacka, Brodie, Böhmann, Maglio, and Nenonen, 2016). An engaged ecosystem actor is disposed to invest a broad range of resources—such as time, technology, and emotional resources—focusing on digital technology as an engagement interface (Li, Juric, and Brodie, 2017; Nenonen and Storbacka, 2018). More actors are engaged in the co-evolution process along with digital transformation through resource-sharing activities to optimize solution creation. At this stage, the unbundling and rebundling of information has been evolving by including more information in the complex ecosystem. Our findings show the involvement of an AI camera with geolocation data to improve the accuracy of shelf management.

Resource sharing also includes information sharing. Once the information has become more complex and mature enough to create new information density, it can be shared with other actors in the ecosystem (Normann, 2001). Outsourcing information by releasing it to different ecosystems and actors can help maximize benefits for entire value chain ecosystems. For instance, retailers can use better shelf management to maximize

the supply chain and logistic networks to manage their product inventory. Retailers can enhance their omnichannel strategy by integrating new solutions with existing information, gaining benefits from the value-chain ecosystems through some information, and offering new value to their customers. Hence, focal actors can benefit from strategic and ecosystem network advantages in this case.

6. Conclusions

This study explains how digital transformation can align with the device's co-evolution so the ecosystem's focal actors can benefit from adopting technology. Following the Bonnet (2022) stages of successful digital transformation, we explain our findings. Our findings reveal that ESL, as a small digital affordance, can be an enabler in the development of other solutions. ESL has co-evolved from hardware into a connected labeling solution through the collaboration of actors in the retail ecosystem. Additionally, we extend Bonnet (2022) three stages by understanding them through the perspectives of actor interaction and information density.

6.1 Managerial Implications

Where and how to start digital transformation are the most important questions to ask before acting. Our results indicate that starting with small-scale pilot tests is the first step of digital transformation before committing to a broader implementation. Companies can conduct pilot tests to validate market needs and create new value. That is, conducting a pilot test is an approach that can help solve potential problems and address how technology will be a viable option for the business by involving actors with different resources. The minimum viable ecosystem (Adner, 2021), as a minor configuration of activities, can create enough evidence of value creation to attract new partners. Through small testing, companies face and conquer both inside and outside challenges. Internally; however, they might encounter backlash from employees as operational processes, employee roles, and work objectives must be restructured.

Externally, incentives are needed to attract new partnerships, connecting actors from new domains for co-creation. Companies can demonstrate immediate benefits to employees through pilot tests, such as letting front-line staff immediately feel the benefits

of human-machine collaboration. It also generates robust evidence of value creation to win important trust and attract various ecosystem actors. At each stage, management must consider how to attract diverse actors, which depends on how these actors can contribute to the digital transformation.

Relevant technology adoption further demands consideration of information as another aspect of digital transformation. Digital transformation can dematerialize information and change it into a digital format. It remains unclear what kind of information can be dematerialized, as the consequences of digital transformation vary depending on the technological feature. However, management should be able to map what type of information is affected and how to better utilize this digital information to create new value for customers. Practitioners should be able to answer how focal actors can use digital information further by collaborating with different ecosystem actors to unbundle, rebundle, and, in the end, outsource the information.

6.2 Theoretical Implications

Our study provides two theoretical contributions on how adopting an emerging technology triggers digital transformation processes in a specific ecosystem. Our study highlights a novel view of two-way digital transformation. First, focal actors adopt digital technology and gain certain benefits for their operations and customers. Then, we enhance this study by pointing out that actors in the ecosystem also involve the co-creation and co-evolution of the technology to synchronize with the technical specification of the digital transformation. Each actor shares this process by leveraging their core abilities to overcome barriers and challenges together to achieve the desirable collective goals in the ecosystem.

Our second contribution regards how information density in digital transformation can shift existing business models. Adopting technology can dematerialize information and separate it from physical and digital environments. Through this process, information is free to flow across different platforms. Focal actors within the ecosystem should be able to capture this process, closing the gap between physical and digital environments. Focal actors should also be able to see this opportunity and shift the existing business models to create new value for their customers.

6.3 Limitations and Future Research Directions

Our research has three limitations that can be addressed in future research. First, this research cannot capture the complexity and compatibility issues during the adoption of ESL and the co-evolution of the device, due to data limitations. Future studies can help extend the current investigation by capturing the complexity and compatibility issues in the digital transformation and co-evolution of the digital device. We expect a prospective study to raise the existing three stages of digital transformation and help reevaluate the model by considering the issues regarding complexity and compatibility.

Second, we cannot capture the dynamic governance relationship between three focal actors to co-evolve and co-create ESL from hardware to connected labeling solutions. Thomas and Tee (2022) mention that a collective of generative actors generates innovation in the ecosystem. Nonetheless, we lack sufficient supporting data sources to understand how actors collaborate in the co-evolution and co-creation processes. Specifically, according to the ecosystem theory perspective (Autio and Thomas, 2020; Jacobides et al., 2018; Thomas and Autio, 2019), there are two views on value co-creation processes: orchestrator-centric and system-community views. Orchestrator-centric views mainly depend on the key orchestrators, which in our case might be retailers. Another view is system community, which postulates that innovation comes from complementors and contributors. We believe that firsthand data from interviews and in-field observation might benefit future studies addressing this governance issue.

Lastly, ESL is one of the applications of e-paper technology. Recently, a critical player has been developing the core technology of e-paper, e-ink. ESL system integrators are also part of the e-Ink ecosystem. However, in this study, we do not capture the role of e-Ink as the owner of e-paper core technology. Therefore, future research can understand how e-Ink participates in implementing ESL. Further, the prospective study can also uncover the implementation of e-paper technology in other sectors, such as automotive, healthcare, and logistics.

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