RFID-Enabled Inventory State Estimation and Automated Replenishment: A Real-Time Machine Learning Framework for Retail Inventory Tracking and Management

Dr. Michael Cooney, Associate Professor of Cybersecurity, Queensland University of Technology (QUT), Australia

1. Introduction

An agile, lean, and responsive inventory is an inevitable aspect of enabling efficient and effective consumer service and satisfaction under the contemporary turbulent, competitive, and uncertain business environment. Due to its numerous dependencies on the internal as well as external complex business environment of an organization, inventory management is always a matter of focal concern for practitioners and researchers. To adapt to the various changes in the business environment, several modifications and extensions in the existing techniques and approaches of inventory management have been proposed. Several traditional vendors, in order to alleviate the challenge of inventory, are using drones, small robots, and other autonomous tools.

In an environment where demand patterns have high volatility and supply chains are complex, it is difficult to manage sufficient inventory at each inventory echelon while also avoiding stockouts. The pandemic has resulted in significantly disrupted supply chains in many sectors around the world, leading to the need for efficient action, decision support, and efficient tools to manage disruptions. Research in emergency and crisis management has guided practitioners to utilize these techniques to meet problems associated with shock inventories, for example, using scanner data in a simple model or a more advanced statistical model. A systematic review of the literature revealed that little research focus has been placed on solving the inventory challenge by companies, and real-time inventory management was explored in certain instances.

1.1. Background and Significance of Real-Time Inventory Tracking in Retail

Inventory management has long been essential to retailers as they manage inputs and deliveries of stock in line with sales. This traditional operation was mainly based on retailers coordinating with suppliers but was relatively infrequent when manually examining inventory stock levels. In recent years, there has been a move away from the traditional practices of inventory management through the awareness of being able to view and record stock levels accurately and efficiently. Real-time inventory levels have become more important from a retailer managerial stance because the retail industry is highly affected by changing consumer trends, and so it is essential to keep on top of stock maintenance. When live inventory updates are not released, the interest of retailers can diminish when it comes to allocating stock on the shop floor and predicting sales forecasts. This, in the long term, can cause consumer satisfaction to decline as they may associate the retailer with low stock levels and poor products.

The availability of an item can be viewed as a false shortage of stock and thereby deter potential customers from purchasing. Retailers place a large emphasis on differentiating their retail practices from large corporations, which have full stock visibility across their vast warehouse stock because they believe it takes away the personal touch from physically shopping in-store. However, they lack the advanced tracking systems that an online system can offer. It is essential to a retailer's success that overheads are kept to a minimum, and being able to accurately track stock levels can aid retailers in achieving this. Additionally, real-time inventory tracking can offer insights in association with sales data on consumer behavior, trends, and past purchasing habits in order to make better business decisions in stocking goods. In the future, as technology advances, there may be further improvements in inventory management by weighting the stated importance of these practices.

2. Foundations of Inventory Management

Inventory management is a discipline comprising numerous interconnected elements. As such, it is paramount to clarify the central terms and concepts that support this domain, many of which have long-standing origins. One such fundamental concept is inventory itself. In the retail context, inventory refers to products and goods that are intended to be sold as part of a retailer's primary business purpose. Setting aside the numerous types of inventories that exist, the basic function of inventory is to be sold at a

margin typically above the cost. Hence, inventories form an essential part of the balance sheet as an asset. Maintaining inventories, however, comes with its costs. For instance, holding a high amount of stock requires additional infrastructure for storage. To this end, inventory management is about handling the conflict between these opposing ends. For this reason, inventory management depends significantly upon attaining a balance between supply—essentially the assortment of goods to be sold—and the consumer demand that the retailer cannot always predict. The ratio that characterizes this balance, i.e., the degree to which stock replenishes itself, is better known as the turnover rate. There are various principles and methodologies that are at play in inventory management today. While certain inventory items move quite fast, others are held up for quite some time. Given this one concept alone, two conflicting practices emerge. Just-in-time aims to have no surplus stock whatsoever. The Economic Order Quantity approach, however, seeks to find a balance. In both instances, the desired outcome is the increased allocation of resources. Fundamentally, sound inventory management can serve as a value-add to a retailer's business model. The goal is to break even. Furthermore, inventory management has been established as the alpha and omega of supply chain management and operations. On its head is the potential for a significant competitive advantage as well as a unique selling proposition. The most direct relevance of inventory management is seen within the broader domain of retail. Retailers across the world manage a wide variety of inventories and hence draw upon a mixture of techniques for managing them. The wine industry is also facing increasingly turbulent times thanks to the digital age. The seminal inversion of economic activity—namely in which end-users produced what was consumed—is a significant turning point in history. Few companies can afford to do so now. Amounting to a cautious use of inventories, i.e., managing the ingredients of production as closely as possible to real consumption, inventory management now has greater relevance than ever. Cultural values have undergone their own revolution at the hands of this technological transformation. End-users demand considerably greater flexibility and visibility. As a result, manufacturers and retailers must become drastically more customer-centered and focused on fulfilling the demand of the consumer. 'Smart' consumerism is the driving force behind this development. Hence, supply chains operate under the banner of 'demand-driven supply chain'. In short, inventory management is at the heart of the retail sector today.

2.1. Basic Concepts and Principles of Inventory Management

Effective inventory management is crucial for maintaining the operational effectiveness of many companies and is one of the oldest and most important fields of research in logistics. Managing inventory is the process of ensuring that an appropriate amount of an item or product is available and in stock for the desired customer delivery time and at the best price. This chapter outlines fundamental inventory management principles. The following terminology and their definitions are essential for understanding inventory management.

Lead time is the time between issuing new orders and receiving incoming inventory. Reorder point (ROP) is the stock level at which a company should place a new order to avoid stockouts. Safety stock (SS) is additional stock needed to protect against disturbances such as variance in lead time or demand. Because of these fluctuations, knowing the reorder point and the current amount of in-stock inventory will not prevent shortages. The further away the lead time or demand estimates deviate from the average, the more stock is needed to protect against a stockout. Inventory should mirror an organization's daily operational activities. To achieve this goal, it is important to forecast the daily demand for a given period and store sufficient stock in the store or warehouse to meet such demand. Many methods can be used for demand forecasting. Maintaining proper inventory quality will also help the company quickly adapt to changing business conditions. The principles of properly organized stock rotation also apply. In retail trade, the date of delivery is particularly important. Goods must be delivered when satisfaction with the product is still the highest, but depending on the season or company policy, the highest profit is only achieved by delivering the goods at a certain time. Goods in stock also have time value, so it is important to keep the time value of goods in stock and inventory under review.

3. Technological Foundations

Retail technologies are currently going through a second wave of digital revolution. Machine and deep learning (collectively referred to as artificial intelligence, AI) have become one of the transformative technologies in retail, especially in inventory management. AI can analyze vast amounts of data, and more than 80% of retailers see inventory optimization technologies as a source of competitive advantage. Applications include demand and promotion forecasting, optimization of inventory parameters and

safety stock, and price elasticity. Although out-of-stock (OOS) is the key performance indicator (KPI) of the success of any inventory management system, multiple factors at the intersection of connected retail technologies limit its analyses. A number of AI tools use AI to power retail inventory tracking. In fact, since 2017, over 40 or about 8% of the top 500 retailers have taken initiatives to blend various AI in their inventory management systems to improve operational and low-level managerial capabilities. The analytic tool is built over machine learning and combines cloud storage for analytics and data management. These tools, despite the promises to be adaptive to market changes, are a step ahead because of the automation features and steering of more strategic decisions. Machine learning is best known for making predictions or calculations based on large amounts of data to make more accurate data-driven decisions. This makes repetitive learning the key factor in the growth of machine learning applications.

Retail technologies combined with advancements in data analysis and execution have become competitive priorities in business strategies. There is a vital connection among technology applications, inventory management, and retail systems that is often not well acknowledged. Technological applications and infrastructure require an intermediary like inventory management to make an impact on retail performance. Similarly, the management of inventory is not up to the mark unless performance at the retail system level gets resolved. While stock optimization is more technology-driven and low-level operational, incorporating some of the latest AI applications are seen as competitive advantages or strategic process enablers in digital transformation. If a connected retail management system is one that is digitally enabled, retail decisions of B2C retail sales are blended, wherein IT applications are used to make business decisions that can stem into personalized promotional offers or individual markdown strategies. This is especially necessary for items that meet the Pareto principle, also known as the 80%–20% rule. AI is an important toolset in managing about 80% of retail merchandise properly, and some companies have already started fostering their ideas through using limited and non-public AI algorithms. Furthermore, there are few that allow integration with real-time source data and real-time insights to transform processes related to data and analytics across various business areas. Although the majority of AI tools leverage big storage platforms for performance, these can certainly be used to augment analytics and low-level business process performance, especially in retail inventory tracking and cash management.

3.1. Overview of AI and Machine Learning in Retail Inventory Management

The current chapter focuses on the potential of AI for adopting more advanced inventory management practices. AI, machine learning, and predictive analytics are used to anticipate future demand accurately and determine optimum stock levels. Different models and algorithms have been developed for the automated decision-making process. Before diving into IoT-powered real-time tracking and inventory management technologies, this section provides an overview of the research and developments in the field that can facilitate the understanding of how a simpler technology, such as an IoT device, can be coupled with much more sophisticated technologies and find synergies with them. Automation and real-time decision-making have been investigated in various works in inventory management for retail purposes. AI and machine learning have a wide range of applications in inventory turnover management practices. An inventory abstraction model with ARIMA models has been proposed to track stock levels and help retailers replenish stock when it reaches a predefined level efficiently. Stock-up problem-based predictions of consumption vectors of products in retail stocks have been proposed as a solution to manage product availability and reduce lost sales. DNN and CNN models were able to effectively generalize and extract features of the time-series data to predict regular consumer purchases. The models were able to determine and apply the dynamic growing deep learning model to determine the stock-up number of upholstery items according to the previous year's demand. The output was the top 10 sellers that needed to be given higher stock than regular, often due to festivals, and these products also stood as candidates for strategic stocking. Overstock prediction has also been performed by creating stock-up logs using DNN models. A service-driven demand-based model has been proposed to estimate demand using time series forecasting, clustering, and k-nearest neighbor techniques, and the results were compared with industry practice as benchmarks. Replenishment algorithms for import goods in the retail setting have been based on multimodal demand prediction based on deep learning. Despite its forecasting algorithm being unable to cope with the sudden demand changes at the beginning, supply chain disruption was minimized as AI was embedded into the system to swiftly clean the demand data, make it resilient, and identify excess stock on time everywhere in the stores, as well as quantify target stock based on a deep learning prediction. One of the retail leaders has innovated stock management based on demand-based sourcing,

using the concept of demand-driven replenishment. A neural network model based on the traditional reorder system but enhanced with machine learning has been used in real-time with this time series data from store stock management. By detecting abnormal sales at retail points, unexpected high demand as a whole is found and stock is dispatched to these affected zones. Failure rates were reduced significantly when learning-based topology prediction was compared with what would be proposed by traditional procedures.

4. IoT Technologies in Inventory Tracking

IoT, playing a crucial role in digital transformation, has the potential to create a smart digital environment, enhancing real-time capabilities. In inventory management, IoT devices, particularly the RFID tag, smart sensor, and monitoring systems, allow automatic and high-frequency data collection for monitoring the inventory status. By integrating IoT-based data collection into inventory systems, it not only provides a real-time overview of the reduction and replenishment of inventories but also minimizes the potential for human errors in manual records and demand forecasts. The innovation in technology has benefits for the retail market to increase inventory accuracy, reduce stock replacement, and eventually provide consumers with the right products. The employment of IoT in inventory tracking has become an active research area among researchers since its capability of real-time data could improve logistics, warehouse management, and reduce inventory costs. The implementation of IoT technology is capable of increasing the visibility of supply chain workers and offering more detail regarding the environment to retailers, ultimately reducing out-of-stock situations. The concept of predictive maintenance is also relevant in inventory tracking. Therefore, the continuous flow of data pickup and the correlation of sensor data with other variables will allow proactive measures to be taken in inventory management. IoT devices are able to initiate reordering processes, with IoT systems preparing component parts automatically after issuing reordering notifications. Recently, cybersecurity has been drawing further attention from researchers and practitioners on how to protect IoT devices and assets and manage a substantial volume of data collected in IoT devices.

4.1. Applications of IoT in Real-Time Inventory Management

Real-time inventory tracking involves the use of IoT devices that continuously and consistently collect and communicate data. A large retailer uses IoT and a cloud

platform to connect all of its stores. Every day, the smart IoT shelves at its stores track and log when stock levels fall below a set threshold or when shelf products are removed or added, which is then shared with suppliers. Similarly, other IoT inventory systems have found use in monitoring the contents and stock levels of stock crates that pass through warehouses and shipping containers. This makes for accurate, up-to-date inventories while enabling automatic replenishments. Retail solutions offered by various providers offer similar easy-to-setup, quick-deploy systems that help store clerks keep real-time inventory counts. A cloud-based management system integrates third-party APIs and offers real-time data monitoring to assist in making sense of all the data for increased visibility in the supply chain. Additionally, tracking solutions identify fast- and slow-selling products via IoT sensors and provide real-time, automated reordering. Such automated inventory management may hold potential to help overcome last-mile challenges and improve responsiveness to consumers through vendors' interconnected and updated inventories.

Inventory management IoT solutions are often included in cloud-based systems provided by the vendor. A major retailer sells its online inventory management tool as a Software as a Service solution, whereby users log into an online platform to receive data from multiple stores. Another company offers a similar cloud-based system for inventory monitoring across multiple stores through an online dashboard. Finally, a cloud-based inventory management system specifically offers access to the inventory count from multiple devices from anywhere as a key feature. Real-time inventory management via IoT often leads into cloud-hosted data analytics and decision support systems. A platform, which may be incorporated into IoT solutions, integrates large-scale, unstructured sensor data into a cloud system, where the data is analyzed by analytics and AI services. The results can then be shared with management to give them an integrated, accurate, and complete view of the supply chain.

However, the use of IoT and cloud platforms is not without obstacles. Integration complexity associated with the sensor side and networking infrastructure dominates the challenges and is only overcome by the cost of implementation when venturing into multi-site real-time inventory monitoring. Furthermore, cloud-hosted data analytics are often offered as an extension of vendor products, meaning users have to buy into the

cost of embedded analytics, although this is often not a huge leap beyond employing the IoT device component.

5. Challenges and Solutions

Negar and Lashgarian conducted an assessment of retailers' real-time inventory management systems and highlighted a number of concerns. In light of these findings, this article considers potential solutions to some of the most pressing concerns. The foremost worry is that inventory size and status are continually changing. Emotional inventory inaccuracies and an increase in situations such as erroneous scanning, incorrect data input, theft, or fraud all have consequences. They may result in unnecessary operational inefficiencies, stockouts, loss of consumer trust, and reduced revenue. All of these situations have various causes, but they share one commonality: human participation and/or immediate access to aetiologies. Modern inventory control systems have a variety of options to minimize their consequences.

The integration of a range of inventory management tools is the foundation of an integrated inventory management platform. These are typically POS systems, warehouse management systems, warehouse control systems, eCommerce solutions, and data warehouses in a retail store. The operations departments maintain and control the majority of these systems. Utilization of these platforms or systems might help avoid inventory inaccuracies. Enhanced monitoring techniques, ranging from barcodes and traditional RFID to multi-technology, are the second concern in inventory accuracy. Lastly, it is noted that even in the most advanced inventory control and management systems, there is still a significant procedural or personnel mistake. To minimize the number of misunderstandings, staff must be trained, and procedures need to be revisited. The main approach for reactive inventory control is the so-called auditable element, which combines the characteristics of the first two standards with condensed audit calibration. In developing and stretching this model, bidirectional communication provides an opportunity for resistance to develop when competing values within retail operations and workforces are convergent in some instances and divergent in others.

5.1. Common Challenges in Real-Time Inventory Tracking and Management

Although inventory tracking and management have extensive literature, real-time inventory management is still challenging due to the following reasons. First, in some practical scenarios, various management systems such as POS, purchase order

platforms, and back-end ERP systems are not totally compatible or integrated, which makes it challenging to synchronize real-time data across these systems. Since many of the inventory management tasks are still done through manual work, there are miscounts, oversights, and human errors during the inventory tracking process in the supply chain. Furthermore, the standard operating procedure may not be effectively followed by all the workers in the supply chain management process.

Second, inventory errors introduced by manual work are significant and regular in parts of the supply chain, mainly in micro and small retailer inventory management. In fact, many times, the error in the inventory is due to incorrect data entry and defects in multiple areas, including data control, software, and computer systems not handling data correctly. The fluctuation in demand and imperfect supply chain management make the inventory considered in this section dynamically variable over time. In fact, stock prediction has its own share of contradictions based on demand, which itself is changing with time. When considering a larger chain of stores on a regional or national level, some of the supply might be affected by local culture, weather, or even tragic activities. Therefore, the uncertainty in the inventory level is significant, which makes it a non-trivial point to track inventory in real-time. However, we consider that by collaborating with all the chain stores situated in one large shopping center or even at a national level, inventory could be predicted or controlled effectively.

To secure inventory, a reasonable amount of stock should be kept on the supermarket shelf to keep items lag-free in case of a short-term stock-out. However, to track the inventory shelves in real-time with a micro stock, these challenges and uncertainties should be tackled soundly. In the presence of these issues, the literature emphasizes the real-time inventory management system. A good retail inventory system would provide supply chain management with all the relevant information across the global supply chain to align supply with fluctuating demand, ensuring the continued operation of the business. However, the effective measurement and tracking of retail inventory are restricted due to some challenges and issues. There are other factors that affect the development of inventory in retail management and are associated with more than one player in the supply chain. They include the facilities and supporting capacities offered by suppliers and manufacturers because of their role in influencing available inventory, production capacity issues, and high delivery demands. Moreover, there must also be

issues that control and cause variations in inventory potential from the overall market as well as the supply chain. Many times, inventory differences do not decrease with increasing technological advancements for inventory tracking and visibility since the supply chain maintains human-technology interfaces.

6. Case Studies and Best Practices

With the rapid development of AI technologies, retailers have continually implemented these into their inventory management strategies to manage their products more effectively. This section presents case studies of retailers and other practitioners that have successfully applied AI and IoT technologies to their operations. It outlines the challenges that these retailers faced and discusses their strategies to increase product accuracy and customer service in practice. The subsequent consideration of "best practices" is mainly based on the case studies. It is discussed that market conditions change over time; therefore, the effectiveness of the strategies discussed here is also likely to change over time. Strategies should be evaluated and adapted continuously to respond to such changes. Each of the following cases is based on the practitioners' statements, which have been anonymized to protect the sensitive data of the companies. Best practice strategies derived from the case studies provide additional examples and insights for practitioners. Retailers should consider these strategies and their suitability for their businesses, products, and market conditions.

All practitioners agreed that technology providers should emphasize the importance of team engagement for successful AI and IoT implementation. Retailers must partner with technology providers who view inventory management as an ongoing and dynamic part of the business. One practitioner also recommended that retailers recovering from the pandemic should integrate all lessons learned into their practices, even if the involved technologies might slightly differ from their current business offerings. The practical case studies provided in this section reveal how different retailers are using today's technologies to advance their inventory management processes in the field. The case studies were based on retailer comments and their experiences. Although "best practice" strategies are included in some sections throughout the presentation, the table below highlights the strategies summarized from the cases that can directly impact a retailer's application of inventory management: flexibility to adapt to changing market conditions.

6.1. Successful Implementations of AI and IoT in Retail Supply Chains

There are many examples of influential players within the retail sector who have made big strides in the supply chain by integrating AI and IoT technologies in retail settings. One supermarket has implemented a solution that utilizes IoT Edge to allow data processing at the edge in order to enhance in-store inventory management. This has led to a reduction in the labor hours needed for restocking, as well as a decrease in stockouts at the retailers' physical stores. Another company's vast digital transformation has also resulted in improved inventory management, which translated to increased visibility and efficiency of the supply chain. In particular, the integration of RFID with demand forecasting technology has led to an increase in the accuracy of sales and demand forecasting.

The use of demand forecasting technologies in tandem with RFID and other IoT devices is proving to enhance inventory management, as validated by the benefits of retail analytics within their organization. In the collaboration, initial concerns of false positives and narrow AI focus were remedied by a flip of the design such that the solution was developed from a technological perspective that can generate large amounts of data from which it is much easier to look for out-of-stock related signals. When deploying a sensor network as extensive as theirs, it is also very important to consider the appropriateness of the technology employed, and prior to implementation, a cost-benefit analysis was conducted to base decisions about which part of the offering was going to be managed at the edge versus the cloud. Ultimately, this combination has proven to prioritize data security at the edge while still being able to realize the full opportunities of cloud-based analytics. The rejection of AI in favor of building an efficient supply chain based on an understanding of co-creation is what has led to overall success for the company.

7. Future Trends and Innovations

There are several trends and technological innovations that are currently evolving and will affect practices in inventory management in the coming years. The use of smartphones, the Internet of Things, and augmented reality technologies, combined with the rise of technology such as drones and robots, is expected to influence the shape of supply chain management and inventory best practices. For instance, robotic systems are not only practical for handling repetitive tasks but also work side by side with

human workers to optimize warehouse operations. In addition, the use of blockchain in the supply chain has the potential to improve transparency to combat some types of fraudulent activity and, at a cost, ensure enhanced security for goods.

Autonomous systems have the potential to change the warehouse entirely or make decentralized micro-warehouses scattered around population centers a more efficient option. More research into the specifics of these kinds of technologies will benefit both practitioners and academics alike. One particular area anticipated to have significant growth is the use of autonomous systems, which are the building blocks for these more futuristic warehouses, since not all warehouses currently have or necessarily require the necessary building infrastructure. It is also likely that scalability may be better with such small facilities than larger centralized ones. Combining humans and robots can create the most effective distribution solutions. Also, the use of devices at the senior staff level is now almost universal, especially among those companies that are considered to be change leaders. This shows that those organizations that have the most to gain from better inventory control already appreciate the value of this sort of technology in gaining a competitive advantage. Supply chain professionals must remain aware of trends and understand the changing wishes and demands of consumers if they are to leverage these expectations to their advantage, coupled with demand for quicker supply and shorter delivery times. Appealing to and maintaining fickle consumers is also compelling firms to be more transparent about their offerings and corporate practices. Tracking technology, which enables consumers to trace the journey of a product from farm to manufacturer and on to retailer, is likely to become more prevalent. Target shoppers who appreciate this sort of service will influence which firms become market winners. Increased consumer and public awareness of environmental factors is pushing sustainable and ethical behavior onto the agenda of organizations, especially toy and electrical manufacturers. Multinational companies are devising ways to prove that they are, for instance, paying fair wages and providing good working conditions in their factories. Marketing as a green or fair trade company would attract the custom of these ethically sensitive consumers.

7.1. Emerging Technologies and Innovations in Inventory Management

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Emerging technologies have the potential to significantly change the way that companies keep track of inventory and maintain high fill rates. In this subsection, we identify some of the current technological trends that may influence the future evolution of inventory management. Real-time AI-driven analytics help in quickly recognizing patterns that might affect the inventory, forecasting possible future demand, and suggesting the most efficient actions. AI models can help in making better replenishment decisions, which permit keeping or improving the fill rate while reducing the stock volume. Automation and smart warehouses eliminate time-consuming operations, reducing the steps any manual interference might derive.

Recently, some of the ongoing applications tackle the supply chain domain. This technology is used mainly to build a base of past events and transactions. This can be either production steps or actual trades. That way, every piece of information stored gets signed by the producing or selling party and added to a new block. In the domain of big data, the Internet of Things (IoT) devices have recently been the main focus concerning inventory. These small, multi-utility machines connect to the internet, collecting information and periodically updating the inventory. They play a significant role in the functioning of just-in-time economies, where stock can be replenished on time. Additionally, receiving real-time alerts and forecasting the initiation of maintenance can be more critical. Finally, one of the main difficulties in taking advantage of this trend, with no signs of slowing down, is adapting to customers' era of customization. Customizing orders and deliveries leads the number of goods and stock a company has to manage to stagnate, but greatly affects the efficiency of the supply chain. Supply chains have to learn every day and explore the use of data and algorithms. The personnel stand to gain from field expertise accompanied by mathematics and algorithm skills in the never-changing quest for smarter and leaner supply chains.

8. Conclusion

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Technology adoption in grocery retail is lagging behind that in the apparel segment because of both high initial costs and a possible lack of customer willingness to pay the higher price that an omnichannel system demands. The desire to reduce costs and exposure to uncertainty does not appear to be sufficient motivation for retailers to change their pricing models. They are particularly unwilling to do so with regard to

commodity-based groceries with high price transparency resulting from the relentless price and discount war. There is nonetheless evidence that both retailers and customers are willing to pay a higher price if service increases. This service includes the up-to-the-minute stock situation in all shopping channels or an order picking software option that works in real time and reports on stock levels and private application integration. This could rapidly become a standard service offering on the stock levels of apparel and non-commodity groceries. In any case, retailers will have to be on the same level of real-time information, if not with regard to stock levels then in order picking.

The need for digitalization and standardization in inventory management and product availability measurement is a consequence of the digitization of retail processes and the growing potential for more detailed, real-time insights into the internal and external supply and demand situation. Artificial intelligence is particularly sought after in the field of automatic sale price calculation and possible additional automated fixed price listing services; just as the first hardware and software services such as automatic sale prices and automated fixed price listing management modules are already being used. The use of artificial intelligence in inventory management for automatic fresh produce order points, previously only suboptimally integrated into the system, is expected to be used by four out of ten retailers over the next few years. The same goes for time-series forecasts and availability reports. The growing significance of inventory management and sales forecasting is shown by the increasing share of revenues of the non-core business in the retail companies' technology budget. The survey found that an average per respondent of 5.7% of revenues is reinvested in technology. The confidentiality of company budgets prevents the actual share of inventory technology and stock management business in the technology budget from being revealed. A further share was allocated to the Digital Acceleration budget - a budget for digitalization and stock management. A further share of turnover went into the stock management and further development-related expenditure of a subsidiary. The average is hardly likely to be enough, especially in a margin-intensive business, given the general outcry and backlog demand for digitalization, artificial intelligence, and real-time solutions such as IoT.