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Review

Assistive Technologies for In-Store Shopping: A Comprehensive Review of Solutions for Visually Impaired Persons

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This review can help researchers, developers, retailers, and accessibility professionals design more inclusive assistive shopping technologies for visually impaired people. It highlights the need for solutions that combine reliable product identification, effective in-store navigation, accessible feedback, a low interaction burden, validation with end users, and minimal changes to existing retail infrastructure.

Abstract

Visually impaired persons (VIPs), including blind people, face persistent barriers when shopping in conventional retail environments, such as store navigation, product identification, price verification, and checkout. Although the number of assistive technologies addressing these challenges is increasing, their usability and their ability to support the entire shopping experience remain limited. This review analyses peer-reviewed literature published between 2003 and 2025 on assistive solutions for in-store shopping by VIPs. The systems reviewed are classified according to their dominant technological approach, including tag-based solutions such as RFID and NFC; computer vision marker-based systems using barcodes, QR codes, or AR markers; computer vision non-marker-based systems; and hybrid solutions. Beyond technical functionality, the review examines supported shopping tasks, interaction demands, infrastructural dependence, usability, and validation with end users. The analysis shows that current solutions often support only isolated parts of the shopping journey, depend on modified store infrastructure or reliable product databases, and are insufficiently evaluated with VIP users in real retail environments. Human–computer interaction factors, including cognitive load, trust, discretion, feedback modality, and compatibility with familiar devices, emerge as critical for adoption and practical usefulness. Future research should therefore prioritise scalable, user-centred, discreet, and low-burden solutions that require minimal environmental modification while supporting the shopping process more holistically. Such approaches are essential for improving autonomy, dignity, and equitable access to everyday retail services for VIPs.

Keywords: assistive technologies; visually impaired persons; accessible shopping; computer vision; human–computer interaction; inclusive design; user experience

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Academic Editor: Douglas O'Shaughnessy

Received: 17 June 2026
Revised: 4 July 2026
Accepted: 7 July 2026
Published: 9 July 2026

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1. Introduction

Visual impairment is a major global public health and social challenge. It is estimated that at least 2.2 billion people worldwide live with some form of visual impairment, including blindness [1–3]. By 2020, an estimated 1.1 billion people were living with visual impairment, including 43 million who were blind, and the total number affected is projected to reach 1.7 billion by 2050 [4–7]. These figures highlight the scale of visual impairment as a daily concern, not only for health and mobility, but also for routine activities that rely heavily on visual information.

Shopping, particularly in conventional stores, is one such activity and remains especially challenging for blind and visually impaired people (VIPs) (in this paper, the term "VIP" refers to visually impaired people, including people who are blind; although the term is used inconsistently in the literature—sometimes referring only to people with low vision and in other cases more broadly to people with visual impairments—it is used here to describe people with very limited or no functional vision). Without reliable access to visual cues, VIPs may face barriers when travelling to the store, orienting themselves within the retail space, locating and identifying products, checking prices, completing payment, and returning home. The shopping process is further complicated by limited access to information on special offers, difficulties in preparing and managing shopping lists, and challenges in recognising, organising, and using products after purchase.

Even for sighted people, grocery shopping can be overwhelming. Supermarkets are often large, densely packed environments, with many shelves, aisles and products competing for attention. An average American supermarket may offer up to 35,000 products across 30 aisles and cover an area of 45,000 square metres [8]. For VIPs, navigating such an environment is a major challenge, comparable to moving through a football field crowded with moving shopping carts, other customers and towering shelves.

Numerous studies confirm that shopping is a complex and often stressful activity for VIPs [8–17]. Assessing product freshness and ripeness, reading labels, and handling products all depend, to varying degrees, on visual and tactile cues, creating an additional burden for people with limited or no vision [9]. A recent study showed that VIPs rely primarily on touch when identifying fresh produce, while smell and hearing play a secondary role [18]. In the same simulated-supermarket study, which included 15 VIPs and 15 sighted participants, VIPs took longer to recognise products, identified them less accurately, had greater difficulty navigating the store, struggled more to retrace their steps, and demonstrated poorer spatial orientation than sighted participants [18]. At the same time, the ability to shop independently contributes significantly to their sense of autonomy and inclusion [11,13].

Limited access to reliable product information may also affect food choices, nutrition, and health-related decision making [17]. People with disabilities are not only consumers but also active participants in economic life, and equal access to services is closely linked to human rights [19]. In the context of shopping, this means that VIPs should be able to make informed choices, maintain privacy, and participate in shopping activities with a level of independence comparable to other consumers. For many VIPs, shopping is therefore not only a practical activity but also one closely tied to autonomy, social participation, consumer normalcy, and dignity.

These findings highlight the need for assistive shopping technologies that support safe, independent, and dignified shopping for VIPs. Numerous technologies have been developed to improve specific aspects of the shopping experience, but they differ considerably in approach, effectiveness, and scope. Several reviews have addressed assistive technologies for VIPs, focusing on indoor navigation, object recognition, wearable systems, mobile assistive technologies, and computer vision approaches. However, existing reviews

typically examine assistive technologies in a general context and rarely focus specifically on the complete in-store shopping process. Furthermore, limited attention has been paid to comparing solutions according to shopping tasks, infrastructure requirements, interaction modalities, user validation, and real-world deployability.

The shopping process differs from many other assistive technology contexts because it brings together several interdependent tasks in a dynamic, information-rich, socially sensitive environment. A user may need to plan a shopping trip, reach and enter the store, navigate aisles, locate a product category, distinguish between similar products, access price and product information, evaluate quality, manage a basket or cart, complete checkout, and later recognise and use the purchased products at home. Technologies that support only one of these steps may be useful, but they do not necessarily enable independent shopping as a whole.

To address this gap, this review provides an integrated analysis of assistive shopping technologies for VIPs in physical retail settings. Rather than simply cataloguing existing systems, it examines how different technological approaches support specific stages of the shopping journey, what requirements they impose on users and retail environments, and how far they have progressed from technical prototypes to user-validated, practically deployable solutions.

This review makes three contributions. First, it classifies existing solutions by their underlying technological approach, including tag-based systems, computer vision marker-based systems, computer vision non-marker-based systems, and hybrid systems. Second, it analyses these technologies in relation to the stages of the shopping process they support, such as navigation, product search, product identification, access to product and price information, checkout, and post-purchase use. Third, it critically examines the extent to which proposed systems have been evaluated with visually impaired end users in realistic shopping contexts, highlighting the gap between technical feasibility and real-world usability. Accordingly, the review is guided by the following research questions:

- RQ1: What types of assistive technologies have been developed to support VIPs during shopping in physical retail environments?
- RQ2: Which stages of the shopping journey are addressed by these technologies, and which stages remain insufficiently supported?
- RQ3: How do different technological approaches vary in terms of infrastructure requirements, interaction modalities, scalability, and suitability for real-world retail deployment?
- RQ4: To what extent have existing systems been evaluated with visually impaired end users, and what forms of validation have been used?

By answering these questions, the review aims to move beyond a descriptive overview of individual systems and provide a structured synthesis of technological, usability, and deployment challenges. Its ultimate goal is to identify the main limitations of current solutions and outline design and research directions for assistive shopping technologies that are scalable, discreet, user-centred, and capable of supporting autonomy, dignity, and equitable access in everyday retail environments.

2. Research Methodology

This review examines assistive technologies developed to support VIPs during in-store shopping. The literature search included peer-reviewed publications from 2003 to 2025 and was conducted in major scientific databases and indexing platforms, including Scopus, Web of Science, IEEE Xplore, ScienceDirect, SpringerLink, PubMed, MDPI, Taylor & Francis Online, and Google Scholar. The ACM Digital Library was not searched directly; however, relevant ACM publications were identified through other indexing platforms. The

search combined terms related to visual impairment, assistive technology, and shopping, such as "visually impaired shopping", "blind shopping assistant", "assistive technology grocery shopping", "accessible shopping", "product identification for visually impaired", "indoor navigation visually impaired supermarket", "RFID shopping visually impaired", "barcode recognition blind users", "QR code assistive shopping", and "computer vision shopping assistant".

To make the literature selection process more transparent, a PRISMA-based overview of the search and screening procedure was prepared (Figure 1). Because the complete historical record counts, duplicate removal counts, and full screening counts could not be reliably reconstructed from the available search notes, only the final analytical corpus is quantified. This approach was used to avoid introducing retrospective numerical data that could not be verified while still showing the main stages through which the literature was identified, screened, assessed, and included in the review.

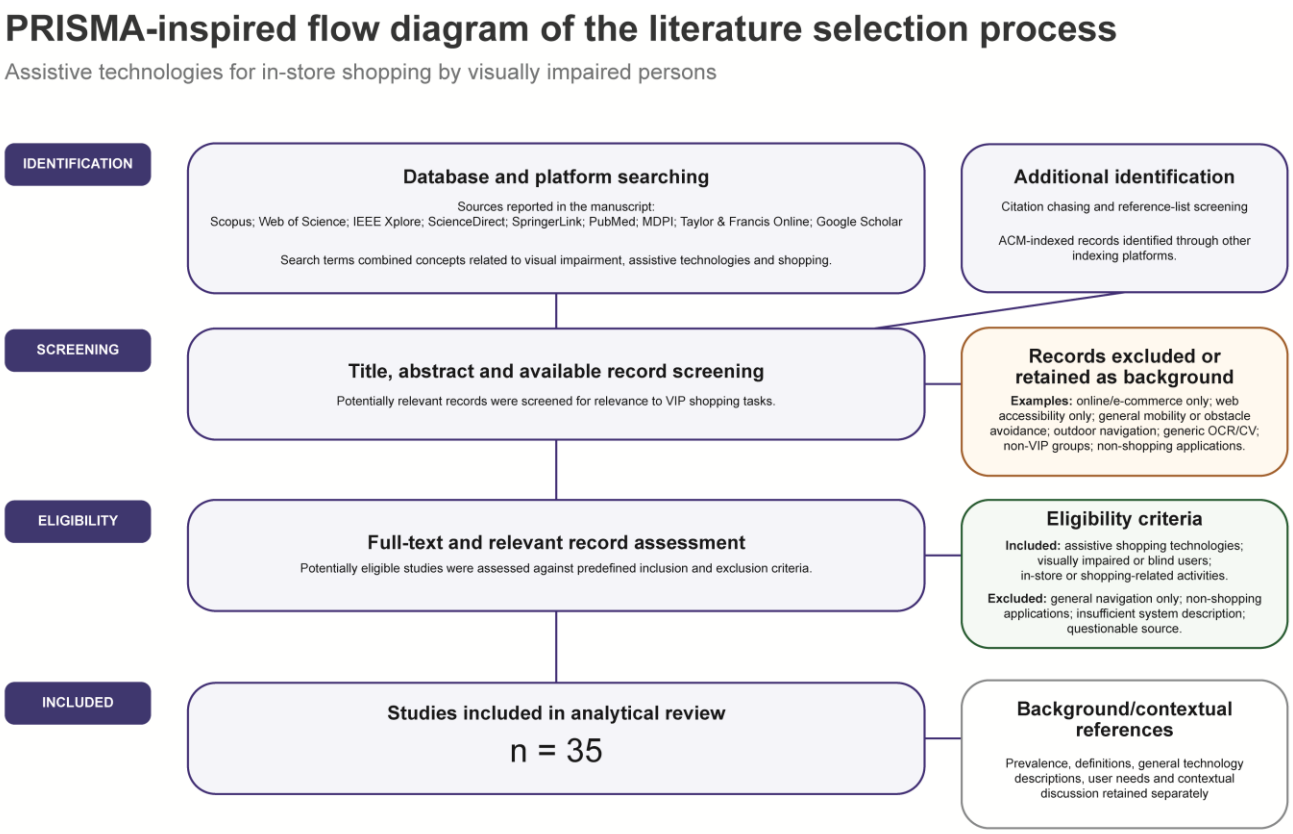


Figure 1. Overview of the literature selection process, based on PRISMA principles (Note: Complete historical record counts, duplicate-removal counts and full screening counts could not be reliably reconstructed from available search notes; therefore, only the final analytical corpus is quantified).

Studies were included if they proposed, described, evaluated, or reviewed technologies directly related to shopping by VIPs. Particular attention was given to systems supporting product search, product identification, access to product information, in-store orientation, navigation to products, price checking, checkout, or post-purchase organisation. Studies focusing on user needs, shopping behaviour, accessibility barriers, or human–computer interaction were also included if they helped define requirements for assistive shopping technologies. Publications dealing exclusively with general indoor navigation, outdoor mobility, obstacle avoidance, or assistive technologies unrelated to shopping were excluded from detailed analysis. However, selected navigation studies were considered where their concepts could be applied to retail environments.

The selected literature was analysed both thematically and technologically. First, studies addressing the needs, behaviours, and preferences of VIPs were reviewed to identify recurring barriers in the shopping process. The assistive shopping technologies were then grouped according to their dominant technological approach: tag-based systems, computer vision marker-based systems, computer vision non-marker-based systems, and hybrid systems. Each group was examined in terms of technical functionality, supported shopping tasks, user interaction, validation with end users, infrastructural requirements and feasibility in real retail environments.

In addition to technological classification, each reviewed system was coded according to the type of validation reported in the source publication. Five validation categories were used: V1, evaluation with visually impaired participants; V2, evaluation with blindfolded sighted participants; V3, evaluation with mixed participant groups; V4, technical evaluation only; and V5, conceptual or prototype systems without clearly reported empirical evaluation. This coding was used to assess the extent to which proposed assistive shopping technologies have been evaluated with the intended end users and to distinguish real user validation from early-stage simulation or technical performance testing. The validation coding also served as a quality assessment framework. Studies evaluated with visually impaired participants (V1) or mixed participant groups including visually impaired users (V3) were considered to provide stronger evidence of practical applicability than studies relying solely on blindfolded participants (V2), technical evaluations (V4) or conceptual system descriptions without empirical testing (V5).

3. Technologies and Systems

This section provides an overview of the main technologies used in developing assistive shopping solutions for VIPs. To clarify their role in this context, the basic principles of each technology are briefly introduced, followed by their relevance to shopping-related support.

3.1. RFID and NFC Technology

Radio Frequency Identification (RFID) is a contactless, wireless technology that uses electromagnetic fields to transmit data between a tag and a reader, enabling automatic identification and tracking of objects. A typical RFID system consists of three components: a tag, a reader, and an antenna. The reader emits a signal through the antenna, which activates the tag and prompts it to transmit its unique identification code. RFID tags are divided into two categories [20–22]:

- Active tags, which have their own power source and can transmit signals over longer distances, up to approximately 100 m;
- Passive tags, which are powered by the reader's electromagnetic field and have a shorter range, typically up to 25 m. As they are smaller and less expensive, they are more commonly used in retail environments.

In assistive shopping applications, RFID tags may be attached to products, shelves, or specific locations in the store to help VIPs identify items or orientate themselves within the store. Once a tag is recognised, the system can provide audio feedback with relevant information, such as the name, price, or special offers. These systems typically rely on a local or server-based database to store and retrieve product information. In some cases, RFID is also used for in-store navigation; for example, a tag reader can be attached to a white cane to recognise nearby tags and provide route guidance through verbal instructions [21].

Near Field Communication (NFC) is a short-range form of RFID, with a typical operating range of up to 10 cm. An NFC-based system usually consists of a tag, a reader—often integrated into a smartphone—and a database containing information about the tagged

product. Communication can occur in active mode, where both the tag and the NFC reader generate a signal, or in passive mode, where only the NFC reader is active.

Compared with many RFID-based systems, NFC is more closely associated with smartphones, making it relatively accessible and familiar to users. In shopping scenarios, the basic principle remains similar: VIPs scan NFC-tagged products or locations with their smartphone to receive relevant product or contextual information (Figure 2) [21].

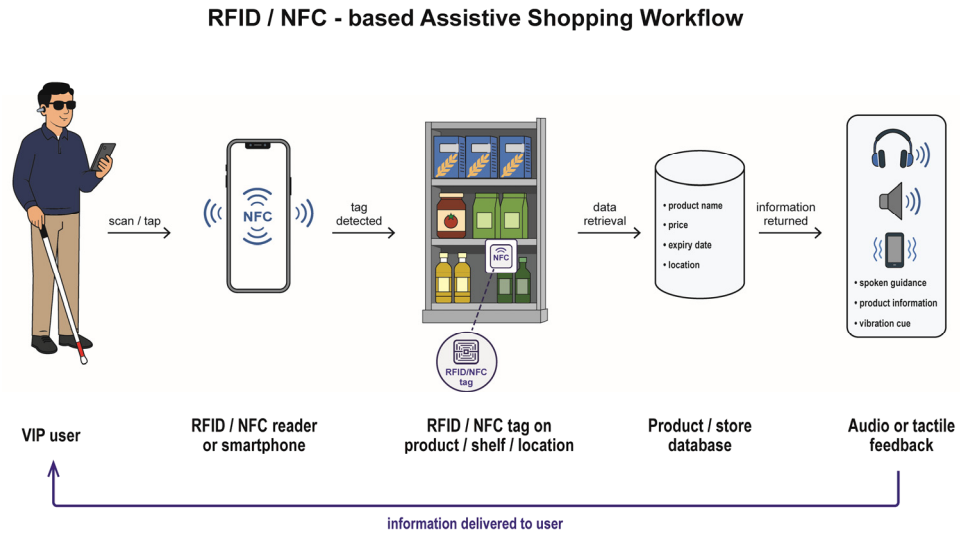


Figure 2. Conceptual workflow of an RFID/NFC-based assistive shopping system for VIP users.

3.2. Computer Vision-Based Systems

Computer vision-based systems use cameras to capture visual input and image processing algorithms to identify, classify, or interpret objects in the surrounding environment. In assistive shopping solutions, the extracted information is usually communicated to VIPs through tactile or auditory feedback. These systems can be broadly divided into two groups [20,21,23]:

1. Marker-based systems rely on visual markers, such as QR codes, barcodes, or augmented reality (AR) markers attached to products, shelves, or locations within the store;
2. Non-marker-based systems identify products by their visual characteristics, such as shape, colour, texture, logos or packaging, using trained recognition models.

In marker-based computer vision systems, the camera captures and analyses a visual marker to retrieve stored or linked information (Figure 3). This may include the product name, price, nutritional information, expiry date, or other details relevant to the shopping task. In some solutions, visual markers are also used for navigation, guiding the user towards a desired product through auditory instructions [20,21].

QR codes are among the most common visual markers. As they store information both vertically and horizontally, they can contain considerably more data than conventional one-dimensional barcodes [24]. They can be scanned with dedicated scanners or smartphone cameras, making them practical for a range of assistive shopping applications.

More recent approaches have explored the use of AR markers, including ArUco markers [25,26]. These markers are black square patterns with embedded binary grids that encode identification and orientation data. Compared to QR codes, ArUco markers can be recognised from a greater distance and may provide more accurate support for indoor navigation [27,28].

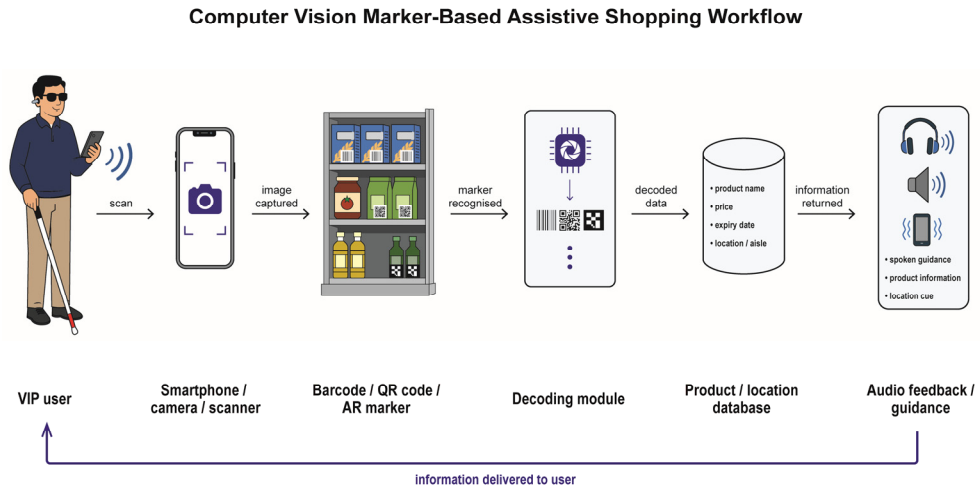


Figure 3. Conceptual workflow of a computer vision marker-based assistive shopping system for VIP users.

However, both QR codes and AR markers remain sensitive to practical conditions. Recognition may fail if the marker is too far away, blurred, distorted, poorly illuminated, or partially obscured [25,26].

Non-marker-based systems use a different approach (Figure 4). Instead of relying on visual markers, they employ object recognition algorithms to identify and classify products based on visual features. These systems usually require substantial computing power and are typically trained on large datasets of labelled images [20,21].

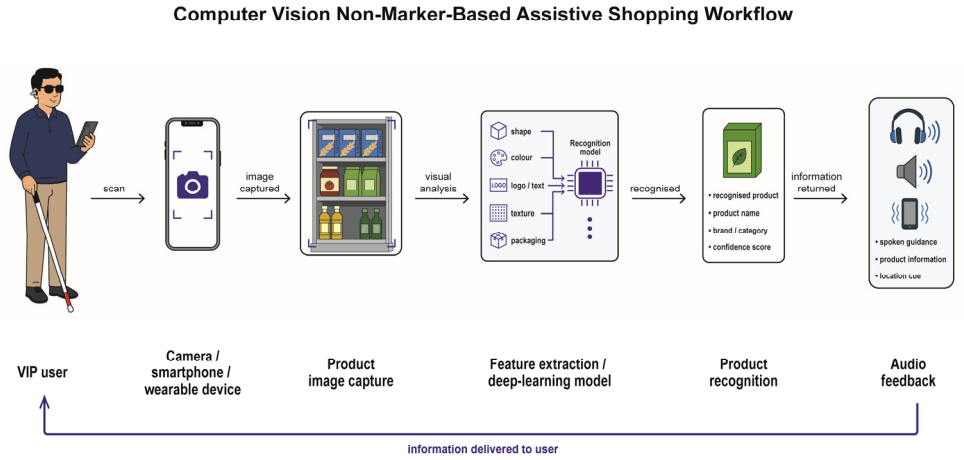


Figure 4. Conceptual workflow of a computer vision non-marker-based assistive shopping system for VIP users.

Object localisation—determining where a product appears within an image—adds another layer of complexity, especially when combined with classification. In such cases, the algorithm often scans the entire image, which increases computational demands [29].

Another challenge is obtaining training data that accurately reflect real retail environments, where products may appear under different lighting conditions, viewing angles, levels of clutter, and packaging variations. Public image databases, both structured and unstructured, can support the development of more robust recognition models [30]. For this reason, non-marker-based computer vision systems are particularly relevant for product identification in uncontrolled environments such as supermarkets, although their practical reliability still depends heavily on image quality, processing speed, and the diversity of the training data.

4. Requirements for Development of Assistive Shopping Solutions

Developing effective assistive shopping technologies for VIPs requires more than technical knowledge of available sensors, devices, and recognition algorithms. It also requires an understanding of how VIPs actually shop, the strategies they use, where barriers arise, and which forms of support are acceptable in everyday shopping environments. Numerous studies have addressed these issues and emphasise the importance of developing systems that respond to the routines and practical needs of VIPs [10,12–14,17,19,31–39].

Research shows that varying degrees of visual impairment lead to different shopping strategies and support needs. In one study, 11 participants with different levels of visual impairment were asked to locate a store and search for a specific product. The most challenging aspect was finding the product once inside the store [12]. Participants often reported feeling lost and frustrated, but they also demonstrated how actively they used their remaining vision and other sensory cues. Although most could not read the text on the packaging, they often identified products by shape, packaging type, and colour. Depending on font size, font type and the degree of visual impairment, some participants could read parts of the product labels. Familiarity was also important: when participants did not know a product, they looked for visual cues such as images on the packaging. Products placed at eye level were easier to recognise due to their proximity and visibility.

The same study also found that self-service checkouts may offer certain advantages for VIPs when information is presented accessibly, for example, through large text, screens positioned at eye level, or audio signals. Participants reported greater confidence in these systems, especially when receiving change. Despite the extra time required, they strongly preferred shopping independently. Smartphones were often used for navigation and orientation, but interpreting the maps was often difficult due to low contrast, sunlight, and the need to perform several tasks simultaneously, such as maintaining orientation, recognising obstacles, and making spatial decisions. These demands created a considerable cognitive burden. The findings suggest that assistive applications should avoid information overload and provide only the most relevant content at the right moment. Participants also suggested simplified visual representations of store areas and aisles, such as icons or abstract illustrations, to support spatial understanding and reduce search time. Where product images are used, they should emphasise key visual features such as size, shape, and colour while avoiding unnecessary visual elements. As VIPs often need both hands for navigation and product exploration, hands-free camera solutions, including body-worn devices, were considered particularly useful.

Shopping is widely recognised as a cognitively and physically demanding activity for VIPs [10–14,17,19,31–39]. One of the most frequently reported difficulties is product identification, which has consistently been identified as one of the most problematic stages of the shopping process [10,12–14]. This is further supported by an analysis of one year of user data from VizWiz Social, an iPhone application that enables people with visual impairments to take a photograph and receive a response from the crowd. The analysis showed that 41% of all questions concerned identifying products or objects, making this the most common type of question. Among frequent users, this share rose to 73%, further highlighting how common and important product identification is in everyday life [36].

The barriers faced by VIPs in shopping environments go beyond product recognition. Studies identify a wider range of recurring issues, including difficulties in locating products, navigating crowded or unfamiliar spaces, interpreting product information, and accessing assistance in ways that preserve dignity and autonomy [10–14,17,19,31–39]. A quantitative study of 500 VIPs provides a broader perspective on these barriers [19]. The most commonly reported problems were difficulties with in-store navigation (77.2%), lack of ramps or adapted access infrastructure (e.g., stairs) (58.6%), indifferent or unhelpful staff (58.4%),

absence of Braille labels or scanning options (54.4%), inaccessible or unsuitable packaging (45.0%), lack of designated checkouts (35.2%), cluttered and disorganised shelves (29.0%), and insufficiently trained staff (18.4%). Most respondents primarily shopped for food (71.4%), while fewer shopped for special needs products (25.4%) or clothing (3.2%). Overall, these findings indicate that shopping barriers are both environmental and informational, and cannot be resolved by technological augmentation alone.

Several studies emphasise that assistive shopping technologies should be based on tools and practices that VIPs already use. A study with two VIP focus groups, including participants who used white canes and others who used guide dogs, highlighted the importance of building on familiar assistive devices rather than introducing unfamiliar or cumbersome technologies [34]. This recommendation is supported by another study, which argued for adapting commonly used tools, such as white canes and smartphones, instead of adding entirely new devices to an already complex shopping situation [35]. VIPs often use their hands to explore products while relying on a white cane for safe movement, so additional devices may increase both practical complexity and cost.

Tactile exploration remains central to the shopping strategies of many VIPs. They often use active touch to understand the size, shape, and texture of products. In many cases, they first identify the general product type manually, then use a digital device to confirm the brand, variant, or other information. Some participants also used tactile perception to understand shelf layout and product placement [13]. Similar findings were reported in a later study, where one participant was able to identify and select a desired type of bread by touch alone, whereas visually similar products, such as canned beans, required more extensive tactile exploration, including scanning shelf labels with their fingers [40].

Another important requirement is that assistive shopping solutions should require minimal adaptation of the retail environment [34]. Technologies intended for real-world use should reflect actual conditions in existing supermarkets and stores, rather than depend on extensive infrastructural changes [35]. This is particularly important for scalability as retailers are more likely to adopt solutions that are affordable, flexible and easy to integrate into current store layouts. Assistive technologies should also support, rather than disrupt, established shopping behaviour, including the planned and routine shopping practices often used by VIPs [35].

Access to product information is another recurring need. In one study, all participants wanted information about expiry dates and prices, while some also expressed interest in storage instructions [19]. Another study found that VIPs want detailed grocery information, especially prices, discounts, expiry dates, freshness, and product quality. Participants also sought contextual information that is difficult to verify without sight or touch, such as the condition of fresh produce or the packaging format of products like fish [17]. A comparable study found that VIPs also wanted information about product types and the location of desired products within the store [39]. As this information is usually communicated visually, assistive systems need to provide it in accessible formats to support informed and independent decision-making.

In practice, many VIPs do not shop alone [10,11,14,15,19,33,37,38,41–43]. They often rely on family members, friends, volunteers, or store employees, as independent orientation and product search can be difficult. Some studies report that VIPs prefer shopping with a sighted person [33], while others show that some avoid or delay shopping due to the effort involved [10]. The availability and quality of assistance strongly influence the shopping experience. However, support from store employees can be unpredictable, and VIPs may struggle to obtain reliable help [15,41,43,44]. Many are reluctant to ask for assistance because it increases psychological pressure, limits product exploration, and may reduce

privacy. As a result, some repeatedly buy the same products to avoid uncomfortable interactions [15].

The social dimension of assistance is particularly important. Some participants reported negative experiences, such as being discouraged from shopping independently or being treated unkindly because of their blindness [40]. Others described discomfort when relying on strangers, especially when buying personal or gender-specific items such as hygiene products [15,41]. These findings help explain why autonomy, privacy, and dignity are central requirements for assistive shopping technologies. Although VIPs may regularly seek help, many still prefer to shop independently whenever possible, even if it takes longer [12,17]. At the same time, unfamiliar store layouts can significantly reduce their ability to find products without assistance [42].

Several studies have examined the preferences of VIPs regarding assistive technologies. A recurring finding is the strong role of smartphones, mainly because they are familiar, relatively affordable, versatile, and already include accessibility features. In one study, participants with low vision used smartphones as their primary assistive device [12]. Another study found that all interviewed participants used smartphones with applications such as VoiceOver, Cash Reader, and Envision to improve autonomy and accessibility during grocery shopping [40]. Similarly, one study reported that all participants owned smartphones and had experience with at least one mobile application designed for blind users [45]. Another confirmed that VIPs often favoured smartphones because of their affordability, ease of use, and built-in screen-reading software, whereas devices such as canes, smart glasses, and headsets were sometimes perceived as expensive, socially conspicuous, or functionally limited [46].

However, technology preferences vary. Regional and cultural factors also influence adoption. In a study conducted in Korea, participants used smartphones and assistive technology applications relatively infrequently, relying more on personal assistants when shopping [38]. In contrast, another study found regular use of wearable devices, particularly smartwatches and headphones, which were valued for their discretion and practicality [14]. In the same study, participants evaluated camera-based wearables and generally preferred devices worn on the head or wrist, while glasses were less popular (Figure 5). All participants reported wearing headphones daily. Across these evaluations, users prioritised accuracy, ease of use, and discretion, indicating a preference for technologies that are reliable yet unobtrusive [14].

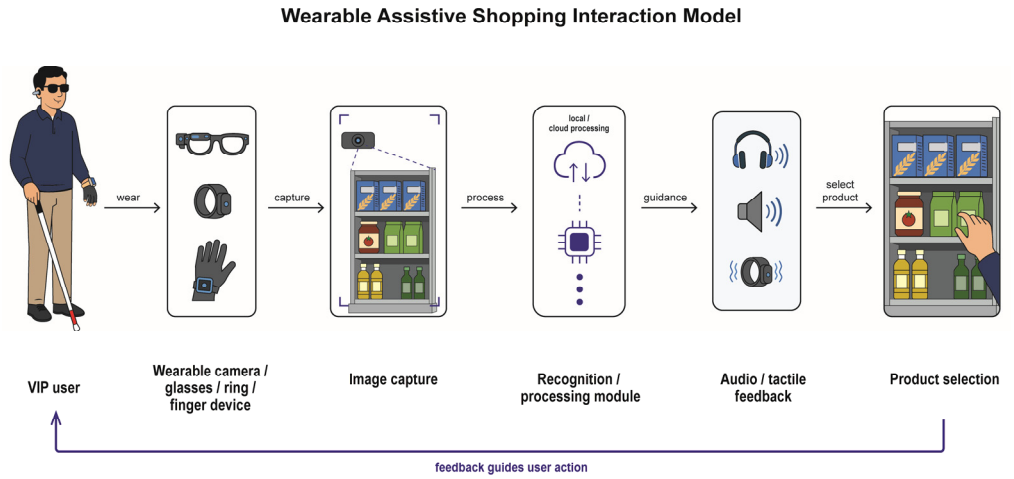


Figure 5. Schematic representation of a wearable assistive shopping interaction model for VIP users.

Other studies also highlight openness to accessible smart services. A study in Greece examined attitudes towards smart packaging and technology adoption among people with

disabilities, including 32 blind participants [47]. The results showed a positive attitude towards smart and intelligent packaging, especially when it supports shopping both in-store and at home. Among blind participants, over 65% reported regularly using specialised mobile applications to assist with shopping [47]. Additionally, almost half of the VIPs surveyed in another study preferred to receive information in audio format, highlighting the importance of accessible auditory feedback in shopping technologies [39].

Economic aspects of shopping should also be considered. One study emphasised that VIPs often need to shop frugally and carefully while facing challenges such as limited access to product information, long shopping times, mobility constraints, and financial difficulties [38]. A major issue is the inability to check calculations at the checkout. If an error occurs during payment, VIPs may be unable to recognise it because transaction details are presented visually. This limitation applies to both in-store purchases and home delivery services. Another challenge is staying within a planned budget. Since VIPs may not be able to monitor the cost of selected products in real time, they often rely on the final amount at the checkout, which may not match their expectations. Recognising special offers and discounted products can also be difficult. Assistive technologies could address these issues by supporting budget setting, shopping list creation, real-time cost tracking, and access to product-specific information such as price, brand, reviews, and discounts [38]. However, as this study was conducted in Korea, cultural and infrastructural differences may affect the generalisability of its findings.

The shopping process should be seen as extending beyond the time spent in the store. Like sighted shoppers, VIPs start at home by checking what they already have, identifying what they need, and preparing a shopping list. For VIPs, this stage can be time-consuming because recognising existing products, estimating quantities, and deciding what to buy may rely on tactile exploration, memory, and significant cognitive effort. After returning from the store, they also need to recognise purchased products and store them systematically so they can be found and used later [37]. Memory plays an important role in identifying products by texture, packaging size, sound, or smell, and in maintaining the spatial organisation of products at home. If family members reorganise products, this can cause confusion and make future shopping preparation more difficult [15].

Although various assistive technologies are available, their use in everyday shopping remains limited. Many VIPs still find it easier to ask for help than to rely on assistive technology solutions [14]. Three barriers to adoption are particularly significant. The first is limited frequency of use: many assistive devices are designed for specific tasks that occur only occasionally, making it impractical to carry or wear them throughout the day. For this reason, users often prefer assistive functions to be integrated into devices they already use, such as smartphones, smartwatches, or headphones. The second barrier is lack of precision. Users need specific and actionable information, not vague or general descriptions. The third barrier is discretion. Many VIPs, especially those with progressive vision loss, are reluctant to use visible devices that draw attention to their disability. One participant even reported feeling unsafe when using a smartphone for in-store product identification [14].

Overall, the literature suggests that future assistive shopping solutions should be accurate, discreet, affordable, easy to use, and compatible with everyday shopping routines. They should minimise cognitive load, avoid unnecessary interaction, support both in-store and home-based shopping tasks, and rely as much as possible on familiar devices and existing retail infrastructure. Most importantly, VIPs should be involved throughout the design, testing, and evaluation process, as the success of these technologies depends not only on technical performance but also on whether they fit the lived realities of the people expected to use them.

5. Assistive Shopping Technologies for Visually Impaired Persons

Various assistive shopping technologies have been developed to address the barriers that VIPs encounter in retail environments and to support more independent shopping. These technologies differ considerably in purpose, technical complexity and practical maturity. Some focus on a single task, such as product identification, while others support broader aspects of the shopping process, including product search, in-store navigation, and checkout. Several studies have examined their effectiveness and potential to promote autonomy and independence [20,21,34].

Given the diversity of available solutions, a clear classification is useful for comparing their functionality, advantages, and limitations. Following the classification framework defined in the methodology section, the reviewed systems were grouped according to the dominant mechanism used to acquire shopping-related information. This criterion was selected because the primary sensing and identification mechanism determines the required infrastructure, the type of user interaction, the likely sources of error, and the feasibility of deployment in real-world retail environments. In this review, assistive shopping technologies are organised into three broad categories: tag-based systems, computer vision-based systems, and hybrid systems [21]. For this analysis, computer vision-based systems are further divided into two subgroups: those that rely on visual markers, such as barcodes, QR codes, or AR markers, and those that recognise products without visual markers by analysing visual features such as shape, size, colour, texture, logos, or packaging [20].

To clarify the classification boundaries, tag-based systems are understood here as systems that rely primarily on electronically encoded markers, such as RFID or NFC tags, which are detected through radio-frequency communication. Computer vision marker-based systems rely on optically detectable markers, such as barcodes, QR codes, or AR markers, which must be captured and interpreted by a camera or optical scanner. Computer vision non-marker-based systems recognise products, shelves, or environmental features directly from visual characteristics, without requiring dedicated physical markers. Hybrid systems combine two or more of these approaches in a way that is essential to the system's core functionality, rather than merely providing optional supplementary support.

When systems incorporate multiple technologies, classification is based on the technology that plays the dominant role in product identification, navigation, or information access. Systems in which multiple technologies contribute equally to core functionality are classified as hybrid systems. This distinction helps explain why RFID/NFC solutions, barcode/QR code/AR-marker-based systems, marker-free computer vision systems, and hybrid systems are discussed separately in the following sections. Table 1 summarises the classification logic used in this review.

Tag-based systems use technologies such as RFID and NFC, where information is retrieved from tags attached to products, shelves, or specific locations in the store. Computer vision-based systems use camera input and image processing to recognise products, labels, markers, or shelf environments. Hybrid systems combine several technologies, such as RFID, NFC, computer vision, audio feedback, and mobile applications, to improve reliability and support a wider range of shopping tasks (Figure 6).

This classification is used to structure the following analysis of assistive shopping technologies. The focus is not only on how these systems function technically, but also on how they support VIPs in practice, including their usability, interaction requirements, dependence on retail infrastructure, validation with users, and applicability in real shopping environments.

Table 1. Classification framework for assistive shopping technologies for VIPs.

Category	Primary Information Source	Typical Examples	Main Classification Criterion
Tag-based systems	RFID/NFC tags	RoboCart; VirtualEyez	Information is acquired from electronically encoded tags detected through radio-frequency communication.
Computer vision marker-based systems	Barcodes, QR codes, AR markers	Trinetra; ShopTalk; Grocery Shopping Assistant	Information is acquired by visually detecting and decoding an optical marker.
Computer vision non-marker-based systems	Visual product or shelf features	ShelfScanner; FingerReader 2.0; AiSee; MobiEye	Information is inferred from image analysis without predefined physical markers.
Hybrid systems	Combination of multiple methods	BlindShopping; SANIP	Two or more approaches are essential to the system's core functionality.

Note: VIPs, visually impaired persons; RFID, Radio Frequency Identification; NFC, Near Field Communication; QR, Quick Response; AR, augmented reality.

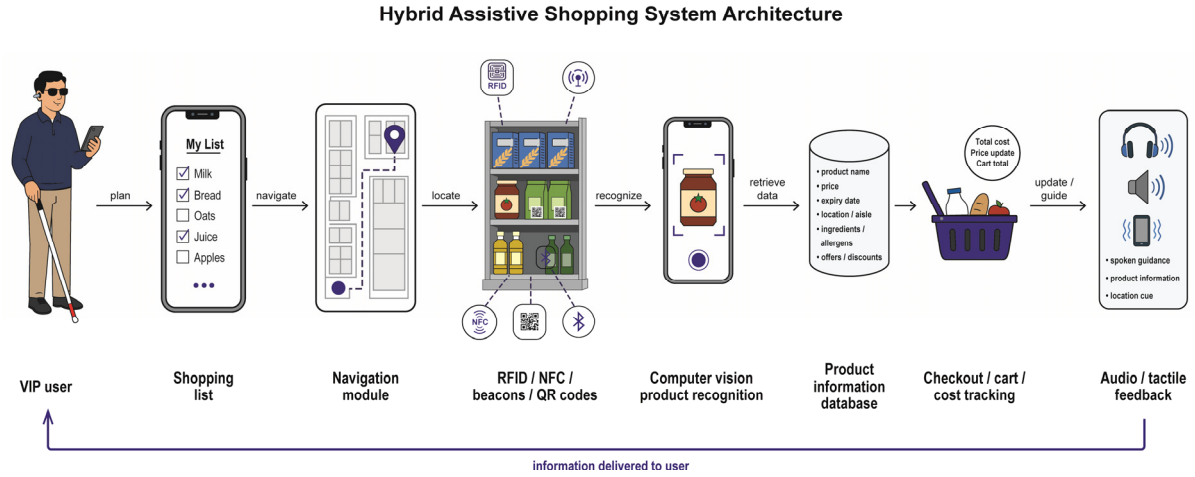


Figure 6. Schematic representation of a hybrid assistive shopping system architecture for VIP users.

5.1. Tag-Based Systems

In this review, tag-based systems are defined as systems in which the main source of product, shelf, or location information is an electronic tag, most commonly RFID or NFC. The user does not identify the product visually; instead, a reader detects a tag and retrieves the associated information from a local or remote database. This distinguishes these systems from barcode-, QR code-, and AR marker-based systems, which also rely on labels but require visual detection using a camera or optical scanner.

RFID technology is widely used in supply chain management, logistics, asset tracking, warehousing, and theft prevention [48]. In assistive shopping, RFID has been explored mainly to support product identification, localisation, and, in some cases, in-store navigation for VIPs.

One of the best-known examples is RoboCart, a robotic shopping cart designed to support VIPs with in-store navigation, product localisation, and checkout-related tasks [49]. The system relies on RFID tags for spatial localisation and combines these with laser-based Monte Carlo Markov Localisation (MCL) to guide users through the store. Interaction is provided via a numeric keypad and a voice-controlled menu. In its original form, RoboCart could guide users to specific shelves but could not accurately identify individual products. A later upgrade introduced a wireless barcode reader with Bluetooth feedback, which

improved the accuracy of product localisation [41]. RFID-based recalibration mechanisms further reduced localisation errors by 20.23%, and shopping time became more stable.

The system was later evaluated with 10 VIPs. The results showed that RoboCart could function as both a haptic and locomotor interface, with users becoming more efficient as they learned to interpret the spatial and tactile cues. Although product placement initially affected performance, users gradually developed spatial knowledge that helped them compensate for this limitation. Participants suggested several improvements, including smoother navigation and more refined feedback mechanisms [50]. In a follow-up experiment, three interface modalities—browsing, typing, and speech recognition—were compared with 10 participants, of whom five were blind and five were sighted but blindfolded. Speech was found to be the most efficient and least cognitively demanding interaction method, while browsing was considered the most frustrating and least effective. Blindfolded sighted participants performed similarly to blind participants, suggesting that such participants may be useful in early-stage usability testing.

Other RFID-based systems have focused on shelf-level product identification. In one solution proposed in 2013, RFID tags were attached to shelves and read by RFID readers, which transmitted product-identifying information to a microcontroller. Each shelf was linked to a pre-recorded audio file that played when the user searched for a product. To finalise a purchase, the user pressed a switch, and the product information was sent to the checkout via a Zigbee system. The authors also proposed further integration with shopping carts equipped with ultrasonic sensors for obstacle detection and collision avoidance. However, the study did not present a fully developed hardware prototype; although the components were described as interoperable in principle, they were not integrated into a single functional unit [48].

A similar solution presented in 2018 combined RFID technology with Zigbee communication and radio frequency (RF) navigation [51]. In this system, RFID tags were attached to shelves, and audio instructions were delivered through earphones. The user wore a glove equipped with an RFID reader, RF receiver, microcontroller, Arduino UNO, earphones, SD card adapter, and Zigbee module. RF transmitters placed in store sections announced department names, while RFID-labelled shelves served as product identifiers. When the user approached a shelf, the reader detected the tag and triggered audio information about the corresponding product. A selected item could then be confirmed by pressing a button, after which the product data were transmitted to the checkout via Zigbee. Although this wearable glove integrated the required components into a single device, it also introduced practical concerns. In addition to typical RFID-related limitations, such as range restrictions and possible tag interference, the system was relatively bulky and expensive, raising questions about its long-term usability in everyday shopping environments.

Another RFID-based system, developed in 2017, was designed to help VIPs locate products on store shelves using auditory instructions [52]. RFID tags attached to products were recognised by readers, and the captured data were sent to a central server. A smartphone application then retrieved the relevant text information and converted it into audio output, supporting both product identification and in-store navigation in real time. Compared with barcode-based systems, this approach enabled faster interaction, provided a stable Wi-Fi connection was available. However, its use remained limited in cramped or crowded environments, where positioning errors could occur and localisation updates could lag behind the user's movement. The authors suggest several improvements, including alternatives to smartphones, information about neighbouring products, integration of global positioning system (GPS) for home-to-store navigation, and software customisation for different retail environments.

NFC has also been explored as a more smartphone-centred, tag-based approach. VirtualEyez is a mobile application that allows users to search for products using voice commands or keyboard input [53]. The application checks the store database and, when a product is available, provides relevant product and location information. By scanning NFC tags placed in the store, users can access details such as product name, price, and special offers while also identifying their current location within the store environment.

A broader smart supermarket concept combined Internet of Things (IoT) architecture with RFID technology to support product search and selection [42]. RFID tags attached to shelves provided basic product information and audio playback of customer comments or reviews, bringing some features of online shopping into the physical store. The system was tested in a simulated smart supermarket with three participant groups: people with visual impairments, sighted participants who were blindfolded, and sighted participants without blindfolds. The results showed that the system improved autonomy and supported both navigation and product selection. However, participants reported difficulties operating the RFID reader and navigating accurately. They valued access to product details and customer reviews, but suggested further improvements, including audio information about expiry dates, nutritional values and allergens, tactile markers such as Braille, more accurate localisation, smaller devices, and the placement of RFID tags on individual products rather than only on shelves.

A related concept was introduced in the Smart Shopping Bag project, which integrates IoT and RFID technologies to display and announce product information such as name, price, and expiry date [54]. The system includes a liquid crystal display (LCD) and a speaker module, while an Arduino microcontroller updates the total cost when products are scanned and enables users to remove products as needed. Payment can be made digitally via a GSM (Global System for Mobile Communications) module or manually at the checkout. The system also provides a security alert if the shopping bag is left behind. Although the concept may enhance accessibility and shopping efficiency, the study does not clarify whether the Smart Shopping Bag system was tested in real-life conditions or evaluated with end users.

Overall, RFID- and NFC-based systems can support assistive shopping by improving product identification, orientation, and interaction for VIPs. Their main advantage is that they do not always require direct visual alignment between the user and the tagged object, reducing the burden of locating labels or visual markers. This makes them particularly suitable for shelf-level identification, location confirmation, and structured navigation in environments where tags are reliably deployed and maintained. However, these systems still depend on tagged products, shelves, or store infrastructure. Limitations related to localisation accuracy, hardware ergonomics, costs, tag maintenance, and validation in uncontrolled store environments continue to restrict wider implementation. Their scalability therefore depends less on recognition algorithms than on retailers' willingness and ability to maintain a consistent electronic tagging infrastructure.

5.2. Computer Vision Marker-Based Systems

Computer vision marker-based systems are distinct from RFID- and NFC-based systems because they require visual detection of a code or marker. In this category, the system does not read an electronic tag directly. Instead, a camera or optical scanner captures a barcode, QR code, AR marker, or similar visual identifier, which is then decoded and linked to product, shelf, or navigation information. This category therefore includes systems that are tag-based in a broad sense, but whose interaction demands and failure modes are closer to those of computer vision systems, as they depend on image capture, marker visibility, camera alignment, lighting, and distance.

Several assistive shopping technologies for VIPs rely on detecting visual markers, such as barcodes, QR codes, or AR markers. These systems typically use a camera or scanning device to detect a code, retrieve the associated information, and communicate it to the user through audio or tactile feedback. The main advantage is that many retail products and shelves already have visual codes, reducing the need for major changes to store infrastructure. However, their practical use depends heavily on whether VIPs can accurately locate, align, and scan the marker.

One of the earliest systems in this category is Trinetra, first developed in 2007 and refined in 2009 [55,56]. The system uses a smartphone, a Bluetooth headset, and a Baracoda barcode scanning pen (Baracoda, Neuilly-sur-Seine, France). An alternative configuration, which was not implemented, proposed the use of generic high-frequency RFID tags with a Baracoda RFID scanning pen. In the implemented version, the user scans a product barcode with the handheld pen. The scanned data are transmitted via Bluetooth to a module on the smartphone, which first searches for a match in a local cache. If no match is found, the system connects to a remote desktop server, where product information is retrieved either from the server cache or from an online universal product code (UPC) database. The information is then sent back to the smartphone and presented to the user through text-to-speech (TTS) output via the Bluetooth headset.

Trinetra is relatively inexpensive, compact, and does not require changes to the store environment. It was also tested with a blind user who contributed as both an evaluator and a co-author, providing insight from an end-user perspective throughout development. However, its main limitation is barcode localisation. The scanning pen must be in direct contact with the barcode, which can be difficult if the user does not know where the barcode is located. The system therefore supports product identification only after the user has already found the relevant product category and positioned the scanner correctly. It does not support in-store navigation, product search, or price verification, which are also important components of an accessible shopping experience [55,56].

Another barcode-based solution is ShopTalk, which uses Modified Plessey (MSI) barcodes, commonly found on store and supermarket shelves, to determine product locations [10]. The system comprises a wearable barcode scanner, a shoulder-mounted keyboard, and headphones connected to a portable OQO computer (Figure 7). The locations of MSI barcodes are mapped in advance, enabling the system to guide the user through the store using a virtual map that links barcodes to spatial coordinates. Each shelf barcode is associated with various types of information, including its relative position on the shelf. The database can be generated from the store's inventory database. When the VIP reaches the desired location, they scan the corresponding MSI barcode to confirm their position. If the scanned barcode matches the expected one, the system assumes the desired product is located there.

ShopTalk has a significant advantage in that it uses existing store infrastructure and can provide detailed product information when connected to an inventory control database, including about prices, ingredients, nutritional information and discounts. It was trialled with ten VIPs, whose feedback was incorporated into system development and evaluation [10]. However, the system has several limitations. It does not directly identify individual products but assumes they are placed correctly on the shelves. Errors may occur when products are misplaced or replaced without corresponding updates to shelf barcodes. The user must also physically locate and scan the barcode, which can be difficult in cluttered store environments. In addition, the required hardware is relatively bulky, as users must carry several components, including a backpack, which may make shopping less comfortable.



Figure 7. ShopTalk wearable assistive system for product localisation and navigation in stores [10].

To reduce hardware complexity, the ShopTalk system was later simplified into a more compact version called ShopMobile [57]. In this version, the main functions were transferred to a smartphone, eliminating the need for several external components. Barcodes were scanned using computer vision algorithms via the smartphone camera, rather than a specialised scanner. The system also included a screen reader and a screen magnifier to support users with varying degrees of visual impairment. A related study developed an algorithm capable of recognising and decoding both UPC and MSI barcodes from camera input [58]. The algorithm detects barcode locations even when they are only partially visible and prompts the user to adjust the smartphone position when the code cannot be fully read. Once recognised, the corresponding product information is delivered through an audio headset. By transferring the system to a mobile platform, ShopMobile retained the core functions of ShopTalk while improving portability and ease of use for VIPs.

Other smartphone-based barcode solutions have focused specifically on helping VIPs locate and read product barcodes. In 2010, a mobile phone application was developed that used the device's integrated video camera to search for barcodes on product packaging [59]. When the barcode entered the camera frame, the system provided audible cues to help the user reposition the phone until the code was fully visible and readable. After successful scanning, the barcode was detected and the product information was read aloud using TTS technology [59].

A more advanced barcode recognition method was proposed in 2017 [60]. In this approach, VIPs capture product images, from which barcodes are detected and recognised to retrieve detailed product information. The process begins with a line segment recognition algorithm that identifies potential barcode areas. These areas are cropped and processed through the ShopWell application, which provides information such as ingredients, nutritional values, and personalised dietary recommendations. The system uses vibration or audio feedback to guide users when the barcode is missing, incomplete, or poorly captured. Its barcode detector, based on the Parallel Segment Detector (PSD) algorithm, was designed to handle motion blur and detect one-dimensional (1D) barcodes effectively. However, performance was limited when barcodes appeared on irregularly shaped products such as bottles or cans. In a dataset of 206 images, the method achieved an accuracy of 70.39%, with most errors caused by incomplete barcode segments. The authors identified the need for a complete end-to-end system, a refined user interface, and further evaluations with VIPs.

A conceptually different approach was proposed in 2008, based on applying QR codes to product packaging [61]. In this system, a QR code scanned with a smartphone is decoded into a Uniform Resource Locator (URL), prompting the phone's web browser to download and play an audio description of the product. Although promising, this concept was neither

implemented nor tested. It also requires products to be labelled with QR codes, which is not yet standard practice in conventional shopping environments. This would necessitate either changes to packaging or an additional layer of product labelling. Each QR code would also need to be linked to a unique, maintained URL, adding further complexity to deployment.

Despite these challenges, QR codes offer several advantages over conventional barcodes. They are more tolerant of imperfect positioning, can be scanned from multiple angles, and have a higher data capacity, allowing more detailed product information to be included or linked [61,62]. Scanning QR codes is also often more flexible than scanning 1D barcodes, which may make them more usable for VIPs in some shopping situations.

Another recent development in this category is Barcode Speak, an application that enables scanning of QR codes and conventional barcodes to provide audio information about physical objects [62]. The application is designed to help VIPs identify and describe product packaging and labels, distinguish similar products, retrieve price and brand information, check expiry dates, and assess basic product quality using the smartphone camera and voice synthesis. In addition to product identification, the application supports a broader shopping workflow. Users can add, update, or remove products from a virtual shopping cart and complete purchases with voice-guided interaction. Audio descriptions support browsing and product confirmation before purchase, and the system also includes a delivery function that allows users to place orders through the application. However, full functionality requires access to the database of the establishment where the application is being used, such as a supermarket or library, which may create integration and scalability challenges. The Barcode Speak system nevertheless illustrates how mobile applications can combine real-time audio feedback, product information, transaction management, and navigation support into a comprehensive assistive shopping platform.

More recent marker-based solutions have also explored the use of AR markers for in-store guidance. In 2024, a robotic shopping cart system was proposed to assist VIPs in supermarkets [28]. The system uses visual reference ArUco markers placed along store paths to continuously track the user's position. When a user requests a product entered into the system by store staff, the system identifies the destination on a predefined digital map, calculates the optimal route, and guides the user to the appropriate location. Navigation is supported by visual real-time localisation and servo-controlled braking. The robotic cart adjusts resistance through servo brakes to guide the user safely, while TTS-based audio instructions provide complementary verbal guidance. The system was tested in a simulated store with six blindfolded participants unfamiliar with the environment. All participants completed the navigation tasks and reached the designated shopping counters. Average route completion times were 30.2 s on the first attempt and 24.0 s on the second attempt, compared to 32.2 s when assisted by a carer. Participants reported feeling safe and in control, and several noted that the system guided them effectively without making the automation feel overwhelming. Although the study was conducted in a simulated environment, the results suggest potential for safe and efficient shopping support in real stores.

Another highly integrated solution was developed in 2022 as a multi-level Grocery Shopping Assistant [63]. The system supports VIPs throughout the various stages of the shopping process, including shopping list creation, in-store navigation, product identification, and checkout. It is based on a Raspberry Pi server connected to a smartphone application and combines QR code navigation, computer vision, TTS/STT (text-to-speech/speech-to-text) interaction, and route optimisation algorithms. The process begins with the creation of a shopping list via STT input on the VIP's smartphone. Once the list is complete, a route optimisation algorithm calculates the shortest path for collecting all products in the store, treating the task as a travelling salesman problem (TSP). The resulting route consists of

checkpoints linked to product locations on the store's digital map. In the store, the smartphone activates a navigation subsystem that uses QR codes placed in the environment to guide the user from checkpoint to checkpoint. The smartphone camera recognises these markers, and verbal TTS instructions guide the user through the aisles. When the user reaches the product location, a product recognition subsystem is activated. Computer vision is used to identify the barcode, after which the system verifies the product and confirms it acoustically. All components communicate with a central SQL database, the "Grocery Assistant", which stores user lists, product data, and store layouts.

Although the Grocery Shopping Assistant was tested under simulated conditions, the authors did not specify whether VIPs participated in the evaluation. Nevertheless, the prototype demonstrated the potential of combining several functions in a single shopping support system. Proposed future developments include self-driving shopping carts, real-time stock tracking, stress-level monitoring, personalised product recommendations, and adaptation of the system for mobile use. The authors also suggested that similar principles could be applied beyond retail, for example in warehouses for inventory management and navigation.

Taken together, barcode-, QR code- and AR marker-based computer vision systems can support product recognition, product information access and, in some cases, in-store navigation for VIPs. Their main strength is their ability to connect physical products or store locations with digital information delivered through audio or other accessible feedback. However, practical adoption remains limited by scanning precision, marker visibility, camera alignment, environmental conditions, hardware integration and the need for compatible retail databases or infrastructure. Compared with RFID- and NFC-based systems, they may require less specialised electronic infrastructure, but they place a greater burden on the user to locate, frame, and scan the correct marker. Their real-world usefulness therefore depends on whether marker detection can be made fast, forgiving and reliable under typical shopping conditions. Future solutions should focus on making marker detection more robust, reducing user effort and ensuring these systems function reliably in real-world shopping environments.

5.3. Computer Vision Non-Marker-Based Systems

Computer vision non-marker-based systems are defined here as systems that attempt to recognise products, shelves, labels, or shopping-relevant objects without relying on RFID/NFC tags, barcodes, QR codes, AR markers, or other predefined identifiers. Their classification is based on the requirement that the system must infer product identity or context from visual appearance alone. This makes them potentially less dependent on modified store infrastructure, but more dependent on image quality, training data, recognition models, and real-time processing.

Computer vision systems that do not rely on physical tags, barcodes, or other visual markers aim to recognise products directly from their visual characteristics, such as colour, shape, texture, logos, and packaging. In principle, this makes them highly relevant for real shopping environments, where products are not always labelled accessibly and VIPs may not be able to locate or scan a specific code. At the same time, these systems must operate under uncontrolled conditions, including variable lighting, cluttered shelves, reflections, different viewing angles, and frequent changes in packaging. The development of robust datasets and the evaluation of recognition algorithms under realistic conditions are therefore central to this category of assistive shopping technology.

An important early contribution was the GroZi-120 database, presented in 2007 [30]. The dataset includes 120 grocery products recorded under both in vitro (ideal) conditions, where products are captured in a controlled setting, and in situ (real-world) conditions,

where products are photographed in shopping environments. It was designed to support practical product recognition tasks and contains images that vary in size, colour, rigidity, shape, illumination, viewing angle, and quality. The study evaluated three widely used object recognition approaches: colour histogram matching curve (CHM), Scale-Invariant Feature Transform (SIFT), and extended Haar-like features.

Among the tested methods, SIFT showed the best overall performance in detecting and recognising different products under real conditions. CHM initially performed poorly but improved significantly under certain conditions, reaching a hit rate of 99%. In contrast, the AdaBoost classifier based on extended Haar-like features produced the weakest results. The study was important, as it demonstrated how strongly recognition performance depends on imaging conditions and product characteristics, and it provided a foundation for later work on grocery recognition for assistive applications.

A more extensive grocery image dataset was developed in 2019, containing 5125 images collected from 18 different stores [64]. The dataset comprises 81 fine-grained and 46 coarse-grained classes, covering both raw and packaged products such as fruit, vegetables, dairy products, and juices. Images were captured with a 16-megapixel Android smartphone and reflect realistic store conditions, including cluttered backgrounds, varying lighting and densely arranged shelves. To improve classification, each category was supplemented with clean, iconic images and semantic product information such as origin, weight and nutritional values. This dataset is particularly relevant for assistive shopping as it supports recognition based on visual features rather than barcode scanning. For VIPs who cannot easily locate product labels or codes, this type of visual recognition can provide a more natural means of product identification. The inclusion of semantic metadata also enables richer auditory feedback, including nutritional content and product-specific information.

A 2023 review of advances in grocery label detection and recognition [65] provides a broader perspective on this field. Although database development and label recognition are not the main focus of the study, these technologies are closely linked to assistive shopping. The authors discuss progress in product recognition, label processing, and object recognition, with particular relevance for VIP users. They also highlight persistent limitations in current datasets, practical deployment, and recognition robustness. This makes the study valuable for understanding the technical challenges that must be addressed for computer vision-based shopping assistive systems to function reliably outside controlled environments.

One of the first systems developed specifically for grocery recognition was ShelfScanner, introduced in 2010 [66]. The system allows users to scan store shelves with a smartphone camera and search for products from a predefined shopping list containing product images. As the user pans the camera across the shelves, the system attempts to recognise listed products and, when a match is found, provides acoustic cues to guide the user to the relevant shelf. ShelfScanner is based on the Grozi-120 database and combines an offline training module with online evaluation. During training, product images are processed using speeded-up robust features (SURFs), which generate local descriptors. These descriptors are then enriched with Lab* colour histograms, excluding the luminance channel, to reduce the effect of lighting differences between controlled product images (in vitro) and real shelf product images. Although ShelfScanner was designed to operate in real time, its actual performance was limited to about two frames per second (fps), which is insufficient for smooth real-time interaction. The original system also required a powerful laptop carried in a backpack, reducing mobility and ease of use. Another limitation is that the system can indicate whether a product is present on a shelf, but it does not reliably help the user select the exact product. The authors therefore suggested integrating text

recognition and barcode scanning to reduce errors caused by packaging variations and misidentification [66].

A related computer vision approach was developed in 2015 [29]. In this study, an algorithm was trained to recognise grocery products from images captured under controlled conditions and was then tested on shelf images from real stores. The recognition system combined two main types of visual information: shape, described using SIFT descriptors, and colour, represented by HSV values (hue, saturation and value). Recognition focuses on brand logos and product appearances using a bag-of-visual-words model, which clusters local visual features into representative vocabulary elements. The evaluation showed that combining colour and shape features produced significantly better recognition accuracy than using either feature alone. Along with ShelfScanner, this work demonstrates the potential of visual-feature-based product recognition, but also highlights persistent challenges related to real-time processing, localisation accuracy, and hardware requirements.

Another mobile solution was introduced in 2014 as an Android-based application for the retail environment [67]. The application enables VIPs to photograph products and use colour reduction to support recognition and extraction of textual information from packaging. The extracted text is processed using optical character recognition (OCR), converted into character strings, and then vocalised through TTS output. The application also features interactive voice control, allowing users to request specific product descriptions from a store-specific database developed with SQLite in the Android framework. Store and product information are indexed with structured constraints to support efficient querying. The application also allows VIPs to mark desired products, calculate the total cost of selected items, and receive the amount through voice output. However, the study does not report evaluation metrics or accuracy results, making it difficult to assess the system's practical performance.

A more comprehensive mobile platform, UCap, was developed in 2015 [45]. This crowdsourcing-based Android application supports product identification through a collaborative database. Sighted users contribute by capturing and annotating product images, which are then uploaded to a central database. At the time of the study, the database contained 3950 images of 296 unique products. UCap uses content-based image retrieval (CBIR), implemented via the LIRE framework, to match images captured by VIP users with those in the database. After identification, the application provides product information such as ingredients and nutritional values. UCap was evaluated with 15 VIPs and 10 sighted users through interviews, surveys, and observational studies. Many VIP participants, already familiar with accessibility tools, appreciated the application's ease of use, particularly the search interface. Before using UCap, only 33.33% of VIP participants reported relying on ingredient or nutritional information when shopping; after using the application, this proportion increased to 80%. However, satisfaction was limited by recognition accuracy, especially when images were blurred or captured under inconsistent lighting conditions. The application ran on a Samsung Galaxy S5 (Samsung Electronics, Suwon, Republic of Korea) and used Android SDK (Google LLC., Mountain View, CA, USA; version not reported in the original study), JSON, and PHP for server–client communication. Data was hosted on Microsoft Azure, with MySQL as the database backend. Feature extraction included descriptors such as the Auto Colour Correlogram (ACC) and the Joint Composite Descriptor (JCD). Planned improvements included gamification to encourage sighted users to contribute, more light-independent detection, and a larger, more diverse database of store environments.

In 2019, a low-cost camera-based product identification prototype was developed using a Raspberry Pi 3 microcontroller (Raspberry Pi Ltd., Cambridge, UK; version not further specified in the original study) [68]. The device supports three main functions:

capturing an image, identifying the product, and retrieving its price for presentation to the VIP user. When activated, the Raspberry Pi Camera Module V2 (Raspberry Pi Ltd., Cambridge, UK; 8-megapixel Sony IMX219 sensor) captures an image, which is processed by a prediction model to determine the most likely product class. The product name is then spoken through TTS and delivered via a connected headset. To provide price information, the system uses a web scraping script to retrieve product prices from the website of a grocery store, Sprouts. However, the web scraping process took between 240 and 270 s, which severely limits real-time use. The authors suggested that this step could be performed before shopping, although future versions would need to reduce latency. All hardware components were housed in a 3D-printed, head-worn unit. The Raspberry Pi was chosen instead of Arduino because it offers greater computing capability and can run multiple applications simultaneously.

To improve classification performance, the same prototype used a convolutional neural network (CNN) trained on more than a thousand product images, implemented with TensorFlow (Google's open-source library, widely known for deep learning) and Keras (a high-level Python (Python Software Foundation, Wilmington, DE, USA; version not reported in the original study) application programming interface (API) for deep learning built on top of the TensorFlow backend) [68]. Although the system enabled basic product identification and pricing, several limitations remained. VIP users still needed support to navigate the store and locate desired products, so additional navigational aids, such as guide dogs or human assistance, were still necessary. The Raspberry Pi platform was also limited in processing speed, affecting classification and response times. These issues could be mitigated by using a more powerful single-board computer, but this would increase costs. The web scraper was another bottleneck, although performance could be improved by accessing a regularly updated product database instead of retrieving data through slow web scraping.

A wearable solution was proposed in 2016, consisting of glasses equipped with a camera that continuously captures images in real time [69]. The user specifies the desired product, and the system analyses the incoming video as the user moves through the store. When early visual cues are detected, the system prompts the user to adjust their position by turning, moving, swiping, or tilting so that the product appears more centrally in the camera view. Once the confidence threshold is reached, the system informs the user that the product is directly in front of them and provides instructions on how to pick it up. The system uses template-based key point matching with SURF descriptors, chosen for their speed compared with alternatives such as SIFT. However, it is mainly limited to products with flat fronts, such as boxes, because curved products such as cans remain difficult for homography estimation.

A related development is Third Eye, introduced in 2017 [8]. This system combines smart glasses with a wearable glove-mounted camera to support product identification. Video from both devices is transmitted via in-store Wi-Fi to a remote server, where image processing algorithms analyse the environment in real time. The smart glasses classify shelf scenes, such as identifying a coffee shelf, while the glove camera enables fine-grained product recognition using SURF and a planogram-based layout. Audio and vibration cues assist VIP users in orienting themselves, and an interactive audio menu enables product selection. Users described the experience as more similar to real shopping than barcode scanning. However, limitations in the glove camera's field of view sometimes resulted in incorrect product selection.

Another user-centred wearable system is FingerReader 2.0, developed in 2018 [13]. The device is worn on the index finger and enables VIPs to point at a product and capture an image with a tap of the thumb. This "point-and-shoot" interaction provides product

information, which is then processed using the Google Vision API (which recognises small fonts and supports more than 50 languages) and delivered through a Bluetooth headset connected to the smartphone or through the phone's speaker. The design includes a wristband that houses the electronics, making the finger-worn component lightweight. While the system offers an intuitive interaction model, it requires accurate pointing, steady hand movement, and favourable imaging conditions. It is sensitive to lighting, reflective packaging, curved text, and unconventional fonts, all of which can reduce recognition reliability. Deep learning tools such as single shot detectors (SSDs) and Google Vision support product recognition, but user feedback emphasised the need for accurate outputs, customisable controls, and fast response times.

Building on this line of work, AiSee was introduced in 2020 as a discreet wearable interface combining a bone-conduction headset, a head-mounted camera, and a smart ring for interaction [14]. The system was developed iteratively with VIPs, who raised concerns about the social visibility and potential stigmatisation associated with devices such as smart glasses. AiSee was therefore designed to be less conspicuous while still supporting text, logo, and label detection and recognition. It was tested in both laboratory conditions and a real store environment. VIP users reported issues with audio latency and overheating during prolonged use, which affected TTS performance. Further improvements were identified in ergonomics, hardware efficiency, and interaction feedback.

A more comprehensive AI-based solution was tested in 2020 using three shopping modalities: autonomous shopping, assisted shopping and device-assisted shopping with an AIoT prototype [15]. In a simulated store, blindfolded university students aged 18–21 interacted with 17 products while wearing a device that identified products from a pre-existing database. The AIoT device transmitted product names, prices, and expiry dates via Bluetooth audio. Device-assisted shopping was slower because recognition was affected by lighting and camera angle, but it achieved reasonable accuracy. Assisted shopping was the most accurate, though less consistent in duration, while autonomous shopping was the fastest but less accurate. The results also suggest gender differences in product recognition, with women performing better than men, possibly due to greater familiarity with certain product categories such as cosmetics. The authors planned to include VIPs in future testing and to improve the handheld device software to increase usability.

MobiEye, developed in 2023, is a mobile shopping assistant that integrates real-time video stream analysis, deep learning, and hand tracking [46]. The system consists of three modules. The voice control module uses iFLYTEK and achieved 93% accuracy in text conversion. The walk assist module uses YoloV5 to identify product zones and stop the user at an optimal distance. The grasping assistant module combines YoloV5 and MediaPipe to track hand movements and support accurate product selection. In a real-supermarket test with 10 VIP users, MobiEye achieved 98.5% navigation accuracy and improved the accuracy of small product selection by 50%. The fold-line navigation method was preferred by users, suggesting that structured but not overly complex guidance can be effective in real retail settings.

The EyeShare system, developed in 2012, combines computer vision with cloud services and remote support [70]. The system enables VIP users to photograph products and send the images to carers, who verify the products via voice or text input. Recognition is performed using an OpenCV image-matching application, while cloud infrastructure, including Amazon EC2 and Google C2DM, supports scalability. Product recognition took less than one minute on average, and speech recognition was effective for naming products. Although the SURF algorithm had limitations, the approach showed potential for product recognition, payment support, and in-store navigation. The authors argued that dedicated

remote assistance, supported by smartphones and cloud services, can provide a viable, flexible long-term solution.

Overall, non-marker-based computer vision systems have strong potential to support a more flexible and natural shopping experience for VIPs, as they do not rely on physical tags, barcodes, or modified store infrastructure. They can recognise products from visual features alone and may therefore better reflect how products are encountered in everyday retail environments. However, their practical reliability is still limited by lighting conditions, reflections, motion blur, cluttered shelves, curved packaging, processing latency, device ergonomics, and the complexity of user interaction. Many systems also remain dependent on large, regularly updated datasets. Future development should therefore focus on lightweight, robust, user-centred solutions that provide accurate, timely, and discreet feedback in real-world shopping situations.

5.4. Hybrid Systems

Hybrid systems are classified separately because their defining feature is not a single recognition or identification mechanism, but the deliberate integration of several technologies to support a broader part of the shopping process. In this review, a system is considered hybrid when it combines two or more major technological approaches—such as RFID or NFC, barcode or QR code scanning, computer vision, beacons, cloud databases, audio feedback, tactile interaction, or mobile applications—in a way that is essential to its core functionality.

Hybrid systems combine several assistive technologies, such as RFID, computer vision, NFC, cloud services, tactile interaction, and audio navigation, to support a wider range of shopping tasks for VIPs. Unlike systems that focus mainly on a single function, such as barcode scanning or product recognition, hybrid approaches usually aim to connect multiple stages of the shopping process. These may include in-store navigation, obstacle avoidance, product identification, access to product information, and checkout. Their main advantage lies in the integration of complementary technologies, where the limitations of one component can be partly compensated for by another. However, this integration often increases system complexity and may require greater infrastructural support from the shopping environment.

An early example is BlindShopping, developed in 2011 [35]. The system was designed to provide infrastructural support for the entire in-store shopping process, which the authors conceptualised as a four-stage cycle: product category navigation, product search, product identification, and product selection. BlindShopping integrates RFID tags, QR code and UPC code scanning, and voice guidance delivered through headphones. The user interacts with the system via a white cane equipped with an RFID reader, which supports navigation and orientation within the store. By combining tag-based localisation with code-based product identification, the system aims to address multiple shopping tasks rather than a single isolated task, moving closer to a complete shopping support model.

Another hybrid solution, developed in 2020, is a smartphone-based indoor navigation system for VIPs [16]. The system uses wireless beacons installed under the store ceiling to locate the user and identify nearby shelves. Each beacon corresponds to a specific product category, which is announced via voice output. The user selects the desired category by voice input, and the application calculates the shortest route using Dijkstra's algorithm. When the user reaches the relevant shelf, the application announces the products available in this area. Product identification is then supported through a combination of tactile and visual interaction: the user touches an embossed tag and positions it in front of the smartphone camera, where it is recognised using the SIFT algorithm connected to a cloud database. In a test with seven VIPs, the navigation module performed very successfully,

while product identification reached 85% accuracy under optimal imaging conditions. However, camera alignment and image blurring, particularly in low-contrast images, remained significant challenges. These findings suggest that, although hybrid systems can support both navigation and product identification, their reliability still depends on the robustness of individual interaction steps.

A further hybrid assistance system was proposed in 2019, organised around three primary use cases: navigation, product identification, and checkout [71]. Collision-free navigation is supported by a Google Glass-inspired optical head-mounted display combined with IoT-enabled gloves that localise Bluetooth Low Energy (BLE) beacons. VIP users can give voice commands, such as "Go to fruits", to retrieve store maps and receive guidance through QR-coded aisles. Product recognition combines visual and tactile interaction with advanced deep learning models, including PointNet 3D for spatial depth information and DeepLab for semantic segmentation. This combination is intended to enable more reliable product recognition using both camera input and tactile cues. Although the system was still in the design phase, it was already being tested in the field and included product recognition functions based on user preferences and purchase history. This indicates a shift towards more personalised assistive shopping systems, although the complexity of the proposed architecture also raises questions about implementation, cost, and long-term usability in ordinary retail settings.

SANIP, developed in 2022, is a mobile application that provides real-time audio feedback to VIPs by integrating barcode scanning, object recognition, and OCR. The solution uses YOLOv4-tiny for product detection and recognition, PyTesseract for OCR-based text recognition, and Pyzbar for decoding barcodes and QR codes. Audio feedback is delivered through a TTS module based on Pyttsx3. SANIP was trained using Google Colab and the Darknet framework, and is designed to help VIPs recognise portable products, signs, and labels without relying on store staff. The authors proposed extending the dataset and developing a TensorFlow-based mobile application to improve scalability and performance. Although SANIP does not cover the entire shopping process, it represents a compact hybrid approach that combines object detection, text recognition, and code decoding in a single mobile-oriented system [72].

A recent 2023 contribution proposed an assistive mobile application supporting three main tasks: navigation, product search, and product identification [40]. Navigation relies on magnetic field localisation, while NFC tags help VIP users locate products and barcode scanning supports product identification. The prototype was designed for both planned and spontaneous purchases, reflecting the need for assistive systems that respond not only to prepared shopping lists but also to decisions made during shopping. The system focuses on intuitive interaction and aims to connect physical and digital shopping experiences more inclusively.

Taken together, hybrid systems demonstrate the potential of combining complementary technologies to support a more holistic shopping experience for VIPs. By integrating RFID, NFC, computer vision, tactile cues, audio feedback, cloud databases, and mobile interaction, these systems can address several barriers simultaneously rather than focusing on a single task. However, this broader functionality often brings increased technical and infrastructural complexity. Many hybrid solutions remain at the prototype stage, require modified store environments, or depend on accurate databases, stable connectivity, and carefully positioned markers or sensors. Compared with single-technology systems, hybrid systems are better placed to support multiple stages of the shopping journey, but they also require more careful evaluation because failures can occur at several points in the interaction chain. Future development should therefore focus on balancing functionality

with simplicity, ensuring that hybrid solutions remain accurate, discreet, affordable, and usable in real retail environments.

Overall, the four categories differ in their central trade-offs. RFID- and NFC-based systems reduce the need for visual alignment but depend on electronic tagging infrastructure. Computer vision marker-based systems can exploit existing barcodes, QR codes, or AR markers, but require users to locate and scan visible identifiers. Computer vision non-marker-based systems reduce dependence on store labelling but remain sensitive to imaging conditions, product variation, and recognition accuracy. Hybrid systems can support a broader range of shopping tasks but often increase technical complexity and infrastructural requirements. This classification therefore provides a basis for comparing assistive shopping technologies not only by technical type but also by usability, infrastructure dependence, validation, and real-world deployability.

In addition to technological classification, the reviewed systems were analysed according to the type of validation reported in the source publications. This additional coding was used to assess whether the proposed solutions were evaluated with the intended end users or remained limited to blindfolded sighted participants, technical testing, simulation, or conceptual development. The distribution of validation types is summarised in Table 2.

Table 2. Summary of user validation categories across reviewed assistive shopping systems and related technical work.

Validation Category	Type of Validation	Number of Systems/ Contributions	Share
V1	Evaluation with visually impaired participants	7	20.0%
V2	Evaluation with blindfolded sighted participants	2	5.7%
V3	Evaluation with mixed participant groups	3	8.6%
V4	Technical evaluation only	16	45.7%
V5	Conceptual or no clearly reported empirical evaluation	7	20.0%
Total		35	100.0%

Note: V1, evaluation with visually impaired participants; V2, evaluation with blindfolded sighted participants; V3, evaluation with mixed participant groups; V4, technical, dataset-level, algorithmic, or prototype-level evaluation without clearly reported target user testing; V5, conceptual or prototype systems without clearly reported empirical evaluation.

The validation coding shows that only a small proportion of reviewed systems were evaluated directly with visually impaired end users. Of the 35 systems or technical contributions summarised in Table 2, seven were evaluated with VIP users only; three used mixed samples that included VIP users; two relied solely on blindfolded sighted participants; sixteen reported technical, dataset, algorithmic or prototype-level evaluation without clearly reported target-user testing; and seven were conceptual or prototype systems without clearly reported empirical evaluation. Thus, only 10 of the 35 reviewed contributions included VIP users in the evaluation process, while the remaining 25 relied on blindfolded sighted participants, technical testing, simulation or no clearly reported user evaluation. This suggests that, although many systems are designed for VIPs, their usability and real-world relevance are often not validated with the intended users.

6. Discussion

This review examined a wide range of assistive shopping technologies developed to improve the shopping experience of VIPs in conventional retail environments. The systems reviewed show considerable potential to support autonomy, improve access to product information, and reduce dependence on sighted assistance. At the same time, their

practical implementation remains shaped by several recurring challenges, including ease of use, scalability, environmental requirements, hardware ergonomics, data availability, user validation, and overall system complexity. This section discusses the main advantages and limitations of the four system categories analysed in this review: tag-based systems, computer vision marker-based systems, computer vision non-marker-based systems, and hybrid systems.

Tag-based systems, particularly those using RFID and NFC, offer several significant advantages. RFID technology is already widely used in supply chain management, warehousing, and asset tracking because it enables reliable data transmission without requiring a direct line of sight between the tag and the reader [48]. This feature is especially relevant for VIPs, as users do not need to visually locate a label or precisely align a camera with a code. RFID tags can also be placed discreetly on products, shelves, or other objects, and multiple items can be scanned simultaneously. In retail settings, this allows faster product identification, more efficient checkout, and improved inventory management, benefiting both VIPs and sighted customers.

However, RFID- and NFC-based systems also face significant limitations. Their wider adoption depends on the availability of tagged products, tagged shelves, and other supporting store infrastructure. This presents practical barriers, as not all products carry RFID or NFC tags, and not all retailers have implemented compatible systems. Installation and maintenance costs can also be substantial, especially when tags must be regularly updated, replaced, or synchronised with product databases. Readability may be affected by materials such as liquids, glass, or metal, which can interfere with radio signals. From the user's perspective, another challenge is information management. When several tags are read simultaneously, the system may provide too much information at once, increasing confusion rather than reducing cognitive load. Privacy and data security are also relevant concerns, particularly when RFID-based systems are linked to consumer behaviour, purchase histories, or location tracking. Finally, environmental issues, including the disposal of RFID components, should be considered when evaluating their long-term sustainability.

Computer vision marker-based systems, including barcode, QR code, and marker-based approaches, offer a more accessible and often less expensive alternative. These systems can usually be implemented on standard smartphones, which many VIPs already use and trust. In many cases, they require little or no modification to the retail environment, especially when relying on existing barcodes or shelf labels. They can also support activities before and after shopping. At home, VIPs may use them to identify products already in stock and prepare shopping lists more independently. After shopping, the same technologies can help users recognise, organise, and store newly purchased products.

Despite these advantages, computer vision marker-based systems remain highly dependent on the user's ability to locate, position and scan a marker. This is often difficult in practice, especially when barcodes or QR codes are small, poorly printed, damaged, reflective, hidden on curved packaging, or placed inconsistently. Lighting conditions, moisture, wear and camera alignment can further reduce readability. If additional labelling is required, such as applying QR codes to products, the process may be time-consuming and difficult to maintain at scale. Many systems in this category also focus mainly on product identification and provide limited support for other parts of the shopping process, such as navigation, product search, price comparison or contextual decision-making. ShopTalk and ShopMobile partly address this limitation by combining shelf barcode scanning with store mapping and navigation, but they still depend on structured retail environments and accurate shelf organisation. In cluttered or crowded stores, scanning several possible tags can become slow, frustrating and cognitively demanding.

Computer vision non-marker-based systems offer a different kind of promise. By recognising products from visual features such as colour, shape, logos, text, texture, and packaging, they can function without requiring physical tags or changes to store infrastructure. This makes them potentially more natural and flexible in real shopping environments. They also align well with the demand for discreet, mobile, hands-free solutions that can operate through devices already familiar to VIPs, including smartphones, head-mounted cameras, smart rings, headphones, and other wearable interfaces. Compared with earlier bulky prototypes, more recent systems are often more portable and socially acceptable.

Nevertheless, non-marker-based computer vision remains technically demanding. Reliable product recognition requires high-quality image capture, which can be difficult for VIPs when they cannot see whether the product is centred, well lit, or in focus. Recognition is affected by motion blur, uneven lighting, reflections, low contrast, curved surfaces, crowded shelves, and unusual typography. Fine-grained classification is particularly challenging because many products differ only slightly in flavour, size, packaging colour, or promotional design. Frequent packaging changes can also make training data outdated, reducing recognition accuracy over time [65]. Inaccurate recognition may lead to incorrect product selection, especially when the system identifies the correct product visually, but the user then picks up an item placed above, below, or next to it. Some systems address this by adding barcode scanning after visual recognition, but this introduces an additional step and may reduce the fluidity of interaction.

Processing speed is another major issue. Several non-marker-based systems do not yet operate reliably in real time, particularly when recognition depends on cloud processing, wireless connectivity, or computationally intensive algorithms. Training, updating, and maintaining recognition models also require substantial resources and large image datasets that reflect real retail conditions. Feedback latency is especially important in shopping contexts, where delayed audio instructions can interrupt the user's movement, reduce confidence, and increase cognitive load. For these systems to become more practical, they must provide fast, accurate, and actionable feedback while remaining lightweight, affordable, and easy to operate.

Hybrid systems attempt to overcome some of these limitations by combining several technologies within a single solution. Using RFID, NFC, computer vision, barcode or QR code scanning, navigation algorithms, cloud databases, tactile interaction, and audio feedback, they can support a wider range of shopping tasks. Some hybrid systems address not only product identification but also shopping list creation, route optimisation, in-store navigation, product search, checkout, and post-purchase organisation. This broader functionality makes them particularly relevant for supporting the complete shopping cycle rather than a single isolated task. Hybrid solutions can also be adapted to different scenarios, including planned shopping, spontaneous product selection, home organisation, and warehouse navigation.

However, this broader functionality brings greater complexity. Hybrid systems often depend on the successful integration of multiple hardware and software components, stable connectivity, accurate store maps, up-to-date product databases and, in some cases, modified retail infrastructure. They may also require user training and ongoing technical support. If the interaction is not carefully designed, the combination of several technologies can overwhelm users rather than support them. Therefore, the central challenge for hybrid systems is not only technical integration but also interaction design. A system that combines many functions must still remain simple, predictable and unobtrusive in everyday use.

Across all four categories, the most important cross-cutting issue is the limited validation of assistive shopping technologies with visually impaired end users. The validation-based quality assessment also showed that most studies relied on technical evaluations,

simulations, or conceptual designs rather than direct evaluation with participants who are visually impaired. The validation coding presented in Table 2 shows that only 10 of the 35 reviewed systems or technical contributions included VIP users in the evaluation process, either as the only participant group or as part of a mixed sample. By contrast, most systems were evaluated only with blindfolded sighted participants, technical performance metrics, simulation, or prototype demonstrations, or they were presented without clearly reported empirical evaluation. This finding highlights a persistent gap between technical feasibility and real-world usability.

Testing with blindfolded sighted participants can be useful in early-stage development, particularly for identifying obvious interaction problems or safety issues. However, it cannot fully replace evaluation with VIP users. People who live with visual impairment often develop long-term strategies based on touch, hearing, spatial memory, residual vision, mobility aids, and familiar routines. They may also experience shopping differently in terms of confidence, privacy, social interaction, fatigue, cognitive load, and perceived safety. These aspects are difficult to reproduce through short-term visual deprivation in sighted participants. As a result, systems that perform well in simulated tests may still fail to meet the practical needs of VIPs in real shopping environments.

The lack of target-user validation is particularly problematic because many assistive shopping systems require complex interaction in dynamic retail settings. Real stores are noisy, crowded, visually cluttered, and socially demanding. Products may be misplaced, lighting may vary, shelves may be reorganised, and users may need to manage a cane, a shopping basket, a smartphone, tactile exploration, and auditory feedback at the same time. Technical accuracy alone therefore cannot demonstrate whether a system is acceptable, discreet, efficient, and trustworthy for everyday use. Future studies should therefore involve VIPs throughout the design and evaluation process, and move beyond laboratory or simulated environments towards longer-term testing in real stores.

Second, many systems still address only part of the shopping process. Product identification has received the most attention, but shopping also includes preparing at home, travelling to the store, orienting within the retail space, locating product categories, comparing alternatives, checking prices and discounts, completing payment, returning home, and organising purchased items. Technologies that support only one of these steps may be useful, but they cannot fully remove dependence on sighted assistance. Future systems should therefore be evaluated not only on recognition accuracy or navigation performance, but also on how well they support the shopping process as a whole.

Third, usability and dignity are as important as technical performance. VIPs may reject a technically accurate system if it is too bulky, slow, conspicuous, expensive, or difficult to control. Many studies show the importance of familiar devices such as smartphones, headphones, smartwatches, and white canes. They also highlight the need for discreet feedback, low cognitive load, fast response times, and interaction methods that do not interfere with the use of hands, mobility aids, or tactile exploration. Assistive shopping technologies should therefore be designed around real user routines rather than solely on technical feasibility.

The successful implementation of assistive shopping technologies also depends on retailers. Many systems require access to product databases, inventory data, shelf layouts, store maps, and physical markers. Without retailer participation, even well-designed systems may be difficult to scale. Inclusive shopping technologies can benefit not only VIPs, but also older adults, people with cognitive or motor difficulties, tourists, customers with temporary impairments, and sighted shoppers seeking more efficient access to product information. Therefore, future development should be framed not only as assistive tech-

nology for a specific user group, but also as part of a broader movement towards more inclusive, accessible, and intelligent retail environments.

Overall, the reviewed technologies show that independent shopping for VIPs is technically possible, but not yet fully supported in practice. The most promising future directions are likely to combine robust recognition, accessible feedback, minimal environmental modification, familiar devices, real-time operation, and strong involvement of VIPs throughout the design and evaluation process. The goal should not be to create increasingly complex systems for their own sake, but to develop solutions that are reliable, discreet, and meaningful in the everyday shopping situations in which they will actually be used.

These findings also point to several directions for future research and development. Future development of assistive shopping technologies should start from a broader understanding of the shopping process. For VIPs, as for sighted shoppers, shopping does not begin at the store entrance. It starts at home, with checking available products, recognising what is already in stock, estimating quantities, identifying needs, and preparing a shopping list. These activities can be time-consuming and cognitively demanding when visual information is unavailable. After shopping, VIPs must also identify purchased products and store them in a consistent and memorable way so they can be found and used later. This full cycle, from preparation to post-purchase organisation, should guide the design of future systems [37].

The needs, preferences, and abilities of VIPs should be central to the design process. Many potential users, especially older adults, may be reluctant to adopt complex, unfamiliar, or highly visible technologies. Solutions should therefore be intuitive, simple, and easy to use. Previous research has shown that VIPs value discretion and may feel uncomfortable using devices that are bulky, noisy, or socially conspicuous [14]. For this reason, adapting familiar devices such as smartphones, headphones, glasses, smartwatches, and white canes may support inclusion and reduce the risk of stigma.

Cost and implementation requirements are also critical. Systems that require major changes to store infrastructure are unlikely to be widely adopted in commercial retail environments. Retailers are more likely to accept solutions that are affordable, easy to install, simple to maintain, and adaptable to different store layouts. Future systems should therefore aim to minimise environmental changes while still providing reliable access to product and navigation information.

Multifunctionality should be considered, but not at the expense of usability. Ideally, assistive shopping systems should support both in-store and home-based tasks, including product recognition, product organisation, and cost tracking. At the same time, they should minimise the need for constant user interaction. Systems that require frequent commands, complex gestures, or continuous attention can increase cognitive load and reduce spatial awareness. Portability, rapid activation, and clear feedback are therefore essential for safe, independent use.

Choosing a feedback modality requires particular care. Auditory feedback is widely preferred; in one study, almost half of respondents reported preferring to receive information through audio [39]. However, audio feedback is not always ideal. It may interfere with environmental sounds that VIPs use for orientation, and it may reduce privacy if delivered through speakers. Vibration or tactile feedback can therefore be valuable, especially when discretion is important or when auditory attention needs to remain available for mobility and safety [8]. Future systems should support flexible feedback options and avoid obstructing the functional senses that VIPs already use to navigate and understand their surroundings.

It is equally important to design for the abilities of VIPs, not just their limitations. People with varying degrees of visual impairment use different strategies when shopping.

Those with residual vision may rely on contrast, shape, colour, layout and enlarged visual information, while people who are blind may depend more on touch, spatial memory, auditory cues and consistent product organisation [12,13]. Assistive technologies should therefore be adaptive rather than based on a single model of visual impairment.

Future research should involve VIPs from the earliest stages of development, not only in final usability testing. Collaboration with users, accessibility specialists, orientation and mobility experts, retailers, and technology developers can help ensure that proposed solutions are technically feasible, socially acceptable, and useful in real shopping contexts. Studies should also move beyond laboratory or simulated environments and include longer-term testing in real stores, where crowding, noise, lighting, product displacement, staff interaction, and time pressure all affect the shopping experience.

Only by combining technical reliability with user-centred design can assistive shopping technologies meaningfully support VIPs throughout the shopping process. Future solutions should help users plan purchases, navigate stores, locate and identify products, access prices and product information, complete payment, and organise purchases at home. In this way, assistive technologies can contribute not only to shopping efficiency but also to autonomy, dignity, privacy, and more equitable access to everyday retail services.

7. Conclusions

This review analysed a wide range of assistive technologies developed to support VIPs during shopping in conventional retail environments. The solutions reviewed address various stages and tasks of the shopping process, including shopping list creation, product search, product identification, access to product information, in-store navigation, price tracking, cost calculation, and checkout. Although many of these systems demonstrate innovative technical approaches and clear potential to improve accessibility, none fully addresses the complete set of challenges that VIPs encounter before, during, and after shopping.

Most existing solutions focus on one or a small number of tasks. Some support shopping list preparation, some help users navigate the store, and others focus mainly on recognising products on shelves or reading product information. Several systems also attempt to simplify checkout or support cost calculation. However, important gaps remain. Price verification at checkout, for example, is rarely addressed comprehensively, even though it is essential for trust, financial control, and consumer protection. If the price charged differs from the information previously provided, VIPs may have limited means of detecting the error independently.

A promising attempt to cover the entire shopping process was proposed in 2022 with an integrated system, Grocery Shopping Assistant, comprising several subsystems [63]. This system links shopping list creation, route optimisation, in-store navigation, product identification, and checkout support. However, it was tested only under simulated conditions, and the authors did not report any evaluation with VIP users. This highlights a broader limitation in the field: many assistive shopping technologies are still developed and tested without sufficient involvement of the intended users. As a result, their technical potential may be clear, but their practical relevance, usability, and acceptance in real shopping situations remain uncertain.

The validation analysis further confirms that the insufficient involvement of VIP users remains one of the central limitations of the field. A considerable number of systems have been evaluated only technically, in simulated conditions, or with blindfolded sighted participants, which limits the extent to which their usability, acceptability, and everyday practicality can be assessed.

Overall, the review shows that assistive shopping technologies are evolving from single-task tools to more integrated systems. However, the most effective future solutions will not necessarily be those with the greatest number of technical components, but those that fit naturally into the everyday routines, abilities, and preferences of VIPs. Successful systems should be accurate, discreet, affordable, easy to learn, compatible with existing retail environments, and capable of supporting the entire shopping process.

Author Contributions: Conceptualization, Đ.V. and G.V.; data curation, Đ.V. and R.U.; formal analysis, Đ.V.; funding acquisition, R.U.; investigation, Đ.V. and R.U.; methodology, Đ.V. and R.U.; supervision, G.V. and R.U.; validation, Đ.V. and R.U.; visualization, Đ.V. and R.U.; writing—original draft preparation, Đ.V. and R.U.; writing—review and editing, Đ.V., G.V. and R.U. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Slovenian Research Agency (research core funding No. P2-0450).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The original contributions presented in this review are included in the article. Further inquiries can be directed to the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

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