The Global Language of Business

GS1 2D Barcode Playbook for Retail Scanners Guide

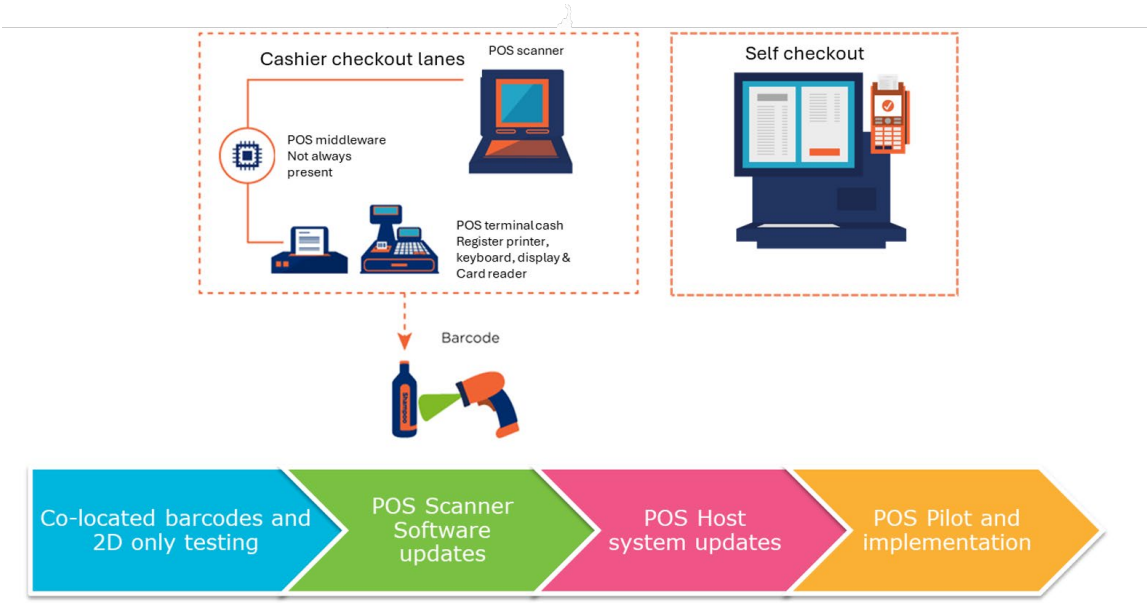

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Table of Contents

1 Introduction 5

2 Understanding the POS Ecosystem 6

3 Preparing for 2D Barcode Adoption 7

4 Scanner Configuration and System Readiness 8

4.1 2D in Retail scanning modes 8

4.1.1 Mode 1 8

4.1.2 Mode 2 9

4.1.3 Mode 3 9

5 Managing Scanner Performance, Data Transmission and Testing 11

5.1 POS Middleware 13

5.2 Test Suite 13

6 Operational Considerations and Best Practices 14

7 Conclusion 15

8 Retail POS Scanner Readiness Checklist for 2D Barcodes 16

8.1 Hardware & Software Capability 16

8.2 Scanner Configuration 16

8.3 System Readiness 16

8.4 Operational Considerations 17

8.5 Collaboration & Governance 17

1 Introduction

There is a rapidly increasing demand for more information about the products we use and consume. To meet this demand, industry has set a goal that, by the end of 2027 (Ambition 2027), all retail POS systems should be capable of reading and processing a defined set of 2D barcodes with GS1 standards, in addition to existing linear barcodes. As the transition to 2D capability at POS unfolds progressively on different timelines across the globe, brand owners should already be exploring and implementing the most appropriate 2D barcode to address priority use cases for their products and meet critical consumer and business needs. The Ambition 2027 will require software upgrades and may require equipment upgrades if the POS scanner is not already imager-based (camera). GS1 and industry are working together to support this migration and generate globally consistent guidance for business use cases. As there is no expectation that there will be a single 2D barcode selected for all industries, GS1 standards are enabling options that empower each industry to choose how they evolve towards more capable 2D barcodes while ensuring globally consistent implementations now and in the future. For example, in healthcare the journey towards 2D started in the early 2000s when industry chose GS1 DataMatrix as the single 2D barcode for product identification. Today there are billions of products with GS1 DataMatrix encoding the GS1 element string syntax. For healthcare products GS1 DataMatrix is the 2D barcode of choice for point-of-sale scanning. Linear barcodes (e.g., EAN/UPC and GS1 DataBar) will not go away and will coexist with 2D barcodes for as long as there are uses for them. During the transition phase, the trade item will feature both the current linear (i.e., EAN/UPC or GS1 DataBar retail POS family) barcode and either a GS1 DataMatrix or QR Code with GS1 Digital Link URI syntax, or a Data Matrix with GS1 Digital Link URI syntax.

This playbook serves as a reference for stakeholders in the retail ecosystem—including retailers, manufacturers, solution providers, and system integrators—to prepare for and implement scanner 2D barcode functionality at point-of-sale (POS). It is intended to supplement the 2D in Retail implementation guideline by focusing specifically on preparation for POS scanner solutions.

2 Understanding the POS Ecosystem

A modern POS environment comprises multiple interdependent systems and hardware components. These include cashier and self-checkout stations, barcode scanners, POS terminals (including printers, displays, keyboards, and card readers), and in some cases, middleware that acts as a data translation layer between scanning devices and the POS host system.

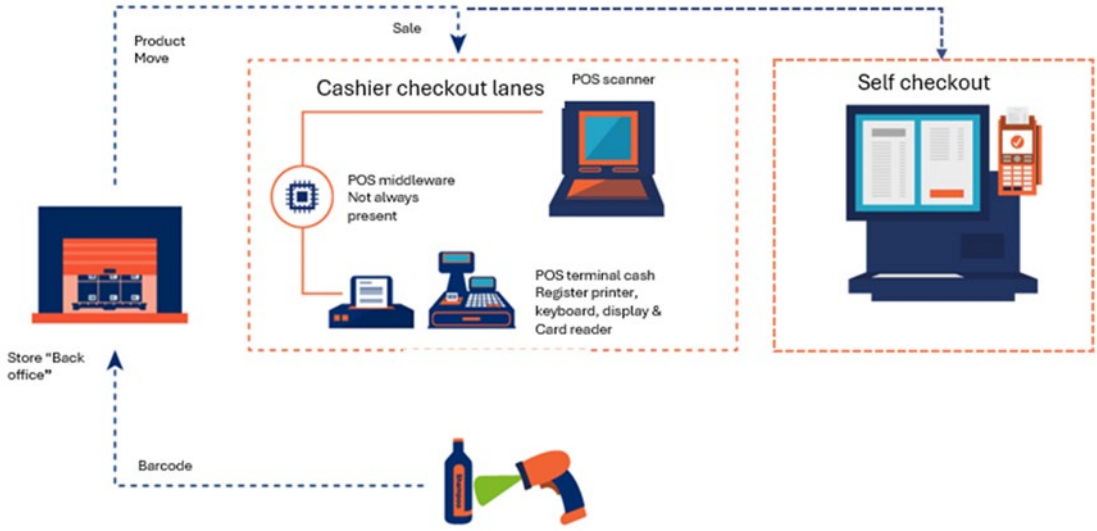

Figure 2-1 Retail ecosystem example

In addition to the front-of-store equipment, the retailer's central/head and back office plays a crucial role in configuration management, software updates, and system monitoring. Any changes to barcode handling—especially with the introduction of 2D barcodes—must be considered holistically across this ecosystem to ensure compatibility, reliability, and efficiency.

A retail scanner can be laser-based, meaning it can only read linear (e.g., EAN/UPC) barcodes or imager-based meaning it can read both linear and 2D barcodes (e.g., QR Code, Data Matrix).

Note: Not all imager-based scanners can scan and decode every type of 2D barcode by default. For example, a scanner that reads GS1 DataMatrix may not be able to interpret a QR Code with GS1 Digital Link URI syntax without software updates or configuration changes. Scanner readiness can vary across technology providers, industry sectors and environments, so it is recommended that organisations contact their scanner suppliers to confirm the capabilities.

3 Preparing for 2D Barcode Adoption

Successful implementation of 2D barcodes, such as GS1 DataMatrix (GS1 element string syntax) in healthcare or QR Codes with GS1 Digital Link URI syntax in retail, requires updates to both hardware and software components. Most importantly, scanner software must be capable of recognising multiple barcode formats on the same product – e.g. a QR Code with GS1 Digital Link URI syntax and an EAN-13 linear code – while correctly interpreting GS1-compliant data structures and ignoring non-retail compliant barcodes.

Retail scanners must be equipped to identify barcodes encoded using Plain syntax (e.g., EAN-13 and UPC-A encoding), GS1 Element String syntax (e.g., GS1 DataBar and GS1 DataMatrix) or the newer GS1 Digital Link URI syntax (e.g., QR Code and Data Matrix encodings). Furthermore, systems should support the conversion of GS1 Digital Link URI syntax into traditional GS1 Element String syntax to maintain interoperability with legacy host or ERP systems.

This shift is not merely a technical upgrade—it also requires stakeholder coordination. Retailers must work closely with scanner, printer, and POS solution providers to verify readiness. GS1 offers valuable tools to support such coordination, including the Barcode Syntax Resource for solution providers, Barcode Test Suites for retailers and brands, 2D in Retail Implementation Guideline, GS1 2D Barcode Colour & Quality Guide and a solution provider capability website on their 2D in Retail readiness.

4 Scanner Configuration and System Readiness

To ensure 2D compatibility, barcode scanners should be configured to recognise all relevant barcode types used in retail, including:

- Linear barcodes
  - UPC/EAN family
  - GS1 DataBar family
- 2D barcodes
  - GS1 DataMatrix
  - QR Code (GS1 Digital Link URI)
  - Data Matrix (GS1 Digital Link URI)
- Reflectance mode
  - Regular (black on white)
  - Reverse (white on black)

Figure 4-1 Data Matrix reflectance example

4.1 2D in Retail scanning modes

Industry has agreed on three primary software modes that should be implemented in scanners. Refer to the 2D Barcodes at Retail Point-of-Sale Implementation Guideline for more information on the scanning modes. Retailers can select their preferred mode based on their systems readiness to accept additional data beyond the Global Trade Item Number (GTIN).

4.1.1 Mode 1

All POS systems can process the GTIN from the EAN/UPC family of barcodes (plain syntax). Many POS systems can process the GTIN and some additional data (e.g., lot/batch, expiration date) from the GS1 DataBar family and GS1 DataMatrix, both of which use GS1 element string syntax. Updated POS systems can process the GTIN from Data Matrix with GS1 Digital Link URI syntax and QR Code with GS1 Digital URI syntax.

Once the first GTIN is identified in a linear or 2D barcode, irrespective of the presence of multiple GS1-compliant retail barcodes on-pack, the scanner promptly process and transmits the GTIN with a single audible (e.g., beep) or visual signal and awaits next product.

Note: This minimum requirement for the Ambition 2027 is software Mode 1

4.1.1.1 Benefits of Mode 1

Mode 1 is a simplified transmission mode wherein the scanner sends only the GTIN. This mode is ideal for environments where software changes must be minimised as it enables the POS host system to:

- Process only the linear or 2D barcode GTIN data, therefore simplifying the software updates on the POS host system.
- Can speed up POS as the scanner delivers the first GTIN found and waits for the next trade item.
- If the scanner further converts 14-digit GTINs to GTIN-8/12/13, no POS host system updates may be needed.

4.1.2 Mode 2

Prioritise GS1 compliant general retail 2D barcodes, decode, "beep" once and transmit the GTIN and any additional data (e.g., lot/batch number, expiration date) in the common format of GS1 element string syntax. If a 2D barcode cannot be found, transmit data from the linear barcode. Any data that the POS system is not able to store or use can be dropped.

Figure 4-1 Example of Mode 2

QR Code encoded data

https://id.dalgiardino.com/01/09506000134352/10/ABC?17=231231 (GS1 Digital Link URI syntax example)

Independent of the direction of travel the scanner transmits:

010950600013435210ABC^17231231 (GS1 element string syntax example)

In this example, the "^" replaces the unprintable hex 1D (Group Separator) character

4.1.2.1 Benefits of Mode 2

Mode 2 is an advanced scan and transmit mode that requires the POS host system to recognise and utilise the 14-digit GTIN and process any prioritised additional data from the 2D barcode. When the scanner decodes and transmits the barcode data, it enables the host POS system to:

- Process only the linear or 2D barcode data, therefore simplifying the software updates.
- Identify if the product has different GTINs **if the linear barcode is found first** and therefore avoid unintended POS transactions. During the transition phase unintended error could happen if 2D barcodes with incorrect GTIN are added to products.
- Due to Mode 2's functionality, POS host systems that already process GS1 DataBar Expanded Stacked or GS1 DataMatrix will seamlessly handle QR Codes and Data Matrix encoded with GS1 Digital Link URI syntax as all compliant retail 2D barcodes will be converted and transmitted in a GS1 element string format.

4.1.3 Mode 3

Identify, decode, and transmit all GS1-compliant general retail barcodes (both linear and 2D) present on a product until the configured scanner timeout is reached or the product exits the scanner's field of view. During this process, generate an **8-digit label identification** to associate multiple barcodes with the same trade item. Upon capturing the initial GTIN from any linear or 2D barcode, the scanner will promptly deliver a single audible (e.g., beep) or visual notification. The scanner subsequently generates an **8-digit label identification** within a standard format header using the barcode's Plain and GS1 element string syntax.

Figure 4-2 Example of Mode 3

QR Code encoded data

https://id.dalgiardino.com/01/09506000134352/10/ABC?17=231231

Independent of the direction of travel the scanner transmits:

12345678~01095060001343521OABC^17231231

12345678~9506000134352

In this example, the "^" replaces the unprintable hex 1D (Group Separator) character and the "~" is not transmitted but shows the end of the label identification.

4.1.3.1 Benefits of Mode 3

Mode 3 is an advanced scan and transmit mode in which the POS host system recognises the scanner-generated 8-digit label identification and uses the 14-digit GTIN to process and prioritise additional data. When the scanner decodes and transmits the barcode data, it enables the POS host system to:

- Process the first barcode's (linear or 2D barcode) GTIN (e.g. EAN-13→GTIN-13) and begin the price lookup transaction and then process any additional data when the data from the same product is decoded.
- Identify if the product has different GTINs and therefore avoid unintended POS transactions. During the transition phase unintended errors could happen as 2D barcodes with GTIN are added to products.
- Due to Mode 3's functionality, POS host systems that already process GS1 DataBar Expanded Stacked or GS1 DataMatrix will seamlessly handle QR Codes and Data Matrix encoded with GS1 Digital Link URI as all compliant retail 2D barcodes will be transmitted in a GS1 element string format.

Note: All scanner software solutions can benefit by leveraging GS1's Barcode Syntax Resources.

As noted above, when there is more than one barcode with GTIN on trade items, it is essential that the POS systems ensure:

- The system SHALL only process one set of the desired data in the final transaction.
- Scanning systems SHOULD only produce one acknowledgement (e.g., beep) when multiple barcodes are scanned from the same trade item if the GTINs are the same.

Important: If the points above are not implemented, unintended POS transactions may occur or non-retail compliant barcodes could be acknowledged with a beep but typically will not complete price look up.

5 Managing Scanner Performance, Data Transmission and Testing

The first mandatory step is to update the scanner software to enable Mode functionality and support decoding of 2D barcodes using the GS1 Digital Link URI syntax. Once this is complete, the scanner settings must be configured to define parameters such as which barcodes will be recognised, the operational Mode to be used, and the scanner timing behaviour. These settings are essential to ensure optimal scanner performance.

A particularly important configuration is the timeout setting, which determines how long the scanner continues searching for additional barcodes after the initial one is detected. While longer timeout values can enhance data completeness—especially for items with multiple barcodes—they may also reduce checkout throughput. Typical timeout values range from 200 milliseconds to 700 milliseconds and should be optimised based on store traffic levels and the complexity of product packaging.

Testing conducted by the GS1 AIDC Lab documented decode and transmission speeds of approximately 200 ms for current generation high-speed bi-optic scanners and around 500 ms for current-generation presentation and handheld scanners. These measurements include the time when a 2D barcode enters the scanner's field of view. For presentation and handheld scanners, the measurement also includes an average pause time of about 250 ms as the item is momentarily held still for decoding.

Below example is the optimal barcode path for a bi-optic scanner

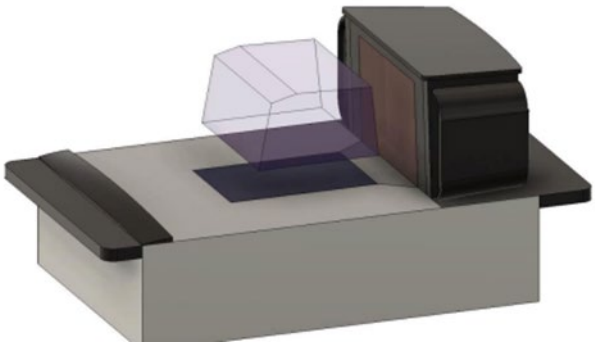

Figure 5-1 Bi-optic scanner barcode scan path example

Below shows the two-mirror camera image in the base of a bi-optic scanner with the 2D going right through the middle of the scanner's field of view. Imaging POS scanners use mirrors to redirect light paths, enable compact designs, expand the field of view, optimize illumination, and reduce the adverse effects of other illumination sources such as sunlight.

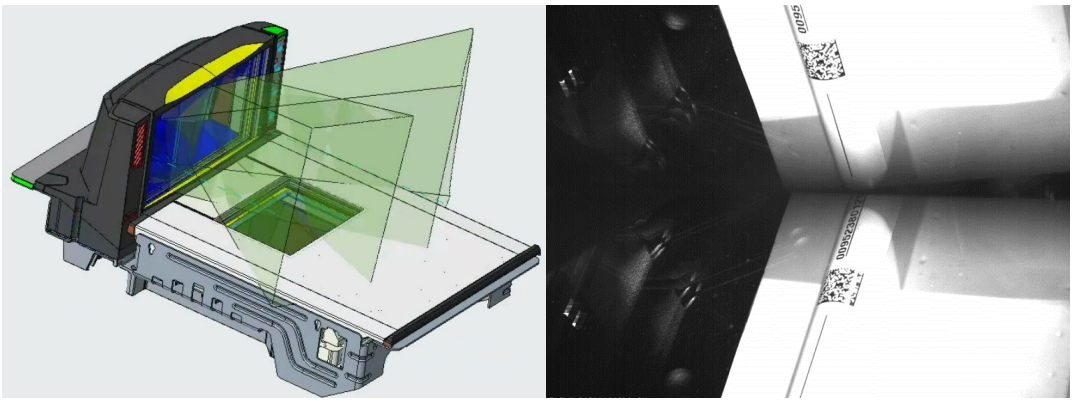

Figure 5-2 Bi-optic scanner two mirror image reflectance example

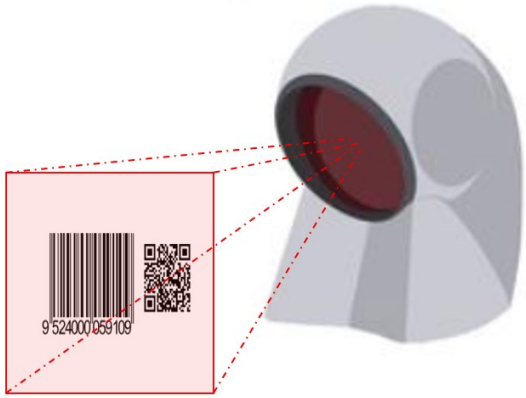

Figure 5-3 Presentation scanner field of view example

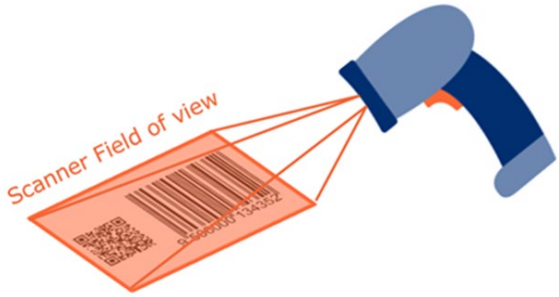

Figure 5-4 Handheld scanner field of view example

Over the past few decades, scanner optics and software have been optimised for linear barcodes (EAN/UPC). While modern scanners are capable of decoding 2D barcodes at a high rate—at least 40 items per minute, based on GS1 AIDC Lab testing—performance can be affected by barcode size and positioning. The GS1 General Specifications define the X-dimension requirements that ensure readability of both linear and 2D barcodes in the retail environment.

The 2D in Retail Implementation Guideline further outlines best practices for barcode placement, emphasises the importance of minimising data content to suit the use case, and provides recommendations on data structure optimisation. Larger 2D barcodes may require the scanner to capture and piece together multiple image frames to decode successfully, which can reduce read speed and throughput.

To maximise performance, it is in the **retailer's and brand owner's best interest** to:

- **Optimise data content** to meet the intended use cases, QR-Code_powered-by-GS1-best-practices
- **Minimise barcode size** while ensuring robustness and print quality, see GS1 2D in Retail colour and quality guide
- **Select the lowest viable error correction level (ECC)** that still supports the item's lifecycle.

These optimisations give the 2D barcode the best chance of being fully captured within the scanner's field of view, supporting fast and reliable scanning at checkout.

The new generation of retail scanners currently on sale include improved software, faster processors, and enhanced optics—advancements that significantly reduce 2D decode and transmission time to approach parity with traditional EAN/UPC performance. These improvements also increase the scanner's tolerance for suboptimal barcode quality or placement.

Scanners must also support the transmission protocols expected by the POS host system. Common data formats include USB HID (Human Interface Device), 7-bit ASCII, Unified-POS (UPOS), Java-POS, OLEPOS (OPOS), and proprietary protocols used by vendors like Fujitsu or ICL. Some

environments may require middleware to decode and reformat scanned data before forwarding it to the host.

5.1 POS Middleware

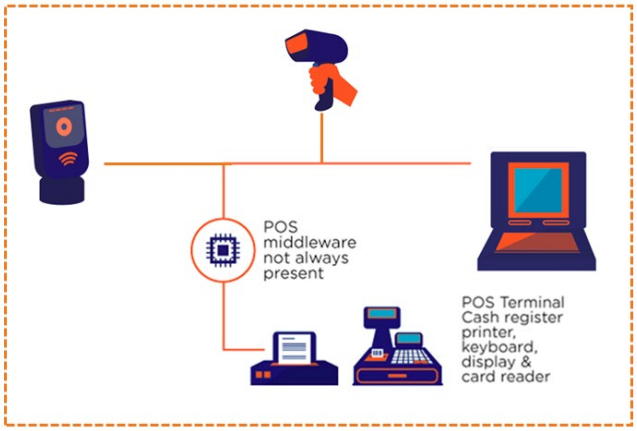

Figure 5-5 POS Middleware example

POS Middleware enables Retail 2D barcode translation, validation, and adaptability in cases where either the legacy scanner or the POS host system cannot process 2D barcode data. Where middleware is deployed, scanner configuration can be more flexible. For example, the POS middleware can manage the decoding process, enforce compliance logic, and provide feedback to the operator—such as triggering a beep only when a valid retail barcode is scanned. Middleware can also facilitate multi-stage data delivery, allowing the scanner to transmit GTINs and additional 2D data in separate transmissions for improved transaction integrity.

5.2 Test Suite

It is essential to ensure that the point-of-sale (POS) system is prepared for 2D barcode pilot programs or broader implementation. The 2D Barcodes in Retail Test Suite is designed to address the technical considerations and operational implications of using 2D barcodes encoded with GS1 barcode syntaxes at retail POS. It supports brand owners, manufacturers, retailers, and solution providers in evaluating their current readiness.

The test suite includes a set of GS1-compliant sample barcodes—both linear and 2D—to help stakeholders accurately assess existing scanning capabilities and system behaviour when interacting with approved GS1 barcodes and their encoded data. This tool is intended to be used as part of readiness evaluations and to help identify necessary system updates to support a successful transition to 2D barcodes in retail.

6 Operational Considerations and Best Practices

Migrating to 2D barcodes is not a one-size-fits-all process. It requires balancing between historical compatibility and forward-looking capabilities. During the transition, it's important to manage the risks of duplicate or conflicting GTINs across linear and 2D barcodes on the same product.

Training frontline staff is equally critical to a successful 2D barcode transition. Cashiers and store managers must understand how the POS system responds to 2D barcodes, including prompts for rescanning or data validation, so they can act confidently and efficiently at checkout.

As discussed in the prior section and detailed in the 2D in Retail Implementation Guideline, product labelling practices must align with scanner capabilities to prevent partial reads or rejected transactions. This includes ensuring barcodes are placed appropriately, sized correctly, and optimised for quick decoding.

For best results when scanning 2D barcodes with current-generation POS equipment, frontline staff should be trained in presentation techniques:

- A brief pause of approximately 250 ms with the barcode in the scanner’s field of view allows the device time to capture and process multiple image frames, improving decode accuracy.
- A slightly elevated smooth motion across the scanner’s window can also help, as it increases the likelihood that the full 2D barcode is captured in a single frame.

In parallel, retailers should maintain close collaboration with their POS solution providers, GS1 Member Organisations, and industry groups. Participating in pilot programs, feedback loops, and industry forums are key to gathering real-world insights, sharing learnings, and staying current with evolving standards and scanner performance updates.

7 Conclusion

The shift to 2D barcodes represents a foundational upgrade for the retail sector, enabling more intelligent POS interactions, better product traceability, and a pathway to digital transformation through GS1 Digital Link and other innovations. Implementing these changes demands coordinated action across scanner configuration, software readiness, middleware architecture, and user training.

By following the steps outlined in this playbook and aligning with GS1's best practices, retailers and their partners can ensure a smooth and future-proof transition to 2D barcode-enabled POS systems. Section 8 has a check list to help ensure no major steps are missed.

8 Retail POS Scanner Readiness Checklist for 2D Barcodes

8.1 Hardware & Software Capability

- ☐ Verify that POS scanners are **imager-based** (capable of reading both linear and 2D barcodes).
  - Partner with your scanner and POS solution providers for guidance on system readiness for 2D.
  - Check the POS scanners 2D in retail readiness
- ☐ Confirm scanner software is updated to support:
  - **GS1 DataMatrix,**
  - **QR Code with GS1 Digital Link URI**
  - **Data Matrix with GS1 Digital Link URI**
  - **Mode 1, Mode 2, and Mode 3** functionality.
- ☐ Evaluate POS host system and backend system upgrades required to leverage additional data.
  - Ensure support for GS1 barcode syntaxes: **Plain, GS1 Element String**
  - Ensure systems can process additional data to support new business use cases.
- ☐ Validate transmission compatibility with POS host protocols (USB HID, ASCII, UPOS, OPOS, proprietary).

8.2 Scanner Configuration

- ☐ Enable detection for all relevant barcode types:
  - UPC/EAN family
  - GS1 DataBar family
  - GS1 DataMatrix
  - QR Code with GS1 Digital Link URI
  - Data Matrix with GS1 Digital Link URI
- ☐ Configure timeout settings (200–700 ms) to balance data completeness and checkout speed.
- ☐ Check scanner capability for regular and reverse reflectance modes (black-on-white, white-on-black).
- ☐ Set scanner mode 1, 2 or 3 based on readiness for additional data

8.3 System Readiness

- ☐ Test scanner-to-host data flow (GTIN, batch/lot, expiration date) using 2D barcodes with GTIN and additional data. Note transmission will use GS1 element string syntax in most cases.
  - Use the GS1 2D in Retail Test Suite with GS1-compliant sample barcodes to benchmark scanner performance.
- ☐ Validate system behaviour when multiple barcodes (linear + 2D) are present on the same product.
- ☐ If applicable, confirm middleware or shim libraries are available where legacy POS scanners or POS host systems require data translation.
- ☐ Validate decoding and transmission speed:
  - ~200 ms for bi-optic scanners
  - ~500 ms for presentation and handheld scanners
- ☐ Ensure scanner throughput meets **40 items per minute** minimum requirement.

8.4 Operational Considerations

- Review product label barcode size, placement, and quality against GS1 General Specifications.
- Minimise barcode content to reduce size and optimise for quick decoding.
- Train staff in correct 2D scanning techniques (e.g., 250 ms pause for presentation and handheld scanner, smooth presentation across high speed bi-optic scanner).
- Establish procedures for handling duplicate/conflicting GTINs across linear and 2D barcodes.

8.5 Collaboration & Governance

- Engage with GS1 Member Organisations and POS solution providers for updates and support.
- Participate in pilot programs to validate scanner readiness in live retail environments.
- Evaluate opportunities for any private label products.
- Identify common goals and measures with collaboration partners.
- Educate in-store associates.
- Monitor regulatory and industry guidance.