The Global Language of Business

GS1 2D Barcode Playbook for Creation and Printing

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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 of 2027 as a key milestone when 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. This transition is not a replacement of existing barcode technologies, but rather an expansion of capability through GS1 2D barcodes. Linear barcodes such as EAN/UPC will continue to coexist with 2D barcodes for the foreseeable future, requiring careful coordination to ensure consistent system behaviour across all retail environments.

While much of the industry focus has been on scanner and POS system readiness, the **creation and printing of the barcode itself is foundational**. A poorly structured, incorrectly encoded, or inadequately printed barcode will fail regardless of downstream system capabilities.

This playbook therefore focuses on the upstream processes required to ensure that GS1 2D barcodes are:

- Structurally conformant with GS1 standards
- Optimised for retail scanning performance
- Reliably printed across a wide range of packaging formats
- Designed to support both current and future use cases

This document complements the GS1 2D in Retail Implementation Guideline and the GS1 2D Playbook for POS Scanners and GS1 2D Playbook for Retail Systems playbooks by providing detailed guidance on **barcode creation, encoding, and print execution**.

● **Note**: This playbook includes a reference section of link to GS1 standards, documents and tools available from GS1 in section 8.

2 Understanding the retail and manufacturing ecosystem for barcode creation and printing

Modern retail and manufacturing environments consist of a complex ecosystem of interconnected systems and physical components, including labelling, printing, packaging, barcode scanners, and enterprise systems. Barcode creation sits at the very beginning of this ecosystem and directly influences how data flows through each of the subsequent stages.

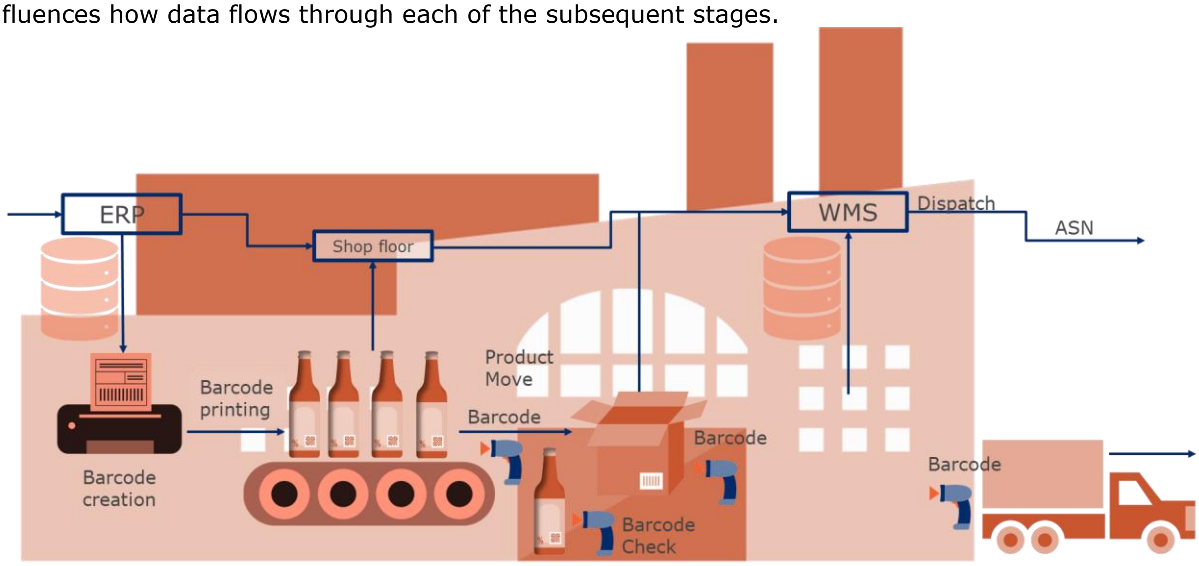

Figure 2-1 Example of a Supplier (manufacturer) ecosystem

When a product is scanned at POS, the barcode data is captured, decoded, transmitted, and processed by multiple systems. As highlighted in the POS scanner playbook, this process must occur rapidly, often within a few hundred milliseconds, to maintain checkout efficiency. Any issues in barcode design or print quality can disrupt this process, leading to scan failures, delays, or incorrect transactions.

The introduction of 2D barcodes increases both capability and complexity. Unlike linear barcodes, which primarily encode a GTIN, 2D barcodes can encode multiple data elements using different GS1 syntax formats. GTIN-only codes can be created during the artwork design phase and printed offline as part of the packaging. A fixed GS1 Digital Link URL can also be included in the artwork. However, more value can be realised when "real-time" data is added to associate batch-level or product-specific information with the GS1 2D barcode printed on-pack, which is typically done inline on the production line. This real-time data and printing capability creates additional benefits but also introduces manufacturing challenges. **This requires careful alignment between:**

- Data structure and encoding
- Printing capabilities
- Production constraints
- Scanner decoding capabilities
- Space constraints on package, critical substrates, contour and/or curvature

Barcode development should be regarded as a **system-aware discipline**, requiring that design and printing decisions are carefully aligned with the capabilities and constraints of downstream systems. It is essential for all stakeholders to communicate their respective use cases to ensure that the 2D barcode contains only the minimum data necessary to support their requirements.

● **Important: Not all printers produce 2D barcodes with sufficient quality for imager-based scanners to reliably scan and decode them in retail settings**. For example, a Continuous Ink Jet printer currently used to print lot and date information on products often has a maximum height of 24 dots, which may not provide sufficient resolution or print height for GS1 DataMatrix or QR Codes with GS1 Digital Link URIs depending on the data required for the use cases. Both barcode generation and printer compatibility can differ depending on technology providers, industry sectors, and environmental conditions. Therefore, organisations are advised to consult their barcode creation and printer suppliers to confirm their capabilities.

3 Preparing for 2D Barcode Creation and Printing

This creating and printing retail conformant GS1 2D barcodes is not merely a technical upgrade—it also requires stakeholder coordination. Retailers and brands must work closely with barcode creation, printer, scanner, and POS solution providers to verify readiness for 2D in retail scanning. 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. See section 8 for other 2D related documents and tools.

3.1 Defining Use Cases

Organisations should begin by clearly defining the specific use cases that will drive the design and creation of the 2D barcode. This step directly influences what data is encoded, how the barcode is structured, and ultimately how it must be printed. For example, use cases such as traceability (lot/batch, expiry), retail POS enablement (GTIN) and consumer engagement (web links via GS1 Digital Link URI) may require different data elements but can be encoded in the same GS1 2D barcode. Decisions made here will determine symbol size, data density, and error correction requirements, all of which have downstream implications on label design and print quality.

In parallel, organisations should evaluate packaging constraints and available print real estate. The size and placement of a 2D barcode, whether using GS1 DataMatrix, QR Code with GS1 Digital Link URI or Data Matrix with GS1 Digital Link URI must align with scanner capabilities while maintaining readability throughout the product lifecycle. Substrate type (corrugate, film, label stock) and print method (thermal transfer, inkjet, laser) must also be considered early, as they directly impact physical barcode properties, symbol contrast, durability, and compliance with quality standards. A well-defined use case ensures that barcode creation is intentional, scalable, and fit for operational conditions rather than retrofitted later.

Successful implementation begins with clearly defining the intended use cases for the 2D barcode:

- POS identification (GTIN only or GTIN + attributes)
  - Price lookup
  - Prevent sale of expired stock
  - etc.
- Traceability (e.g., product variant, batch/lot and serial number)
- Consumer engagement
- Regulatory compliance
- Inventory and operational efficiency

Organisations should prioritise use cases and avoid overloading barcodes with unnecessary data, as excessive data can negatively impact symbol size and scanning performance. Size of the GS1 2D barcode can also be impacted by long URLs and lowercase characters.

3.2 Stakeholder Engagement

Effective implementation requires early and ongoing engagement across stakeholders who influence barcode creation, printing, and usage. Packaging engineers, brand marketers, label designers, and print vendors must collaborate closely with IT, supply chain, and retail operations to ensure the barcode design meets both technical and operational requirements. For example, print vendors need clarity on symbol specifications, Quiet Zones, and contrast targets, while IT teams must ensure that encoded data aligns with system capabilities and data governance policies.

External stakeholders are equally critical. Suppliers, manufacturers, and retail partners must follow the standards from GS1 to ensure interoperability and consistent scanning performance across the ecosystem. This includes agreement on data structures, application identifiers, and symbol quality expectations. Without this alignment, inconsistencies in barcode generation or print quality can lead to scan failures, operational delays, and increased exception handling. Early stakeholder alignment reduces rework, supports smoother rollout, and ensures that barcode printing processes are standardised and repeatable across all trading partners.

Examples of these stakeholders include:

- Packaging and artwork teams
- Marketing
- IT and data governance teams
- Printing and production partners
- Solution providers
- Retailers

- GS1 Member Organisations

Early collaboration ensures that barcode design decisions align with retail system capabilities and operational requirements.

3.3 2D Barcode creation and printing Considerations

When it comes to barcode creation and printing, organisations must evaluate several technical factors to ensure reliable performance. Symbol quality is paramount—this includes meeting minimum print quality grades (see GS1 General Specifications Section 5.12 Barcode production and quality assessment), maintaining sufficient physical 2D barcode properties like the contrast between light and dark modules (squares), and ensuring proper Quiet Zones. Printer capabilities should be assessed to confirm they can consistently produce symbols at the required size, resolution, module alignment, and production speed, particularly in high-throughput environments. Additionally, organisations should validate that printed barcodes remain scannable under real-world conditions such as handling, abrasion, moisture, and temperature variation.

Data encoding and verification processes are equally important. Organisations should implement controls to ensure that the correct data is encoded every time, including validation against business rules and standards. Inline or offline barcode verification systems can be used to grade symbol quality and catch defects before products enter the supply chain.

Verification may include:

- Measurement using ISO/IEC 15426-2 devices to produce comparable results across the supply chain.
- Layout checks that simulate measurement. These can compare layout and data content at each point in the supply chain, but physical barcode properties still require a dedicated measuring device rather than camera inspection alone.

Finally, scalability should be considered, barcode generation and printing solutions must support increasing data complexity and volume over time without compromising performance. By addressing these considerations upfront, organisations can ensure that their barcode printing processes are robust, conformant, and capable of delivering long-term value.

Before implementation, organisations should evaluate:

- Packaging constraints (space, material, curvature)
- Printing capabilities and limitations
- Scanner capabilities across all environments
- Data requirements and complexity
- Coexistence with linear barcodes

These considerations help ensure that the barcode is both technically conformant and operationally viable.

4 Barcode Data Structure and Encoding

4.1 GS1 Barcode Syntax

GS1 standards provide three different barcode syntaxes:

- **Plain:** This syntax is just the GS1 identification key with no additional characters or syntactic features. For example, a Global Trade Item Number (GTIN) is represented as a 13-character string, each character being a digit. The plain syntax is usable in a context where only a single type of key is expected. Examples of such single-key contexts include: a barcode symbology that is defined to only hold one type of key (e.g., ITF-14 which can only hold a GTIN), a column in a database table that is intended to hold only a single key.

UPC-A **EAN-13** **UPC-E** **EAN-8**

6 14141 00003 6 9 501101 530003 0 614193 9 9505 0003

Figure 4-1 Examples of EAN/UPC barcodes (plain syntax)

- **GS1 element string:** GS1 element string syntax consists of a short two- to four-digit Application Identifier (AI) followed by the associated GS1 identification key or AIDC data value. The AI indicates the meaning and format of the data that follows, enabling different types of identifiers and attributes to be uniquely distinguished and interpreted. (e.g., (01) for GTIN, (10) for batch/lot, (17) for expiration date). This syntax is optimised for machine readability and operational efficiency. It is commonly encoded in barcodes such as GS1 DataMatrix and supports consistent parsing by scanners and backend systems worldwide. Retail Point-of-Sale barcodes utilising GS1 element syntax include the GS1 DataBar family (comprising both linear and stacked linear barcodes) as well as the GS1 DataMatrix (a two-dimensional barcode).

(01)09524810000339
(3103)000480

(01)09524810000339
(17)271231
(10)AB-123

Figure 4-2 Example of GS1 DataBar Expanded Stack (left) and GS1 DataMatrix (right)

  - Retail example of a GS1 element string syntax in a GS1 DataMatrix
    - (01)09524810000339(17)271231(10)AB-123

(01)09524810000339

Figure 4-3 Example of a retail GS1 DataMatrix

    - (01) Global Trade Item Number - 09524810000339
    - (17) Expiration date - 31 December 2027
    - (10) Batch or lot number – AB-123

● **Note**: For a more details on GS1 element string syntax see the GS1 General Specifications.

- **GS1 Digital Link URI**: The GS1 Digital Link URI provides a syntax for expressing GS1 Identification Keys (Primary Keys), Key qualifiers and data attributes in a format that can be used on the Web in an intuitive manner (via a straightforward Web request) to enable direct access to relevant information and services about products, assets, locations, etc. All GS1 Application Identifiers are placed into one of three categories that dictate where they are placed in the data string.

Primary key	Key qualifier	Data attribute
• (01) Global Trade Item Number • (00) Serial Shipping Container Code • (8006) Individual Trade Item Piece • (417) Physical location GLN • …	• (22) Consumer product variant • (10) Batch/lot number • (21) Serial number • (254) GLN extension component • (8020) Payment reference number • …	• (17) Expiration date • (243) Packaging component number • (30) Variable count of items • (320n) Net weight, pounds • …

Figure 4-4 Example of GS1 Digital Link URI primary keys, key qualifiers and data attributes

- The GS1 Digital Link URI syntax transforms traditional GS1 data into a web-compatible format by embedding GS1 identification keys, key qualifiers and data attributes in within a structured URL (e.g.,). This enables a single barcode to serve both supply chain and consumer-facing use cases, allowing scanners or smartphones to resolve the same code to different digital resources depending on context. GS1 Digital Link maintains GS1 standards compliance while adding flexibility, such as linking to product information, authentication services, or sustainability data. It effectively bridges physical products and the digital world, supporting more dynamic and scalable data sharing. Retail Point-of-Sale barcodes utilising GS1 Digital Link URI include the QR Code and Data Matrix two-dimensional barcodes.

(01)09524810000339 (01)09524810000339

Figure 4-5 Example of Data Matrix (left) and QR Code (right)

- Retail example of GS1 Digital Link URI syntax in a QR Code

Figure 4-6 Example of a QR Code with GS1 Digital Link URI syntax

- **Note**: For a more details on GS1 Digital Link URI syntax see the [GS1 Digital Link URI Syntax Standard]

- **Note**: POS systems may convert GS1 Digital Link URI syntax into GS1 element string format to maintain compatibility with legacy systems. Therefore, data must be structured and encoded accurately to ensure consistent interpretation. For more information see the GS1 2D

Barcode Playbook for Retail POS Host and Backend Systems and the GS1 2D Barcode Playbook for Retail Scanners Guide.

4.2 Data Content Design

As noted earlier, communication between all impacted stakeholders, including stakeholders internal to each organisation, is essential to ensure solutions are interoperable and the minimum data is used to unlock all stakeholders' the use cases.

Optimising the size and data encoded in a GS1 DataMatrix, Data Matrix or QR Code can improve scanning performance as 2D barcodes with an overall smaller size are generally, faster to scan and take up less space on-pack. Stakeholders should optimise the GS1 2D barcode encoded data and link to online data whenever possible, see the 2D Barcodes at Retail Point-of-Sale Implementation Guideline section 4.6 and the Principles and Criteria for High-Capacity Data Carriers in the GS1 system for more information.

- **Important:** The size referenced is the overall size of the barcode and not the size of the barcode's X-dimension. X-dimension that goes below the allowed sizes in the GS1 General Specifications Symbol Specification Tables are more difficult to scan than retail conformant X-dimension sizes. See the 2D in Retail – Tier 3.2 Test Report X-dimension Stress Test for the impacts of X-dimension on scanning performance in the retail scanning environment.

When the 2D barcode data is compact, it reduces the time required for a scanning device to capture and interpret the information as the 2D barcode is completely in view of the scanner faster. When printing GS1 DataMatrix, Data Matrix or QR Codes on small trade items, or on curved surfaces the size becomes a critical factor. In addition, small efficiently encoded 2D barcodes can reduce the amount of data that needs to be transferred over a network and ease the printing of dynamic data (e.g., serial numbers) based barcodes. **There are several other advantages to having a 2D barcode size that is optimised, such as:**

- **Transition period:** During the 2D migration transition period both linear and 2D barcodes will need to coexist, so optimising the 2D barcode size helps ensure brand marketing and packaging designers still have sufficient space for their purposes.
- **Readability and reliability:** An optimised 2D barcode is more likely to be readable under various conditions. This includes scenarios with poor lighting, low-resolution cameras, or when the code is partially obscured or if the surface is not flat. Optimising size and data encoding helps improve the reliability of scanning.
- **Mobile app performance:** Mobile devices, especially older models or those with limited processing power, may struggle with decoding large or complex 2D barcodes. Optimising size and data encoding can improve performance on a wide range of devices.
- **Aesthetic considerations:** In applications where 2D barcodes are part of a design, such as marketing materials or product packaging, a smaller, well-optimised code can be more aesthetically pleasing and less obtrusive.
- **Printing Process:** Barcode size also affects the choice of printing process. If the GS1 2D barcode remains within the capability of the brand's current printer, implementation costs can be reduced.

For more information, see the following references:

- GS1 DataMatrix Guideline: https://www.gs1.org/docs-/barcodes-/GS1_DataMatrix_Guideline.pdf
- Best practices for creating your QR Code powered by GS1: https://ref.gs1.org/docs/2023/QR-Code_powered-by-GS1-best-practices
- Connecting barcodes to related information: https://ref.gs1.org/docs/2024/connecting-barcodes-to-related-information

- GS1 Digital Link quick start guide: https://ref.gs1.org/docs/2024/digital-link-quick-start-guide
- Video about "Why QR Codes powered by GS1 are more than a marketing tool" https://youtu.be/2VFsVfYd6Z0
- GS1 2D barcode size estimator https://gs1.github.io/moduleCount/

4.3 Selecting which barcode to use

Multiple GS1 2D barcode options exist because different retail use cases have different requirements. No single symbol meets every need. Factors such as available packaging space, the need to encode additional data, consumer engagement requirements, and compatibility with mobile devices all influence which barcode is most appropriate.

To support globally standardised adoption of GS1 2D barcodes across retail, industry stakeholders agreed that three GS1-compliant options are needed to collectively address these requirements.

4.3.1 GS1 DataMatrix with GS1 Element String Syntax

Best suited for: Supply chain and retail use cases where consumer interaction or web connectivity is not required.

GS1 DataMatrix with GS1 element string syntax is ideal when products require more information than can be carried in a linear barcode, such as expiry date, batch/lot number, serial number, or other Application Identifiers. It provides high data density and can achieve a smaller symbol size than traditional linear barcodes, making it particularly suitable for space-constrained packaging and operational use cases.

Typical applications include:

- Fresh foods with expiry dates
- Healthcare and pharmaceutical products
- Traceability and inventory management
- Products requiring batch or serialisation information

4.3.2 QR Code with GS1 Digital Link

Best suited for: Use cases requiring consumer engagement and full smartphone compatibility.

QR Codes encoded with GS1 Digital Link provide a bridge between physical products and digital experiences. They are supported by virtually all mobile device camera applications and can deliver both point-of-sale functionality and access to online information through a single symbol.

Typical applications include:

- Consumer engagement and marketing
- Product information and transparency
- Sustainability and recycling information
- Recipes, loyalty programmes, and promotions
- Digital product passports and regulatory information

4.3.3 Data Matrix with GS1 Digital Link

Best suited for: Consumer engagement applications where package space is limited.

Data Matrix with GS1 Digital Link combines the compact size and high data density of Data Matrix with the flexibility of web-enabled GS1 Digital Link. It is particularly useful for small products where symbol size is critical.

However, unlike QR Codes, Data Matrix symbols are not universally supported by default smartphone camera applications and therefore may require dedicated scanning applications or software support on mobile devices.

Typical applications include:

- Cosmetics and personal care products
- Small consumer packaged goods
- Products with limited label space

● **Note**: The optimal choice depends on the intended use case, available space, required data, and whether consumer engagement and native mobile device compatibility are important requirements.

5 Barcode Creation and Artwork Design

Barcode performance is heavily influenced by how the symbol is created, sized, positioned, coloured, customised, and reproduced within the packaging artwork process. Even when high-quality printing equipment is used, poor symbol generation or artwork design decisions can significantly reduce scanning reliability across retail POS environments, distribution operations, and consumer mobile applications. Factors such as low contrast colour selections, decorative customisation, embedded logos, excessive styling, or alterations to the standard symbol structure may negatively impact scanner recognition and decode performance if not carefully designed and validated. Organisations should establish barcode creation procedures that align with applicable GS1 and ISO standards to ensure consistent interoperability throughout the supply chain. While customised QR Code designs and branded visual treatments are increasingly used for marketing and consumer engagement purposes, organisations should recognise that aesthetic modifications may reduce barcode robustness and should be avoided.

For retail and supply chain applications, barcode creation should align with the requirements defined within the GS1 General Specifications. The GS1 General Specifications establish the technical requirements for data carriers, Application Identifiers (AIs), symbol dimensions, Quiet Zones, and encoding structures. In addition, barcode print quality and verification requirements are commonly evaluated using ISO/IEC standards, including ISO/IEC 15415 for two-dimensional symbol print quality testing, ISO/IEC 16022 for Data Matrix and ISO/IEC 18004 for QR Code technical specifications. For linear barcodes, like EAN-13 the quality test method is defined by ISO/IEC 15416.

5.1 Symbol Generation

Symbol generation is the process of converting structured data into a machine-readable barcode symbol. The barcode generation process should always begin with properly structured and validated source data. Incorrect formatting, missing Application Identifiers, invalid character structures, or improper data sequencing can produce technically conformant symbols that still fail operational requirements.

Organisations should use barcode generation software or platforms that:

- Support current GS1 standards and specifications
- Properly encode GS1 Application Identifiers
- Support GS1 Plain, GS1 element string and GS1 Digital Link URI syntaxes
- Generate symbols using correct error correction methodologies
- Maintain conformant Quiet Zones

- Export vector or high-resolution production artwork
    - Alignment to printer resolution is required
- Support validation of syntax and data structure

Note: GS1's open-source Barcode Syntax Resource tool has been adopted by several barcode creation solution providers. For more information see GS1 Barcode Syntax Engine GS1 recommends that the barcode syntax is validated using this tool or an alternative, before printing, even if produced with barcode generation software.

5.1.1 Data Matrix and GS1 DataMatrix

For GS1 DataMatrix and Data Matrix symbols, ISO/IEC 16022 defines the technical requirements governing symbol structure, encoding methodology, error correction, module placement, and decoding behaviour. GS1 DataMatrix and Data Matrix 2D barcodes uses Reed Solomon (called ECC 200) error correction, which provides strong resilience against symbol damage, print defects, and partial obstruction. GS1 DataMatrix is particularly well suited for healthcare, pharmaceutical, medical device, and direct part marking applications where symbol size may be limited and operational reliability is critical.

GS1 DataMatrix and Data Matrix symbols contain finder and timing patterns that allow scanners to determine symbol orientation and module positioning during the decode process. Because GS1 DataMatrix is capable of encoding large amounts of structured data within a relatively compact area, it is frequently selected for applications requiring lot numbers, serial numbers, expiration dates, or traceability information in constrained packaging environments.

- **GS1 DataMatrix and Data Matrix uses:**
    - **"L" finder pattern**
    - **clock track pattern**

Figure 5-1 Example of the Data Matrix finder pattern

Symbol size and X-dimension selection are critical to achieving reliable scan performance. Very small module sizes may exceed the practical capabilities of print technologies or scanners, particularly when printed on challenging substrates or curved surfaces. Organisations should ensure that selected symbol sizes align with both the production print capability (i.e., printer resolution and print height/width) and operational scanning requirements shown in the GS1 General Specifications Symbol Specification Tables in.

While Data Matrix symbols are generally less likely to include extensive visual customisation compared to QR Codes, the addition of logos, decorative modifications, colour variations, or reduced Quiet Zones may negatively impact decode performance. Any customised Data Matrix implementation should be avoided.

5.1.2 QR Code

- For QR Codes, ISO/IEC 18004 defines the technical requirements governing symbol structure, finder patterns, alignment patterns, masking, error correction, and encoding methodology. Error correction (ECC) is a key capability within QR Codes that allows a symbol to remain readable even when partially damaged or obscured. This capability is achieved through Reed-Solomon error correction, which adds error correction codewords to the symbol alongside the encoded data. Together, these codewords enable the recovery of the encoded data when a portion of the symbol has been damaged or obscured. **QR Code uses:**
  - **Three square structures in its corners**
  - **Alignment + clocking pattern**

Figure 5-2 Example of the QR Code finder pattern

- **QR Codes support four levels of Reed-Solomon error correction:**
  - Level L — permits recovery of approximately 7% of the encoded data.
  - Level M — permits recovery of approximately 15% of the encoded data.
  - Level Q — permits recovery of approximately 25% of the encoded data.
  - Level H — permits recovery of approximately 30% of the encoded data

- Identifying the ECC level

Figure 5-3 Example of ECC level indicator

Higher error correction levels improve damage tolerance but also increase symbol density and overall size requirements. Organisations should balance robustness, available print area, scanner capability, and intended operating conditions when selecting an error correction level.

The X-dimension is another critical barcode parameter during symbol generation. The X-dimension refers to the width of the smallest individual module or element within the barcode symbol. In 2D barcodes, this is commonly referred to as the module size. Smaller X-dimensions allow for more compact symbols but may reduce scanner readability if print quality, substrate quality, or scanner resolution are insufficient. Larger X-dimensions generally improve scan reliability but require additional packaging space, therefore optimising the data encode is critical as noted in section 4.2

5.1.3 Artwork Placement

Barcode placement within packaging artwork directly affects scanner accessibility and overall read performance. Symbols should be positioned in areas that minimise distortion, glare, creasing, and print inconsistency. Poor placement can negatively impact omnidirectional scanning performance at retail POS systems and may create difficulties for consumer smartphone scanning. See 2D Barcodes at Retail Point-of-Sale Implementation Guideline barcode placement section 5.6 and GS1 General Specifications section 6

Organisations should avoid placing barcodes:

- Across package folds or seams

Figure 5-4 Examples of printing across folds or seams

- Near cut lines or package edges

Figure 5-5 Examples of printing near cut lines

- Over highly reflective coatings or foils

Figure 5-6 Example of printing on a reflexive substrate

- On highly curved surfaces when possible

Figure 5-7 Example of printing on curved surfaces

- In areas subject to abrasion or damage

Figure 5-8 Example of printing on an area subject to damage

- Translucent surfaces

Figure 5-9 Example of printing on a translucent surface

- Surfaces that shrink inconsistently

Figure 5-10 Example of printing an area that could shrink inconsistently

- Adjacent to visually complex graphics that may interfere with symbol detection

For cylindrical products and flexible packaging, barcode orientation becomes especially important. Excessive curvature may distort module geometry and reduce decode reliability. Smaller 2D barcode symbol sizes or adjusted placement strategies may be required to compensate for package shape.

Artwork teams should also evaluate how barcode placement interacts with mandatory labelling content, branding elements, and consumer usability expectations. In many smart packaging implementations, the barcode serves both operational and consumer engagement purposes, requiring placement that supports both scanner accessibility and customer visibility.

- **Note**: the 2D Barcodes at Retail Point-of-Sale Implementation Guideline has extensive examples and guidance for 2D barcode placement

5.1.3.1 2D barcode placement during the 2D in retail transition period

Placement of 2D barcodes and the rules for multiple barcodes on-pack are critical to ensure POS remains efficient. Without these rules, high speed retail point-of-sale (POS) may be unable to meet their productivity target rate of 40 to 70 items per minute (IPM). Section 4.15 of the GS1 General Specifications Standard provides a set of barcode management practices intended to permit the use of multiple barcodes on the same trade item. This includes rules for adjacent and non-adjacent placement and rules for the transition to 2D barcodes.

Extensive, independent testing showed that the 2D barcode needs to be within 50 mm (1.97 inches) of the linear barcode's centre to achieve the target retail IPM. To learn more about barcode placement rules see section 6 of the GS1 General Specifications and 2D Barcodes at Retail Point-of-Sale Implementation Guideline.

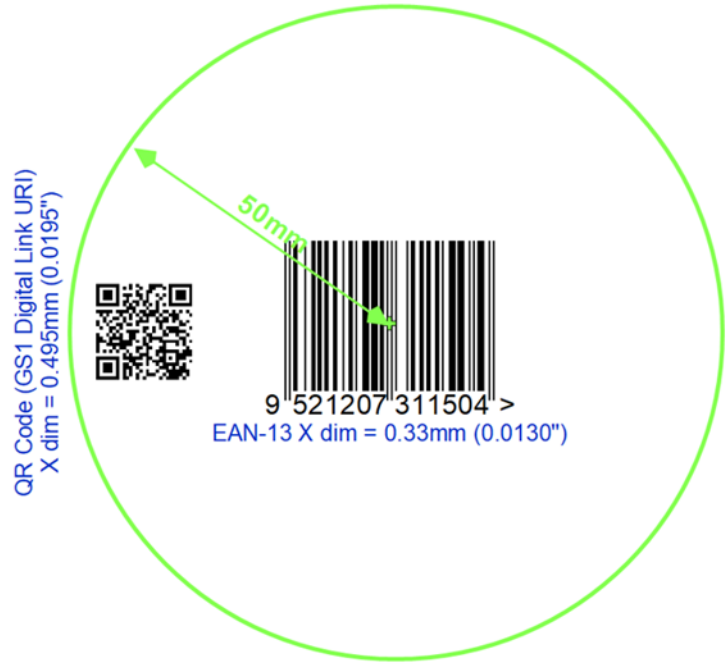

Figure 5-11 2D barcode placement in relation to the linear barcode for POS

5.1.3.2 2D barcode used for marketing purposes

In some use cases, the 2D barcode is being added for marketing purposes with a sole focus on consumer engagement. These barcodes tend to contain only the Global Trade Item Number (GTIN) using the GS1 Digital Link URI syntax and would be in addition to a GS1 conformant linear or 2D barcode placed for retail point-of-sale (POS) use. These barcodes may be placed on a front or side panel separate from the POS barcode and do not require human readable text as shown below. For more information see [2D Barcodes at Retail Point-of-Sale Implementation Guideline barcode placement section 5.6]

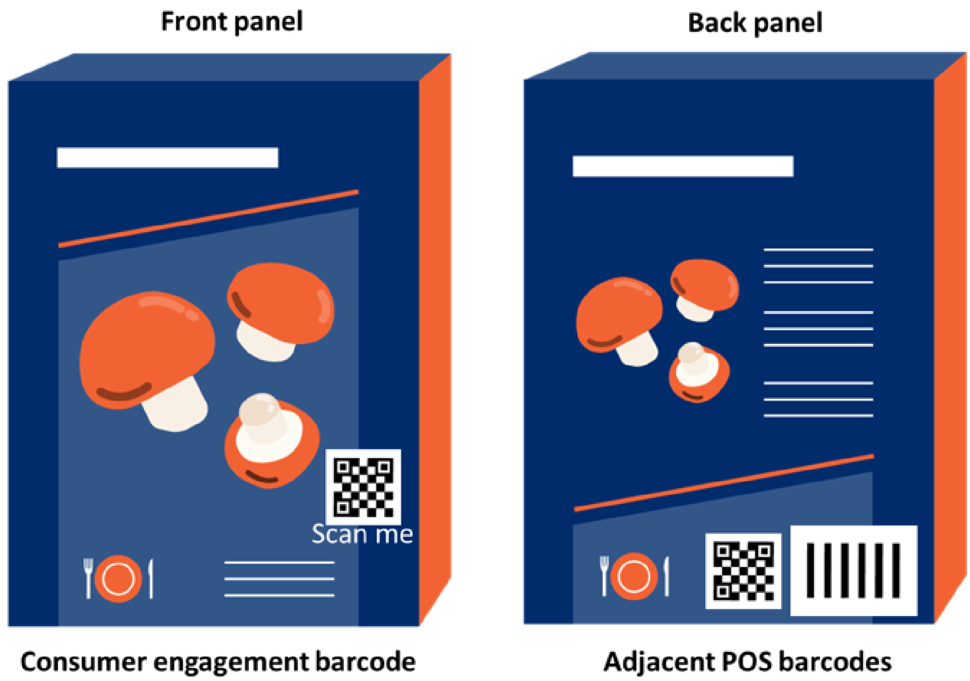

Figure 5-12 Example of consumer engagement 2D barcode on front panel

5.1.4 Quiet Zones

Quiet Zones are the clear spaces surrounding a barcode symbol that allow scanners to properly identify the beginning and end of the symbol. Quiet Zones are a mandatory component of most barcode design and are defined within GS1 and ISO specifications.

For 2D barcodes, insufficient Quiet Zones are one of the most common causes of scan failure. Graphics, text, cut marks, package edges, or other design elements that encroach into the Quiet Zone area may interfere with scanner recognition and decoding algorithms.

Quiet Zones should:

- Remain completely free of text including HRI (e.g., GTIN) or graphics
- Maintain sufficient contrast with the barcode symbol
- Be preserved throughout all artwork revisions and print processes
- Be evaluated after package die lines and finishing processes are applied

Organisations should ensure Quiet Zones remain conformant not only within digital artwork files but also after printing, trimming, laminating, varnishing, or package forming processes are completed.

GS1 normatively references the ISO/IEC requirements for the rules on the 2D barcodes Quiet Zone:

- Data Matrix – 1*X-dimension, see pink outlined area

(01)09521101530001

Figure 5-13 Data Matrix Quiet Zone

- QR Code 4*X-dimension, see figure 1 pink outlined area

(01)09521101530001

Figure 5-14 QR Code Quiet Zone

5.1.5 2D barcode colour

Colour selection plays a critical role in barcode scanning reliability and overall symbol performance. Barcode scanners operate by detecting differences in light reflectance between the dark and light areas of a symbol. Insufficient contrast between these areas may prevent scanners from accurately identifying barcode patterns and decoding the encoded data.

Most barcode scanners, including retail POS scanners and many industrial imaging systems, use red illumination or red laser technology during the scanning process. Because of this, certain colour combinations that work with smartphones and appear visually acceptable to the human eye may perform poorly when scanned. Colours that reflect red light, such as red, orange, yellow, or some metallic inks, may appear effectively invisible to scanners when used as dark barcode elements.

Best practice recommendations generally include:

- Dark symbols printed on light backgrounds (or reflectance reversal for QR Code and Data Matrix only)
- Black or dark blue symbols on white backgrounds
- Matte finishes rather than highly reflective surfaces
- Strong contrast between the barcode and surrounding packaging graphics

Organisations should avoid:

- Red, orange, yellow, pastel or dot screening barcode modules
- Transparent or low-opacity substrates
- Metallic, fluorescent, or highly glossy inks within the symbol area
- Colour gradients within the barcode symbol
- Decorative backgrounds that reduce edge definition

(01)09521101530001 (01)09521101530001

Figure 5-15 View of red QR Code by a smart device imager (left) and a red illuminated POS imager (right)

- **Note**: the GS1 2D Barcode Colour & Quality Guide has extensive examples and guidance for 2D barcode quality and colour selection

5.1.6 2D barcodes with logos

The use of logos, branding elements, or marketing graphics within a 2D barcode is common for single purpose marketing QR Codes. However, these elements are not part of the internationally approved QR Code (ISO/IEC 18004) and Data Matrix (ISO/IEC 16022) standards and are therefore not recommended by GS1. Any logo placed inside or over a symbol intentionally obscures encoded data and is effectively treated as barcode damage. While 2D barcode error correction may keep a symbol readable, excessive or poorly positioned logos can interfere with critical finder patterns and structural features, causing decode failures. Packaging or label space constraints often require smaller GS1 2D barcodes; in these cases, an embedded logo can quickly consume the available error-correction capacity and increase the risk of scanning failure.

Figure 5-16 An example using a logo within a QR Code with ECC (M) error correction results in a failure

- **Note**: Some consumer smartphones and supply chain scanning devices may be able to read this GS1 2D barcode; however, it fails verification because all the QR Code's error correction codewords are used to recover data obscured by the logo.

If organisations choose to incorporate logos or branding within a 2D barcode, the level of error correction should be increased to compensate for the loss of data caused by the image. Higher error correction enables the barcode to recover more damaged information but requires additional codewords, resulting in a larger symbol size. Furthermore, consuming error correction capacity to accommodate a logo reduces the barcode's ability to tolerate additional damage encountered during printing, packaging, transportation, and retail handling. For this reason, GS1 recommends avoiding the use of embedded logos and instead maintaining a clear, standards conformant GS1 2D barcode to maximise robustness and scanning performance throughout the supply chain. For more information see the GS1 2D Barcode Colour & Quality Guide.

5.1.7 Human Readable Information

Human readable interpretation (HRI) refers to the text printed near a barcode that allows people to manually read key information when scanning is not possible. HRI supports operational continuity during scanner failures, package damage events, or manual verification processes. HRI serves as a fall-back option in situations where there is a need to manually interpret or process barcoded data. The HRI rules enable industry to create consistent packaging designs that can be distributed to multiple countries and used in the same way.

Refer to *GS1 General Specifications*, section 4.14 for human readable text rules on HRI and non-HRI.

For GS1 barcodes, HRI commonly includes:

- Global Trade Item Numbers (GTINs)
- Batch or lot numbers
- Expiration dates
- Serial numbers
- Other GS1 Application Identifier data

HRI should remain legible throughout the product lifecycle and should not be obscured by package folds, seals, or finishing processes. Font size, contrast, and placement should support readability under expected operational conditions.

Note: see the GS1 Human Readable Interpretation (HRI) Implementation Guideline for extensive examples of HRI placement

6 Printing Considerations

Printing quality is one of the most significant factors affecting the successful implementation of 2D barcodes. A technically correct barcode design may still fail operationally if the print process cannot consistently reproduce the required symbol geometry, contrast, edge definition, and module consistency. Because 2D barcodes often encode significantly more information within a smaller physical area than traditional linear symbols, they may be more sensitive to print variation, distortion, contamination, and physical damage.

Organisations should evaluate printing capability across the full product lifecycle, including production, packaging, transportation, warehousing, retail handling, and consumer use. Print quality should not only be evaluated immediately after printing, but also after exposure to environmental and operational conditions such as abrasion, compression, moisture, temperature variation, and package flexing.

Barcode print quality management should align with applicable GS1 requirements and relevant ISO standards, including ISO/IEC 15415 for two-dimensional barcode print quality verification. Consistent print quality requires alignment between artwork design, print technology capability, substrate selection, production controls, and operational handling practices. To achieve consistent and comparable measurement results an ISO/IEC 15426-2 compliant measuring instrument is required.

6.1 Print Process Evaluation

Different printing technologies produce barcode symbols using different imaging methods, resolutions, ink transfer characteristics, and substrate interactions. Each printing technology has advantages and limitations based on requirements such as maximum height, print resolution, speed of print, substrate to be printed on, the printing environment and the expected 2D barcode durability. A GS1 2D barcode can be preprinted on commercial presses, much like today’s EAN/UPC barcode, when only a GTIN is needed. When variable data such as serial numbers is required, inline production processes are typically necessary.

The major printers used in manufacturing include:

Continuous Ink Jet (CIJ): CIJ is a non-contact printing technology that uses a continuous stream of ink droplets. The ink is expelled through a small nozzle and then charged and deflected by electrodes to create characters on a substrate. CIJ is commonly used for high-speed printing on various materials, including packaging. Most CIJ applications involve printing dates or other traceability information. GS1 2D barcodes can also be printed, provided the barcode height and production speed remain within the printer's capability.

Figure 6-1 Example of CIJ printer and printing method

- **Thermal Ink Jet (TIJ)**: TIJ is a non-contact printing technology that uses tiny resistors to heat and vaporise ink, creating small bubbles. The expansion of these bubbles propels ink droplets onto the substrate, forming characters or barcodes. TIJ is often used in desktop printers and smaller-scale printing applications like 2D barcodes. One of the largest TIJ applications is GS1 DataMatrix printed in healthcare applications. Most TIJ printheads can print 12.7mm high, whereas the new generations print up to 25mm high, making them a good fit for most QR Codes with GS1 Digital Link.

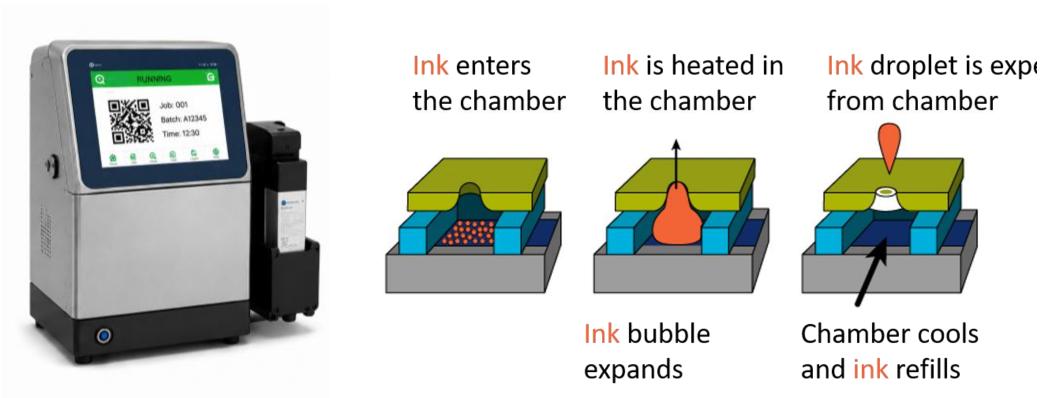

Figure 6-2 Example of TIJ printer and printing method

- **Thermal transfer and direct thermal**
  - **Thermal Transfer**: A printing method where a thermal print head applies heat to a ribbon, transferring ink onto the substrate, usually label or film. It is commonly used for high-quality and durable printing, such as 2D barcodes on labels.

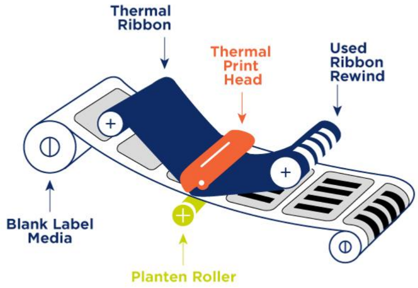

Figure 6-3 Example of thermal transfer printing method

- **Direct Thermal**: This method uses heat-sensitive paper or label stock. When the thermal print head applies heat, it activates the chemicals in the paper, creating characters or barcodes. It is often used for shorter life span labelling applications.

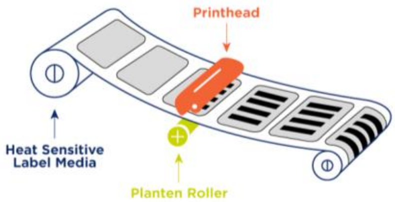

Figure 6-4 Example of direct thermal printing method

Within these thermal printer methods, there are three main categories:

- **Thermal Transfer Overprint (TTO)** is a variation of thermal transfer printing that is commonly used in the packaging industry. It involves printing variable data, such as expiration dates or batch/lot numbers, onto flexible packaging materials.

Figure 6-5 Example of a TTO printer

- **Desktop label printers** are compact printers designed for small to medium printing volumes. They are commonly used in office settings, retailer or smaller production environments for tasks such as printing labels, barcodes, and shipping tags.

Figure 6-6 Example of a desktop thermal transfer label printer

- **Print and apply systems** are automated solutions that print labels on-demand and apply them to products or packages. These systems are often used in industrial settings for labelling products with variable information.

Figure 6-7 Example of a print and apply printer

- **Laser:** Light amplification by stimulated emission of radiation (LASER) technology is used in marking systems to produce high-quality 2D barcodes. In the context of industrial printing, lasers are often used for marking and coding on various materials.

Figure 6-8 Example of Laser marking printer

  - Laser marking quality is dependent on the substrate reaction to the laser wavelength, the size of the GS1 2D barcode and the printing speed required by the application. There are multiple wavelengths and three laser processes:
    - **Ablation** removes layers of material (ink) exposing lower surfaces and can generate 2D barcodes scannable by the majority of imaging scanners.

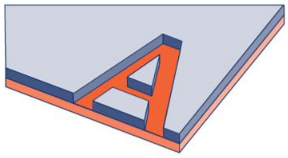

Figure 6-9 Example of laser ablation

- **Engraving** melts (plastics) or fractures (glass) creating grooves or pockets in the substrate. The 2D barcode created by engraving requires specialised lighting and vision systems.

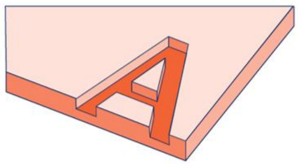

Figure 6-10 Example of laser engraving

- **Thermo-chemical** uses the reaction of a material within the substrate (e.g., mica) or added to the surface (e.g., water-based finishing). The contrast is often capable of being scanned by the majority of imaging scanners.

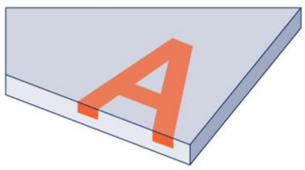

Figure 6-11 Example of laser thermo-chemical reaction

- **Drop on demand (DOD):** DOD is a category of inkjet printing technology where ink drops are precisely ejected from a print head onto the substrate. This method allows for precise control over droplet placement and is often used in industrial and commercial printing. There are two major types of DOD printers.

Figure 6-12 Example of a DOD printer

  - **Valve jet** is a specific type of DOD technology where ink droplets are ejected through a valve mechanism. Most large valve jet printers are not appropriate for retail 2D printing applications, but smaller valve jet methods like micro-electro-mechanical systems (MEMS) valves are known for their high-speed and high-resolution capabilities that can generate quality 2D barcodes.
  - **Piezo** DOD technology generates ink droplets by changing the shape of piezoelectric crystals within the print head. Piezo technology is known for its versatility and compatibility

with a wide range of inks. High-resolution piezo printheads are capable of printing high-quality 2D barcodes at very high speeds.

- **Commercial printing presses** are used across a wide range of industries for producing printed materials such as packaging, labels, newspapers, magazines, books, promotional materials, and more. Various printing technologies used in commercial printing operations include gravure, flexography and offset printing processes. These printing presses print static data unless a digital section is added.

Figure 6-13 Example of a commercial printing press

  - **Rotary Gravure** printing is a high-speed, high-quality printing process that uses engraved cylinders to transfer ink onto a substrate, often used for long print runs of magazines, catalogues, packaging materials, and decorative print.
  - **Flexography, or flexo printing**, is a widely used printing process that utilises flexible relief plates to transfer ink onto a variety of substrates. It is commonly used for packaging materials, labels, newspapers, and corrugated cardboard.
  - **Offset printing**, also known as lithography, involves transferring ink from a plate onto a rubber blanket and then onto the printing surface. It is suitable for a wide range of substrates and is commonly used for books, magazines, brochures, and packaging.

They play a crucial role in the production of printed media and are essential for meeting the printing needs of businesses, publishers, advertisers, and consumers. The process of created transfer plates means the 2D barcode data will be static for the production run unless a digital printer is added to the printing press processes.

- **Digital printing (Piezo)** involves the precise control of ink droplets through the deformation of piezoelectric crystals. It is commonly used in various printing applications, including graphics, textiles, packaging and industrial labelling. Digital printing allows for dynamic data printing and customisation. Inline production applications are emerging but require very good material and product handling. Offline preprinted application labels and product packaging are the most common solution for adding 2D barcodes.

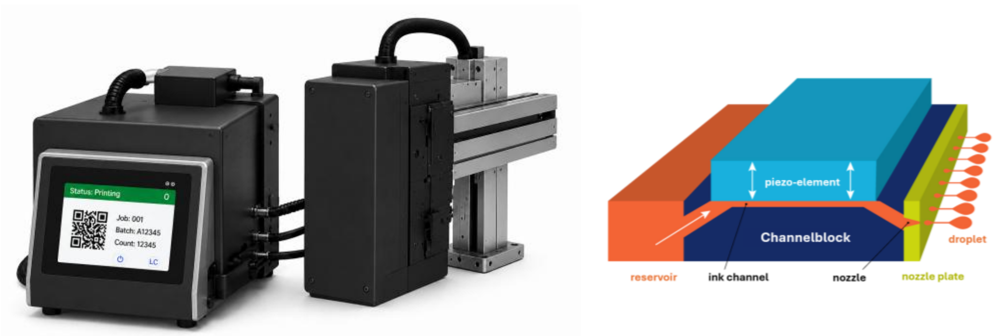

Figure 6-14 Example of a Piezo printer and the printing method

- **Digital offset printing** uses an electrophotographic process in which electrically charged ink particles are transferred to a photo imaging plate and then offset via a heated blanket onto the substrate. This technology combines the image quality and consistency of offset printing with the flexibility of digital printing. It is widely used for labels, flexible packaging, folding cartons and commercial print applications. Digital offset printing supports variable data and serialisation, enabling the production of unique 2D barcodes and customised packaging. It is used widely in offline production of preprinted labels and packaging and remains a common method for applying high-quality 2D barcodes to products.
- **Emerging printing technologies** have been resetting the upper limit for printing 2D barcodes. This next generation of printers includes binary array lasers, super piezo inkjet, high-speed piezo, MEMS valve jet and thermal reactive ink coatings that enable current laser to achieve new top speeds. These next generation printers are achieving 120 meters per minute, exceeding the needs of most high-volume production lines.

Organisations should establish print qualification procedures that evaluate the printing technology:

- Minimum achievable X-dimension
- Edge definition consistency
- Symbol contrast and Modulation
- Registration accuracy
- Print repeatability
- Production speed impacts
- Impact on consumables needed
- Durability throughout product lifecycle

6.2 Static Printing Versus Dynamic Printing

Organisations implementing 2D barcodes should distinguish between static printing and dynamic or variable data printing processes.

- **Static printing refers to barcode content that remains identical across an entire production run or product SKU and is usually preprinted. Examples include**:
  - Fixed web URLs
  - Standard product identification (GTIN)
  - General consumer engagement links
  - Non-serialised retail packaging data such as Consumer Variants (CPV)

Static barcode artwork is commonly incorporated directly into preprinted packaging designs using conventional print processes such as flexographic or offset printing.

- **Dynamic printing, also referred to as variable data printing, involves changing barcode content during production. Dynamic printing may include:**
  - Batch or lot numbers
  - Expiration dates
  - Serial numbers

  - Traceability data
    - Production timestamps

Dynamic barcode printing typically requires real-time integration between production equipment, print systems, serialisation software, databases, and quality management controls. The best implementations link the printing equipment to the business systems ensuring that the data is loaded correctly into the printers and therefore to the 2D barcodes.

Because every dynamically printed barcode may contain unique data, **organisations should implement robust verification and inspection processes such as in line validation cameras to ensure:**

- Correct data assignment
- Proper syntax formatting
- Print quality consistency
- Database synchronisation
- Prevention of duplicate serial numbers
- Accurate production record management

Note: Inline validation cameras often provide ISO/IEC 15415 results. These results are “relative” only because inline validation cameras are not ISO/IEC 15426-2 compliant measuring devices.

6.3 Variable data environments

Variable data environments may also introduce operational challenges related to production speed, printhead maintenance, ink management, and data communication reliability. Barcode quality may degrade during extended production runs if maintenance and monitoring procedures are not consistently applied.

Where serialised or regulated products are involved, organisations should also consider data retention, audit trail requirements, and system validation procedures.

6.4 Product or packaging substrate

The physical characteristics of packaging materials and label substrates may significantly influence barcode print quality and scanning performance.

Factors affecting barcode performance include:

- Surface smoothness
- Absorbency
- Gloss level
- Reflectivity
- Material flexibility
- Coating composition
- Thermal sensitivity
- Environmental durability
- Curvatures or uneven surfaces

Highly absorbent substrates may increase ink spread and reduce edge definition. Highly reflective materials, metallic foils, or glossy coatings may create glare that interferes with scanner illumination and image capture.

Flexible packaging materials may distort barcode geometry during filling, sealing, transportation, or consumer handling. Corrugated materials may introduce surface inconsistency that affects module uniformity.

Organisations should evaluate barcode performance after all finishing and converting processes are completed, including:

- Lamination
- Varnishing
- Embossing
- Shrink application
- Folding and sealing
- Label application

Substrate testing should reflect actual environmental and operational conditions expected throughout the product lifecycle. If the brand does not have its own methods for simulating substrate environmental conditions, it can work with its printer solution provider or an external product testing laboratory to carry out the evaluation.

6.5 Product Handling and Operational Impacts on Print Quality

Barcode print quality may be significantly affected by conditions occurring directly on the production line during printing and product handling operations. Even when barcode artwork, printer configuration, and initial print quality are properly validated, real-world manufacturing environments often introduce variation that can negatively impact barcode readability and consistency.

2D barcodes are particularly sensitive to production variation because they rely on precise module geometry, edge definition, and consistent spacing to support successful decoding. Small changes in print conditions may alter module shape, symbol dimensions, contrast, or registration accuracy.

Organisations should evaluate how production line dynamics influence barcode quality throughout normal operating conditions, including:

- Production speed variation
- Line acceleration and deceleration
- Frequent stop-and-start conditions
- Conveyor instability
- Product movement during printing
- Mechanical vibration
- Printer mounting stability
- Product positioning variation
- Environmental contamination

Production speed variation is a common cause of inconsistent barcode quality. Rapid acceleration or deceleration can affect ink transfer, print timing, registration accuracy, or synchronisation between the product and print system. An encoder can measure movement and send that data to the printer controller to compensate for speed variation.

Product positioning relative to the printer is another critical factor. Variations in distance, angle, or orientation between the product and printhead may alter symbol geometry and image clarity.

Examples include:

- Products moving closer to or farther from the printhead
- Tilting or rotation during transport
- Package wobble on conveyors
- Inconsistent label application positioning
- Variations in product height
- Flexible surfaces deforming during movement

For inkjet systems, excessive distance between the printhead and substrate may increase droplet spread, reduce edge sharpness, or distort module geometry.

For thermal transfer systems, inconsistent contact pressure between the ribbon and substrate may create incomplete or uneven module formation.

Mechanical vibration within manufacturing environments may also affect barcode print quality. Vibration sources may include:

- Conveyor systems
- Packaging equipment
- Compressors and motors
- Nearby production machinery
- Forklift or fork truck traffic
- Facility floor vibration

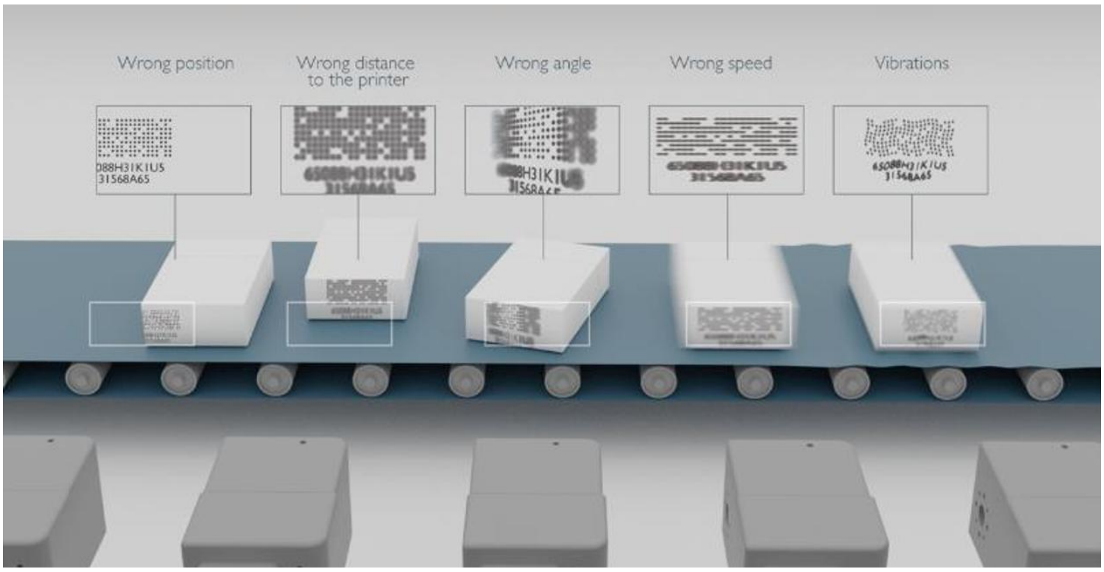

Figure 6-15 Example of printing issues due to poor product handling

Environmental conditions may further influence barcode quality during production. Temperature variation, humidity, dust, condensation, static electricity, and airborne contamination may affect ink behaviour, substrate performance, label adhesion, or printhead reliability.

Organisations should implement production monitoring and preventative maintenance programmes designed specifically to maintain barcode consistency under actual operating conditions.

Recommended practices may include:

- Real-time print inspection systems
- In-line barcode grading
- Automated rejection systems
- Regular printhead cleaning
- Verification after line restarts
- Production speed validation testing
- Environmental monitoring
- Preventative maintenance schedules
- Mechanical stability assessments
- Validation across normal operating speed ranges

Barcode validation should reflect the full range of expected production conditions rather than ideal laboratory environments. Testing only under controlled startup conditions may fail to identify intermittent print defects that occur during actual manufacturing operations.

7 Conclusion

The transition to 2D barcodes in retail represents a significant evolution in how products are identified, authenticated, tracked, and connected to digital information. While much industry attention has focused on scanner and POS system readiness, successful implementation ultimately depends on the quality, structure, and print performance of the barcode itself. A poorly designed or inconsistently printed 2D barcode can undermine even the most advanced retail infrastructure.

Creating retail-ready 2D barcodes requires organisations to take a system-wide approach that aligns barcode data structures, packaging design, printing technologies, scanner capabilities, and operational environments. Decisions regarding data syntax, symbol size, X-dimension, print technology, substrate selection, placement, and environmental durability all directly influence scanning reliability throughout the supply chain and at retail point-of-sale.

Organisations should also recognise that 2D barcode implementation is not solely a technical exercise. Successful adoption requires collaboration across packaging, production, IT, marketing, retail operations, and solution providers to ensure interoperability and consistent execution. During the transition period, where linear and 2D barcodes will coexist, adherence to GS1 standards and placement rules will remain critical to maintaining retail efficiency and minimising operational disruption.

As the industry progresses toward Ambition 2027 and broader adoption of retail conformant QR Codes and Data Matrix barcodes, organisations that invest in strong barcode governance, validation, print quality management, and operational testing will be better positioned to support future use cases such as traceability, sustainability, consumer engagement, regulatory compliance, and digital product information.

Ultimately, reliable barcode creation and printing form the foundation upon which successful retail 2D barcode ecosystems are built.

8 References

Below are links to reference materials and tools available from GS1. The standards and guidelines were developed through the GS1 Global Standards Maintenance Process (GSMP). All other materials, tools, guides, case studies and playbooks were created with the help of industry experts, with support from GS1.

Table 8-1 2D related reference documents and tools

Reference document
2D Barcode Size Estimator
2D Barcode Colour & Quality Guide
2D Barcode Verification Process Implementation Guideline
2D Barcodes at Retail Point-of-Sale Implementation Guideline
2D Barcodes Factsheet
2D Barcodes in Retail: Test Suite
2D case study library
2D Pilot Toolkit
Best practices for creating your QR Code powered by GS1
Connecting barcodes to related information guideline
GS1 Application Identifiers
GS1 Barcode Syntax Engine
GS1 2D Barcode Playbook for Retail POS Host and Backend Systems
GS1 2D Barcode Playbook for Retail Scanners Guide
GS1 DataMatrix Guideline
GS1 Digital Link Standard: URI Syntax
GS1 General Specifications
GS1 Human Readable Interpretation (HRI) Implementation Guideline
GS1 2D Store
GS1 Resolver Conformance Test Suite
Migration to a single GS1 compliant 2D barcode for retailer private label and in-store labelled products
Principles and Criteria for High-Capacity Data Carriers in the GS1 system
Quick start guide for GS1 Digital Link
Redirection: from Scan to Content
Solution Provider 2D Readiness Guidance
The How and Why of GS1 Digital Link

9 Barcode creation and printing Readiness Checklist for 2D Barcodes

9.1 Barcode Creation Checklist

9.1.1 Business & Use Case Definition

- Define the intended business use cases for the 2D barcode.
- Confirm whether the barcode will support:
  - Retail POS
  - Traceability
  - Consumer engagement
  - Regulatory requirements
  - Inventory and operational processes
- Minimise encoded data to only what is operationally necessary.
- Confirm whether linear and 2D barcodes must coexist during transition.

9.1.2 Standards & Data Structure

- Validate compliance with GS1 standards.
- Select the appropriate GS1 syntax:
  - Plain syntax
  - GS1 element string syntax
  - GS1 Digital Link URI syntax
- Confirm Application Identifiers (AIs) are correctly structured.
- Validate GS1 Digital Link URI formatting where applicable.
- Ensure data structures align with downstream POS and backend system capabilities.

9.1.3 Symbol Design & Generation

- Select the appropriate symbology:
  - GS1 DataMatrix
  - Data Matrix
  - QR Code
- Validate X-dimension and overall symbol size against GS1 General Specifications.
- Confirm appropriate error correction level selection.
- Verify Quiet Zones comply with ISO/IEC requirements.
- Avoid unnecessary barcode customisation, decorative styling, or embedded graphics.
- Avoid low contrast or problematic colour combinations.
- Generate symbols using validated barcode creation software.

9.1.4 Artwork & Placement

- Confirm barcode placement supports retail POS scanning.
- Avoid folds, seams, cut lines, and highly curved surfaces.
- Maintain required Quiet Zones after artwork and package finishing.
- Ensure placement supports consumer usability where applicable.
- Verify compliance with GS1 barcode placement rules during coexistence with linear barcodes.
- Validate that 2D barcode placement is within retail guidance distances relative to linear barcodes.

9.1.5 Validation & Verification

- Validate syntax and encoded data before production.
- Verify barcode quality against ISO/IEC 15415 requirements (using ISO/IEC 15426-2 compliant devices).
- Test symbols using representative scanners and mobile devices.
- Validate barcode readability under operational lighting conditions.
- Conduct testing on final production substrates and packaging

9.2 Barcode Printing Checklist

9.2.1 Print Technology Evaluation

- Confirm selected print technology can reliably reproduce retail-quality 2D barcodes.
- Validate achievable X-dimension at required production speeds.
- Evaluate:
    - Resolution capability
    - Edge definition
    - Contrast and Modulation performance
    - Registration consistency
    - Durability requirements
- Confirm printer compatibility with selected substrates.

9.2.2 Static & Dynamic Printing

- Determine whether barcode printing will be:
    - Static
    - Dynamic / variable data
- Validate serialisation and variable data workflows where applicable.
- Confirm integration between print systems, databases, and production controls.
- Implement controls to prevent duplicate or incorrect data assignment.

9.2.3 Production Line Conditions

- Evaluate barcode quality across expected production speed ranges.

- Validate print consistency during:
  - Line acceleration
  - Deceleration
  - Stop/start events
- Assess effects of:
  - Conveyor vibration
  - Product movement
  - Product rotation
  - Product height variation
  - Printer-to-product distance variation
- Evaluate environmental impacts including:
  - Temperature
  - Humidity
  - Dust
  - Condensation
  - Static electricity

9.2.4 Product & Substrate Validation

- Validate print quality on all intended packaging materials.
- Assess barcode durability after:
  - Filling
  - Sealing
  - Folding
  - Shrink wrapping
  - Transportation
  - Retail handling
- Confirm barcode readability after abrasion or environmental exposure.

9.2.5 Quality Management & Maintenance

- Implement barcode measurement (verification) procedures.
- Establish first article inspection processes.
- Use in-line inspection or grading systems where appropriate.
- Implement preventative maintenance procedures for printers and printheads.
- Validate barcode quality after maintenance or production restarts.
- Establish escalation procedures for barcode quality failures.

9.2.6 Operational Testing

- Test printed barcodes using:
  - Retail POS scanners

    - Handheld scanners
    - Presentation scanners
    - Mobile devices
    - Distribution scanning systems
- Validate scanning performance under real operational conditions.
- Confirm scanning performance throughout expected product lifecycle.