Proposed Architecture and Principles for Digital Product Passports

About this document

In the context of the EU Green Deal, the EU has adopted the Sustainable Product draft regulation which introduces the horizontal product passport concept in the EU legal framework. The new requirements have a global impact because they demand to all companies to share product data around a data structure pre-decided by EU legislation.

GS1 in Europe supports the EU sustainable Product Initiative and this paper intends to give a first overview of the data architecture, based on GS1 standards suite, that could serve the product passport data structure.

Using open and global standards as a foundation of the EU system is central to enable the free movement of goods globally, to minimize disruption along global supply chains and to ensure data interoperability for all.

Outline statement

GS1 in Europe supports an architecture for EU Digital Product Passports that:

1. is based on the identity of the product, which is persistent, not on identity of the data service or passport;
2. gives maximum flexibility and future-proofing to economic operators and regulators by providing machine-readable data;
3. emphasises the potential business and marketing benefits of creating a Digital Product Passport and increases efficiency by minimising the effort needed to create them;
4. is decentralised so that although all stakeholders are identified and connected, with the physical product itself as the starting point, there is no central point of failure for the data infrastructure and therefore no vendor-locked service;
5. defines the role of an archive/notary as a body that can monitor compliance and act as a repository of record;
6. is based on open standards, as developed at GS1 and elsewhere and ensures interoperability;
7. is ready to be enhanced with new technologies that add proofs of veracity.

A user story

The consumer journey

Jo wants to install a floor in her loft. To make the job easier, she wants to buy a new electric screwdriver. In what follows, we refer to the use of QR code as, today, this is the most likely kind of 2D barcode to be used. However, as we discuss in later sections, other types of GS1-conformant data carriers may be used.

Jo's new best friend: an electric screwdriver by Phil cc by-nd

Scan 1: At the store, she uses an app on her phone to scan the QR codes on several electric screwdrivers. The app accesses the Digital Product Passports for each of the ones on offer and displays a comparison that Jo uses to choose the one that has the specification she is looking for. This includes a description of its sustainability, the CO_2 emissions of its manufacturing process etc.

After several years, an accident occurs causing the screwdriver's charging station to be damaged beyond repair.

Scan 2: Scanning the product's code, which is printed on the screwdriver itself, Jo finds information that the charger is no longer made and, regrettably, returns the screwdriver and its charger to the store or to the economic operators allowing those operations in Jo's country for recycling.

Repair café by Wordshore cc BY-NC-ND

The business journey

Scan 3: On receipt of the damaged screwdriver, the recycler scans the QR code and finds the Digital Product Passport which includes details of the metals used in the battery. This allows the battery to be sent as high-grade scrap metal to the correct destination and to continue its journey.

Scan 4: Again, scanning the same QR code, the recycler is presented with sufficient details of the screwdriver itself to allow it to be dismantled, and for many of its component parts to be reclaimed for future use or, if possible, recycled.

All four scans enable **two-way communication**. As well as scanner receiving information, the act of scanning sends information. For example, the screwdriver brand might receive end of life information to be able to pay taxes based on precise product information. This is explored later in this document.

Dependencies

Each of the four operations sketched above depends on:

1. A persistent global identification system for the item and its components.
2. The means to connect that item to multiple sources of data.
3. Data being exchanged by different parties in a way that is *machine-readable and interoperable*.

As we'll explore below, however, they *do not* require a central data service nor the duplication of data across a network of energy hungry computers.

Persistence of identity

ISO/GS1 standards explain how to apply an identifier to a physical product's packaging, and in the last 50 years the GS1 barcodes have been globally used cross sectoral and globally. However, there are challenges in ensuring that the product itself carries its identifier so that it persists, even after the outer packaging is removed and discarded. For items such as batteries and electronic goods, this can be achieved by printing or etching the identifier on the item itself. Textiles can have the identifier printed or woven into a label or carried in a robust RFID tag embedded in the fabric itself. For construction goods, it is probably necessary for the identifier to be applied in multiple places as once cut to size, the piece carrying a single identifier might be discarded.

For virtual products, the identifier needs to exist independently of the product itself. This ensures that if the economic operator ceases trading, changes name or ownership, the identifier is unaffected.

Independence aids persistence

It is seen as essential that identifiers *identify the product itself*, not the Digital Product Passport (which is useful only at certain moments in a product's lifecycle).

The underlying need is that the product identifier persists throughout its lifetime from purchase to eventual disposal and is useful throughout that time.

The GS1 identification system

Items are created with raw materials and components from different locations and economic operators situated in various regions, marketed for the first time either in the physical world or in the digital one, sold and resold in many different contexts. Gift packs might include several different products that are all available separately. Items may vary in size and colour but might otherwise be identical. On top of that, products evolve over time. Even if the product is 'the same', different batches might source components from different places over time and this will have an impact on issues important for Digital Product Passports (DPPs). For some product categories, therefore, it will be relevant to assign an additional identifier to a production run (batch) or an individual serial number to each instance of the product.

These issues are covered in GS1's GTIN Management Standard and lie at the core of product identification.

For almost five decades, GS1 has administered a globally accepted standard for identification of products called the Global Trade Item Number, GTIN. The GTIN is an ISO standard. This identifier was designed for open supply chains from the very beginning and is currently the most widely used and

globally accepted standard for product identification. The GTIN is the number that is encoded in the ubiquitous barcode seen on almost all consumer items sold in retail all over the world, including online retail.

Figure 1 GTIN 9506000134369 encoded in an EAN barcode

In the GS1 system, there are separate standards for the identifiers themselves, for the way the identifiers are encoded/formatted and for the data carriers (e.g. barcodes). In the context of product identification, the most relevant identifiers are:

- **GTIN** (Global Trade Item Number) that identifies the trade item. All identical trade items from the same source should carry the same GTIN.
- **Batch/lot number**, that identifies a production batch of products sharing the same GTIN.
- **Serial number**, that uniquely identifies each individual instance of the product. Combined with the GTIN, this is a globally unique number for each product instance.

Encoding extra information like these, as well as others like expiry and best before dates, requires high capacity barcodes such as QR codes, Data Matrix codes etc. The GS1 identification standard is part of the ISO/IEC 15459 structure for automatic identification and data capture techniques, and GS1 is an issuing agency under the ISO/IEC 15459-2 registration procedure.

Using GS1 identification standards in the whole supply chain and product life cycle

GTINs can be used by companies to uniquely identify all of their trade items. GS1 defines trade items as products or services that are priced, ordered or invoiced **at any point in the supply chain**. This means that, although GTIN is most widely known to identify products sold in retail to consumers, it is also well suited to identify upstream products such as raw materials and components, which are themselves trade items, typically sold B2B. The GTIN Management Standard (referenced above) has a specific section for rules to be applied for upstream scenarios, including cases when products identified with GTIN is used as a component or an ingredient by a downstream trading partner that makes another product.

Combined with a serial number, GTIN can be used to identify the final product throughout its complete life cycle, thus serving as an asset identifier.

The GS1 identification standards can also be used to identify other business objects anywhere in the supply chain such as parties, locations, shipping containers, shipments, consignments, documents and more. Some examples of parties and locations that can be identified with a Global Location Number are primary producers (farms, mines, forest lots, etc), processing and packing facilities, warehouses, distribution centres, retail stores, repair shops, buildings, etc.

Use of globally unique identifiers in supply chains

Figure 2 Simplified jeans supply chain

The simplified picture shown above may be what's in most people's heads when thinking about a supply chain but it is actually an *over-simplification*. Supply chains are almost always more complex and should be referred to as supply networks that involve far more participants.

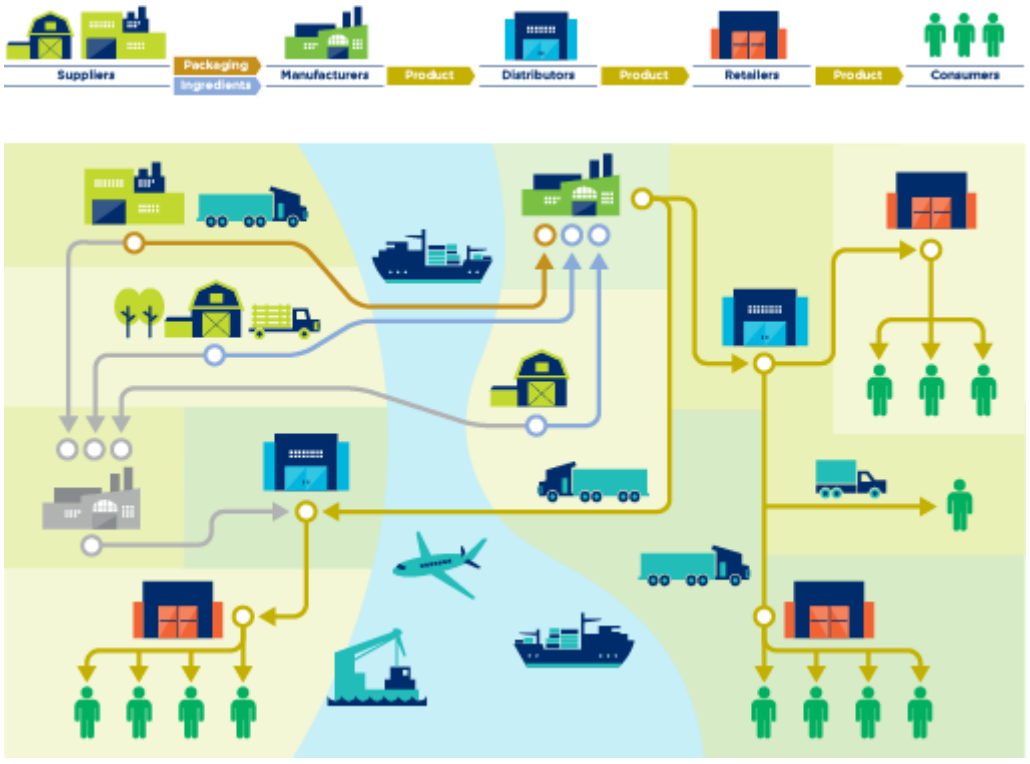

Figure 3 Supply networks are not always linear and simple

During its journey from multiple primary producers to the final user, raw materials are aggregated and processed in many steps to become the final trade item that the end user purchases and uses. At each process step, a set of raw materials or components, each identified with a GTIN, is turned into a new product with a new GTIN. This aggregation can be recorded at each process step and shared with other supply chain participants using GS1 standards.

The graphic below contains a simplified example of multiple products, each identified at batch/lot level (using GTIN + batch number) or at class level (GTIN only) are aggregated into the final product.

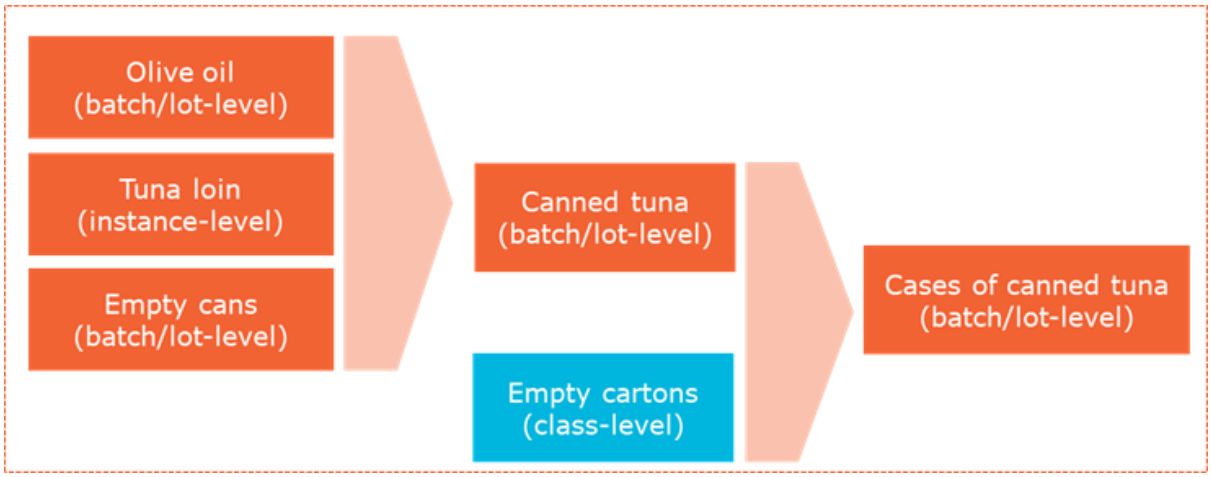

Figure 4 Example of aggregation of raw materials into a finished product

Details of how the process of aggregating and sharing traceability event data is available in GS1's Global Traceability Standard. GS1 also offers a technical standard called EPCIS (Electronic Product Code Information Service) which specifies on a technical level how traceability data can be managed by each supply chain participant and shared across the whole supply chain. EPCIS is also an ISO standard, submitted to ISO by GS1.

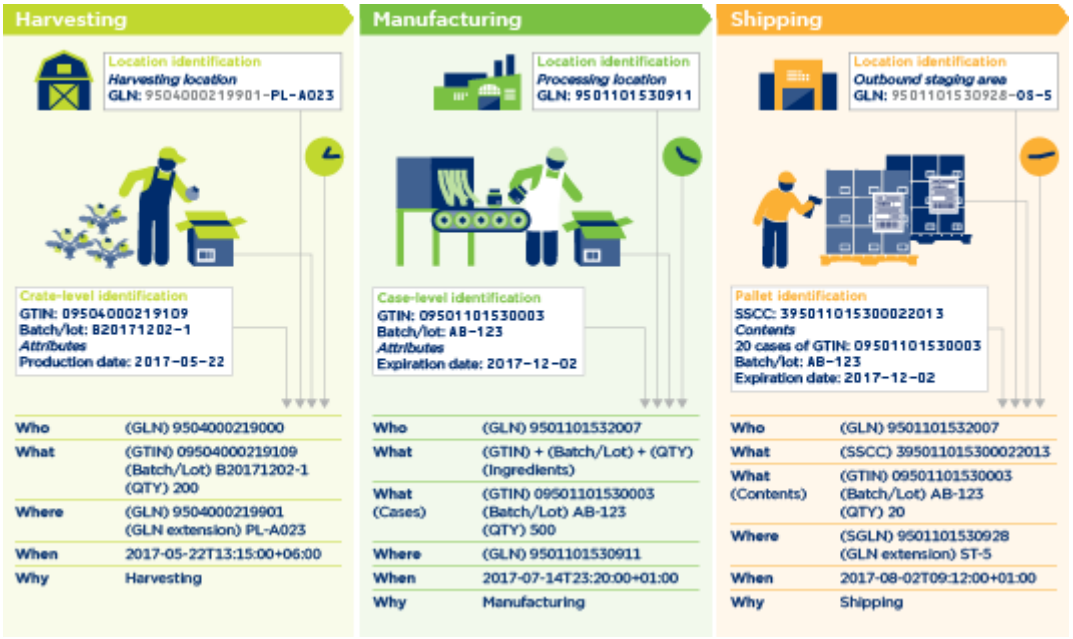

Figure 5 Sample illustration in the GS1 Global Traceability Standard

Closing the loop

It's necessary to be able to close the circle so that the output of the chain is the input to a new cycle. In our tuna fish example, it's the used cans that are the raw material for the production of new cans.

The product identifier can be used to record the consumer's action of placing the empty can in the recycling bin, perhaps triggering some sort of reward, and used to look up the type(s) of metal and coating used in the can's production. Once the empty can re-enters the cycle it becomes raw material. Therefore, a bale of collected empty cans – scrap metal in other words – is itself a trade item that can be assigned a Global Trade Item Number. Each event in the process can be recorded and shared using EPCIS. If the product is identified at batch level, it will be relatively straightforward to assess the percentage of cans recycled. Just to name two concrete cases, the GS1 identifiers are used in several EU and extra EU countries for deposit return schemes and the GTIN is more and more used against food waste because of the expiry date availability.

Indentifiers, barcodes, tags and scanners, GTINs, batch numbers, serial numbers and more can all be encoded in different types of 1D and 2D optical barcodes, as well as different types of radio frequency tags (RFID). The general term for all these different artifacts is *data carrier*. Different data carriers have different capabilities, strengths and weaknesses, details of which are not covered here; however, it is important to be aware of some core facts:

1. 1D barcodes, QR codes, Data Matrix codes, RFID tags and NFC tags are well-known types of data carriers. Most of these, and more, are defined by the relevant ISO/IEC standards.
2. All data carriers can encode numbers; most can also encode any string of characters although the encoding of numbers is more efficient.
3. The syntax of the string of characters (the punctuation used to separate different identifiers, the order in which they are placed etc.) is *independent* of the data carrier and is defined in application standards of Issuing Agencies such as GS1. This means, for example, that the same set of identifiers can be encoded in any data carrier, in a choice of different syntaxes. It is for the manufacturer to determine which syntax to use in which data carrier to best meet their needs.
4. Cameras in modern smartphones read QR codes without the user having to launch an application before they scan. Most will also read NFC tags (if enabled). Only a few currently recognise Data Matrix in this way.
5. It is the *content* of the data carrier that triggers the relevant behaviour on the device, not the type of data carrier.
6. Mobile phone apps can be programmed to work with *any* optical data carrier.
7. No smartphones currently recognise RFID tags without additional hardware.

Examples of two of GS1's syntaxes are given in the diagram below, which shows the same four pieces of data encoded in a single message but in two different ways.

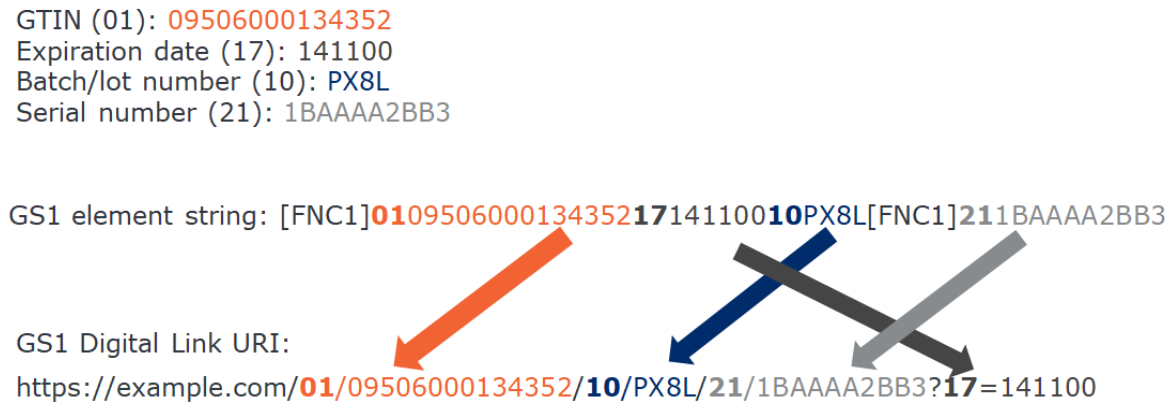

Figure 6 The same four pieces of data encoded in two different GS1 syntaxes.

GS1 element string syntax is optimised so that it uses as few characters as possible. This syntax is most commonly used in Data Matrix symbols and larger 1D symbols such as GS1-128. A GS1 Digital Link URI contains *exactly the same identifiers* but expressed within a URL that is optimised for online data applications. In this context, the domain name in the URL is not part of the identifier.

Both syntaxes make use of the *numeric* form of the identifier type. So '01' is used in preference to 'GTIN' (Global Trade Item Number) as it is more efficient, especially in barcodes.

The centralised model (not recommended)

Before addressing the remaining points listed in the introduction and going into the architecture proposed by GS1, it's worth considering an alternative approach that is seen commonly, that of a centralised repository. In this model, irrespective of the product identifier, such as a GS1 barcode, all products carry an *additional* identifier for the Digital Product Passport. All product data is stored in the database operated by a single DPP service and manufacturers are required to provide relevant data to it.

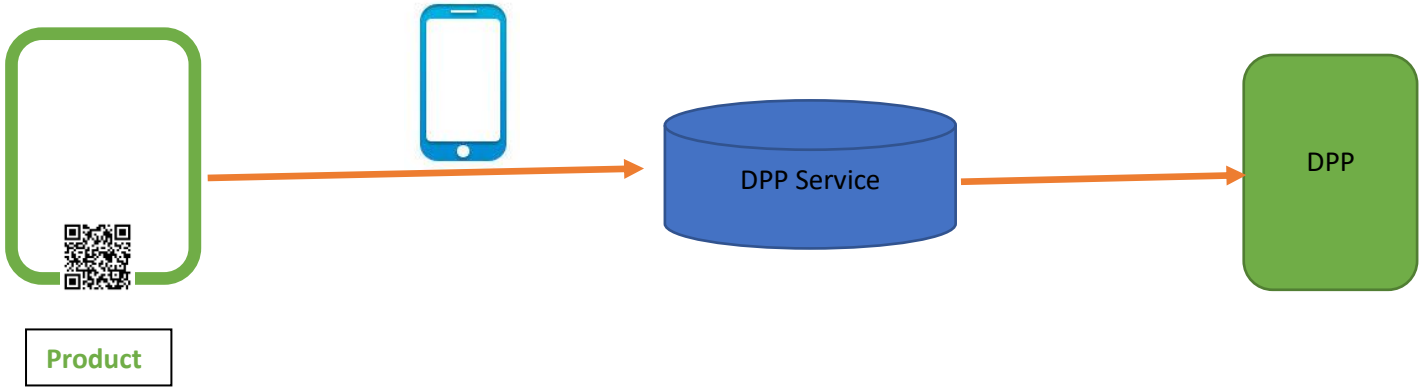

Figure 76 The centralised model (not recommended)

This centralised approach is attractive since it allows a single contract to be signed with a single provider. That provider can be certified as *the official source of information*. One can easily imagine a DPP logo placed near the QR code. Consumers will come to know that this is the QR code to scan to

find a product's DPP. It's possible that there could be multiple DPP Service providers, each one, perhaps, specialising in a particular sector. However, this, centralised approach has significant drawbacks.

1. The QR code will identify the data record within the DPP service, not the product. This will not be usable by anyone else and is useful only so long as the initial DPP Service operates and follows its initial design pattern.
2. Consumers only have access to the information provided by the DPP Service. Further information may be available online (found using a search engine) but it is not tied to the item itself as there is no inherent link between the product and its passport.
3. Manufacturers will treat the provision of their DPP as a necessary chore, a 'cost of doing business' separate from their other operations designed to market their products and engage with their consumers.
4. This is all good news for the operator of the DPP Service who now effectively controls everything. There is substantial inertia to be overcome if the service provider is ever to be replaced by another. In particular, the old operator's identifiers will no longer function and there will be no easy way to retrieve the product's DPP.
5. Any single service is a single point of failure and a monopoly.
6. The centralised data service will be a large, cumbersome copy of the economic operators' own data, not the original datasets. Therefore, data can easily become out of date as updates made by the economic operator may not be reflected in the copy.
7. Maintaining any copy of data, which itself will have multiple backups, means an additional IT infrastructure which in turn means additional hardware and energy consumption.

Connecting the *product identifier* to the DPP with GS1 Digital Link

GS1 Digital Link is an open standard that defines how identifiers, such as product identifiers (GTINs), location and organisation identifiers (GLNs), can be encoded in a URL. It is based entirely on existing, mature Web technologies, including Linked Data. One of the features of the standard is that the identifier is independent of the internet domain name that is also part of the URL.

Figure 8 The GTIN, the number encoded in a typical barcode, is included in a URL

The domain name 'example.com' used in Figure indicates that this is a placeholder for any domain name. The product identifier is unchanged whether the domain name is owned by the economic operator, retailer or third party. This is crucial as it ensures that it is the product that is identified, not the data service. The '01' before the GTIN is, however, critical, as it states that what follows is a GTIN rather than, say, a Global Location Number, a Serialised Shipping Container Code or anything else. In

addition to the GTIN, the GS1 Digital Link standard allows the full range of identifiers to be included, such as batch/lot numbers, serial numbers, expiry dates and more.

Table 1 Examples of GS1 Digital Link URIs containing different combinations of GTINs and other identifiers

GTIN + batch number (01 indicates GTIN, 10 indicates batch/lot)	https://www.example.com/01/9506000134369/10/JSKLA87
GTIN + serial number (01 indicates GTIN, 21 indicates serial number)	https://www.example.com/01/9506000134369/21/kla982hs
GTIN + batch number + serial number (01 indicates GTIN, 10 indicates batch/lot, 21 indicates serial number)	https://www.example.com/01/9506000134369/10/JSKLA87/21/kla982hs

The GS1 Digital Link standard further defines how an identified item can be linked to any number of resources, wherever they may be. This can, of course, include the Digital Product Passport.

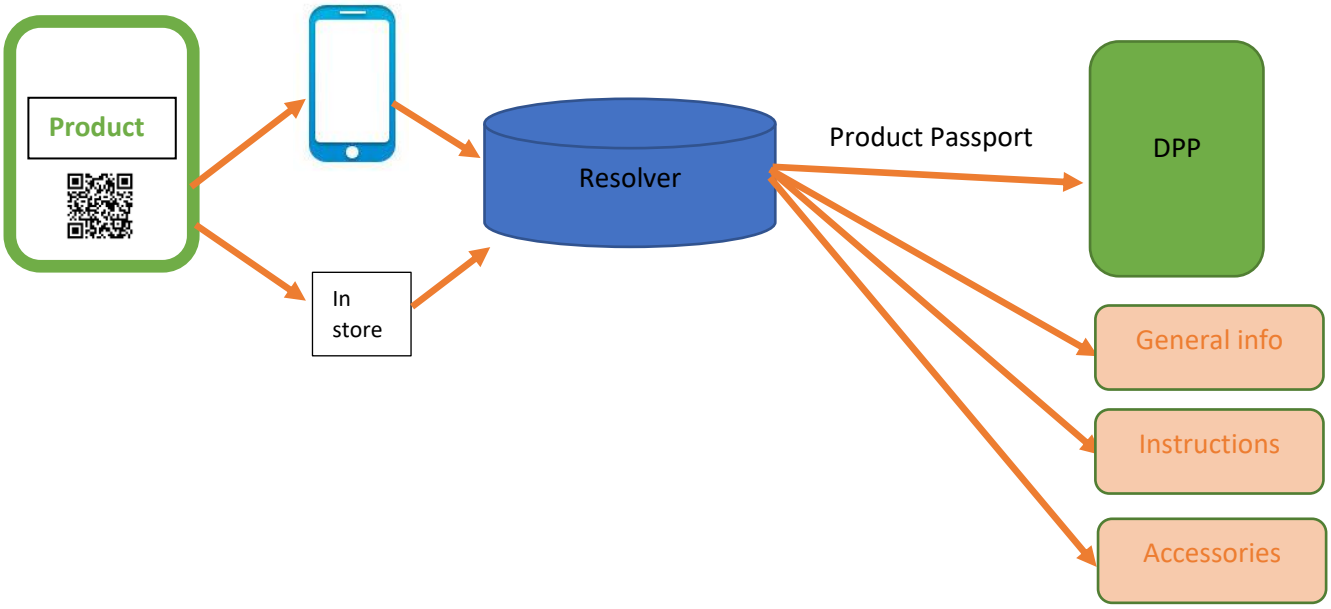

Figure 9 The GS1 Digital Link model, where the product is linked to multiple sources of relevant information

The role of the resolver

Figure 9 shows 'a resolver'. Without entering too much into detail, the resolver provides the connections between the identifier and one or more sources of information about it. None of the actual information is stored in the resolver, just the URL of each piece of it. Links are 'typed' so that a human or a computer can find the URL of the *type* of information they're after.

It is not a centralised service. Rather, it is a network of resolvers that connect to each other via a common API. A request can start at any point in the network and be routed to the required information, wherever it may be, via multiple resolvers if necessary. This is not technically

complicated. A conformant GS1 Digital Link resolver is essentially a regular Web server with some additional functionality to 'understand' GS1 identifiers. As documented in The How and Why of GS1 Digital Link, it is based on long-established ideas and techniques that will be familiar to anyone with an understanding of websites, mobile apps etc. It is not energy intensive as data is not duplicated in multiple nodes in real time (like a blockchain). GS1 makes all the links stored in its resolver available as a dataset that can be ingested by other resolvers to avoid it becoming a single point of failure in the network.

Flexibility and future proofing

Whether someone scanning a QR code on a product needs machine-readable data or something provided only for reading by humans will depend entirely on what the person needs to know. In all four of our scan scenarios for the electric screwdriver, the user is looking for specific information. This is unlikely to be what the manufacturer would today want to offer as a response to a casual request of "tell me more about this thing". The GS1 architecture supports this with what's known as the 'default link.' That's almost always a general information page about a product. From a consumer point of view, they use their phone's native camera to scan a QR code and get the manufacturer's product description. No app necessary.

In our user journey in the introduction to this document, the consumer is performing a specific task in the first scan and so it is reasonable that they use a more specialist tool – an app that is able to find data about multiple products and present a comparison. The Digital Product Passport would be ideal for this consumer-led use case. It requires that the relevant information is available as interoperable, machine-readable data, not as prose. **GS1 strongly recommends that Digital Product Passports comprise machine-readable data**. Human-readable representations of the data are generated from that data by any consuming application.

For example, the machine-readable data might include:

Estimated CO_2 emitted in production	.5Kg
Estimated CO_2 generated by packaging	.3Kg
Estimated distance travelled by air	0
Estimated distance travelled by sea	20,600km
Estimated distance travelled by road	500km
Gross weight	450g

These are just examples. If regulators will demand more precise data or different data, the system will reflect those requirements.

The second scan in our user story is a straightforward case where human-readable information is sufficient, although one can imagine that things like a map of the location to which a product can be returned to be recycled or repaired would be useful, so that 'human readable information' should not be taken as meaning a static document.

From an engineering point of view, the two scans made by the recycler are no different than the original scan to make the comparison. As with the first scan, the need is to start from the product and end up at specialised information about it. That data might be included in the DPP but could equally be elsewhere – it depends on the precise data to be included in the DPP which will vary between

different sectors. The path from the item to the required data is flexible but the anchor is the product's identity, not the identity of the data.

In summary: using GS1 Digital Link, casual queries can be made without any specialist software being used by the consumer, whereas more specialised requests for data will need more specialised software, in the form of an app. In every case, however, it is the *same* data carrier that is scanned, one that identifies the product itself, not the information that is being sought. GS1 doesn't develop apps, we are active in the data standards only as described above.

ANNEX

An inexhaustive list of relevant standards required or implied by the above discussion is provided below.

ISO/IEC 15458 (GS1 identifiers GTIN, GLN, SSCC, GIAI, GRAI)

ISO/IEC 15418 (GS1 Application Identifiers)

ISO/IEC 6523 (GS1 identifiers GLN and GTIN)

ISO/IEC 15420 (EAN/UPC barcodes)

ISO/IEC 15417 (GS1 128 barcodes)

ISO/IEC 16022 (Data Matrix)

ISO/IEC 19987 (EPCIS)

GS1 Digital Link

GS1 Web Vocabulary

schema.org

W3C Linked Data standards

GS1 in Europe is a neutral, not-for-profit organisation dedicated to the implementation of GS1 global standards, services and solutions to improve the efficiency and visibility of products and locations internationally and across sectors in Europe. We represent more than 500.000 companies and gather 49 national GS1 Member Organisations. We bring these companies around the table and foster collaboration in order to establish common rules and common standards. We strive to empower businesses to improve their efficiency, safety, security and sustainability.