Circular Economy Infrastructure: why we need track and trace for reusable packaging

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Abstract:
Information and communication technologies are recognised to be sufficiently mature to support traceability for reusable packaging at large scale, however, issues of data management, data integration, trust and collaboration in this complex ecosystem remain under-explored. We suggest that Digital Passports and mandatory reporting could provide a way to audit and incentivise reuse of packaging, allowing governments to focus on *prevention* and framing packaging as an asset, rather than inevitably turning into waste after a short single-use cycle. Digital Passports can address business' concerns (or excuses) for not investing in reusable packaging from helping with determining affordability through measuring packaging lifespans; meeting health and safety standards through batch coding and evidencing cleaning checks; addressing reputational concerns through clear documentation on the environmental impact of reusable items; and making reusable packaging competitive through waste taxation that actually measures reuse and not weight. We explore Digital Passports, not simply as a technical intervention but as boundary objects that are useful in supporting collaboration, identifying points of miscommunication between key actors along the value change, from misconceptions of health and safety regulations to a distinction between retailers and manufacturing brands appetite for investing in reuse. Thus, we provide a solid foundation for future research on Digital Passports, the digital circular economy and reusable packaging to build.

Keywords: circular economy, reusable packaging, digital passports, extended producer responsibility, waste management

1. Introduction

Packaging waste is a growing global concern, accounting for 36% of municipal solid waste (Eurostat, 2019 in Coelho et al., 2020b) and it is a major consumer of virgin materials using up 40% of plastics and 50% of paper in Europe (Coelho et al., 2020b). Moreover, less that 5% of plastic packaging is currently recycled (Jager and Piscicelli, 2021). And yet, packaging is useful - it provides "a system that enables the safe, cost-effective and efficient storage, handling, transportation and marketing of goods along the supply chain" (Meherishi et al., 2019). A key question for policy-makers then is: how can we reduce packaging waste whilst ensuring the free movement of goods in a market economy that such packaging supports (Marques and da Cruz, 2015). In this sense it is the disposability of packaging that presents a problem. With this starting point, the paper sets out to contribute to discussions on how to create systems for reusable and refillable packaging.

The topic of reusable packaging intersects with a rapidly growing and cross-disciplinary body of academic work, divided between several approaches. First, there is a large literature on the circular economy (CE) which aims to create space for visioning a successful economy based on reuse rather than disposability. This concept has been developed and driven largely by practitioners (e.g., policy makers, businesses, charities, etc.) (Korhonen et al., 2018a) and this opens the notion of CE up to critique. A recent critical review of the concept by Corvellec et al. (2021) challenges CE for being generally ill-defined, presented as a panacea, and lacking concrete visions for which kind of circularity it sets up (e.g., of a particular product; a business limiting efforts to only certain parts of their activities). Much of the CE scholarship that emerges from management and business studies focuses on circular business models, reviewed by Rosa et al. (2019) and Salvador et al. (2020). Another related strand of CE scholarship emerges from industrial design, engineering, and sustainable supply chain management. Much of the latter builds on a long history of related scholarship on returnable transport packaging/items, reverse logistics, and monitoring through radio frequency identification (e.g., for pallets) (Angeles, 2005; Ilic et al., 2009; Yusuf et al., 2017) and explores recent opportunities from the widespread deployment of new digital technologies which offer greater control and monitoring abilities throughout production processes (i.e., Industry 4.0) (Tseng et al., 2021). Related to reusable packaging, there is also a body of literature on waste management (Wishart and Bebbington, 2020) and market-based incentives, such as Extended Producer Responsibility legislation and Zero Waste policies (e.g., Magrini et al., 2020; Marques and da Cruz, 2015). Across these diverse literatures there is a common critique of an absence of concrete case studies that "go beyond mere declarations of principles about the necessity and possibility of a transition to circularity, and […] delve into what a transition to circularity would actually require […] and therefore provide a more realistic frame for such a transition" (Corvellec et al., 2021: 2). Mindful of this critique, our paper presents findings on a specific, novel innovation – the world's first Open Data Standard to standardise data collected by Digital Passports for tracking reusable packaging [1] – that we argue has widescale implications for reimagining packaging not as a disposable resource, but rather as an asset that ensures goods can be safely stored and transported in a more cooperative CE. Coehlo et al. (2020b: 11) suggest that reusable packaging "[r]esearch should be done in collaboration with stakeholders (e.g. producers, trade, retail, logistics) in the various supply chains to get realistic insights" and in this paper the focus on standardising data for Digital Passports emerges from practitioners' observations of manufacturing environments; discussions with retailers, expert NGOs, and regulatory bodies; and the emergent recognition that purpose-built digital

[1] The reuse.id (Reath, 2020) was created with support from the Open Data Institute (a global thought leader on using open data to address today's global challenges), Zero Waste Scotland (a not-for-profit environmental organisation, which aims to create a society where resources are valued and nothing is wasted), and GS1UK (the global barcode organisation operating in over 150 countries and representing all retailers who use barcodes).

infrastructure for reuse is a key first step to enable a wide-range of stakeholders to work together and create systems for reusable packaging.

We assert that framing packaging as an asset requires systems for track and trace because in a CE, it is "not that one company closes the loop, but the ecosystem does" (Antikainen et al., 2018: 48), and thus reusable packaging requires collaboration, communication and coordination in an unprecedented way. Even with revolutionary changes in information and communication technologies, a central challenge remains around collaboration (Tseng et al., 2021). Issues of traceability and trust reinforce that waste packaging is a consequence of complicated socio-material dynamics (Hawkins, 2013) and are a reminder that organisations continue to rely on infrastructure designed for a linear system. This infrastructure is built on individual businesses operating in competition with each other whilst a CE requires cooperation and collective response (Antikainen et al., 2018; Pauliuk, 2018; Korhonen et al. 2018) from commercial, government and civic organisations (de Souzza Jabbour, 2019). To support cooperation, "the coordination of material and information flows is crucial" (Antikainen et al., 2018: 47) and thus in this paper we explore the CE opportunities presented by digitalisation (Tseng et al., 2021) and, in particular, Digital Passports which track products to gather data on material durability, robustness of the design, and retention in a closed-loop supply chain (CLSC). Digital Passports have been a cornerstone in government recommendations on resource efficiency for nearly a decade (European Commission, 2013 in Lieder & Rashid, 2016), in part because monitoring is an essential component to build strategic and effective waste prevention initiatives. Information and communication technologies are recognised to be sufficiently mature to support traceability for reusable packaging at large scale, however, issues of data management, data integration, trust and collaboration in this complex ecosystem remain under-explored (Antikainen et al., 2018; Pagoropoulos et al., 2017; Uçar et al., 2021). Accordingly, this paper adopts a socio-material lens to understand the role Data Standards and Digital Passports can play in creating CLSCs as boundary objects that crucially creates a safe-haven for collaboration and trust in an increasingly complex, competitive and globalised world (Corsaro, 2018).

The paper begins by exploring literature on reusable packaging, revealing why the current system fails due to issues of trust and transparency and a focus on individual effort – every business for themselves – highlighting the potential of track and trace to address these challenges as a boundary object that simplifies, contextualises and allows communication across time and space. Section 3 moves onto explaining our methodology involving auto-ethnography and interviews with stakeholders who are creating purpose-built digital infrastructure for reuse. Section 4 presents the results, identifying four business concerns about reusable packaging, that can also be alleviated by standardising data collected from Digital Passports. Section 5 discusses our findings, reflecting on the potential of Digital Passports to shift the ontological status of packaging from waste to asset and address key business concerns that prevent businesses from adopting reusable packaging in their supply chains. Finally, we conclude in Section 6 by reflecting on limitations of the study and offering some possible directions for future research.

2. Literature Review

In CE and waste literatures, it is widely recognised that the concept of 'waste' is socially constructed, constantly changing, varying temporally and spatially. Indeed, "it is difficult to define exactly when a material with economic value becomes waste with no or negative value" (Korhonen et al., 2018a: 45). In the *Ethics of Waste,* Hawkins (2006: 7) expertly captures how "waste is much more than what we want to get rid of" and carries a "minefield of emotions and moral anxieties". For example, an almost new bed may be taken to the landfill after a bad breakup and in this way an item can go from useful to useless even when someone else may consider it functional and desirable. In developing a system for

tracking packaging, we aim to disrupt this ontological shift from usefulness to uselessness (Hawkins, 2006). The notion of disrupting the moment that packaging transitions from an asset to waste is not new (Corvellec et al., 2021): reusable forms of packaging have been used in both Business-to-Business (B2B) (e.g. crates, pallets, transit packaging) and in Business-to-Consumer (B2C) (e.g., beer bottles) contexts historically and still are today. However, there has been a trend away from reusable packaging towards single-use containers in all countries because disposable packaging simplifies logistics for manufacturers and retailers in increasingly long and complex global supply chains (Coelho et al., 2020b).

2.1 Why packaging becomes waste

Why packaging becomes waste varies by industry and business model. For instance, Coelho et al. (2020b) offer the example of breweries in Germany finding reusable bottles cheaper, while the soft drinks industry asserts the opposite. In some cases, more packaging turning into waste is defended because some studies (Blazejewski et al., 2021; de Oliveira et al., 2020; Coelho et al., 2020a; Cottafava et al., 2021) suggest that reusable packaging has a higher environmental impact compared with single-use containers. Admittedly, life cycle analysis comparing reusable options to single-use counterparts are difficult to carry out (considering variation of transport distances, inputs for cleaning, and variation in the containers' lifespan) and are thus relatively scarce (Accorsi et al., 2020). For example, Coehlo et al. (2020a) set out to review all life cycle assessments research on packaging using a common methodology (i.e., ISO 14040- 14044 standards) since 2000 and found only 32 articles. Coelho et al.'s (2020a) synthesis conveys the complexity and context-specificity of the environmental impact of reusable packaging: with factors including but not limited to the volume of the product per package, transport distances, recyclable content, and return points all influencing whether there is a better performance compared to its single-use alternative. Clearly, a diversity of factors (e.g. assessment of affordability; organisational barriers including marketing, retailer relations, industry, culture and regulation) raise questions of suitability for CLSCs, and packaging will likely remain disposable and single-use in many cases.

CLSCs, and preventing packaging from becoming waste, do not simply require re-imagining and re-designing of products, an overhaul of infrastructure and innovation in supply chains are also necessary (Lieder and Rashid, 2016). In Europe, a mix of market-based incentives to reduce packaging waste have been prioritised since the 1970s and Extended Producer Responsibility (EPR) legislation, one of the main CE instruments, is aimed at shifting part, or all, of the responsibility for waste management from taxpayers, local authorities and conventional waste organisations to producers (McKerlie et al., 2006). Yet so far EPR has failed to reduce packaging or electronic waste streams (Magrini et al., 2020). This is partly due to a lack of mechanisms to support or reward design for environment improvements for durability, recyclability or reuse (Atasu, 2018; Gu et al., 2019). Currently when EPR data is collected it primarily measures weight of packaging going to landfill or recycling centres and so regulation and subsidies target the disposal phase, focusing on collection rates, and overlooking opportunities for prevention in design, manufacturing and use phases of products. Instead of the rampant focus on disposal or recycling (Rhein and Sträter, 2021), we seek to explore what features are required so that packaging could be reframed *as* an asset for businesses and society.

2.2 Re-framing packaging as an asset

Korhonen et al. (2018) frame the CE as a production-consumption nexus (i.e., an integrated system which relies on the cooperation of all stakeholders). Such a definition they argue allows consideration of solutions which move beyond organisation and products boundaries allowing for more collective (and paradigm shifting) responses to resource issues. Partnership and cooperation have been identified

as key considerations for CE organisational operations (de Sousa Jabbour et al., 2019) with collaborative initiatives resulting in better environmental and economic outcomes (Flygansvaer et al., 2018). For example, coordination is identified by researchers and practitioners as key to supporting a recycled plastics value chain. Reframing waste as assets in a production-consumption nexus, particularly in relation to the transition from goods to services have wider social implications such as issues of ownership and responsibility (Fischer and Pascucci, 2017). In these instances, issues of knowledge of material flows as well as trust and transparency in that supporting information system become paramount (Antikainen et al., 2018; Fisher and Pascucci, 2017). This is because in a CLSC, there are multiple interrelated cycles as a product passes between many different actors in its production, delivery, use, return, repair, redistribution and removal from the closed-loop. However, packaging is not systematically tracked, so there is currently no way to establish trust (e.g., a retailer cannot determine where an item was lost or damaged and who is responsible) as it moves between manufacturers, retailers, customers, or regulators. Indeed, the idea that a package could be uniquely identified and is expected to come back from the consumer (e.g., B2C) shifts the dialogue to packaging being an 'asset' rather than 'waste' as soon as it leaves the shop floor.

Digitalisation has widely been recognised as a solution to this issue of traceability and an important enabler for CLSCs as software, big data, blockchain technology and machine learning can ensure transparency and support collaboration as they enable tracking on quantity and quality of products, their material components, and location in real time (Ajwani-Ramchandani et al., 2021; Antikainen et al., 2018; Bockel et al., 2020; Demestrichas and Daskalakis, 2020; Nandi et al., 2021; Okorie et al., 2018; Papetti et al., 2019). While research on digitalisation and reusable consumer products is relatively recent, there is a long history of related scholarship on returnable transport packaging/items, reverse logistics, and monitoring through radio-frequency identification and much of the digitalisation and CE literature draws on concepts from these related fields, which evidence how monitoring is essential to manage CLSCs (Angeles, 2005; Ilic et al., 2009; Yusuf et al., 2017). Yet new challenges and complexities are posed by reusable packaging for products that must be recollected, refilled, and resold to consumers (e.g. shampoo/B2C) rather than, for instance, transferred between manufacturers and retailers (e.g. pallets/B2B). Therefore, we set out to explore whether and how the digital technologies for establishing track and trace can support the adoption of reusable packaging, analysing this intervention through the lens of boundary objects (Carlile, 2002; Corsaro, 2018; Hawkins et al., 2017).

Boundary objects are defined by Carlile (2002) as "a means of resolving the consequences that arise when different kinds of knowledge are dependent on each other" particularly in scenarios where knowledge presents as a competitive advantage. As a consequence, boundary objectives can be helpful in supporting shifts around product development and product system services (Carlile, 2002; Bertoni et al., 2016) and are useful in supporting collaboration between actors whose activities cross local and wider contexts (Kimble et al. 2010; Cosaro, 2018), such as organisations involved in the production-consumption nexus of sustainable packaging. They can also be helpful in "pushing boundaries" (Lee, 2005) and so have the potential to transform conceptualisations of sustainability (Benn et al., 2013; Hawkins et al. 2017). Boundary objects which take the form of repositories - that is libraries and banks of data – can assist in sensemaking (Benn et al., 2013) an essential element in the process of interorganisational trust (Adobor, 2005). Repositories can help provide a common language and vision to enhance cooperation toward sustainability goals (Pan Fagerlin et al., 2019; Benn et al., 2013) but also present as a 'pragmatic' form of boundary object, that is an object which permits different organisations to "communicate, coordinate or collaborate" (Cosaro, 2018). Although many of these repositories will be digital in nature, research on boundary objects in digital contexts is still in its infancy, at the same time it's recognised that the move towards digitalisation has shifted organisational boundaries, requiring businesses to work beyond their local context and reinforcing the need for boundary objects (Cosaro,

2018). Digital systems to support circular global supply chains are notably complex with multiple different stakeholder engaged in the process at different times (Rosa et al., 2020). Cosaro (2018) argues that boundary objects in a digital context can improve the effectiveness of business relationships by simplification, contextualisation and extending experience across time and space but warns that they should not necessarily be considered "controllable" or "natural". Boundary objects are socio-political and it is recognised that "form emerges through the relational practices of human and non-human entities, rather than as a result of an artefact's brute characteristics" (Hawkins et al., 2017: 305) in part because they are used by actors in different ways (Sapsed and Salter, 2004). As a consequence the effectiveness of a boundary object is also determined by the integration of potential users as contributors to the design process (Wilkinson and Rycroft-Malone, 2016). This is particularly important in considering boundary objects in a digital context – where issues of trust can also relate to the technology (Kamble et al., 2018). Oskan-Ozen et al. (2020) note that trust of Industry 4.0 is a potential barrier to the use of digital solutions for the circular economy which suggests that any research which seeks to understand a boundary object in a digital context in the circular economy should involve potential users of that technology.

As well as emerging from practitioners, "digital standardisation" has been highlighted in the literature on the digital CE as being essential to cooperation and transformation (Tseng et al., 2021: 12). As noted above, reusable packaging requires the ecosystem (e.g., manufacturers, retailers, customers, waste collectors, and regulators) to work together, and an Open Data Standard for reusable packaging provides a common vocabulary for data collection as a container passes between different stakeholders and is tracked with a Digital Passport. Open Data Standards are used when it is important to maintain consistency, support comparison, or share understanding (BSI, 2021) and are available for anyone to access and use for free, which is critical as many organisations charge a license fee because of the cost that it takes to build and maintain them (such as the ISO standards for life cycle assessments). We conceptualise an Open Data Standard and Digital Passports for reusable packaging as boundary objects in order to highlight the sense-making (Benn et al., 2013) and communicative (Hawkins et al., 2017) roles digitalisation plays in the CE.

2.3 Summary and Research Questions

This section has briefly outlined the basis for developing an Open Data Standard for Digital Passports for reusable packaging, conceptualising these as boundary objects and key infrastructure to support the ecosystem of stakeholders in CLSCs to work together. What the preceding literature review has therefore attempted to do is indicate the potential of digitalisation to support collaboration and also to enable the re-imagining of packaging as an asset, rather than waste once it passes onto the consumer. Highlighting the calls for specific examples and case studies and narrowing onto digital technologies to establish track and trace for reusable packaging, we identified underexplored areas still existing in terms of issues of data management, data integration, trust and collaboration in this complex ecosystem and thus we have sought to address these in our own research. Accordingly, the main research questions addressed in this paper were:

1. What are key challenges (or excuses) identified by businesses for not creating systems for reusing packaging?
2. Could Digital Passports play a role in addressing these challenges?
3. What specific and standardised data should be collected by Digital Passports for business and governments to support investment in the creation of systems for reusable packaging?

This sets the stage to explore standardising data collected by Digital Passports for reusable packaging empirically, and the paper now turns to outlining the methods adopted in our investigation.

3. Methods

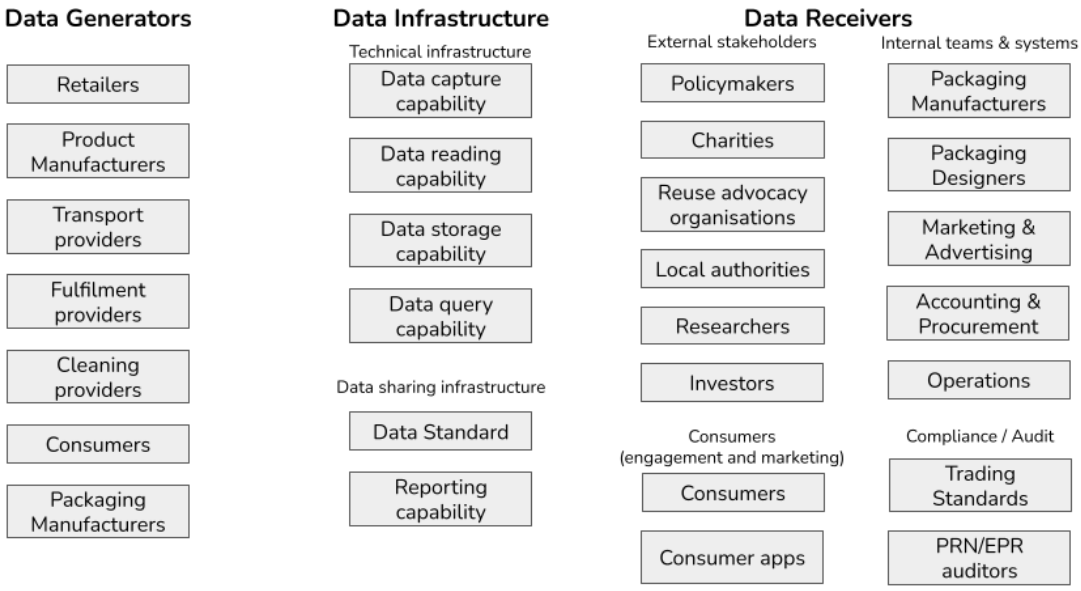
Adopting a qualitative approach, this study combines data from two main sources. Firstly, a series of discussions between the authors produced a wealth of notes and auto-ethnographic reflections on the design and development of software enabling reusable packaging which informs the analysis and argumentation of the paper (Anderson, 2006). The paper is co-authored with practitioners that started a business in 2019 to create purpose-built digital infrastructure for reuse. The second, third and fourth authors have industry backgrounds in product management, design and data analysis. This auto-ethnography includes three of the authors' in-person observations of manufacturing environments where reuse is being practiced; in-depth qualitative interviews and surveys with manufacturers and retailers; as well as five research sessions with expert NGOs and regulatory bodies. It was this background knowledge and engagement that led to the aspiration to create the world's first Open Data Standard for reusable packaging.

A second method involved semi-structured interviews with key organisations needed to create the Open Data Standard for reusable packaging. Four key types of stakeholders were identified because they critically define when and what data is exchanged in a CLSC:

(1) Manufacturing Brands, the brands who produce the consumer goods which are packaged;
(2) Retailers/Supermarkets, the companies owning the end relationship with the individual consumer, and with the Manufacturing Brands;
(3) Environmental Compliance bodies, the relevant national organisations in charge of implementing and upholding environmental safeguarding policies and ensuring that businesses comply with regulation; and
(4) Health & Safety bodies, the relevant national and local organisations in charge of implementing and upholding health and safety standards to protect the end-consumer, and ensure that businesses comply with regulation.

This stakeholder mapping was iterative and emerged in part though the interviewing process, snowballing as certain issues and related stakeholders (e.g., health and safety bodies), were repeatedly identified. Therefore, the sampling strategy was adapted until all the most relevant types of stakeholders had been included for interview or research sessions (i.e., all of these stakeholders have a critical role to play in generating, disseminating or reviewing reusable packaging data) (Figure 1).

Figure 1. Reuse.id Data Ecosystem Mapping



Based on this, we recruited organisations, with both UK and international footprints, to represent a variety of roles within these organisations who would have to be consulted to implement tracking and reuse of products (e.g. packaging manager, packaging designer, operations manager, chief-executive-officer, sustainability manager, compliance officer, environmental protection officer, customer relations). In total, we conducted 26 professional interviews at 18 different organisations, specifically including eight manufacturing brands, three retailers, two health and safety bodies, two environmental protection organisations, and three specialists working with organisations on reusable packaging (Table 1). Our recruitment targeted a diversity by size with five small-medium enterprises (SME) and four corporate companies as well as by sectors with products from food and beverage, cosmetics, and household products in order to capture different challenges depending on regulation for different packaging (e.g., food container compared to soap health and safety) and related CLSC logistics.

Table 1. Sample details for development of the Open Data Standard

ID	Category	Descriptor (sector; sales channel; company size)	Representative
B1	Manufacturing Brand	Packed food & drink; Distribution via 3rd party retailer; Corporate	Packaging Manager
B2	Manufacturing Brand, Retailer	Prepared frozen food; Direct-to-consumer (in-store & online) & Distributor via 3rd party retailer; SME	Packaging Manager
B3	Manufacturing Brand	Food & Drink, Household products, Cosmetics; Corporate, SME	Packaging Designer
B4	Manufacturing Brand	Household products; Direct-to-consumer (online), SME	CEO
B5	Manufacturing Brand	Packaged food and drink; Distributor and Direct-to-Consumer (online & in-store); Corporate	Operations Manager

B6	Manufacturing Brand	Packaged drinks; Distributor; Corporate	Sustainability Manager
B7	Manufacturing Brand	Prepared frozen food; Direct-to-consumer (in-store & online) & Distributor via 3rd party retailer; SME	Head of Sustainability and Safety Compliance
B8	Manufacturing Brand	Cosmetic products; Direct to Consumer (online) with some Distribution; SME	CEO
H1	Food Hygiene Policy	Fresh & Frozen prepared food & drink; Packaged food & drink	Compliance Officer
H2	Food Hygiene Policy	Fresh & Frozen prepared food & drink; Packaged food & drink	Policy
C1	Reuse Specialist	Works across food & drink and household products, specialising in Direct-to-consumer (in-store and online)	Consultant
C2	Agency	Packaging design agency with experience in reusable packaging	Design
R1	Retailer	Food & drink refill service in-store	Operations Manager
R2	Retailer	Food & drink refill service in-store	Sustainability Manager
R3	Retail	Manages retail purchase and buyer data	Data Scientist
E1	Agency	Environmental Protection	Environmental Protection Officer
E2	Charity	Environmental Protection	Reuse advocate, Policy writer
P1	Brand	Financial/Digital Services	Product Manager

Interviews were generally 45-6o minutes in duration, taking place through video or audio calls, during summer 2020. Professional interviews involved open-ended questions on (1) the key concerns and (2) the drivers for businesses to adopt reusable packaging, as well as (3) what utility an Open Data Standard might have in this context, and if so (4) what specific data could be collected to support their CLSC. A qualitative approach was deemed most appropriate because little information exists on this topic, subsequently the analysis was to allow themes to be identified by participants through the research process instead of relying on quantitative methods which may impose inappropriate categories (Cresswell, 1994). The authors met regularly to discuss and review the development of open and axial coding (Charmaz, 2014). Being exploratory, the main themes presented in the paper were not simply the most frequently discussed codes, topics were also included if they presented an important consideration in creating track and trace for reusable packaging. Approval was gained from the Lancaster University Faculty of Arts and Social Science's Ethical Board (FL20149). To protect confidentiality, all participants are identified by their position (Interviewee ID from Table 1).

4. Results

This section explores the main perceived challenges to adoption of reusable packaging for businesses, which centred around affordability (section 4.1), health and safety compliance (section 4.2),

reputational concerns (section 4.3), and competition (section 4.4). Within each section, we also identify what data could be tracked through a digital passport in order to address these key concerns.

4.1 Business concern 1: Affordability

First and foremost, affordability was unsurprisingly a key challenge reported by manufacturing brands and retailers to adopt reusable packaging into their business models.

> "Changing the system is expensive; it's important to get it right rather than continually having to start over" (Packaging Designer, B3).

> "Reuse is not insurmountable in any way, shape or form but it would mean such a massive shift in the way that the business operates, and the investment required, at the moment it's a 'nice to have'" (Packaging Manager, B2).

Operation managers and designers were well-aware that changing the system and design of a product was expensive, it was better to delay and get it 'right.' There was also awareness of additional costs related to storage and the risks of bringing back dirty materials that must be cleaned and then evidenced that they are in a state to be reused.

That said, tracking and collecting data on items was recognised to be critical to determining financial viability in terms of reuse and failure rates. The "reuse rate" was the Key Performance Indicator raised by every business interviewed and this is a key finding. The focus on reuse rates was voiced primarily as an environmental concern, but there is a financial implication as well considering that businesses could recoup the costs and even save money if the packaging is reused and refilled enough times. Furthermore, since this packaging is not currently tracked, there is a lack of data about how many times it can be used before being worn out:

> "We're asking the impossible of a piece of packaging; that it can be frozen, withstand being dropped while frozen, then go straight from frozen to 200'C in an oven. So I don't think I could confidently sit here and say what packaging could do all of that 400 times and still be the same specification when it started" (Packaging Manager, B2).

Container lifespans are currently unknown, and this echoes the Packaging Manager (B2) who feared implementing a new system with too little data to base the decisions on. Nonetheless, investing in tracking offers a clear way to determine return and failure rates to enable more informed business innovations. Certainly, the Head of Sustainability and Safety compliance at one business emphasised that "the data would be very useful because the Directors will already have their own emotive decision made on this so this is a situation where the data would swing it" (B7).

Interestingly, it was financial pressures from changes in the EPR legislation, rather than reputational pressure from customers, that was explained to be driving a move to reuse for manufacturers:

> "The additional carbon tax might push reusable to more favourable than recyclable" (Sustainability Manager, B6).

> "The single-use model is under scrutiny. More stringent EPR [extended producer responsibility] costs mean we must look at where our packaging is going and how we can adopt [a] more "cradle to cradle" approach" (Packaging Manager, B1).

Here both managers are referring to a Plastic Packaging Tax motivating their reflection on reusable packaging, this is due to come into force in April 2022 in the UK (HMRC, 2020) and these changes illuminate the significance of governing bodies, such as environmental protection agencies, to facilitate innovation in CLSCs.

4.2 Business concern 2: Health & safety

The introduction of reusable packaging is further complicated by a perception of increased risks, particularly for meeting health and safety standards.

> "Anything reusable is a phenomenal challenge for us...it's about the traceability element and it's about getting things back and making sure they're fit for use again" (Head of Sustainability and Safety, B7).

> "Taking packaging back is a big concern to retailers, because of the implications of returning all this material. Where do you store it? And there's a food safety and hygiene issue around making sure that the material returned to you is safe and clean" (Operations manager, R1).

Working in an industry with stringent customer safety requirements, such as Food & Drink or Cosmetics, brings unique challenges, and reusable packaging potentially requires new systems to evidence the return and cleanliness of products for redistribution. This was a major concern in interviews and identified by the authors whenever they begin to discuss reusable packaging with businesses, however, some interviewees pushed back on this as a barrier:

> "I wouldn't consider reuse to be higher risk; if the business followed a suitable Hazard Analysis and Critical Control Point plan end to end. But it would be a flag to have a closer look." (Health and Safety body, H1)

Here, an Environmental Health Officer highlights that there is no rule against reuse, and companies should not worry unduly, as long as they are following adequate health and safety procedures and this was echoed by one participant from a business already using reusable packaging.

There were two main considerations for meeting legal and practical requirements of health and safety regulation, which were 'batch traceability' and that reusable packaging will likely struggle to be inclusive to those with severe allergies:

> "Part of our commitment to our customers is that we can trace each product to its batch just in case we need to investigate any issues that could possibly arise" (Customer relations, B2).

> "We're talking about reuse for the 80%; we're not trying to serve an allergen-free group of people, as it's too hard to guarantee that. We have to treat that as an edge case" (Reuse specialist, C1).

Traceability has an important role supporting the reduction of contamination risk (e.g. a business can maintain a ledger of gluten free products only in certain packaging, or give customers a notification if they are filling packaging that has had a known allergen in it previously). A Digital Passport collects a log of everything that has been inside of the reusable packaging, including allergens, and ensures that this is collected in a consistent way that fits with a business' Hazard Analysis and Critical Control Point plan (HACCP), making audits much easier for Environmental Health Officers and the businesses themselves. In the case of Health and Safety, Digital Passports provide the required traceability to demonstrate to other professional bodies (e.g., insurance providers) as well as customers, that a business is taking the safety of their reuse system seriously and are able to meet legal requirements to recall a contaminated product by its batch number.

4.3 Business concern 3: Brand reputation

Business' reputation was another key consideration in adoption of reusable packaging. There was a divide however between how retailers and manufacturing brands perceived the reputational

implications of implementing reuse systems. For retailers, there was a perceived financial benefit in terms of competition for press and brand goodwill:

> "I think [having reusable packaging has] been more beneficial for our reputation; it has served as a marketing piece and increased customer footfall" (Operations Manager, R1).

> "It absolutely can be commercially-viable from a marketing/PR perspective. If you turn the headlines it [turns] into ad equivalency" (Sustainability Manager, R2).

Whereas, the assumption of reusable packaging being good for both marketing and the environment was questioned by some of the manufacturing brands. Largely, these businesses had little faith in customers returning packaging to make it financially or environmentally effective:

> "We're more interested in the actual facts than the perception from the customer […] People are lazy...I'm not sure how you could get enough of a percentage of your packaging coming back to you. It's not just about commercial viability, but also about environmental [impact]. I would suggest that it has to be over 70% [returned], because otherwise you're just filling everybody's kitchen drawers up with junk" (Head of Sustainability and Safety Compliance, B7).

> "With reuse, you are trying to convert the people who are doing the most recycling to go into refill, you're not converting the 60% who don't care" (Packaging Designer, B3).

This was of interest to environmental protection agencies as well, because it is "key to carry out a life cycle analysis to ensure the reusable product provides an environmental benefit overall, over its single-use counterpart" (Environmental protection agency, E1). Here again, the importance of tracking is raised, without it an organisation cannot determine whether, or evidence that, their reusable product is more environmentally-beneficial.

4.4 Business concern 4: Competition

Finally, competition was a key business concern considering that many businesses saw reusable packaging as an opportunity for them to differentiate their brand in saturated markets. Considering consumer pressure and the potential for publicity, there was a competitive advantage to not collaborating with others. So while at times, some of the brands and retailers interviewed were hesitant about the feasibility for reusable packaging and changing their supply chains, one of the environmental protection charities emphasised that there was more going on behind the scenes:

> "Businesses are keen to reach the market first; it has become a race. Don't necessarily believe them if they say it's not happening!" (Reuse advocate, E2).

At the same time, several businesses (B2, B6, and B7) and an environmental protection agency (E1) informed us how regulations in the UK make reusable packaging less competitive than single-use containers. In the UK, companies who have a turnover of over £2 million and handled more than 50 tonnes of packaging the previous year are liable for Packaging Recovery Note (PRN) payments. Currently, a business will have to pay the PRN the first-time packaging is released onto the market, but in the future, it would be possible, with appropriate monitoring, to exempt them from paying the PRN every time that packaging is re-filled. Under the current system, it is challenging to monitor and enforce guidelines, for example, in the UK the only way of auditing is through reviewing financial statements (HMRC, 2020). This limits the scope of incentivising businesses to increase the reuse rate of packaging. In fact, because PRNs are based on weight, it was revealed that companies already investing in reusable packaging are penalised because in order to improve durability these containers are often heavier than their single-use counterparts. Clearly, having a way to track individual packaging and trace this to the manufacturer or retailer is crucial for effective EPR legislation. Environmental protection agencies will

have to require proof that packaging is being reused in order to offer incentivised payment plans and approve exemptions from packaging waste taxes. This is an important example of the lack of coordination between regulatory bodies and businesses because current regulations, through the PRN, penalise reusable packaging which limits business' willingness to change.

5. Discussion

In the development of an Open Data Standard for reusable packaging, we sought to intervene in the ontological status of packaging (Hawkins, 2006), to extend its usefulness and re-imagine how these containers could be seen as an asset for businesses. Our research with potential business users identified that barriers to this ontological shift are not technical but socio-economic and political. As a consequence, we explored the traceability offered by digitalisation not simply as a technical intervention, but rather in light of the opportunities an Open Data Standard and Digital Passports could provide in overcoming the business concerns related to affordability; healthy and safety; brand reputation; and competition. From this discussion we can begin to see Open Data Standards and Digital Passports potentially acting as boundary objects that allow for the transfer of knowledge, shared understandings, and collaboration between stakeholders in a CE (Corsaro, 2018).

As a boundary object, the Open Data Standard simplifies knowledge transfer through the standardising of what data is collected by regulators (for enforcing health and safety or waste taxation), manufacturers (for innovating design, through more knowledge about material and durability, etc.), and retailers (for evidencing compliance, calculating life cycle assessments to support marketing). In this example the Open Data Standard presents what Cosaro (2018) calls a pragmatic boundary object – one which standardizes syntax and facilitates communication between different groups. The standardisation of data or synactic approach (Carlile, 2002) allows multiple organisations based across different scales and time zones in the production cycle to communicate (Cosaro, 2018).

Boundary objects also create space for multiple stakeholders to facilitate conversation around contested issues (Corsaro, 2018), and the process of developing the Open Data Standard highlighted some (mis)understandings between stakeholders who define when and what data is exchanged in a CLSC. For example, health and safety bodies did not perceive HAACP as a barrier to reusable packaging, while this was assumed to be a major hurdle for retailers, supermarkets and manufacturing brands. In this way, the process of developing an Open Data Standard identified contested areas, such as clarification on health and safety regulations and HACCP for reusable packaging and points to an opportunity to overcome semantic barriers to reusable packaging (Carlile, 2002). This echoes the idea that boundary objects can be useful to address organisational concerns that differ in diverse contexts (Kimble et al. 2010). In some sectors digitalisation already supports health and safety knowledge-sharing, for example, there is a breadth of research on food and beverage products related to quality inspections required for returned and re-filled packaging (Jetten, 2010; Junior et al., 2019) as well as testing on the safety of using recycled materials (Geuke et al., 2018). In the food industry, the utility of blockchain, internet of things and machine-readable trackers to improve supply chain traceability and visibility for food safety has been identified for over a decade (Tian, 2017), yet there are few case studies or examples of implementation (Behnke and Janssen, 2020). Our research has shown that more attention is needed to understand the role of these boundary objects could play in other communities of practice, such as cosmetics and household products.

Digital Passports also offered opportunities as pragmatic boundary objects – solving particular problems around different forms of knowledge required to support a (new or transformational) system (Carlile, 2002). Open Data Standards and Digital Passports allow retailers and manufacturers a better understanding of a globalised, complex systems in new ways which cross space, time and levels

(Cosaro, 2018). Digital Passports have the potential to address questions about determining financial viability (e.g., based on return and failure rates, and allowing for more refined taxation and incentive schemes). Having data on reuse rates, a Key Performance Indicator identified by businesses in this paper, supports streamlining the returns process through predictive models, or arranging decentralised, digitally-connected drop-off points that acknowledge each individual container has been returned. Collection again is dependent on cooperation and coordination, underpinned by the boundary object function of contextualising knowledge, whereby digital technologies log physical interaction almost in real time, creating the ability to coordinate business relationships across digital and physical contexts (Corsaro, 2018). This supports our depiction of reusable packaging systems as an infrastructure forming part of a production-consumption nexus (Korhonen et al., 2018b) and reinforces the idea that boundary objects boost creativity through connecting different stakeholders (Corsaro, 2018) in common visions (Benn et al., 2013; Pan Fagerline et al., 2019). This potential was highlighted by the manufacturing brands discussing how an Open Data Standard and Digital Passports could help them re-imagine and re-design packages for refill-ability and reuse-ability because it enables the development of a common materials library, which could inform failure rates by collecting data on the most durable materials and designs of reusable packaging. There was a great deal of enthusiasm by professionals involved in packaging design about this possibility because designing for reusability is not easy: they are "asking the impossible of a piece of packaging" (B2).

Retailers were also enthused by the opportunities to share their sustainability credentials through tracking reuse and refill because of the potential positive media coverage. This relates to another function boundary objects offer businesses, which is being able to tell stories in an appealing way (Corsaro, 2018), and here Digital Passports allow retailers a way to verify and quantify their reuse activities for marketing purposes because without the guarantee that a reusable item would be used a certain number of times, businesses are risking causing more harm to the environment, which was also a common concern identified in CE and life cycle analysis literature (Salvador et al., 2020; Mahmoudi & Parviziomran, 2020). This intention to increase customer footfall and sales could be interpreted two ways, and will of course depend on the specific industry, supply chain and product. On the one hand, Open Data Standards and Digital Passports could be "transformative, as they can generate new concepts and new paradigms, which are not only temporary but also become stable changes of the system" (Corsaro, 2018: 230) offering a transformational shift (Benn et al., 2013) in packaging ontology from waste to asset. Conversely, traceability could be critiqued for encouraging more consumption through a rebound effect where people buy more products because they are seen as sustainable (Dauvergne, 2020; Schulz et al., 2019). Yet arguably this turns the focus of research and intervention back onto consumers and their behaviours (Hobson et al., 2021) which misses the point that systemic change required for a more CE must be a collective responsibility (Maniates, 2001; Korhonen et al., 2018b). Arguably, we need further research on the responsibilities of business and organisations within that system (Murray et al., 2017) because the ontological shift required to see waste packaging as an asset requires an overhaul of infrastructure and innovation in supply chains (Lieder and Rashid, 2016).

That is why we focus on how to enable the ecosystem to close the loop, speaking with key actors - regulators, manufacturers, and retailers and the professionals that are required to work together to create systems for reusable packaging (e.g., Digital Services Product Manager, Food Hygiene Policy Compliance Officers, Packaging Designers, Retailer Data Scientists) (Figure 1). The difference in response between retailers' optimism is reminder of the significance of bringing together different stakeholders in the supply chain to identify unique barriers and discuss how to overcome these collaboratively (Jager & Piscicelli, 2021; Meherishi et al., 2019). This also illuminates how important it is to work with different types of stakeholders within a supply chain in order to determine who has the ability and willingness to drive change particularly where a potential facilitator of that change is a

boundary object. Research reinforces that boundary objects should be seen neither as "controllable" nor "natural" (Cosaro, 2018) with outcomes varying depending on users' enthusiasm (Wilkinson and Rycroft-Malone, 2016) and unintended consequences of standardisation of knowledge practices (Leigh Star, 2010). This suggests our final research question should remain a continued point of reflection for stakeholders involved in developing innovative CLSCs supported by an infrastructure of reusable packaging.

6. Conclusions

This paper responded to the critique of an absence of concrete case studies that delve into what a transitioning to a CE would actually require (Corvellec et al., 2021: 2) by exploring the potential that an Open Data Standard and Digital Passports offer in reimagining packaging as an asset that ensures goods can be safely stored and transported in a more cooperative CE. We therefore contribute to understanding how digital technologies, as boundary objects, could support business's adopting reusable packaging into their supply chains, presenting a case study for the fledging scholarship on the digital CE (Antikainen et al., 2018; Demestrichas and Daskalakis, 2020; Okorie et al., 2018; Papetti et al., 2019; Pagoropoulos et al., 2017; Uçar et al., 2021).

We argued that the ability to monitor individual containers was a major challenge for governments, perpetuating a prioritisation on recycling in waste management approaches (Gu et al., 2019; Magrini et al., 2020). Our study therefore supports creating traceability for reusable packaging by identifying business's perceived barriers (or excuses) to implementation alongside how Digital Passports could help alleviate these challenges. Four main business' concerns about reusable packaging emerged and all of these have the potential to be partly addressed by digital traceability: determining affordability through measuring return and failure rates of products; meeting health and safety standards through batch coding and evidencing cleaning checks; addressing reputational concerns through clear documentation on the environmental breakeven point; and supporting waste taxation that make reuse competitive charging by reuse not simply weight. Some studies have begun to trial using information and communication technologies to improve traceability and create systems of reusable packaging (Papetti et al., 2019), yet most research is focused only on the food and beverage sector, while we have aimed to identify standard data challenges that could arise across a diversity of CLSCs such as calculating lifespan of containers, life cycle assessments and meeting environmental and safety regulations.

Despite the promising contributions offered to CLSC collaboration and traceability, this paper has some limitations that need to be acknowledged. First, is recognition of the geographical context and that we fail to expand beyond the concentration of CLSC research in Europe and North America (Meherishi et al., 2019). While the UK may reflect relatively advanced recycling systems and disposable packaging becoming the norm in Europe and high-income countries, this will not be homogenous around the globe. Reusable packaging may be more common and accepted in low-income countries or those with strong national policies that prohibited a move to single-use. Indeed, digitalisation and creating track and trace systems for B2C reusable packaging may be unaffordable and entirely inappropriate in these contexts. Similarly, the impact of regulatory bodies for both safety and environmental compliance will vary geographically and future research could validate our findings in other countries and for even more sectors (e.g., electrics, automotive, textiles, construction). The benefits of Digital Passports and a data standard likely hold true for other track and trace systems for reusable packaging, but this could be confirmed and possible differences need to be empirically determined.

By exploring the utility of Digital Passports and a shared data standard as boundary objects we have identified several areas in which future scholarship may offer a more critical and holistic investigation

of track and trace to support an ecosystem of stakeholders closing the loop on packaging. Specifically, we argue for managerial implications and the potential of environmental protection agencies to explore ways to utilise track and trace in Extended Producer Responsibility legislation. Digital Passports and mandatory reporting could provide a way to audit and incentivise reuse of packaging, allowing governments to focus on waste *prevention* and framing packaging as an asset and producers' responsibility rather than being passed to consumers and becoming waste. Furthermore, how to establish trust frameworks, between different businesses in a supply chain and to support regulatory compliance, are deserving of more attention. Digital technologies have increased the amount and accuracy of data collection, yet little progress has been made in data integration and utilising this to operationalise CLSCs (Chiaroni et al., 2020). Thus, we also emphasise the boon Digital Passports offer to future life cycle assessment research. Certainly, track and trace is the foundation for calculating reuse rates, a Key Performance Indicator for businesses implementing reusable packaging systems, and more trials that can offer insights into what factors determine customers engagement and actual figures on containers' lifespans is essential. The influencing factors will become apparent in the coming years as the UK Government plans to set up a National Materials Datahub to enable visibility of material flows and share knowledge about container lifespans, but while Digital Passports can be used, for information on the material components of products to facilitate more effective recovery and reuse of their materials the potential for Digital Passports to make packaging reusable and refillable is currently overlooked in the UK's waste prevention strategy. Track and trace therefore presents retailers, manufacturers, regulators, and consumers with a new set of challenges, but equally with new opportunities. The development and trialling of Digital Passports and a shared data standard offers a novel foundation for future reusable packaging research. We thus conclude with a plea to recognise that the digital economy is ready to meet the circular economy, with digital traceability presenting exciting possibilities for reuse of a diversity of products and sectors.

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