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Abstract

Circular business efforts, such as recycling, increasingly rely on interdependent digital technologies, including IoT, open data, big data analytics, and automation. These digital technologies typically require advanced infrastructure and existing data that can be aggregated, moved, and morphed for different purposes. Yet what happens when the infrastructure is there, but the data points are unavailable or irrelevant? What are the processes of data requirement gathering when there is a mismatch between the selected infrastructure and the data? This paper explores how an ecosystem of circular businesses created their own data commons and, in turn, filled the existing data voids. Using a case study approach involving multiple sources of data collection, we present a process of "data commons curation." We show how this process involved three key phases - collective imagination, data collection, and digital mediation. By theorizing about "data voids," our study contributes to the growing research on data in the circular economy.

Keywords: Data voids, Data commons, Data creation, Circular economy, Collective Imagination

1 Introduction

It is well known that the energy, materials, and mobility sectors are the most significant contributors to global carbon emissions (World Economic Forum, 2022). In these high-polluting industries, the energy, materials, and mobility sectors contributed 34%, 21%, and 19%, respectively, to total emissions (World Economic Forum, 2022). A major challenge associated with these sectors is managing and handling material waste. Prior research has highlighted the need for a systemic approach that integrates diverse stakeholders with expertise in various fields to collaboratively address complex problems (Kurtz & Snowden, 2003), such as managing material waste. One notable strategy involves adopting circular economy (CE) principles, which focus on maintaining the flow of materials within closed loops or slowing down their lifecycle (Geissdoerfer et al., 2017). The CE concept promotes a shift from the traditional linear economy (take, make, dispose) to one that emphasizes reusing, recycling, and reducing materials. This approach is often conceptualized as the 3Rs (reuse, recycle, and reduce) framework (Ghisellini et al., 2016), which forms the foundation of CE strategies.

Research in Information Systems (IS) has demonstrated that the complexity of implementing the 3Rs framework varies based on the specific practices utilized (Ranta et al., 2021; Zeiss et al., 2021). For instance, reuse involves extending the lifecycle of high-quality products and materials to ensure their recirculation over a prolonged period. Recycling entails converting waste materials into new products, while reduction strategies concentrate on minimizing material consumption and energy use, often relying on renewable energy and natural regeneration efforts (Kirchherr et al., 2017). Among the three, reduction is typically regarded as the least complex, as it can often be implemented by a single organization with adequate digital infrastructure (Zeiss et al., 2021), such as a manufacturing company, utilizing Industry 4.0

technologies like data analytics and automation to decrease energy consumption and material waste (Bag, Dhamija, et al., 2021; Bag, Gupta, et al., 2021; Gupta et al., 2019).

Our primary focus in this paper is on material waste *reuse* and *recycling* strategies. These strategies are complex due to the involvement of numerous actors and unclear boundaries in material flows, stakeholders, and processes (Zeiss et al., 2021). Approaching such complexity, emerging CE businesses and key stakeholders emphasize the need for technological and digital innovation. For example, the World Economic Forum suggests that widespread adoption of digital technologies in these sectors could reduce global emissions by up to 20% by 2050. Indeed, digitization and digital platforms have already facilitated existing processes' transition toward some CE strategies (Rajput & Singh, 2019; Srhir et al., 2023). For example, digital platforms such as eBay and Meta have enabled individuals to buy and sell used or refurbished products, thus supporting the circular flow of goods. Additionally, the sharing economy, represented in businesses like Uber and Airbnb, promotes the continued use of underutilized resources.

Yet, Industry 4.0 technologies such as IoT, 3D printing, autonomous vehicles, drones, blockchain, and artificial intelligence rely on the ubiquitous availability, exchange, monitoring, and interoperability of data (Kristoffersen et al., 2020; Liu et al., 2022; Rajput & Singh, 2019). Data also plays a pivotal role in circular economies, enabling the monitoring of material and information flows while coordinating activities among various stakeholders throughout a product's lifecycle (Kristoffersen et al., 2020; Zeiss, 2019; Zeiss et al., 2021). In sustainable supply chains, for instance, stakeholders are encouraged to share operational data openly. Access to such data is crucial for optimizing logistics in supply chains oriented toward circularity (Haleem et al., 2019; Walden et al., 2021).

Essentially, data serves as a crucial boundary object that connects all stakeholders involved in the CE business. However, the creation and sharing of data are complex. For instance, transferring data beyond individual organizational boundaries introduces issues related to data governance and management, and questions of data sovereignty often arise. Businesses need to overcome uncertainties about how to share information without losing control over it (Gelhaar & Otto, 2020; Lauf et al., 2022). Lastly, and critically, CE businesses rarely fully consider the challenges associated with data creation and sharing. For instance, while there has been some attention at the EU level to approaches like digital product passports (DPPs) (data.europa.eu, 2024)—a tool that aims to consolidate product and material data—its implementation is hindered by a lack of transparency, data-sharing mechanisms, and standards across organizations (Walden et al., 2021). The example with digital product passports highlights the critical need for access to diverse datasets that are currently inaccessible, hindering the enablement of a circular economy (CE). Again, complexity becomes visible; for example, digital product passports risk perpetuating inaccessible data regimes due to centralized or privately managed systems, potentially monetizing access or data contributions. For instance, the cost of recording 1–3 product passports in the privately-owned DPP system, Cirmar is €63 per month, and a single user's subscription for calculating carbon footprints and other features is €25 per month (Cirmar DPP, n.d.). Such monetization could exclude some organizations from data participation and usage, mirroring the scholarly community's challenges where publishers, as Jean-Claude Guédon (2001) observed, turned academic information into "big business."

In response, grassroots movements like the "information and knowledge commons movement" (Hess & Ostrom, 2005) have emerged to make scholarly information accessible, exemplified by platforms such as arXiv.org and Creative Commons (Fisher & Fortmann, 2010). Similar initiatives are seen in free and open-source communities, striving to make data and software tools universally available. These successful information and knowledge-sharing models suggest that data commons could provide a promising solution for circular businesses, where access to comprehensive data is crucial for circular strategies.

However, many circular economy initiatives currently face what we term a "data void"—a situation where the data necessary for enabling circular practices like reuse and recycling is either missing, inaccessible, or fragmented across isolated entities. Data voids have been explored and problematized in other contexts, including search engine algorithms (Golebiewski & Boyd, 2018). Yet, how to maneuver CE strategies and digital innovation for reuse and recycle initiatives in the presence of data voids has not received much attention. In this study, we draw on "data commons" as one possible strategy for making information and data accessible. Data commons are domain-specific and often local databases that communities collectively create, maintain, and make openly accessible (Hess & Ostrom, 2003).

While the concept of commons has proven effective in other domains for making information accessible, research on how to curate data commons that effectively address the specific data needs of circular businesses remains limited. Essentially, there is a dearth of practical solutions. This study aims to bridge this gap by exploring the following research question: How do circular economy businesses establish data commons to address data voids?

To investigate how circular economy businesses establish data commons, we conducted a case study (Eisenhardt, 1989) of a circular business initiative in Ghana, West Africa. Through qualitative methods, including interviews and archival research, we documented the specific manifestations of data voids in this context. Then, we traced how key actors developed a data commons to address these challenges. Our analysis revealed three key phases that were instrumental in overcoming data voids and establishing data commons: Collective imagination (through brainstorming strategies (Davis, 1982)), Data collection (sourcing and aggregating), and digital mediation (assistance of digital data functions, editability, and portability (Alaimo et al., 2020)).

We direct our contributions to two key research streams: the emerging literature on smart or digitally enabled circular economies and the steadily growing discourse in Information Systems on sustainable transitions.

2 Data and Data Commons: Concepts, Applications, and Implications in the Circular Economy

Data commons are domain-specific databases communities collectively create, maintain, and make openly accessible (Hess & Ostrom, 2003). The concept and idea are built upon Elinor Ostrom's (1990) work on common pool resources (CPRs), which is how communities collectively manage natural resources like rivers or grazing fields to ensure sustainable use. Just as communities develop governance systems to protect natural commons, similar principles guide the management of information, data, and knowledge commons (Hess & Ostrom, 2003, 2005). Ostrom's design principles for successful commons emphasize collective governance, shared responsibility, and mutual benefit, providing a framework that could extend from natural resources to digital data management. Guided by the philosophies of the commons, common-pool resources are either publicly owned by a community or have no owner (Hess & Ostrom, 2003).

Information and knowledge commons are intellectual extensions of these principles, applied in contexts like academic libraries and scholarly repositories, where the creation and sharing of knowledge are collective efforts (Hess & Ostrom, 2003). Like natural resources commons, these systems require careful analysis of their core elements: the resources themselves, the user community, key stakeholders, and governing rules. This analysis helps prevent what Hardin (1968) termed the "tragedy of the commons"—where individual users benefit from resources without contributing to their maintenance. In data commons, this tragedy manifests when "free riders" extract value without supporting the system's sustainability, potentially undermining the collective benefit (Hess & Ostrom, 2003).

Data commons have been applied across various sectors, including medical research and environmental monitoring (Pauliuk et al., 2019; Wilson et al., 2017). It transforms data and information consumers from passive users reliant on governments, private entities, or markets into active contributors and users (Hess & Ostrom, 2003). Through informal rules and policies, these commons work to remove barriers to data access, reducing harm and increasing the benefits of accessible knowledge (Hess & Ostrom, 2003). Although data commons have yet to be widely implemented in circular economies, the concept offers significant potential for collective action to make otherwise inaccessible or non-existent data available. In the context of data commons, information, knowledge, and data are conceptualized as ideas—intangible content that stimulates creativity and innovation (Hess & Ostrom, 2003, p 130). These ideas are non-subtractable, meaning that one person’s use of an idea does not deplete its availability to others, unlike natural resources like grazing fields, where one person's use reduces the resource. Ideas are stored in artifacts such as databases, websites, books, and articles, making them nameable and observable. These artifacts are made accessible through facilities like libraries, the Internet, and e-print repositories (Hess & Ostrom, 2003).

In the Information Systems field of research, open data, IoT, and distributed ledgers are frequently suggested as technologies with the potential to enable practices related to the circular economy (Zeiss et al., 2021). By making data freely available, open data facilitates access information about complex product systems, helping businesses reuse and recycle materials. However, this suggestion assumes that advanced data and IoT infrastructures already exist for data collection. The challenge is simply to make data open or adjust data analytic requirements to fit central CE strategies (Kristoffersen et al., 2020). Arguably, the application of Industry 4.0 technologies is still evolving, and their widespread implementation is not mature enough to fully support CE strategies. Even organizations with advanced infrastructure face challenges at the micro (individual organizations), meso (networks), and macro (ecosystem) levels. These challenges include processes that lack a holistic approach, consensus, and insufficient infrastructure to meet CE and digital needs (Spaltini et al., 2024). At the macro level, technological challenges such as poor IT infrastructure, low readiness levels, and increased data volume and complexity are significant. At the micro and meso levels, there are issues with community support and reliable data and information.

But what happens, when necessary, data is missing or existing data proves inadequate for addressing emerging global challenges? During the COVID-19 pandemic, for instance, existing data systems failed to track infections effectively. Similarly, in the realm of algorithmic search engines, Golebiewski and Boyd (2018) identified "data voids" posing high risks for producing low-quality, misleading, or malicious content. The situation becomes further complicated when critical data is privately held, inaccessible, or locked behind paywalls, preventing organizations and individuals from making informed, sustainable decisions. Circular Economy (CE) businesses frequently encounter similar challenges with missing data (Kanda et al., 2024), significantly hampering efficiency and leading to unfavorable outcomes.

To address data voids in search engines, Golebiewski & Boyd (2018) call for proactive content creation in areas prone to data voids to mitigate the risks of manipulation and misinformation. At the EU level, digital product passports (DPPs) are being promoted as a solution for circular economy data voids, serving as databases for information on product components and materials. While DPPs are not data commons, they represent another approach to addressing data voids and enabling a circular economy. This paper uses the notion of "data void" to describe situations where data necessary for enabling circular strategies like reuse and recycling is either missing, inaccessible, or fragmented across isolated entities.

If sustainable development is to be our common future, ensuring free and open access to data is essential (World Commission on Environment and Development, 1987). Without access to comprehensive data, businesses struggle to make informed decisions that align with circular principles, often resulting in higher transaction costs (Zeiss, 2019). These costs arise from insufficient or fragmented data regarding the supply and demand for materials. For example, a company aiming to use recycled plastics in its manufacturing process to support circularity must identify suppliers who meet both quality and quantity requirements. If data on available suppliers is incomplete or fragmented, the company incurs significant costs in searching for, negotiating with, and verifying the quality of suppliers. These transaction costs, driven by unreliable data, hinder efficiency and increase procurement costs. As a result, CE businesses struggle to access the data necessary for achieving sustainable outcomes, which impedes broader goals, such as the United Nations' Sustainable Development Goals (SDGs).

The literature on data commons for sustainable development remains limited, particularly in underdeveloped regions or organizational contexts with data voids. However, recent research on knowledge commons in rural India by Qureshi et al. (2022) provides valuable insights. Their study demonstrated how knowledge commons can be established to serve the needs of rural farmers through intermediaries. The process involved several stages: identifying latent knowledge, realizing knowledge, soliciting, organizing, encoding, and examining. Two key mechanisms—"technoficing" and "scaffolding"—were identified as crucial to this process. "Technoficing" refers to using accessible technologies that address local needs, while "scaffolding" involves supporting individuals in contributing to the knowledge commons by guiding them through learning curves and helping them share their knowledge effectively. This approach could serve as a model for creating data commons in the context of the CE, particularly in data-void contexts. By employing accessible technology and providing scaffolding support, local communities can be empowered to share and utilize data essential for circular strategies.

Despite advancements in the field, there is still a limited understanding of how data commons can be created in contexts characterized by data voids. Therefore, it is essential to investigate how data can be curated in contexts marked by data scarcity and inadequate infrastructure to gain practical insights into the processes involved.

3 Methodology

To address our research question, we conducted a cross-sectional single case study (Eisenhardt, 1989) of an emergent and growing circular business ecosystem seeking to tackle waste management in Ghana, West Africa. The case is well suited to respond to our research question because we aim to study how emerging circular economy businesses establish data commons to address data voids.

3.1 Case selection: Circular economy ecosystem

The circular ecosystem under study was initiated by “WasteGroup,” an international development non-profit organization in Ghana, a country in West Africa. The recycling rate of Ghana is a mere 5%, and waste generation is estimated to continue to increase, such as a tripling of plastic waste by 2040. Ghana is committed to establishing a local recycling industry that protects the environment and supports the socio-economic well-being of waste pickers, who are predominantly impoverished and often female. There have been several attempts to use digital innovation to help support the waste recovery effort in Ghana. Some initiatives include the Global Plastic Action Partnership (GPAP) through the Plastic Action Initiative Tracker (2022) and the plastic traceability project by SAP and the Ministry of Environment, Science, Technology & Innovation (MESTI), aimed at reducing plastic waste (SAP News Center, n.d.). These efforts have helped organize waste pickers better, incentivizing them and increasing the value of plastic waste.

However, these attempts did not make significant strides. What was needed was a collective action involving all stakeholders in the waste recovery sector – the ambition of the WasteGroup initiative. WasteGroup brought together approximately 500 diverse stakeholders ranging from individual companies operating independently to solve environmental waste challenges to non-governmental institutions, entrepreneurs, public organizations, and information technology firms. Prior to the initiation of WasteGroup, these stakeholders worked in isolation or in partnership with only a few others. Most stakeholders did not have a website, only a handful had Facebook pages, and some could not be found on Google’s search engine or Google Maps. Moreover, most did not have digital record-keeping procedures, making it difficult to document their waste management activities. This initiative was the first attempt to fill the data gap and have a holistic view of waste management challenges.

Ghana can be considered an information-poor country, as most information and data is manually collected or stored on the local hard drives of many institutions, thus lacking the infrastructure to make the data necessary for informing citizens and businesses to make informed decisions. Additionally, Ghana's public statistical service releases data, including census and household data every decade. The collection mode can be considered inaccurate as it comprises computer-assisted personal interviews. A critical problem is related to inadequate, absent, and untimely data adversely affecting the pace of the economy’s ability to become circular. In this research, we followed how WasteGroup, a group of circular economy businesses, established data commons to address data voids. From the curation of data commons, WasteGroup also co-created digital innovation ideas and successfully developed an information website to fulfill the informational needs of all members, including a digital waste resource map that mapped over 100 waste collection and recycling points in the capital city of Ghana. The goal was to increase awareness and patronage of Ghana’s existing circular economy businesses and to scale recycling and reuse practices.

3.2 Data Collection and Analysis

We conducted our research using a mix of semi-structured interviews, archival data analysis, and a detailed review of the informational platform to examine how stakeholders collaboratively established a data common to address data voids (see Table 1 for data sources). Our initial focus was on how digital technologies enable circular waste management practices. We began with semi-structured interviews, asking key questions such as: *What digital tools do you use? How did you select these tools? How do they meet your waste recovery needs?* We initiated the study by interviewing the initiative's coordinators to understand how digital technologies were used. These early interviews revealed a significant initial barrier: the lack of data about ecosystem stakeholders and their waste recovery activities, which hindered the identification of effective digital solutions and innovation. As a result, ecosystem coordinators prioritized establishing a foundational dataset – a data commons - to fill the data gaps.

Rooted in this initial understanding, we shifted our attention and focused on the data commons initiation, development, and visualization. We updated our interview questions to include inquiries such as: *What kind of data was lacking and why? Which data was important to the ecosystem? Who decided which data was essential to collect? What was the decision-making process?* Upon our request, we received a list of all the members grouped into different sectors and archival materials such as meeting summaries, PowerPoint presentations, and PDF documents associated with creating the data commons. We selected one to three businesses from each sector for interviews.

ID	Type of Organization	Number of People	Number of Interviews	Duration of Interview
O1, O2	Development Organization (Coordinator)	2	O1(1) O2(2)	1hr 40 min
NGO1, NGO2, NGO3	Non-governmental Organization	3	NGO1, NGO2, NGO3	3hrs 20min
C1	Civil Society Organization	1	C1	44 mins
WA1, WA2, WA3, WA4, WA5	Entrepreneur (Waste upcycling)	5	WA1, WA2, WA3, WA4, WA5	4hrs3mins
WB1, WB2, WC3	Entrepreneur (Waste recovery and selling)	3	WB1, WB2, WC3	3hrs
GOV1	Public Data Institution	1	GOV1	54 mins
P1, P2	Pioneering Team	2	P1 (2) P (1)	121 mis
F1	Funding Partner	1	F1	38 mins
B1	Business Capacity Building Partner	1	B1	41 mins
IT1	Open-source map expert	1	IT1	60 mins
IT2	Web mobile app developer	1	IT2	60 mins
IT3	Web and Mobile app developer	1	IT3	60 mins
Total		22	25	20hrs 1mins
Secondary Data				
PDF documents and PowerPoint presentations			10	>100 pages

Reports	14	>100 pages

Table 1. Data Collection.

Our data analysis was conducted iteratively alongside data collection, focusing on categorizing emergent themes to build new theories (Gioia et al., 2013). We inductively analyzed the data using open coding while bracketing our knowledge, allowing themes to emerge from interview transcripts and archival materials. Our open coding revealed first-order themes that describe all tasks and interactions, including collaborative actions (evidenced by phrases like "our ideas," "together," and "inclusive") and data preparation processes (evidenced by phrases like "we collect," "we compile," and "we take"). We identified the types of data and their purposes, such as types of waste, GPS location, and quantity of waste. We also observed interesting dynamics in technological implementation, including digital tool selection and activities such as testing and experimenting with open-source tools and joint ownership. We went back and removed some of the themes that were redundant and removed some themes that were irrelevant to the study. For example, peripheral activities such as waste recovery activities and business partnerships were excluded to focus on the curation of the data commons. Further analysis and iterative grouping of several first-order themes resulted in six second-order themes: collective data requirements, co-creation and expert-led brainstorming, co-created requirements, material and location-related data collection, data visualization, and digital infrastructure selection.

We referenced the IS literature to find out if the second-order themes could be aggregated into third-order dimensions informed by existing research. Our analysis yielded three aggregate dimensions informed by literature on datafication, data innovations (Alaimo et al., 2020; Lycett, 2013), and information ecology (Wang, 2021). First, "collective imagination" emerged as a category encompassing collaborative brainstorming and requirements-gathering activities (Davis, 1982). Second, "data collection" consolidated themes related to data gathering and visualization. Finally, "digital mediation" captured the technological infrastructure and tools enabling data accessibility use (Heeks, 2020; Yoo, 2010).

4 Findings

Our case study examines how circular businesses in Ghana collectively addressed data voids through the curation of a data commons. The WasteGroup initiative united diverse actors to tackle inaccessible and fragmented waste management data, including businesses, government agencies, NGOs, and IT experts. Through our analysis, we identified three key phases that enabled the development of the data commons: collective imagination, data collection, and digital mediation. The following sections examine how these interdependent phases transformed and connected isolated actors into an interconnected community capable of sharing crucial waste management information.

4.1 Dealing with Data Voids

The WasteGroup specifically collaborated with small and medium-sized circular businesses, government and non-governmental organizations, and civil societies striving to improve waste management. Its primary objective was *"to address several waste challenges, including fostering partnerships among key stakeholders throughout the waste management and recovery chain."* The initiative had emerged from frustration over the insufficient coordination among different entities. One participant noted: *"You realize that many people are doing so many different things to solve the same problem. But the impact is not at scale because they are all working in silos. There is no connection, no relationship between policy and the private sector, and NGOs are doing their own thing*" (P1). Another participant similarly noted: *Although all stakeholders were present, there was a lack of coordination and connectivity, underscoring the need for a unifying coordinator to bring them together effectively"*- (O1). This reflected a shared perception of inefficiencies in waste recovery initiatives.

Early on, the initiative encountered challenges not only in "identifying data" but also in *"accessing comprehensive data and information, which limited stakeholders' ability to effectively plan or invest in innovative waste management solutions*" (O1). Moreover, there was a significant data deficiency: *"There's no data; people are not connected. We don't know the right technology. So why don't we all come together? Using a snowball approach, we could form a community by connecting with recyclers and research institutions"* (P1). It stood clear that circular businesses needed to connect to exchange waste materials for reuse or recycling; however, the lack of information about these businesses and their waste recovery activities posed a barrier. The lack of information also prevented households and other waste generators, such as hotels, from identifying nearby waste collection points for efficient waste drop-off and collection.

This created uncertainty and frustration about waste supply and demand for businesses and hindered proper waste handling by waste generators, as one of our respondents commented: *"So people should know who their waste management contractors are, services provided, people should know waste recovery companies are close to them. People should know that they can make money from their waste. So, I think the key thing is getting the information to the public. So, it's not really so much data that is important for only us. But also, how data can really get to the society. I think that's a key thing."* (WB3). To address these data gaps, it became essential to gradually bring together all businesses to gather data that would enable them to connect and coordinate circular activities effectively. What was needed was a form of "data commons," where data could be shared and reused across actors in the ecosystem rather than waiting for the government to mobilize this data for them.

During our data analysis, we identified three primary phases, each with sub-processes that drive the curation of data commons in a data-void context: collective imagination, data collection, and digital mediation (see Table 2).

Stages	**Tasks and Interactions**		**Challenges**	**Outcome**
Collective Imagination				
Collective data requirements co-creation	In-person dialogue, negotiation, idea generation, asking, and brainstorming	Imagining future data value, predicting data requirements, and potential value creation.	Achieving joint agreement on data requirements was challenging	Identified data requirements included material-, actor-related data.
Expert- led brainstorming	IT and Data Experts led the discussion that led to the decision on application. requirements	Bring prior knowledge from expertise as well as from similar digital products.	Tedious including all ideas and coming to consensus	Identified data requirements for both data and website and hosting.
Data Collection				
Actor-related data collection	Data sharing, collection and management. Data encoding and aggregation.	Editable and portable data functions.	Standardizing data collection formats, manually entering data into digital mediums.	Collected and consolidated data included raw data of actors and operations.
Material and location-related data collection	Data sharing, collection and aggregation.	Editable and portable data functions.	Accessing GPS location coordinates.	Collected area location data, types of waste materials.
Digital Mediation (Alaimo et al., 2020; Yoo, 2010))				

Data visualization	Experimenting with different open-source tools.	Portable and recontextualizing data, programming, memory	Challenging adapting new data structures and new opensource APIs	Created an informational website and a digital resource map.
Digital infrastructure selection	Purchasing a domain name and hosting the website and waste map	Portable, editable, and contextualizable. Memory and storage functions	Hosting and domain ownership tensions.	Collaborative ownership of the jointly created system.

Table 2. Emerging themes

4.2 Collective Imagination

Our analysis noted the importance of collective imagination in addressing the data void. This collective imagination manifested in various forms, including asking questions, sharing ideas, brainstorming, and engaging in discussions. The need for data and its importance was well documented: *"Desired: up-to-date, representative, comprehensive data to facilitate maximum waste recovery and reporting (SDG 11 & 12)" (PowerPoint), Data Group and Policy Group 2018).* Our analysis shows that collective imagination emerged from two somewhat overlapping phases: co-creating data requirements and expert-led brainstorming sessions.

Collective data requirement co-creation. The foundation of the data commons emerged through collaborative workshops where waste management businesses, coordinators, and IT experts jointly identified critical data needs for circular economy activities. Beginning in 2018, these in-person sessions brought diverse stakeholders together to envision data-driven solutions for Ghana's waste management challenges. Achieving a joint agreement on data requirements proved challenging due to the myriad ideas about what was possible and what data was necessary. The group engaged in several discussion sessions before arriving at a consensus. As one participant noted, *"During that time, we write out what we think, we share it with them. They [businesses] give us their ideas, tell us what is possible, what is not possible. Sometimes, we face challenges where we think it should be possible, and they think it's impossible, but we negotiate along the line and eventually come up with something else"* (O2).

Through this collaborative process, stakeholders systematically identified both immediate and future data requirements for their circular economy initiatives. They mapped out not only what data would be necessary but also potential sources and collection methods to fulfill their collective vision. For example, *"[we need data on] …the number of recyclers within a particular area, [and] data on the amount of plastic recovered within a given time"* (NGO2). Strategically, they needed comprehensive data to track material flows: *"how much waste has been generated, how much has been collected for recycling, how much is going into new products and materials, and where those products and materials are being consumed or exported"* (P1). These requirements encompassed several key areas: investment opportunity mapping, policy documentation, stakeholder identification, material exchange facilitation, and tracking of waste reduction and recycling activities.

The collective imagination phase also included "**expert-led brainstorming.**" During these meetings, coordinators enabled expert-led brainstorming sessions with IT and data experts and organized different actors into subgroups intended for knowledge sharing and visualization. One such group was the IT and data group, tasked with exploring data-driven digital innovations to meet their informational needs. "*Normally we convene and have a discussion. We sit, we discuss, we generate ideas and plan.*" (WB3).

Members of this subgroup included software development companies, public statistical services, web development firms, geographical information experts, mobile developers, and devops engineers. They could visualize possibilities and future scenarios that could later be discussed by the groups. For example, IT experts often led the discussions in these sessions, contributing innovative ideas based on their experience with digital technologies and similar implementations in other countries, such as the London waste map: https://apps.london.gov.uk/waste/. The other sub-groups would then review any ideas. As one participant noted, *"You can imagine it was quite a lot, you know, because we always had to meet with about 20 people at a time from different institutions. And everybody had their own ideas, their own arguments. It was quite challenging, but ultimately, it was successful."* (IT3) Once the necessary data was identified, they envisioned a website where all information could be accessed. They planned to feature all businesses in the waste recovery sector and discussed having a directory for easier connection among them. They also envisioned a digital map to display each business's location and the materials they handle, a mobile application for purchasing waste materials and products, and a comprehensive digital representation of the waste sector. An IT expert elaborated: *"Upon my arrival at the meeting, we had a considerable number of technical experts present. A committee was subsequently formed to deliberate on the platform's choice of technologies and discuss the development approach. The decision-making process centered around the requirement to visualize key stakeholders in the waste sector on a map. Additionally, stakeholders' contact information was to be incorporated into a directory-like structure on the platform, facilitating easy access for users searching for information on these entities"* (IT1). However, realizing this vision required data that was not readily available, prompting them to begin the data collection process.

4.3 Data Collection

Implementing the stakeholders' vision required extensive data. Yet, much of the needed information was either fragmented or nonexistent. Facing the data void - the data collection (and creation) process emerged as a collaborative effort, with businesses contributing their information. At the same time, IT experts and coordinators managed the systematic data gathering. For example, they manually entered data into digital formats, like spreadsheets, and physically visited business locations to collect GPS coordinates. For example, information about the different waste businesses was gathered through various means, including collecting business cards, manually recording names and contact numbers, and, in some cases, using Google Forms to gather additional details from those with websites. The data collection effort focused on two key categories: actor-related data and material/location data.

Actor-related data was collected primarily through industry events and direct engagement. *"We usually take names during programs. If we're hosting a fair, we collect people's names, a list of what they do, their sector, and their activities. Then we compile this information, and, of course, we ask their permission if we can share it"* (O1). For *material and location data*, IT experts partnered with the open-source community to create a custom digital waste map. This required physical visits to business sites to collect precise GPS coordinates. However, this process revealed significant data inconsistencies—registered business addresses often differed from actual waste collection points, complicating the mapping process. Sometimes, they relied on verbal directions from businesses to locate them, causing challenges *"…you call this person and then they're not picking Right? So, you call them, and they will be tossing you. They will say I am not around; I'll give you another person's number to call. A lot of back and forth"* (IT2). More so, small waste management businesses were often transitory and were difficult to locate. *"Most of the stakeholders weren't permanently positioned; they didn't have offices or anything of the sort, right? Sometimes, too, some of these organizations were run by individuals, right? Or, let me say, their main focal persons were individuals, and either you get them, or you don't get them."* (IT1).

Over time, the WasteGroup initiative successfully collected and consolidated raw data on different actors, their operations, service areas, and locations. They also gathered data on the types of waste materials recovered and recycled, innovations developed from the waste, and the precise location coordinates of each business.

4.4 Digital Mediation

The collective imagination and data collection phases were followed by what we refer to as digital mediation - a phase where digital technologies and their core functions (programming, memory, storage, and data tracing) were used to enable the transformation of collected data into accessible visual formats and build a sustainable infrastructure. This phase was critical for translating the stakeholders' vision into practical digital solutions. For example, after data collection, encoding, and aggregation, a new data object emerged, providing possibilities for **data visualization**. The decision to visualize the data to make it visible and accessible to both circular businesses and the public was also a collective effort. *"The process was highly collaborative from the very beginning. It wasn't about presenting a pre-defined plan or dictating how things should look. Instead, it was more about exploring fundamental questions: What should this even look like? Do we even need to build a platform? Should it be a website or an app?"* (IT3)

The primary activities involved programming and experimenting with various web-based technologies and tools, such as content management systems (CMS) and connecting to different Application Programming Interface (APIs). Upon discussion, the group decided to choose free and open-source technologies because the platform is a non for profit. IT experts participated in the platform development, and their knowledge of open data and open-source software helped them select free, cost-effective tools. In Ghana, a significant portion of the country's infrastructural data – including street names and businesses - is scattered across public and private offices and is often only accessible for a fee. As one IT expert noted, *"There was a street naming, I think, two or three, if not four years ago. That data is sitting on somebody's machine; we chased that data for close to two years and eventually stopped trying. We have a lot of data available, but it is isolated, sitting with individuals who are not making it accessible or open."* (IT2). Again, open-source tools proved critical for the project, particularly for visualizing each business's locations and the waste materials they recover and recycle. The team deliberately chose OpenStreetMap over Google Maps for the digital resource map because, while adding locations to Google Maps is free, creating custom maps incurs costs. *"OpenStreetMap offers individuals the flexibility to create maps according to their specific preferences and needs. This allows us to build maps in various capacities. Consequently, many humanitarian organizations heavily rely on OpenStreetMap data. The appeal lies in the freedom it provides, enabling these organizations to customize maps free of charge"* (IT1).

They also chose Drupal, and WordPress CMSs to build a website and the custom waste resource map, respectively. They faced challenges in customizing, reprogramming, and adapting to new API changes while experimenting with WordPress and Drupal open-source CMS as noted by the IT experts *"So even though I'm familiar with Drupal, there was a bit of a learning curve as well as working with Drupal's data structure. Right? Whereas if I was building the application from scratch, it's just a matter of putting together the various, ER diagrams and the architecture and all of those things, right? And then I match up the data values just from a CSV file and I am done. But Drupal has an abstraction layer for data management that is querying and inserts so I had to understand how that worked behind the scenes"* **(**IT1). Nevertheless, they successfully created an informational website and a custom map detailing each business's locations and the waste materials they recover and recycle.

"The digital mediation" phase also involved selecting a digital infrastructure that could host the jointly created system containing information from all actors and additional resources. The coordinators were not interested in hosting and taking full ownership; instead, they intended for the businesses to manage their data. However, none of the actors were willing to take on ownership. They needed a volunteer to manage the hosting infrastructure, handle domain name purchases, and oversee applications like the website and the waste map. "*The problem was determining who owned the project. We are not a waste management company; we are a software company that builds technical products. Our work relates to that scope. However, we cannot own this platform—it does not belong to us. So, who does it belong to? The advocacy group suggested it is a financial asset. Then who owns it? They responded by saying, 'The coordinators organized us, so they should own it. They added, 'We brought this up so that you people [circular businesses] can come together and take ownership"* (IT3).

The solution was to distribute hosting and domain responsibilities among the coordinators and IT experts periodically. "*The process was surprisingly complicated. We spent almost three months just deciding who would buy the domain. Initially, there was uncertainty about the domain name itself. Eventually, we had to agree on a clause that stated: "You are the technical experts. For now, you purchase the domain, as you* *know how to manage these things. You can keep it in your system temporarily, and once we determine who it will be transferred to, you can hand over the domain to the appropriate party".* (IT3)

5 Discussion and Contribution

This study examined how CE businesses faced with data voids can collectively establish data commons to bridge these gaps and enhance data accessibility. Our analysis of WasteGroup, Ghana's circular economy initiative, revealed three main phases in this process: collective imagination, data collection, and digital mediation. The steps involved in these phases encompass co-creating collective data requirements, expert-led brainstorming, actor- and material-focused data collection, data visualization, and infrastructure selection. This progression illustrates how collective action can help address data voids and foster the creation of circular data commons. This study advances the scholarship of the digital circular economy (Gupta et al., 2019; Zeiss et al., 2021) by introducing a process model for establishing data commons aimed at tackling data voids (Figure 1).

Our model identifies data voids—the absence of information crucial for circular economy practices—as the starting point. In response, a collaborative process unfolds: first, through collective imagination, where grassroots organizations, stakeholders, and experts work together to define ideal data requirements through brainstorming, scenario analysis, and speculative problem-solving. This conceptualization then guides targeted data collection that is aligned with circular practical needs. The collected data undergoes digital mediation—processing, structuring, and visualization—to enhance accessibility. This enables the creation of a data commons online platform, where data becomes collectively owned and shared. Once established, using the data commons generates new insights that reveal additional gaps, prompting further data collection. This cyclical process ensures continuous improvement of data resources in response to evolving needs.

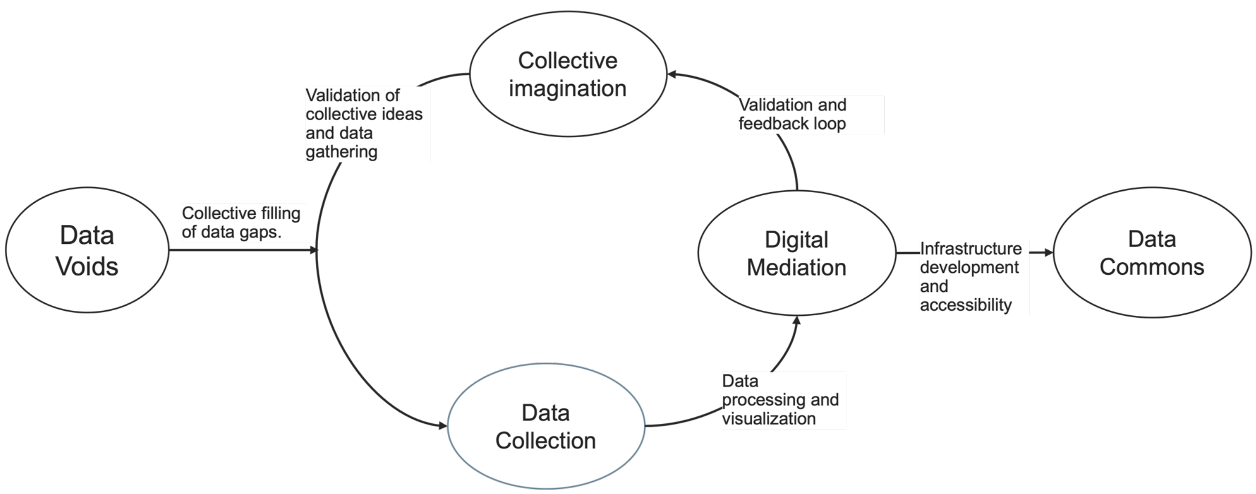

Figure 1. Circular Data Commons process model

Our study enriches the literature on digital mediation and data work by demonstrating how data qualities—including editability, portability, and recontextualization (Alaimo, 2022; Alaimo et al., 2020; Yoo, 2010)—enable collective imagination and action. We show that successful data commons require more than just data objects; they depend on fundamental digital functions such as memory, storage, and programmability (Yoo, 2010) to facilitate data visualization and sustainable infrastructure development. Our study complements the perspective on data or digitally enabled circular economy and digital sustainability (Kotlarsky et al., 2023; Kristoffersen et al., 2020; Luo et al., 2023) with that of data commons, particularly in the context of data voids. There is a dearth of research on data commons in information systems; current studies are mainly found in medical sciences, where data commons are established to consolidate large volumes of data and enhance reusability (Fedorov et al., 2021; Wilson et al., 2017; Zhang et al., 2018). In these studies, data commons emerge not from data voids but from the necessity to make data available and standardized for reuse in research. Related research on strategies for information gathering (Davis, 1982) does not adequately address the unique challenges posed by data voids and data commons in circular environments, where local data related to waste materials and their availability are crucial. Furthermore, previous circular economy studies have largely neglected the issues of data scarcity and inaccessibility, which adversely affect digital circular economy practices (Spaltini et al., 2024). Instead, most research has focused on Industry 4.0 technologies such as IoT, 3D printing, autonomous vehicles, drones, blockchain, and artificial intelligence, which rely on the existence of ubiquitous data exchange, monitoring, and interoperability (Kristoffersen et al., 2020; Liu et al., 2022; Rajput & Singh, 2019). While prior research has highlighted the complex, systemic nature of recycling and reuse practices and called for greater data accessibility (Zeiss, 2019; Zeiss et al., 2021), empirical studies of data creation in circular economy ecosystems remain scarce. Through our in-depth examination of a complex circular economy initiative, we provide practical insights into how organizations and networks of circular businesses can overcome data voids through collective action.

Our study also contributes to commons research by showing that the commons are not only valuable when resources already exist (Ostrom, 1990) or are only inaccessible (Ostrom, 2003, 2005) but are essential for enabling the generation of previously inaccessible or nonexistent information. Traditional common-pool resource studies focus primarily on the governance of existing natural resources through collective action. They demonstrate that communities can develop formal and informal rules to manage these resources sustainably (Ostrom, 1990). Offshoots of this perspective to digital information and knowledge commons (Hess & Ostrom, 2003, 2005) emphasized not just the governance of existing resources but also the collection and transformation of ideas into artifacts stored in distributed online repositories for easy access (Hess & Ostrom, 2003, 2005). Our study demonstrates that collective imagination, fueled by brainstorming ideas and digital mediation tools, can be utilized to create non-existent data. Collective governance can also be created bottom-up, through idea generation to artifact creation and decision facilitation, and ongoing governance continues.

Our analysis reveals that data voids often signal broader systemic challenges, particularly in infrastructure and governance. While Hess and Ostrom (2005) identify ideas, artifacts, and facilities as crucial elements of commons governance, our findings highlight how critical infrastructure decisions for data storage and visualization and infrastructure choices—such as data storage and visualization tools—must align with the ecosystem's characteristics and needs. In our case, the non-profit nature of the initiative and its collaborative spirit led to the adoption of open-source solutions and shared ownership models. As Davis (1982) stated, "The requirements for the information system are thus determined by the characteristics and procedures of the organizational system."

Our model does not consider activities that mobilize the circular economy business or strategies to organize and sustain it over time. Therefore, we urge future research to investigate the process of mobilization and governance

5.1 Practical implication

Our study has practical implications by exploring how to curate and make data accessible in contexts characterized by data voids through data commons. This concept is an extension of commons research by Ostrom (1990), Fisher & Fortmann (2010), and Hess & Ostrom (2005), who provide extensive frameworks for commons governance.

We propose that a transition to a circular economy, supported by digital technologies, may require a step back into information and application requirement gathering at the micro (organizational), meso (network), and macro (ecosystem) levels. This could overcome challenges in data-rich contexts (Kristoffersen et al., 2020; Liu et al., 2022; Rajput & Singh, 2019) and data-void contexts. For circular strategies such as recycling and reuse, it is essential to gather requirements at the ecosystem level to inform the application and organizational level requirements (Davis, 1982), allowing for the selection of an appropriate solution that benefits all involved. Our findings suggest that digital product passports (DPP), while currently driven by EU policy initiatives, would benefit from circular data commons as a data resource. Rather than relying solely on government or corporate leadership, these systems should emerge from grassroots collaboration among stakeholders who understand local needs and practices. Such community-driven development could lead to higher adoption rates and more effective implementation.

In conclusion, overcoming data voids is crucial for circular businesses, as they hinder organizations from realizing the full potential of circular initiatives (EMF, 2013), which aim to close or slow the loop of material flows. Our study bridges the research and practical gaps through an empirical examination of how emerging circular businesses, via collective action, established a data commons to address the issue of data voids.

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