

Libraries of Things: Understanding the Challenges of Sharing Tangible Collections and the Opportunities for HCI

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Figure 1: Libraries of Things (LoT) are collections that enable the sharing of tangible objects such as tools (A), musical instruments (B), or cooking equipment (C). Images courtesy of our study participants: (A, B) opted not to self-disclose, (C) courtesy of Meg Dorwart at Library of Things YXE.

ABSTRACT

“Libraries of Things” are tangible collections of borrowable objects. There are many benefits to Libraries of Things such as making objects and skill-building accessible, reducing waste through the sharing of items, and saving costs associated with purchasing rarely-used items. We introduce the first HCI study of Library of Things by interviewing 23 librarians who run a variety of collections such as handheld tools, gear, and musical instruments – within public institutions and more grass-roots efforts in the private sector. In our findings, we discuss the challenges these collections experience in changing behavioural patterns from buying to borrowing, helping individuals ‘try new things’, iterating to find sharable items, training staff, and manual intervention throughout the borrowing cycle. We present 5 opportunities for HCI research to support interactive skill-sharing, self-borrowing, maintenance recognition and cataloguing ‘things’, organizing non-uniform inventories, and creating public-awareness. Further in-the-wild studies should also consider the

tensions between the values of these organizations and low-cost convenient usage.

CCS CONCEPTS

• **Human-centered computing** → **User interface toolkits.**

KEYWORDS

library of things, Libraries of Things, thing library, sustainability, tangible exchanges, tool library, makerspace, sharing economy

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1 INTRODUCTION

Human Computer Interaction (HCI) as a field is increasingly exploring how we can support sustainable and pro-social behaviours [56]. One way of doing so is in designing systems, devices, and interfaces that make those positive behaviours more usable and improving the user experience of engaging in those activities. This paper is the first to introduce the challenges that Libraries of Things face, and in doing so we begin to tackle the complicated problem of our

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household objects and possessions, and how we can encourage the sharing of rarely used items instead of relying on excessive buying. We describe an interview study on Libraries of Things where we gather the challenges, breakdowns, and manual interventions that are needed throughout the borrowing cycle, in order to gather opportunities for automation and technologies to improve the convenience of these services so we can further support and scale these sustainable sharing practices.

1.1 What are Libraries of Things?

Libraries of Things (LoT) are borrowable collections of tangible objects. These collections enable individuals to access items other than books from a library. For example, someone might borrow a sewing machine, a board game, a tool like a hand drill, or camping equipment [110]. Though ‘thing’ libraries and tangible collection examples have existed for several decades [120], their current rise and spread coincides with several intersecting social movements. These social movements are changing and guiding current conversations within both HCI and library sciences research.

One of them is the maker movement, which frames tools as a way of learning [99]. Rather than consuming goods, the maker movement aims to make tools accessible through workshops such as maker spaces so that individuals can make objects for themselves, and in doing so, learn new skills. In the context of libraries, the maker movement is increasingly transforming libraries into spaces for making and learning new skills, rather than their previous primary focus on sharing information. Within HCI, our community is increasingly focusing on how we can support users as makers rather than just consumers of technology.

Thing libraries also coincide with the growing sharing economy, which aims to match underused goods and services with individuals who are looking for them, and in doing so, change behaviours in favour of sharing rather than buying [33]. Rather than libraries just sharing books, the sharing economy questions what else can be shared among community members. Within HCI, libraries become a possible platform for sharing tangible objects when peer-to-peer sharing is more difficult, impractical, or considered ‘risky’ [85].

The urge to borrow and share items, rather than buy them new, also stems from sustainability motivations for communities that are increasingly aware of the negative impacts of throw-away culture [28]. Within HCI, we are increasingly exploring the sustainability of the technologies we design, with calls to evaluate the long-term impacts these devices will have [15, 54, 115], while also recognizing that we need to ‘study up’ different fields to better understand what technologies they need before we design solutions [20]. At the same time as these social movements are gaining momentum, libraries are also changing to offer new services beyond books, such as borrowing laptops or offering spaces to meet [110], and for HCI this will increasingly require new technologies and interfaces to support these changing needs and requirements.

Due to the variety of things that could be collected, Libraries of Things can at times be difficult to define. In a recent book on these collections, Robinson et al. define a thing collection in a purposefully broad way, as: *“any collection of physical objects that serve a utilitarian purpose as tools, equipment, or goods; that circulate beyond the walls of the library; that provide a cost-savings benefit*

to patrons by supplying something for which they have an existing need; that have an inherent appeal to patrons; and that defy standard processes of acquiring, cataloging and circulation” [110].

This definition highlights both the opportunity and the challenge of Libraries of Things, as well as the gap where HCI and technology can work to support these efforts. Libraries of Things provide access, help to reduce material consumerism, and help to reduce the costs of using an item. In doing so they provide prosocial benefits to their communities and the environment [56]. At the same time, because ‘things’ are different than books –in shape, materials, and use– they are often difficult to manage, and require new processes and technologies for acquiring, cataloging, and circulation.

1.2 Contribution

In this paper, we take a broad view of different ‘thing’ collections to better understand the depth and breadth of the challenges they face. We then map out the opportunities for HCI and Tangible User Interface (TUI) researchers within this growing movement. To gain insight into the unique operational contexts of ‘Libraries of Things’, we interviewed 23 individuals from a variety of collections such as tool libraries, gear libraries, and musical instrument libraries – both within public institutions (traditional libraries) and in the private sector. Importantly, many of these collections focus on a single type of tangible collection due to the difficulties in scaling the manual and cognitive aspects of managing each new type of collection. Our research goal was to deeply understand these difficulties that thing collections face so that HCI, as a field, can design useful and practical solutions that respond to the needs of these institutions. This paper has two main contributions:

- (1) **Introducing HCI researchers to Libraries of Things:** Our findings provide a summary of the aims and goals of Libraries of Things, and the challenges and barriers they face that prevent them from scaling.
- (2) **Providing opportunities and next steps for HCI:** We provide an overview of the HCI-specific questions and research directions to support sustainable sharing practices and Libraries of Things technology infrastructures. Our goal in doing so is to ensure that these practices can be more broadly adopted.

2 RELATED WORK

Here we discuss the shift towards sustainability in HCI, the increase in sharing with the sharing economy, previous work on Libraries of Things, and the transformations occurring within ‘traditional’ libraries.

2.1 Sustainability in HCI

Sustainable HCI incorporates a variety of perspectives. One is Sustainable Interaction Design (SID), which is the concept that sustainability should be a central part of HCI research, with concerns for sustainability ingrained in our design values, methods of research, and how we think about use, reuse, and disposal [15]. Sustainability in HCI often focuses on environmental sustainability with a variety of research approaches [36, 82]. Some focus on behavioural change, such as persuasive technologies that use sensors and data visualizations to make individuals more aware of their behaviours

and consumption habits [24, 30, 49, 50, 108]. Others focus on the materials we use in HCI such as designing with biodegradable materials [10, 71, 128], designing with waste [11, 27, 32, 55, 60, 69], designing technologies that can be easily taken apart for reuse [66, 90–92, 132], designing for ‘remixing’ [57, 97, 111], and designing for repair [64, 81]. In designing and considering solutions to environmental sustainability, we also need to consider whether solutions will scale [36]. There are also the energy consumption considerations of different digital services [83, 105].

However, sustainability is broader than just environmental sustainability, and includes thinking about all future results of an activity and whether it is ‘sustainable’ in the long term [15]. For example, Scuri et al. [115], discuss how HCI as a field needs to broaden its approach to sustainability to include the “triple bottom line” of environment, economy, and society. HCI has been critiqued as focusing heavily on responsible consumption and production rather than other equally important sustainable development goals, such as reducing poverty and inequality [54]. Recent work has also criticized sustainable HCI for proposing specific technology solutions without “studying-up” other fields to fully understand their challenges and constraints [20]. In this paper we follow previous work that aims to better understand groups that engage in sustainable behaviours [35], such as groups involved in urban gardening [96] and repair [64, 81]. Previous work has demonstrated that Library of Things help to reduce consumption and resources [28], extend the life of donated items, while also making items and corresponding activities financially accessible. In this work we want to understand the areas where they experience challenges and could use support so that these positive sharing behaviours can scale.

2.2 The sharing economy

Libraries of Things are part of a greater movement towards sharing and the sharing economy. When an individual needs an item or service the next step is making a decision on how to obtain it. Traditionally, this has meant looking up a contractor or purchasing an item from a store. During these decision-making moments, the sharing economy aims to match underused or “idling” goods and services with individuals who would like to use them [33]. The recent rise in sharing economy industries is due to technological innovations and platforms that are able to make these matches and sharing more convenient; both for individuals who want to share, and for those who are looking for items or services. Botsman et al. [16] describe these services as requiring four things: 1) trust between strangers, 2) idling capacity, 3) critical mass, and 4) belief in the commons. Modern platforms like Uber, Airbnb, and TaskRabbit act as “middleman” services, and have been successful through providing these characteristics, which enable individuals to feel safe, for example, as a passenger in a stranger’s car, or as a visitor in a stranger’s home, without the ambiguity or uncertainty of traditional sharing [75].

When it comes to borrowing physical objects, providing Botsman’s et al. [16] four characteristics is more complicated. For example, in peer-to-peer object sharing platforms, individuals felt more comfortable sharing their own objects with individuals within their neighbourhood [42], or within social groups based on perceived similarities [89], and borrowing at times felt less convenient than

buying the object [42]. There can also be a disconnect between what items individuals would like to borrow versus what others are willing to share. For example, individuals often want to borrow expensive but rarely-used items, but lending out expensive items from one’s own collection is perceived as more “risky” [85]. In exchanges of physical goods individuals also want to avoid uncomfortable feelings like indebtedness [85] and need to be able to “browse” offerings before feeling comfortable participating [122].

2.3 Libraries of Things

Based on the limitations mentioned above, Libraries of Things provide a possible solution, whereby the perceived risks of lending are offloaded from individuals to an organization. Logistics of borrowing are also more centralized based on the library’s location, and libraries can remove some of the uncertainty and discomfort around borrowing as the collection is there specifically to be borrowed and the steps involved in borrowing will be more uniform.

Though public libraries are increasingly creating collections of ‘things’, many of the most well-known examples, such as tool libraries, often exist outside of the public library system. These collections tend to be developed by grassroots volunteers with an inventory of donated items [1, 2, 7] and with the aim of making the collection accessible [7]. These collections are often value-driven with environmental and social goals, and rely financially on memberships and grants [28]. Previous work has discussed the potential for making these services more convenient through understanding their community needs and user centred design [3, 28], but starting up a Library of Things is often a difficult task that requires huge amounts of volunteer effort, with many collections struggling for financial stability [7].

2.4 Technology in the library

‘Traditional’ libraries with books are prime locations for technologies and automation due to the relative uniformity of the objects they store, but this is also changing as libraries themselves go through their own transformations in response to the scarcity or abundance of books and information. For example, Bennett [13] highlights how in the history of libraries they have gone through three distinct phrases: from reader centred, to book centred, to learning centred. When books were scarce or a luxury, libraries were places for reading (rather than borrowing and taking items home). As books became more available, libraries became centred around book storage and shelving for large borrowable collections that could be taken out of the library to be read. Today, with the vast amount of digital information, and books that no longer need to be physically stored, libraries are once again transforming to focus on learning.

There are three main areas where technology plays a role in the library. These include research into navigating, searching, and retrieving items from the collection, providing assistance and self-serve technologies, and supporting education and learning.

2.4.1 Navigation, search, and retrieval. Libraries are increasingly incorporating robots into their systems. Most research has focused on the time-consuming tasks of finding and retrieving books [23,

112, 129]. The tricky part of search and retrieval in libraries compared to other systems like warehouses is that books have a relative location in the library (i.e. in relation to other books) rather than absolute locations like most warehouses [23]. Increasingly researchers are incorporating computer vision in libraries to recognize individual books within a collection by their spine and where they are located [61, 93, 101], and even using text recognition and keyword search to link those physical books with the catalogue [26, 126]. These image recognition systems either rely on static cameras throughout the library or “roaming” robots who can scan the shelves [104, 109, 124]. Researchers have also explored tangible systems such as conductive object pads that enable individual objects to be recognized on “smart shelves” [62], or lighting systems where a specific section lights up to help individuals find the exact location of an object. [116]. Robots can perform maintenance tasks such as scanning and re-shelving books [4], for example, roaming robots with robotic arms are increasingly able to “stack” books on library shelves, though this is easier when each book has been given an absolute location [68, 106]. Though research into these automation supports exist, they rely on the relative uniformity of books as tangible objects that, for example, have a spine, are square, are of a similar weight and size, and are stored in a specific way.

2.4.2 Providing assistance and self-serve technologies. Another group of technologies aim to help patrons “help themselves”. For example, Radio-frequency identification (RFID) self-checkouts initially proposed at CHI [114] are now common in many public library systems with self-checkout kiosks for books, and for returning books with after-hours book drops or slots. There are also systems for providing assistance and requesting information such as chatbots to answer questions [86], personal assistants that can navigate individuals to areas of the library [9, 51], or navigational apps that help individuals find specific books within the library [100]. Roaming robots have also been added to libraries for visitor interactions, and to guide patrons to items they are searching for, for example, to help children locate library books [78, 79]. Technologies can also help with searching for information such as the tangibles used for The Search Wall [31], which aims to help children tangibly look for items in the library catalogue through keyword blocks. Researchers are increasingly exploring how Artificial Intelligence (AI) and Intelligent Systems (IS) can be used to help individuals retrieve information from the library, recommend resources, or summarize information [5, 98, 133].

2.4.3 Education. Libraries are well suited to becoming progressive hubs for technology and learning as a “third place” [38, 84], i.e. as public social spaces where we can exist outside of the private spaces of home (“first place”) and work or school (“second place”). As classes move online with distance learning, spaces like libraries could help to support MOOC’s, and instead of providing information, could provide the spaces to focus and learn [112]. Individual laptop use has increased within libraries [21], and libraries are becoming important places for borrowing not only books but also providing access to “tools” such as laptops [63, 123, 130]. But even adding a laptop collection requires huge amounts of work such as new procedures for “acquisition, budget allocation, processing, cataloging, check-out, replacement, and security of the equipment, as well as marketing the service” [52]. Interestingly, these same

questions are asked of many new collections, such as the introduction in the 1970s of slide projectors into library collections [8]. Once implemented, collections with many devices, for example one library that had over 30 types of devices such as e-readers, game controllers, cameras, and projectors, are increasingly gathering data on circulation metrics and trends to help manage the circulation of these devices [25]. Screen-based device lending can also be limited or constrained by the designs of consumer devices, which are often designed for use by a single user [46, 58]

Leveraging the library as a space to learn, there have also been pilot projects of makerspaces built within libraries [72, 88, 119, 131]. Previous work found that makerspaces help foster community and reframe libraries as spaces where things are created rather than consumed [119], but they also deal with issues such as staffing the makerspace and librarian and patron training, often relying on librarian peers with skills in makerspace technologies or online resources [88]. ‘Libraries of Things’ fall into a similar category within public libraries, in that they help to reimagine what a library can offer, and we include similar pilots of musical instrument collections within public libraries in our study.

3 METHODOLOGY

We conducted an interview study with a variety of Library of Things collections to understand the challenges of creating and organizing these collections, and opportunities for technological interventions. We designed our study to address the two research questions:

- **Question 1 (Q1):** How do these collections operate and organize themselves?
- **Question 2 (Q2):** What are the challenges and constraints that Libraries of Things face in managing their tangible collections?

3.1 Participants

To better understand Libraries of Things and what is involved in the process of creating and maintaining one, we interviewed 23 participants who run Library of Things (P1-P23), see Table 1. We purposefully chose a broad range of collections including general collections (who often branded themselves as ‘Library of Things’ and had a wide collection including items for camping, crafts, tools, games, and catering equipment), tool libraries, gear libraries, and musical instrument libraries, both within the public and private sector. All but one had a physical location - and one of them was a mobile van that moved to specific locations throughout the week. We recruited our ‘librarians’ through email and included individuals who set up and maintain a Library of Things collection.

3.2 Procedure

We emailed individuals who expressed interest in our study a Qualtrics [107] online consent form. We conducted semi-structured interviews through video calls (Zoom) [29] where we asked participants a set of questions with the main topics including: motivations for starting the collection, definitions of a thing collection, boundaries around the collection and expected community interactions, maintenance of the collection, and feedback they have received from the community. These interviews lasted from 45 minutes to a maximum of 1 hour.

Table 1: List of our study participants with the type of collection and type of library they run in, and location by province, state, or region depending on country.

ID	Collection	Library type	Location
P1	Tools	Independent	NS, Canada
P2	Library of Things	Independent	ON, Canada
P3	Tools	Independent	ON, Canada
P4	Library of Things	Independent	SK, Canada
P5	Library of Things	Independent	ON, Canada
P6	Tools	Independent	ON, Canada
P7	Tools	Independent	PEI, Canada
P8	Tools	Independent	WA, USA
P9	Musical Instruments	Independent	ON, Canada
P10	Gear	Independent	ON, Canada
P11	Tools	Independent	NB, Canada
P12	Musical Instruments	Public Library	NL, Canada
P13	Tools	Independent	MB, Canada
P14	Gear	Independent	ON, Canada
P15	Tools	Independent	WA, USA
P16	Library of Things	Independent	SE England
P17	Musical Instruments	Public Library	SK, Canada
P18	Library of Things	Independent	SW England
P19	Musical Instruments	Public Library	NS, Canada
P20	Musical Instruments	Public Library	NB, Canada
P22	Musical Instruments	Public Library	BC, Canada
P23	Musical Instruments	Public Library	AB, Canada

A second, and optional, portion of the study was a Qualtrics survey where participants could submit photos of their collection, with the option to self-disclose for image credit or to remain anonymous. We obtained clearance from our institution’s research ethics board.

3.3 Analysis

We used verbatim transcription to transcribe 20 hours of video recording using Zoom transcription [29], and both the first and second author reviewed and edited all transcripts. We then performed reflexive and inductive thematic analysis as described by Braun et al. [17–19] that aims to generate analysis from the bottom up (in this case our interviews around the creation and maintenance of Library of Things collections) rather than around existing theoretical frameworks. This approach emphasizes the active role of the researchers in meaning-making, where coding is an iterative process rather than made with a codebook [19]. We used this reflexive approach to analyze the data as HCI researchers with a focus on the challenges that Library of Things collections must manage.

This first involved familiarization and immersion in the data with reading and notetaking, and then an initial coding of the complete dataset with line-by-line data-derived semantic codes for each quote that aimed to mirror the language and concepts our participants discussed. The first and second author analyzed the first interview transcript together, and then divided the remaining transcripts. These were coded in MAXQDA which enables easy iteration of codes [47]. With this initial list of codes, we then grouped them

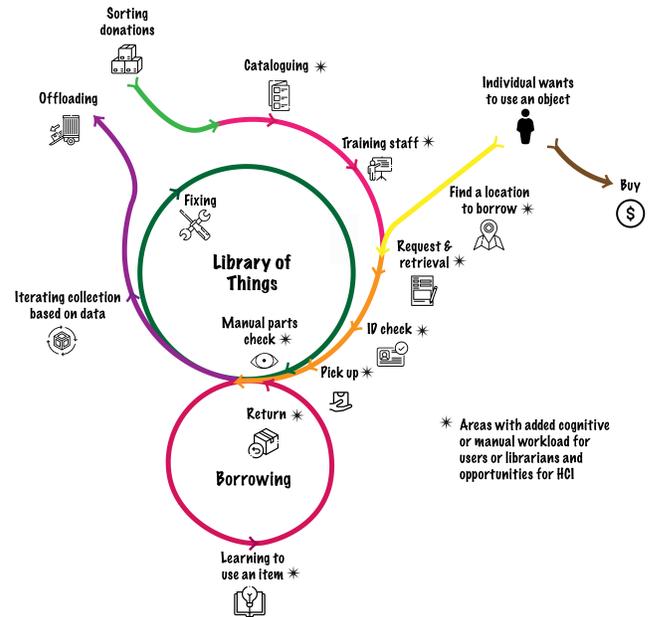


Figure 2: The Library of Things lifecycle and circulation process involves added manual processes and challenges. For the user: challenges such as discovery, added restrictions on check-out and returns, and learning how to use an item. For the library: managing donations, training, navigating things rather than uniform books, added ID checks, manual part checks at checkout and return, fixing items, and offloading excess inventory. *Opportunities where HCI can support librarians or end users are marked, and discussed in Section 5.

into central organizing concepts to create narrative themes. These themes and subthemes were reviewed to create a thematic map. This thematic map was then used to develop the final themes with descriptions of each of the codes with data extracts to illustrate them.

4 FINDINGS

Our participants from a variety of thing collections discussed five main areas where they experience ongoing challenges. Libraries of Things required changing ingrained behaviours from buying to borrowing. They were often designed for helping individuals learn or try new skills. Our participants described iterating their collection based on items their communities wanted to share. Each new collection required new training and skillsets. Librarians, volunteers, and technicians needed to be manually involved in the circulation process.

4.1 Changing behavioural patterns from buying to borrowing

Our participants described the challenge of changing behaviours from buying to borrowing, even if it is in an individual’s best interest. Thing libraries are a relatively new concept, and our participants described the effort required to get established and known within a community. This creates added challenges because most

thing libraries rely on membership models, and as a result require a critical mass of users for financial sustainability.

4.1.1 A mindset shift to sharing. Most of our participants (N=19) discussed how their collection involved changing ingrained habits of consumption from “individual ownership” (P1) to sharing and “community access” (P7). So instead of every household each having a single item that they used infrequently, they could share an item from the collection and borrow it during periods of need. As P2 summarizes: “We all have tons of things in our lives that we use once or twice a year, so we’re focusing on giving people the opportunity to make use of things that we simply do not need to buy”. The tangible collections were part of this “mindset shift” (P16), with the aim of encouraging individuals to think of sharing before turning to buying options. Many of our participants saw this as expanding beyond Library of Things and turning towards sharing in general: “Even if we [the library] aren’t lending people things; if they think ‘Maybe I should ask a friend if they have this and I can borrow it’” (P4). Our participants saw their collection as one part of a greater movement towards sharing.

4.1.2 Their community doesn’t know they exist. Due to the novelty of thing libraries, and the shift in thinking and behaviours they required, half of our participants (N=12) found marketing and creating awareness challenging and relied on “word of mouth” (P14), features in news articles, sharing to their followers on social media, and connecting with like-minded organizations. Many of our participants (N=18) expressed that the feedback they received was overwhelmingly positive, but that they had trouble creating awareness and reaching those they could help. Our participants discussed the “surprise” that patrons expressed once discovering them. “I think a lot of people are surprised, pleasantly surprised, that it’s something that they can do” (P12). “People just love that we exist, and I wish we could extend that to more people” (P2). Their main challenge was that “people don’t know it [the collection] exists” (P8). Four of our participants gave the advice that it takes a long time to gain a foothold in the community. P3: “You just have to realize that maybe it’s going to take you five years before you’re actually firmly established, or that’s how long it took us”.

4.2 Enabling patrons to ‘try something new’

The core aim of many of these organizations was to make the collection accessible to enable individuals to gain new skills.

4.2.1 Making items and skill-building accessible. Almost all our participants (N=22) discussed how the aim of the collection was to make skill-building accessible, and to remove barriers to accessing the collection. One of the ways of making the collection accessible was through teaching individuals how to use items in the collection. For example, at the tool libraries, individuals often consulted with the volunteers for advice on what they would need for a project rather than browsing the collection:

“Somebody comes in and they’re like ‘I want to do this thing that I’ve never done’ and we get to talk to them about it, figure out the tools, and teach them how to do it. Then they go off with the skills they need, and you know, maybe some YouTube links to get some more ideas, and then go do the thing” (P8).

4.2.2 Spaces for learning. The tool libraries especially either had makerspaces or workshops (see Figure 3) where individuals could learn those skills with volunteer support:

“It was always very important for us that we not only provide access to the resources, but also to knowledge and skills, so we always had envisioned a space where we can teach workshops. We now have what we call the workspace. Other tool libraries sometimes call it the maker space, or the workshop, so it’s very similar in essence”. (P6)



Figure 3: Workshop within a Tool Library. Image courtesy of NE Seattle Tool Library.

The other collections also worked to support skill building through events like “repair cafes” (P3, P4, P6, P7, P15, P16), as well as events for specific collections such as “basic gardening” (P3), and “how to use a sewing machine” (P4). The musical instrument collections within public libraries focused on providing educational material on the collection. P23: “Not only can they pick up a ukulele, but then they can pick up a book about how to learn to play the ukulele”. At the same time, many of the public libraries also received requests for, and wanted to provide, more hands-on support for instruments beyond books. Similar to the makerspaces in tool libraries, several of the instrument libraries wanted to offer spaces such as recording rooms or sound rooms for individuals to use the library’s space if they could not do so at home.

The collection also helped to alleviate potential issues with individual storage space as they “allow people to either try things or use things that take up a lot [of] space” (P5). This is especially important in urban areas where individuals might have smaller living spaces, and this came up as an issue with patrons – “people are always like ‘this is great, but you know I live in a condo’” (P6). As P14 describes the lack of affordable housing: “a lot of us are going to be renting for a while and living in smaller apartment spaces. Space is a big concern, so it doesn’t really make sense to have like a tent lying around your house”. This was another benefit of makerspaces and music rooms where individuals could not only try the items but also have a space to do so.

4.2.3 Financial accessibility. Our participants wanted to make the collection financially accessible, and collections with membership

fees discussed the tension that arose between wanting to make the collection as accessible as possible (and removing financial barriers) while also bringing in enough income to survive as an organization. To do this, the libraries our participants worked at offered subsidized memberships, different levels of memberships, sliding scale donations as memberships, volunteer or service trades for memberships, or free memberships.

Libraries of Things aimed to make object exploration affordable by enabling individuals to “try out” an object. This was especially true of the instrument libraries within public libraries, where it is unlikely that an individual would learn an instrument in the average three-week loan period. This aspect of being able to try out objects before purchasing them also aimed to reduce waste and individuals purchasing items that they won’t need or use long term. P4 described this feature as part of the value thing libraries provide so patrons can try out “something that you’re not quite sure you want to buy yet”.

Overall, the combination of access and affordability was valuable for what it enabled patrons to try, make, or do:

“People get all excited ‘I planted my own garden, I tilled the soil, I built the bed, I did all of it’, and they’re so excited or ‘I finally got to try doing this’ and that’s the thing you’ve empowered people to do. They may have thought they couldn’t do, and really, it’s just as simple as making the tools accessible and affordable”. (P7)

4.3 Iterating to find and define ‘shareable’ things

Through their experiences running tangible collections, our participants offered recommendations on what they have found to be the characteristics of a shareable item.

4.3.1 What makes an ideal item for a thing library. The collection categories our participants discussed were broad, especially for the five general ‘thing libraries’ we interviewed. Collections included categories of things such as: arts and crafts tools (like a sewing machine), gear (like snowshoes), kitchen and catering, entertainment (like board games), garden (like a lawn mower), construction (like a saw), and musical instruments. In line with the aims of the collections (to learn new skills and help individuals avoid purchasing rarely used items) the items that were most useful for the collection were targeted to these purposes. For example, all of the musical instrument collections (N=8) discussed how an ideal item was for beginners – “entry level instruments” (P9). “Our most popular instrument is the ukulele. They are great for us because they’re actually not expensive. They’re light, they’re portable. They’re perfect for a lot of beginner programs” (P17).

The other category of items that did well in collections was rarely used items. Some of our participants (N=8) described ideal items as items needed for one-off tasks: “There’s tons of things that we need just once – why do you need to own it?” (P7). Ideal items that get used once can be used for novelty, for example, party supplies: “One of the libraries has a cake pan collection. That’s such a great idea. People aren’t going to walk off with a cake pan. You want to do a Kermit the Frog cake one year; you’re not going to do a Kermit the Frog every year” (P17). Another area is items used for large one-off jobs – like carpet cleaners: “big-expensive-complicated-cleaning or DIY tools that you would never bother buying” (P18).

4.3.2 Managing and filtering donations. All of our participants had at some point accepted donations into their collections, but there was a clear distinction between what was donated and what had to be purchased. The musical instrument libraries we interviewed that existed within public libraries had sponsored collections where most items were purchased but the occasional item was donated from the community. Our other collections were almost entirely created from community donations of goods.

Managing donations was described as a massive undertaking, and most collections received an excess of donations based on what their space could manage. “It’s a big challenge and effort for us to keep up with the donations and then to decide which donations we keep” (P1). One of the public libraries decided to stop taking donations due to the time and effort needed to manage and filter through donations. Many of our participants made policies or rules for what they would accept “because we want to make sure that whatever it is we’re gathering is going to be shareable and we don’t want [to become] a dumping ground for people’s junk” (P5).

Exclusion criteria that made an item unsuitable for a thing library included:

- **Safety:** Safety items like helmets, ladders, or scaffolding were not accepted through donations and had to be bought new, or excluded from the collection, for safety purposes. “So the only things that I can think of that we definitely don’t include are like safety items, because we did get a few donations of like safety hats like hard hats and harness equipment and we’re like wait we don’t wanna be liable for this” (P4). Gas powered items were often excluded due to safety requirements for storage.
- **Excess wear or broken:** Items that arrived needed to be useable. This was related to the safety concerns mentioned above: “We want to make sure that things are in good shape, you know relatively good shape” (P20).
- **Maintenance or cleaning:** Items that required high maintenance were either excluded from the collection or often had an additional cost to pay for maintenance. The musical instrument libraries in public libraries did not include wind instruments in their collection due to the need to clean them for sanitation purposes. Other collections decided not to include specific types of kitchen equipment due to the risk of it coming back dirty. Tools that required consumables or replacement parts like sandpaper often included an added cost.
- **Expense:** Expensive items were often more valuable for the collection to sell to fundraise for collection maintenance or to buy less expensive items. Especially for the musical instrument collections, specific “fashionable” or easily re-sellable items such as electric guitars tended to be the ones that would go missing and were more useful to the organization as an item to sell for fundraising. Our gear libraries discussed how they didn’t include items like golf clubs or other gear that required extra memberships or added expenses to participate.
- **Oversize items:** Due to their own space constraints many collections excluded items that were oversized. “We’re not going to collect anything that’s overly large, it has to be able to

fit in somebody's vehicle and they have to move it themselves" (P5).

There was at times a mismatch between what was donated and what the collection needed. For items that were not suitable for the collection many of our participants (N=16) had methods for moving those items 'downstream' rather than throwing them out. The most common method was using the item for fundraising: *"If it's not really suitable, we will sell that, and you know get 80 or 100 bucks or so for it, which helps us buy a more suitable tool"* (P3). If they can't resell the item, they will give the item away to their community members or other charitable organizations: *"We allow our volunteers to have first crack [at picking items]"* (P1).

4.3.3 Iterating collection based on community. Our participants discussed how their collection changed over time and how they iterated it based on their community. *"I think it's just like very important to be flexible, because you never know what people will really like and what's going to be in circulation"* (P10). Many of our participants (N=10) only had informal methods of getting feedback that included asking individuals about their experience when they returned an item. *"When people return items, we always ask them like 'How was it? How well did it go?' so there's that kind of informal feedback"* (P14). A smaller number of participant (N=7) received formal feedback through methods such as surveys to members, or surveys that were included with the borrowed item.

Participants also used data to inform their collection (N=17), such as keeping track of high-request items or items where individuals were put on waitlists. For example one Library of Things discussed moving away from construction tools to more craft tools and entertainment due to what the community borrowed: *"I found that in [this location] our tools aren't as popular as the other locations"* (P4). Long waitlists made collections less convenient to use, so our participants made adjustments to their collection by either getting more of the item or shortening wait times with shorter lending periods. If wait-lists got too long then participants might just buy the item instead: *"They like the idea of the tool library, they would love to use it, but they just needed to get these things done"* (P1). To iterate on their collection participants (N=9) did community call outs for specific items: *"we get requests, and so we have a wish list on our website"* (P4). If the item did not come through a call out then they would often buy that item: *"If an item that people have requested has never been offered to us, we just go and buy it"* (P3).

4.4 Each type of collection requires new knowledge, training and skill sets

More than half of our participants (N=14) discussed speaking with other Library of Things projects before starting their own either through having *"conversations about managing rental systems"* (P13), or through online support groups such as Google groups for tool libraries – *"it's a phenomenal resource"* (P6). One of our participants worked at a traditional library before joining a Library of Things and described the benefits of being on support groups:

"I know for me personally I've learned a ton. Having worked in traditional libraries, like I said, we've always had non-traditional library items in almost every library I've worked in, so the concept wasn't new to me, but having a library that's dedicated to this has

really been interesting in communicating and connecting with other people who have already done this. It's worldwide so people are sharing in a Google group. You can post your questions there, [and] somebody from Hawaii or Denmark or wherever is going to respond". (P5).

Beyond speaking with and learning from other collections, developing a thing library required training staff, human resources, and new types of skills such as technicians or 'fixers'.

4.4.1 Training staff on collection. Participants who ran independent collections, such as the independent tool libraries or musical instrument libraries often had experience and expertise in the area of their collection. In contrast, in our interviews with participants who worked within the public library system, the musical instrument collection was outside of the area of expertise of their staff (i.e. library and information systems). One of the challenges in incorporating this new collection into the public library system was training staff on how to work with, explain, and provide information on musical instruments. Initially library staff felt *"a bit of trepidation at the beginning that there was going to be some expectation that they would [need to] know about the instruments"* (P12).

To support staff during this process teams had to create training material on the collection. Libraries created and sent *"a data sheet to all of our frontline staff and our branch so they knew all the details and can answer basic questions"* (P19). Having a central document helped ensure that the teams could explain the collection and lending expectations to patrons. One library had someone with musical instrument expertise come visit the library *"to talk to staff before we launched to show them all the instruments that we had, and just to get familiar with them"* (P20).

Though training started with how to manage the circulation of the collection, maintenance was often harder and ongoing. Our participants described how it was a challenge to *"train up staff to know how to evaluate damage on an instrument as opposed to a book, and how to make sure instruments are tuned. How do you train up people to tune various types of instruments? That's an ongoing process, even now, it is six years later and we're still training. We have so much stuff and so many people who don't work in our department all the time. So how do you have that sort of training implemented?"* (P21).

But there were also limits on how much training individuals in the library can be expected to participate in due to more clearly defined roles. *"We're in a unionized environment, we don't take volunteers, so it's not like we can get a volunteer from the community to help us accept the instruments. Also, there are very clear job classifications for people, so we had to be very careful about like what kind of work we assigned to different job classification schemes"* (P22).

Though training for a specific collection (musical instruments) was manageable for the libraries, the challenge would exponentially increase with the addition of different categories of items. As one of our participants summaries: *"If you're a library and you're adding another item, how do you maintain it, how do you explain it, how do you educate about it, how do you make processes? If you are [a music store] and you're renting out instruments, then you already have that expertise"* (P22).

4.4.2 Large amount of human resources required. To run a Library of Things requires a wide variety of roles, especially for independent libraries which required a lot of volunteer effort. Most of our

participants (N=14) with independent libraries relied on volunteers, and they discussed how this is a trend across the non-profit sector of Library of Things – “they’re almost all run by volunteers” (P5). Our participants recommended gathering “a network of volunteers” (P3), “gathering your allies” (P8), because without a critical mass of volunteer support the team gets “overwhelmed and burnt out” (P1).

“It’s not a solo job. The only two libraries I know of [that tried to do it solo], they did not succeed. They were like one or two people. Something happens, you have a health crisis, you move, [and it] all falls apart. I would say make sure you’ve got a group” (P3).

When the independent libraries started many of them recruited volunteers by seeing what their community could offer: “You know we’re trying to get this going, let us know if you want to help us [and] how you want to help us. Are you a marketer? Are you [a] fundraiser? Do you know anything about tools? So, people could sign up and register how they would like to volunteer with us” (P6).

At a certain point the collections found that they needed more structure and often hired a paid employee to oversee things: “You get to a point where you can’t just do stuff with the odd volunteer anymore. [You have to start] building an organizational infrastructure and volunteer coordinators. A big part of that is someone who is overseeing things, like an office manager and a project manager” (P3).

Though many volunteers had an interest or background in the collection, they still required training on how everything is organized and protocols for interacting with patrons during the lending process. “Volunteers are sort of the front face [of the library]. They run the counters, they’re the librarians, so we have to train them and have quite a rotating roster of librarians” (P3). For example, when volunteers were starting, they could be matched with a more experienced volunteer: “if someone was training, we would have them working with one of the seasoned volunteers” (P4). Volunteer recruitment and training were ongoing tasks due to the expected turnover of volunteers. “It’s a lot to ask for volunteers to be consistently there” (P16).

4.4.3 Maintenance technicians or ‘fixers’. All of our participants discussed maintenance as an ongoing challenge with tangible collections. Due to the often-donated collections, half of our participants (N=11) thought it was normal that items would occasionally break down, and all our participants found that the vast majority of patrons were respectful of the collection. Our participants discussed how consumer items are not built for constant use. Donated items included “consumer grade tools and equipment so that doesn’t necessarily speak to regular use and durability” (P1). Since most items were already on their second life, breakdowns were not unexpected: “Considering that most of our items are second-hand, they’ve already been used, and you know, unfortunately, that’s how it works. Especially nowadays things are not made to last” (P18).

Based on the challenges of donated goods and consumer grade items, maintenance was “the biggest challenge in keeping the service running. Things need replacing and there’s lots of maintenance” (P16). Maintenance occurred throughout the life of an object. For example, most donations had to be inspected by a technician to ensure they were in working order before going into the catalog: “when instruments come in, [the technician] inspects them, gets them ready, puts stickers on them with numbers, and all that kind of thing” (P9). Rather than preventative maintenance, most of our participants

put items into maintenance mode based on feedback from patrons returning items: “We track when a member brings back the tool and they report a problem. We track it for our fixer team so that when they come in, they have an easy job looking at this tool that [is] sitting in the in the tool hospital [...] so they can focus on the issue right away” (P1). The problem with reactive maintenance is that sometimes patrons would get frustrated when they took home an item and it didn’t work: “the biggest thing is when the devices aren’t up to the job” (P16). This is especially important because individuals using the items are likely novices: “This might be something somebody has never put their hands on before, like you can’t have a violin going out that somebody needs to tune themselves” (P12).

As a result, several of our participants were starting to build “maintenance plans for things that will need to be sharpened or oiled or cleaned or [to] make sure they’re still working” (P5). “It’s something that we are looking into – setting up a schedule, because we were so new and then all of a sudden now it’s kind of the time”. (P4). Items that needed a lot of maintenance or supplies came with extra maintenance costs embedded into their fee or on top of membership costs. “There’s a couple of tools we charge really minimal for but it’s not significant enough to call it a revenue stream because it’s like mostly just takes care of those tools. Pressure washers they break a lot [so] we asked for \$10 per reservation of pressure washers just to kind of keep those in working order” (P8).

To handle the maintenance work, almost all of our participants (N=21) had team members dedicated to maintenance with roles called technicians or “fixers”. For the musical instrument libraries (N=8) they had external contractors (technicians) who they would send the musical instruments out to, or who would come to the library to fix the instruments. “They require maintenance, especially the stringed instruments. They come back, people aren’t necessarily musicians and set the strings badly, tune the strings, this string snaps, they’ll be in the wrong order, you never know what you’re going to get, so we also have to hire a part-time technician who comes in” (P17). Repairing the instrument collection was a unique skillset that was difficult to teach to public library employees due to the variety of instruments: “It takes obviously a unique skill set to be able to repair instruments. Book repair is not that hard to teach someone, we can have people at any branch trained to help put a book back together when pages fall out” (P19).

In contrast to the public libraries who had contracted technicians for repair and maintenance, many participants in independent libraries had in-house volunteer “fixers” or “tool doctors” (N=14). These volunteers came in regularly and usually as a team so they could collaboratively problem solve and work to fix the items. These volunteers either worked reactively or proactively. Reactive fixers responded to issues brought up by patrons: “We mark things as in maintenance, we put it in the back room and then every Wednesday night we have three or four people who come in and they are volunteer fixers” (P3). The few proactive fixers would work on maintenance schedules, though this was much less common than reactive maintenance: “They get together regularly where they meet and they say, ‘Okay today we’re maintaining all the angle grinders so let’s go pull them off the shelf [and] let’s see if they work and are sharp’” (P6).

Due to the process of setting these items aside and volunteers fixing them within the space, these collections often needed ‘a fixer room’. For example, P8 stated that: “During our open hours, [the

fixers] just hang out back there and fix the broken tools, because there's always broken tools". Fixer volunteers tended to have backgrounds in engineering, tool use, construction, or were hobby fixers. The team relied on them for their expertise to "answer some of the more technical questions that maybe myself or other volunteers don't know about, because they're just like a lot of the retired engineers or retired contractors. We rely on them to tell us what's needed".

4.5 Manual intervention throughout the borrowing cycle

One of the greatest challenges our participants experienced was the amount of manual intervention that was needed throughout the borrowing cycle.

4.5.1 Library software and cataloguing 'things'. To catalogue items the majority of our participants used My Turn¹ (N=14), and one used Lend Engine². These two platforms were developed specifically to support Library of Things projects. The musical instrument libraries all used public library software (N=8), and the same one that is used to catalogue books and other traditional library materials.

My Turn was used by the independent collections we interviewed, and many of them discussed how it was the most common software used by these types of collections – "many tool libraries globally use My Turn" (P3). My Turn provided the collections with features such as a back-end for their catalogue (with useful categories for thing library collections), for checking out and returning items, and building automatic reports as well as reminders for patrons (such as delinquent items). On the front end – they also enabled patrons to purchase memberships, browse the collection online, and view their loans and renewals. For human resources, the software had scheduling features so teams could manage shifts. Our participants particularly valued the automatic reporting features that enabled them to see data such as memberships numbers and items borrowed, and being able to share that with their team "I love giving actual data" (P4).

To connect their catalogue on My Turn to individual items a few (N=3) used barcoded items, but the majority (N=10) wrote numbers on each item by hand ("just black magic marker with a number on everything" (P2)) or with a label maker (N=1). Though marking each item manually was accessible and easy, it also caused issues with maintaining the catalogue: "Volunteers use this software lot and change the inventory in wrong ways, things get checked out or things don't get returned, numbers get rubbed off the tools, so the inventory is a little skewed" (P8). This occurred especially with tools due to natural wear: ("you know you mark it [the number] on a shovel and people are holding the shovel with oily hands and it rubs off" (P8). Some of the collections in thing libraries were multiples of small items where making individual entries and numbering items wasn't useful such as with tennis balls ("we'll give you the tennis balls but it's not a certain one" (P14)) or screwdrivers ("we don't put individual numbers on screwdrivers" (P15)).

For public libraries they had teams specifically for cataloguing the collection, but thing collections were unique compared to the

traditional collection. A tangible item is "a little different than cataloguing a book that has an ISBN [number]. It doesn't have an author. [These are] some of the things that we normally catalogue things by" (P17). They also had to catalogue items with both enough and not too much specificity with consideration for what characteristics a user or patron might find important. "When you catalogue something you don't want to make the record so specific. You want to keep it general like 'nylon string guitar' so then it doesn't matter what kind of nylon string guitar they get. So how you classify and organize them so they're retrievable and broad enough so that they capture like a range of things. You have to balance that with your user who [might] want a very specific item" (P22). The instruments were also catalogued with items that were not individually tagged – "none of the instruments themselves have like a barcode on it" (P23). Instead, the case had a luggage tag on it, and the items within the case such as the instrument, tuners, and accessories were all untagged. This meant that librarians had to oversee and manage returns to ensure that everything was within the case.

4.5.2 High-touch collection. Most of our participants (N=21) described thing collections as requiring manual intervention throughout the borrowing cycle. Most membership registrations begin with identification (ID) checks, and –even for traditional libraries– accessing the instrument collection also required an ID check due to the relative high value of each item. For tool libraries this included liability waivers: "there's a waiver for the tools and there's a waiver for the workshop" (P1). For musical instruments, the process also included signing agreements that individuals are responsible for the instrument if lost or damaged.

Checking out and checking in items had to be done with a member of the collection team, rather than through automatic checkouts. This was to ensure that all parts of the item were there, and to check its condition to make sure it's safe to use. "They go through with the library staff that all the parts are in there, that everything's in good condition and looks good [...] and then, when it's returned, we go through a reverse process of checking that all the parts are there" (P17). The lack of self-checkouts added to the librarians' workload: "There's just more we touch with the instruments, much more than when someone passes a book through the book shoot [and] you don't even touch it, and then it goes to the automated handling machine, and it's all done. There's just so much more staff time involved [with instruments] because you can't use the self-checkout machine for it" (P23).

Due to limitations in storage, many of the musical instrument collections were not available on the circulation floor, and had to be requested through the circulation desk. This meant that librarians had to continually go back and forth from the front desk to the back storage: "We keep it behind the scenes. That's in part because of just not really having a great space on the floor to put them. You wouldn't be able to browse stuff here anyway" (P19).

4.5.3 Circulation management. Many of our participants (N=16) discussed the challenges of managing the circulation of items in the collection, and the ways the collection differed from book collections. The most difficult challenge was opening hours and when individuals could return tangible objects. Unlike traditional libraries with after-hours book drop slots, the tangible collections we interviewed could only accept returns during opening hours (N=23).

¹<https://myturn.com/>

²<https://www.lend-engine.com/>

Our independent collections often had limited hours in order to make efficient use of their volunteer and human resources (e.g. being open only a few days a week). But these limited hours made borrowing less convenient, and if an individual could not return an item on time, it would then be late and cause delays in the holds other members put on them. The most common request our participants received was for longer opening hours – but this felt unattainable: *“I wish we could be open more hours, but then we need more and more volunteers, so that limits us”* (P3). One participant we interviewed was trying to manage this challenge by offering hours as a fundraising goal: *“We wanted to open more hours, but we kind of needed more members to justify more hours. So, we said if we can get 120 new members this month, which is like a little more than double what we usually get this time of year, we will open up Sunday shifts, which is what most people want. It’s been nine days and we’re halfway there”* (P8).

Along with returning items during opening hours, all but one of our collections with multiple branches or locations required items to be returned to the same branch (N=7). This was due to objects like instruments being harder to transport than traditional objects like books: *“There was no way to safely transport the items between libraries, [so] they couldn’t be part of a regular delivery system”* (P23). For libraries with large networks this limits who can access the instrument collection: *“We were talking about trying to expand. Right now you can only pick up and drop off your instruments downtown at the big central library, so that doesn’t make it accessible”* (P22).



Figure 4: Non-uniform objects in a tool library defy library standards for cataloguing. Image courtesy of study participants who opted not to self-disclose.

4.5.4 Browsing, navigation, and retrieval. All of our participants (N=23) found cataloguing, sorting, and retrieving items from a tangible collection to be difficult. Compared to collections of books, with Libraries of Things *“the physical space is definitely a consideration. It takes up physical space. These are large items”* (P12). Due to the expense of space, thing collections often required an initial investment, or relied on inexpensive, under-used, spaces they were able to find. When asked why teams chose their current space, the most common reply was: *“The rent is cheap”* (P9). Finding space was often the *“most expensive part”* (P4) of running a thing collection due to the amount of items that they need to store, and yet *“every tool library would like their space to be bigger”* (P8). They described putting items anywhere they could find as: *“hanging from the ceiling”* (P6) or *“in every nook and cranny”* (P8), see Figure 4.

Space limitations impeded their ability to make the collection browsable. *“We’d love to have more space. We’re a little room full of stuff rather than a beautifully presented, inspiring shop”* (P16). *“It would be nice to have a bigger space [where] we can have more*

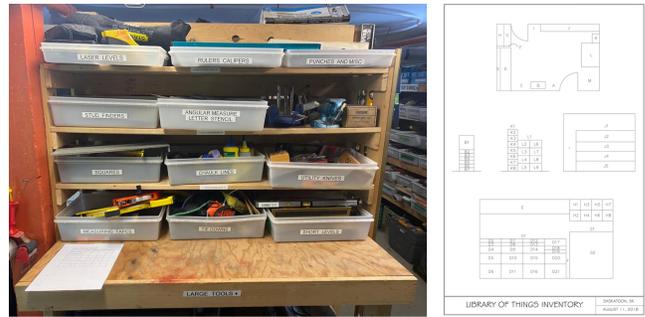


Figure 5: Navigating and retrieving objects in a library of things currently requires manual work-arounds and cognitively heavy ‘maps’. Image courtesy of study participants, (left) opted not to self-disclose, (right) Meg Dorwart of Library of Things YXE.

stuff and be organized, more browsable. Not like a bunch of stuff shoved in a drawer” (P4). All our participants had issues with *“stuff management”* (P8) — keeping the space clean. *“Cleaning up the shop — it’s the screw that keeps coming loose [...] it’s a hard one to stay on top of”* (P11). The main concern was not being able to find or locate items in the collection when they were requested by a patron. To manage this, our independent libraries had *“inventory management teams”* of volunteers that continually worked to keep the space organized: *“It’ll be a permanent task”* (P3).

There were a variety of ways of managing their space. Items were organized by category: *“the space is divided up - acoustic guitars are in one spot the corner, we have electric guitars on one wall, and we have the percussion table it’s overflowing with stuff”* (P9). Some organizations created visual *“maps”* of where items were that corresponded to labeled physical storage — *“we’ve just kind of coded the walls A, B, C, D. We have a volunteer now going through and making sure every item is in the right place”* (P2), see Figure 5. This was especially helpful for collections that had items of a wide variety of sizes — such as small items that had to be in drawers and larger items that had to be oversized shelves — where the category of item couldn’t dictate where it could be located.

5 OPPORTUNITIES AND CHALLENGES FOR HCI

Based on our study findings, we discuss next steps for Libraries of Things and HCI by addressing each challenge and using the insights from our interviews to develop research questions for future work. The ‘human touch’ and the communities these collections create are an incredibly important part of them, but in previous work collections that have automated or streamlined parts of their processes (such as the London Library of Things³), enabled members and volunteers to focus on activities that are valuable to them and genuinely community-building (such as workshops and events that help to further their mission) [7]. We use the *“How might we...?”* question structure to be purposefully broad [59]. Rather than suggesting a particular solution, we aim to first contribute the right

³<https://www.libraryofthings.co.uk/>

question from a deep understanding of the issues these collections are facing.

5.1 Providing expertise and instruction on tangible and embodied use of an item

Many of the individuals using items from a thing collection will be novices learning a new skill or trying something new. With the tool libraries, individuals working there often had a background related to the collection (such as experience with construction, tools, or hobbyist DIY) and could provide informal instruction or guidance based on what individuals wanted to do with the collection. For example, they could help decide which tool or techniques to choose for a specific task, or provide basic instruction on how to use the tool. In contrast, in the public library system, or in broader Library of Things collections, individuals are hired for other areas of expertise (such as library and information systems) and cannot take on expertise on every new collection. This training had to occur with new collections in ‘traditional’ libraries such as laptops [8, 52], and is similar to the challenges public libraries deal with when incorporating makerspaces – namely staffing, training librarians, and training patrons [88]. Previous work in HCI has aimed to crowdsource this information, such as the Roaming Objects platform [43], by enabling individuals to see what other patrons have used an object for. Patrons can upload feedback, photos of what they did with the tool, or suggestions to support other patrons who will use the same tool later [43]. Researchers are also increasingly exploring how we can provide augmented tutorials of embodied activities [39, 48, 70, 102, 127]. For example, systems such as MakeAware [121] and HowDIY [14], which aim to provide in-place tutorials on maker activities. These efforts to support making and learning from home have been accelerated by the increase in distance learning [125] and constraints of the pandemic [12, 22], and researchers could build upon this work to further support tangible collections. The research question for future work is: *“How can we design and provide interactive tutorials for individuals on using tangible objects, and the embodied activities involved in doing so, from home?”*

5.1.1 Next steps for HCI. to enable individuals to learn how to use an item from a thing collection from home include:

Automatically crowdsourcing “good” tutorials: In order for Libraries of Things to scale, and have more than one type of collection, there needs to be ways of teaching novices the tangible skills involved in using the collection without librarians having to become experts on each new item, such as how to play a guitar or the correct use of a hand tool. While books have standards for basic information – i.e. book summaries and publisher metadata – tangible objects would benefit from guides on how to get started. For example, how can Libraries of Things automatically leverage the vast amount of online tutorials on Instructables or similar platforms [74], but also without having to manually assess whether they are “good” tutorials.

Embedding tutorials within, or linking them to, physical objects: While previous work has crowdsourced experiences with tool library objects (such as user ratings and experiences using a tool) [43], how can we provide this type of information and link it to the object itself in a more tangible way? For example, previous

work such as Documented [40] enabled individuals to embed documentation into the physical design of 3D printed files using AR. For Libraries of Things, how can we add these links to pre-made items? Currently, libraries often have this link from the library side, but how can users more easily connect with information on the tangible object they have borrowed?

Designing tools for safety and sharing: Many of the tool libraries we interviewed expressed a desire to be part of the public library system, but also described barriers relating to safety. This was similarly found in previous work on makerspaces within libraries that require safety training, and investment from staff [88]. HCI research in this area has added items such as location beacons with informational displays in makerspaces [121], but there is a gap on how to provide this information within the objects itself [65] or through its physical affordances and “guardrails”. More fundamentally, how can we design interactive tools so that individuals can’t get hurt, i.e. so that individuals don’t need safety training, especially for shared spaces, borrowable objects, and self-learning.

5.2 Convenient borrowing and returning

Most Libraries of Things we interviewed have limited opening days and hours, which made borrowing and returning less convenient for users, and often added to the wait time on requested items. Currently, many traditional book libraries have RFID [114] or barcodes on items for self-checkouts and after-hours book slots, which enable individuals to help themselves and also drop off items when it is convenient for them, while also avoid delinquencies and late fees. To make borrowing more convenient, HCI researchers could explore how to expand the hours that an individual could pick up or return an item. For example, one area with initial explorations is the concept of smart lock containers such as ShareBox for peer-to-peer sharing [45, 76]. This is also an approach taken up by the London Library of Things, which has a very small collection (approximately 70 items per location) but smart lockers make the collection more convenient since it is accessible all the time [7]. HCI researchers could explore how we can further support larger collections of things when individual lockers are not possible, while also leveraging the recent focus in HCI on “contactless” pick-up and drop-offs accelerated by the COVID-19 pandemic [117]. The research question for future work is: *“How can we facilitate interaction with Library of Things through a self pick up and return process, at the user’s own convenience?”*

5.2.1 Next steps for HCI. to enable self pick-up and drop-off of tangible items includes:

Flexible smart lockers: Previous research on smart lockers for peer-to-peer or library-to-borrower sharing included examples that were designed for a small number of people [45, 76], or a relatively small collection [7]. Currently, there are flexible examples for systems such as smart luggage storage systems that leverage RFID cards [103] or facial recognition [87] to enable locker access. The next step for HCI is exploring how these interactions can scale to support larger collections, as well as protection for items that are not as uniform or as durable as luggage. To support librarians, there also needs to be considerations for how items are requested and transferred from the “warehouse” to the lockers, or whether

the collection is continuously stored in the same locker similar to the system at the London Library of Things [7].

Automatic ID check: Due to the cost of these types of collections compared to those of books, Library of Things have ID checks or the gathering of credit card information before items can be borrowed. By leveraging these types of systems, an individual could for example use their credit card to then open a connected locker for convenient borrowing and returning. Though the use of payment cards as an alternative to membership cards would support borrower identification and accountability, this might also hinder the accessibility of the collection. This is an important gap since accessibility is a central goal of these types of collections.

5.3 Tracking the status and maintenance of an item of parts

Library of Things collections create an added cognitive and manual workload for librarians due to the need to look over items before check out, and again at check-in, to make sure all parts are present, and that the item is in working order.

5.3.1 Maintenance. Maintenance is an ongoing issue for tangible collections and becomes even more of a burden because issues with maintenance need to be manually captured when items are returned through visual inspections, checklists, and discussions with patrons returning items. Our participants discussed how patrons felt frustrated with the collection when they took time to borrow an item and then brought it home and it did not work. This occurred when a previous patron did not report damage, breakage, or wear, and the collection team did not catch it upon return. In this case, an item will go back into the borrowing cycle damaged. To ensure that this does not happen it needs to be easier for patrons to report damage, for collections to track damage, and for damage to be automatically assessed (i.e. without manual visual inspections or checklists). For enabling patrons to report damage, previous work such as the Roaming Objects platform [43], included the ability to rate an item and provide feedback. Platforms such as this could be further extended to be incorporated directly into maintenance pipelines and automatic tracking once the item is returned. For example, participants could be directly probed for issues along with their star review. Computer vision can also be used for condition monitoring [6, 37], for example each time an item gets returned to compare it to its previous scan, and to help offload cognitive tasks from collection members (such as checklists, manual inspections, and testing). The research question for future work is: *“How can we create interactive systems that automatically capture or recognize the need for repair and/or maintenance?”*

5.3.2 Tracking an item of parts. Unlike books or other uniform packaging, collections of things can be difficult to physically label and catalogue (with varying shapes, materials, and surfaces). Our participants used a variety of ways to catalogue their collections from markers, to bar codes, to label makers, and each one had issues that required manual intervention. The usefulness of these current label standards is also limited. Some small multiples were not convenient to label: such as tennis balls or hoola hoops from the gear library, or the many items within these collections that come with sub-items. As a result, labels did not provide automatic

recognition of items when they were borrowed or returned. For example, if someone borrows a guitar, our participants highlighted that there would only be a label on the case, and every individual part of the ‘guitar’ (the guitar, the strap, the tuner, the pick, and any other accessories), would need to be manually checked over by a librarian. On the extreme end, when librarians are checking in a item such as a board game, with many tiny parts, this requires manually counting that each one is there and having the staff capabilities for doing so. The labelling and cataloguing difficulties that things collections face result in extra workload for the team working on the collection, who end up having to manage manual object inspections, and find and investigate lost items or records. These inspections also occur throughout the borrowing cycle: such as checking items before they go out, as well as checking items when they get returned. HCI researchers are increasingly exploring how we can recognize objects without visually inspecting them, such as recognizing items within a package [95], that could further support recognizing kits of parts in a Library of Things context. The research question for future work is: *“How can we create cataloguing and labelling systems that enable automated recognition of the tangible parts of borrowable things?”*

5.3.3 Next steps for HCI. to address these questions include eliminating the need for manual checks:

Recognizing items without labels: Many tangible items in collections contain sub-items or parts that are not labelled. For example, board games do not have labels on each individual piece, yet need to be manually counted at check out and check in. Another issue is how with small multiples users check out a type of item rather than a specific object. For example, checking out a tennis ball as a category of items, and grabbing one from a pile, rather than checking out an individual and specific tennis ball. As a result, in comparison to books which have one label for each book item, Library of Things demand manual checks from librarians to confirm that what was returned matches what was checked out.

Recognizing changes to an item: In future work, researchers should explore how an item can be flagged for servicing without requiring a manual check or a librarian testing the item. For example, how user reviews can be automatically captured as part of the check-in process (such as they are in platforms for other commercial sharing economy services) and incorporated into servicing cycles. For tools and other shared items they can be better designed and created to support sharing, for example, when designing tools for makerspaces or Libraries of Things, it would be useful for HCI researchers to explore how an item or tool could recognize its own functioning or non-functioning status. Another avenue would be exploring how the system could automatically recognize changes in the object during the check-out and check-in process – such as comparing before and after images, and completing the manual part check tasks that create an added burden to the librarians’ workload.

5.4 Search and retrieval of tangible collections of non-uniform objects

Cataloguing and retrieving non-uniform tangible objects in a collection is difficult and an ongoing challenge. This is compounded by the variety of categories of items within each Library of Things, and the different ways that they organize their item categories

(such as by size or use) within their space. Most of the work in libraries within HCI resides within this area on navigation, search, and retrieval [26, 61, 93, 101, 126], but the limitation is that identifying, organizing, and maintaining relatively uniform objects, such as books with similar metadata categories, and topics that fit into systems such as the Dewey Decimal System, is a very different task than cataloguing non-uniform objects of varying categories, materials, sizes, and storage. Previous work has explored systems for finding items within storage [44, 67, 73, 80, 118], finding items within indoor spaces or rooms [53, 94, 113], and recognizing misplaced items [101, 129]. With uniform books these can include camera vision for book spine searches or Internet of Things (IoT) shelving, but these types of solutions aren't possible with objects of varying sizes, weight, and labeling standards. The research question for future work is: **“How can we support the navigation, retrieval and organization of non-uniform items?”**

5.4.1 Next steps for HCI. to address this question include removing the upkeep and workload of manually organizing a diverse collection:

Moving from category hierarchies to digital search: Library systems and catalogues, similar to file management systems, make use of hierarchies and categories for book discovery, navigation, and retrieval [34]. These relative systems, such as the Dewey Decimal System, work well for uniform objects such as books, but become more complicated with objects that are diverse and likely have different metadata categories or fields. Next steps would involve moving the cognitive workload of organization and navigation from the individual to the system, and making tangible user interfaces and tools that can search and find items for us. Previous work has focused on small scale search of tangible items, such as using computer vision to remember and later find items within drawers [44, 67, 73, 80, 118]. The aim of these systems is that rather than having to organize items by category hierarchies, we can place any item where it fits based on physical space constraints (such as placing small items in drawers and large items in closets) and the cognitive workload of remembering, navigating and finding items is offloaded from the librarian onto the system. For example, imagine shelving where any item could be placed on any shelf, and the system would direct you on where to find it. HCI researchers have explored similar systems with uniform smart rectangular file folders and shelving [62], but the next step is, for example, how shelving could recognize non-uniform objects of different shapes and sizes.

5.5 Creating awareness and connecting collections

Many of our participants highlighted the difficulties of encouraging behavioural change from buying to borrowing, and the challenge of getting embedded and known within a community. Future work could explore how organizations could support each other through mutually beneficial collaborations. For example, Light et al. [77] proposed a ‘mesh’ or ‘platform-of-platforms’ to further support sharing economy initiatives. They proposed the concept primarily to support trust in a network, but the concept could be further studied to support discovery as well. Such as being able to search

multiple thing libraries for an item, rather than having individual memberships to each one, and adding to the convenience and potential frequency of sharing. We could also encourage greater awareness by working towards solutions that will support ‘Library of Things’ collections within public libraries. The research question for future work is: **“How can we support the social awareness of Library of Things and make interactive ‘search and discovery’ more convenient?”**

5.5.1 Next steps for HCI. to help individuals find items they want to borrow:

Moving from individual collections to public libraries: Other than a few pilot projects, most Library of Things collections exist outside of the public library system. These private membership ‘libraries’ often carry one type of collection (for example, tools), which creates issues when an individual just wants to use the collection for a specific task or project, and afterwards no-longer needs their membership. The benefit of scaling the ability of public libraries to house diverse Library of Things collections is that individuals can use current infrastructures (such as library cards, associations with public libraries and borrowing, etc) to access things, but also to borrow a broad range of items as the need arises, rather than having multiple memberships to different collections.

A ‘Platform of Platforms’: Another approach is for HCI researchers to work to support a ‘Platform of Platforms’ approach [77], that would enable individuals to borrow from diverse collections – such as private tool libraries, gear libraries, musical instrument libraries, etc. For example, instead of having to search for and find an individual collection, being able to search for an item on a ‘Platform of Platforms’ and be able to borrow from one starting or access point, with one membership for all.

5.6 Balancing tensions between convenience and values

Our study showed that many of the independent collections started from value-driven motivations for sustainability and access. However, to gain a critical mass of users, these services will need to be convenient (i.e. as easy or easier than buying the item) [3] as possible. Design tools such as the Sharing Economy Design Cards⁴ [41] could help refocus teams on user experience and convenience, as well as the increase in data from tools like My Turn, which was already starting to be leveraged among our participants. The benefits of using data has also been highlighted in previous research on the London Library of Things [7]. By only providing their 70 top requested items (rather than a larger collection) they were able to focus their efforts on making the experience of borrowing those 70 items as convenient as possible [7]. Though many of our participants were starting to use data, and iterating their collection based on requests and demand, many of the collections felt stuck on qualitative feedback problems, like requests for longer opening hours, due to resource limitations. By unpacking some of their main challenges here, our aim is that researchers in future work will be able to provide possible solutions that might address their challenges in ways that also consider the limited resources of many of these independent libraries.

⁴<https://www.sharingeconomy.cards/>

6 CONCLUSION

In this paper, we explored the concept of ‘Libraries of Things’ from an HCI perspective, and discuss how communities are building collections of non-uniform tangible objects that can help support social, financial, and ecological sustainability by making rarely used items accessible for sharing. Through our qualitative user study with 23 participants, from three countries, running a variety of Library of Things collections, we were able to better understand the challenges and gaps where technology researchers could work to help support their processes. Our findings show that these collections enable public members to borrow communal objects rather than buy their own, which reduces the financial cost of using an item, extends the use of each item, and provides access to the community. At the same time, many of these collections deal with challenges in managing and maintaining their collection. Their main challenges included: changing behaviours from buying to sharing, supporting novices in using the collection, iterating to find the characteristics that make an item shareable, the new skills required with each collection, and the manual labour involved in managing the collection. In our discussion, we provide next steps for HCI and the CHI community around these grand challenges or gaps through 5 design opportunities. This call-for-action agenda includes research questions for future work in each area where technology can help support their skill-sharing, self-borrowing, repair recognition, cataloguing ‘things’, non-uniform inventory, public-awareness, and sustainability, in addition to all the tensions between these areas where technological intervention might not be the answer. Overall, this paper aims to provide an understanding of the constraints and challenges that these community-based organizations face, and the areas that could use further automation and support so that these sharing behaviours can be convenient, scalable, supported with technology where needed, and more broadly adopted.

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