

Article

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Internet of things (IoT) and its application for sustainable library practices: a narrative review of literature

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Abstract

The article synthesizes literature on the application of the Internet of Things (IoT) for sustainable practices. To achieve this, the article first found out what is known about the concept of IoT in libraries and examined the relationship between IoT and the three pillars of (economic, social, and environmental) sustainability, as well as the challenges of IoT application for sustainable library practices. A narrative review design was adopted for the study, with Scopus, EBSCOhost, ProQuest, and ACM searched for relevant literature. Multiple searches were made across these databases using themes that were combined with Boolean operators AND and OR. The inclusion and exclusion criteria used for the review were based on publication source, language, and years of publication. The review found that IoT applications in libraries enhance library operations, users' experiences, and sustainability outcomes. The application of IoT in libraries was seen to impact the economic, social, and environmental dimensions of sustainability in libraries. However, these applications are challenged by factors including the high cost involved in application, lack of skilled manpower, privacy and security issues, and lack of training programs.

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1. Introduction

The current industrial revolution has fundamentally altered workplace practices and coerced institutions and organizations to leverage on emerging technologies as a stride towards efficiency and effectiveness, with the ultimate goal of ensuring sustainability. The concept of sustainability though not new, gained massive popularity in the wake of the sustainable development goals. It simply implies an ability to meet present needs without compromising those of the future generations. Sustainability is the establishment of social, environmental, and economic conditions that support human health and well-being as well as the health of

the natural world for both the present and future generations (Jochumsen et al., 2022). The goal of sustainability is to improve or enhance the well-being of humans within the confines of the carrying capacity of the Earth's supporting ecosystem (The International Union for Conservation of Nature in Singh and Mishra, 2019). Activities carried out in order to improve the standard of living for humans without straining the natural resources within the ecosystem is thus considered as sustainable practices.

Sustainable practice is the eco-friendly tactic that organizations adopt to lessen their reliance on fossil fuels, cut carbon emissions, and encourage the responsible use of renewable energy sources (Kem-Laurin, 2012) or natural resources, without compromising their availability for future use. This underscores the need to adopt appropriate production and consumption practices that fully align with the natural cycles of the earth (Mensah & Ricart Casadevall (2019). While all stakeholders are expected to contribute to sustainable development through sustainable practices, libraries, as key developmental stakeholders, must transition from conventional practices to sustainable ones (Igbinovia, 2016). Sustainable practices in libraries encompass activities, routines and services carried out in the library to meet its current needs in an eco-friendly manner. It is libraries effort to create a sustainable future and they seem to be taking a more practical approach in doing so (Jochumsen et al., 2022).

Consequent to the aforementioned, the American Library Association (ALA) has projected libraries' call to action for sustainability by addressing workplace practices in libraries through several resolutions, including that of achieving carbon neutrality (ALA, 2022). The Association stressed that sustainability should be a core value for librarianship, reflected in their practices that are environmentally sound, economically feasible, and socially equitable. This is the underlying principle of the tripartite dimension of sustainability, otherwise referred to as the three fundamental pillars of sustainable development (Taylor, 2016). This classifies the global sustainable agenda into three broad categories of social, economic, and environmental sustainability (Igbinovia, 2022). These three pillars of sustainability are relevant in resolving issues in life and raising living standards in the social, economic, and environmental dimensions (Igbinovia, 2023). Studies like that of Purvis et al. (2019) have assented to this unbundling of sustainability in this manner. As such, a robust examination of sustainable library practices in libraries is expected to address the issue from these three domains. In the wake of the current technological dispensation, libraries are adopting emerging technologies like the Internet of Things (IoT) to achieve sustainability.

Emerging technologies like IoT have been considered as an enabler and a panacea for sustainability practices in libraries (Bakare, 2023). IoT is the connection of physical devices over the Internet to communicate with each other and perform certain tasks without human intervention (Purnik, 2024). IoT works by the principle of the interconnection of everyday devices in the libraries, making the library smarter while addressing pertinent issues around sustainability. By implication, the application of IoT in libraries is expected to produce economic efficiency defined by the effective and efficient utilization of library resources

without straining the future availability of such resources. It is also expected to solve environmental challenges, which have been heightened by globalization, and stimulate the social connectedness of people through the library's core values of equality, diversity, and inclusion. There have been several scholarly investigations on the application of IoT in libraries (Ahmed & Abdulateef, 2022; Asim et al., 2022; Kumar, 2023), but there seems to be a gap in how such applications stimulate sustainable library practices, particularly from the lens of sustainability dimensions. This narrative review, therefore, explores how IoT will enhance sustainable library practices through the three fundamental pillars of sustainability (economic, social, and environmental sustainability). Consequently, the objectives of the study are to:

1. find out what is known in the literature on the concept of IoT in libraries;
2. examine the relationship between IoT and economic sustainability in libraries;
3. examine the relationship between IoT and social sustainability in libraries;
4. examine the relationship between IoT and environmental sustainability in libraries, and
5. find out the challenges of IoT applications for sustainable library practices.

2. Methodology

The study adopted a narrative review design to comprehensively synthesise existing literature on IoT applications for sustainable library practices. This type of review, though non-systematic, allows the researchers to describe what is known about IoT and sustainable library practices through a subjective examination and critique of literature, synthesizing multiple points of view to provide an overall summary (Sukhera, 2022). To retrieve potentially relevant literature for the review, electronic databases like Scopus, EBSCOhost, ProQuest, and ACM were searched. The choice of these databases was made either due to their relevance to the subject matter or their generality. Google Scholar was consulted as a complementary source for relevant literature not captured by the identified databases. Multiple searches were made on the databases using a combination of keywords or themes such as "Internet of Things," "IoT," "smart devices," "sustainable library practices," "economic sustainability," "social sustainability," "environmental sustainability," and "library practices." These keywords were combined over multiple search strings using the Boolean operators of AND and OR. This optimizes search results, maintaining the norm of a review study (Andrikopoulou et al., 2022).

The inclusion and exclusion criteria considered for the study were based on publication source, language, and years of publication. For the publication source, articles in journals, books, book chapters, and conference proceedings were considered for the study; exclusion was made for articles in preprints, blogs, and editorials. For language, only articles published in English or for which an English version was available were included for the study; exclusion was made for articles published in languages other than English. For years of

publication, articles published between 2015 and 2025 (within a 10-year time frame) were included for the review; prior articles were excluded. At the screening stage, the authors first removed duplicated records retrieved from across the various databases. Thereafter, the titles and abstracts of the retrieved articles were screened for relevance, removing records that do not seem to address the topic. Full texts of potentially relevant records were assessed by the authors to determine those that meet the inclusion criteria and address the variables of the review. The selected records were analyzed by identifying key themes and concepts relating to the review and identifying patterns connecting variables of interest based on the review's objectives.

3. Results

The studies included for the review after the screening process were reviewed by the authors to generate relevant themes, identify concepts, and show relationships between concepts. Figure 1 is a visual representation of the main themes or concepts generated from the studies and presented based on the review's objectives. It reveals the place of relevance of IoT in library operations and how IoT technologies can impact the three pillars of sustainability towards improving sustainable library practices. The studies also show some potential challenges of IoT application for sustainable library practices.

3.1 Concept of Internet of Things in libraries

The current technological revolution birthed emerging technologies that are transforming workplace practices and redefining the pattern of organizational efficiency in institutions, including libraries. One of such technologies that have fully penetrated libraries is the IoT, which springs from the understanding that machines or physical objects can be connected and working as a system to achieve set goal(s). Rana and Gohil (2021) defined IoT as the utilization of systems and devices that are intelligently connected to acquire data collected by actuators and embedded sensors in machines and other physical items. In understanding the concept of IoT and describing its scope and functionality, several related terms have emerged, like the Internet of Everything, Internet of All Things, Web of Things, or Internet of Smart Things. The goal is to adapt to users' needs and enable automated functions that make everyday activities easier and more convenient (Deshpande & Sajana, 2020). This underscores the potential of IoT to enhance ease and convenience in library activities.

The application of IoT in libraries minimizes human intervention, save time and cost, enhances self-services with high level of convenience (Igbinovia (2021). The author noted that IoT can be applied in the security of library resources, enables manual proximity triggers that facilitates self-check-out and stock-taking in libraries, and to alert library patrons of the availability of library space and resources. This suggests that IoT is essential in creating a smart library, ensuring efficiency in service operations, stimulate positive users' experience and ultimately foster the actualization of the library's objectives. King (2018) affirmed that IoT helps in the smart control of temperature within the library by using a smartphone app

to adjust the cooling, heating and lighting system. For instance, RFID as an IoT technology, monitor or track information resources as a security measure. In addition, IoT reinforces library statistics by collecting library usage data, keeping record of number of visits, resources consulted, and library space utilization, which helps to make strategic decision towards providing better service delivery.

Hoy (2015) considered what IoT portends for libraries and referred to an OCLC survey that listed ways with which IoT can be integrated into library practices to include inventory control, mobile payments, ticketing and event registration, climate and room configuration, accessibility, and way-finding and mobile reference. IoT can revolutionize inventory management in libraries using (RFID tags and automated shelving systems, enhance environmental monitoring sensors and improve user experience through personalized notifications and interactive spaces (Adewojo & Monjolaoluwa, 2025). This confirms that IoT enhances the overall experience of library users through personalized services, enhanced accessibility and convenience, an interactive and engaging environment, improved resource management, and enhanced security and comfort.

While Pujar and Satyanarayana (2015) hinted at the potential of IoT to enhance the smartness of library buildings and the connectivity of their systems, it also provides information literacy through self-guided virtual tours of the library, helps with collection management in terms of charging and discharging, and enhances access to library resources. It provides information literacy through self-guided virtual tours of the library and helps with collection management in terms of charging and discharging. In integrating data from several connected devices, IoT enhances automation of library tasks and provides data on users' interaction with the physical library space, which can be a reference point for improving service experience (Hahn, 2017). Also, the application of IoT in libraries is demonstrated in the installation of sensors on books for easy retrieval and theft management (Anurag et al., 2025). IoT helps in theft management in libraries through the theft detection system, tracks the movement of library resources even when they are outside the library, provides a smart circulation system, prevents fire outbreaks through the fire detection system, reinforces library security through smart doors and locks, automatically notifies users of new arrivals, and facilitates self-guided virtual tours. From the aforementioned, it can be established that IoT is a technological innovation with the capacity to revamp library structure, operations, and management. While the adoption of IoT gradually infiltrates libraries, and their adoption of it is progressive and systematic, it opens up libraries to several possibilities, including the implementation of sustainable practices.

3.2 Internet of Things and Economic Sustainability in Libraries

The concept of economic sustainability connotes an organization's capacity to make immediate profit or gains without compromising future profitability. According to Elkington in Elsayy & Youssef (2023), economic sustainability often refers to the organization's long-term profitability while taking into account its social and environmental implications.

Although this concept seems squarely applicable to financial or profit-oriented organizations, it can be applied in the context of other organizations in line with their core mission statement. For instance, it is established that libraries exist mainly to provide resources and services that meet the information needs of their users. Doing this in the most cost-effective manner portrays the idea of economic sustainability in libraries. According to Kamińska (2022), one of the goals of economic sustainability in libraries is to ensure cheap and easy access to information. Thus, an IoT application for economic sustainability in libraries implies the use of IoT for cost effectiveness in library operations.

One of the vital relevance of IoT in library operations is cost savings (Asim et al., 2022), like saving money on human labor (Dongare, 2022) and providing digital access, which, according to Talikoti (2023), reduces the cost of distribution and eliminates the need to pay for the storage and delivery of printed resources. IoT offers a lot of potential for libraries, which translates into executing library operations with relatively low cost in terms of money, time, and human resources. Li in Asim et al. (2022) asserted that IoT can help with self-borrowing and self-returning, smart inventory management, intelligent search, and the integration of information systems and books. This could reduce human efforts and, by extension, a lesser workforce, which invariably saves costs in getting more personnel in the library. While financial constraints hinder the implementation of IoT in libraries (Cheung et al., 2023), it could become more economical for libraries in the long run.

IoT technologies could help in the recycling of different resources (Qiu et al., 2019), which have the potential of converting wastes or materials without significant value to a new product that is valuable to the library. This saves the cost of purchasing such a new product, exemplifying the relevance of IoT applications for economic sustainability in libraries. Nižetić et al. (2020) further stressed that IoT applications minimize resource utilization (raw materials and energy). This implies that in minimizing the use of raw materials and energy, IoT would be contributing to economic sustainability in libraries. By monitoring the flow of materials on library shelves, within and outside the library building, as well as the status of those materials (loan, return, and technical operations), IoT aids the management of financial and material resources (Ahmed & Abdulateef, 2022). IoT devices are able to monitor the use of resources like chemicals, raw materials, and water. This information can optimize resource allocation and guide sustainable behaviors (Ross, 2023). IoT makes it possible to track resource usage in real-time, which helps stakeholders make wise decisions (Saiful et al., 2024), like financial decisions.

Also, IoT averts occurrences that could have serious financial implications on libraries reinforcing their roles in ensuring economic sustainability. Bhoir and Shivarama (2022) noted that IoT enhances theft management through its robust security mechanisms, and early detection and prevention of fire incidence. Thus IoT serves an economic good as both incidences are capable of undermining the economic wellbeing of the library. Although there is a dearth of studies showing a direct link IoT applications and economic sustainability in

libraries, there are indicators that IoT when applied in libraries minimizes cost of operations and enhances 'profitability'. This becomes a springboard for launching a robust investigation on how emerging technologies like IoT enhances library's economic sustainability particularly in terms of minimizing operational cost and enhancing profit-returns in a way that doesn't compromise its future.

3.3 Internet of Things and Social Sustainability in Libraries

Libraries are generally considered a social and learning space (Kim & Yang, 2022), an inclusive space (Dahake et al., 2024), and a safe place (Cox, 2023). This implies that libraries bring together people bound by common affinity, with the goal of meeting their needs and promoting their well-being. As such, the resources, services, and personnel in libraries act as a system to ensure that library users receive an excellent user experience and the satisfaction of their information needs that contributes to their overall well-being. This is the underlying concept of sustainability, particularly social sustainability.

Social sustainability is the process of identifying and controlling the good and negative effects that organizations, processes, systems, and activities have on individuals and social life (Balaman, 2019). Social equality, well-being, safety, creating sustainable spaces and balance across quality of life metrics are considered aspects of social sustainability (Ånestad et al., 20253). Addressing the well-being of people and/or the society is a critical pointer towards social sustainability (Swartz et al., 2018). The provision of fair and equal access to information in order to enable an informed and healthy society is the goal of social sustainability (Kamińska, 2022). However, the difficulty in quantifying social sustainability accounts for it receiving the least research and scholarly attention when compared to economic and environmental sustainabilities (Balaman, 2019). This review attempts to strengthen scholarly discourse around social sustainability in the library context, particularly from the lens of IoT.

Libraries, through information provision, promote social sustainability by ensuring equitable information provision, social inclusion, social cohesion, bridging the digital divide, providing lifelong learning, and community building, among others (Panda & Das, 2022). This was corroborated by Engström and Rivano Eckerdal (2019) when they averred that libraries as social advocates promote social sustainability through social cohesion or social inclusion, enhancing community building and social capital. While libraries are adopting emerging technologies across their activities and services, it is pertinent to consider how IoT as an emerging technology can help them promote social sustainability.

The IoT helps in the organization of public space (Tokareva et al., 2018) for better interactivity and social inclusion. Libraries can use IoT to improve their services and patrons' library experiences by gaining users' trust in them, educating them about data security and privacy, and providing the necessary infrastructure and training. This improved service is sine qua non to improving users' well-being through equitable and quality information access and lifelong training. According to Hadi (2022), IoT may help libraries by optimizing space use

and enhancing the visitor experience. The author added that IoT would afford librarians more time, which they can devote to other activities that require human ingenuity. Librarians could devote such time to offering better social services in terms of addressing the challenge of inequality and bridging the information and digital divide.

Due to the automation of several repetitive home tasks, the liberation of free time, and the provision of previously unattainable opportunities, IoT helps to improve quality of life (Tokareva et al., 2018). IoT-enabled information literacy programs, virtual tours of the library, and personalized services could enhance the experience and satisfaction of their patrons. According to Bhoir and Shivarama (2022), IoT can help libraries by providing a self-guided virtual tour of the space. Installing wireless guideposts at different library sections is necessary to do this. Visitors' mobile phones will begin playing a video or audio that gives them more details about a particular library location and outlines the best ways to use its resources as soon as they get to that area.

According to Ahmed and Abdulateef (2022), IoT enhances users' experience by monitoring the usage pattern in order to optimize the facilities of libraries by enabling the remote reservation of reading space and meeting rooms and monitoring the availability of reading tables. From the assertion of Nižetić et al. (2020), IoT applications can enhance effective networking and communications among people. This enhances connection among people and brings about cohesion for peaceful coexistence.

From the empirical investigation of Kumar (2023), students perceived IoT to support remote learning, improve service efficiency, and enhance convenience in the use of the library. This reflects the potential of IoT to strengthen the social sustainability of libraries by improving the overall user's experience. IoT provides personalized care to users, a user-friendly navigation system, and enhanced user satisfaction and supports the growing needs of users. The Orlando Public Library's BluuBeam application shows the use of IoT in libraries, which assists users in finding resources and using their context queue to increase their level of interest. BluuBeam sends location triggers to mobile devices (Qin, 2018). Features of the application include its high context search utility, conceptual simplicity, and ease of user interpretation. It allows personalized service delivery and better user engagement through improved access to information services, contributing to social sustainability.

3.4 Internet of Things and Environmental Sustainability in Libraries

Environmental sustainability, as one of the tripartite dimensions of sustainability, entails the efficient and reasonable consumption of natural resources to avoid depletion that erodes such resources from existence or the use of such resources in a responsible manner that causes no harm to the environment. This implies the need to protect natural resources and the ecosystem in a bid to guarantee quality health and well-being both now and in the future (The Sphera's Editorial Team in Igbinoia, 2022). In the context of library practice, environmental sustainability is the responsible utilization of natural resources (and their by-

products) to fulfill the library's current needs without compromising the library's ability to meet its future needs and the responsible utilization of the library's resources and disposal of its waste without causing harm to its environment. This section examines how IoT could potentially enhance environmental sustainability in libraries to ensure sustainable development.

In examining the potential application of IoT for sustainability, Okot et al. (2023) strongly showed that the implementation of IoT devices presents significant promise for bolstering sustainability initiatives in several industries. In terms of water conservation, IoT devices can efficiently track water usage in home and business environments and instantly alert users when water levels are low or when water is being wasted. IoT devices provide the ability to measure and monitor the usage of renewable energy sources, like solar, wind, and hydroelectric power, allowing users to manage their energy consumption. IoT devices can facilitate trash management by keeping track of garbage levels and coming up with plans to reduce waste production while encouraging recycling. IoT devices can quickly identify dangerously high pollution levels in the air and notify users. By the same principle and approach, and in the context of library practices, IoT will enhance the efficiency in the management of waste, as well as water and energy consumption. Further on how IoT optimizes waste management, Ross (2023) averred that IoT enables the deployment of smart bins equipped with sensors to signal when they are full for efficient waste collection routes, minimizing unnecessary pickups, reducing fuel consumption, and lowering emissions.

When the study of Saravanan et al. (2022) is applied to the library context, it can be extrapolated that IoT could help in reducing energy consumption and enhance the use of renewable energy sources. By implication, IoT reduction of energy consumption in a library is made possible through the smart control of library appliances and electronics. From the assertion of Saiful et al. (2024), IoT can enable environmental monitoring by monitoring the quality of air and water as well as tracking biodiversity in libraries. The role of IoT in environmental monitoring was reinforced by Ahmed and Abdulateef (2022) when they affirmed that IoT enables environmental monitoring in libraries by automatically detecting fire presence, activating ventilation and cooling systems using a heat sensor, and automatically activating lighting based on necessity and energy conservation in libraries. The results from the empirical investigation of Kumar (2023) revealed that a majority (92.4%) of the study's participants who are students from the university under investigation believe that IoT can help conserve energy and aids efficiency in water consumption in the university library.

3.5 Challenges of IoT Application to Sustainable Library Practices

The application of IoT for sustainable library practices has not yet attained its full potential. While some libraries are gradually and consistently showing commitment towards its implementation, other libraries are still at the level of understanding and embracing the idea and merely considering its adoption. However, for libraries to optimally implement and

maximize the full potential of IoT, certain issues that act as challenges to its successful application should be addressed. This section of the review, therefore, examines some of the challenges that libraries could possibly encounter in applying IoT in library operations and service delivery.

The application of IoT in ensuring sustainable library practices is hinged on the availability of robust institutional factors like technological infrastructure, related policy, and requisite technical skills by employees. Thus, their unavailability in most libraries challenges their successful implementation and application of IoT to library practices. The findings of Shahzad et al. (2024)'s investigation revealed that obstacles to the successful adoption of IoT applications in university libraries included lack of technical infrastructure, security and privacy concerns, a lack of technological skills, and the absence of policy and strategic planning.

Hoy (2015) noted that the more devices are connected, the greater the risk or likelihood of a data breach, which could cause harm to the systems, resources, and people. This corroborates Massis (2016), who averred that IoT applications are prone to privacy and security challenges as a result of possible hacks due to the vulnerability of networks. This was emphasized by Ram et al. (2023) in their article as a demerit of IoT applications in libraries. The authors opined that this application creates an avenue for possible data security breaches resulting in unauthorized access, violation of privacy, and vulnerability of systems and networks.

Cybercriminals can take advantage of the vulnerabilities in IoT devices, operating systems, or software to obtain data that is kept on varieties of IoT devices, including mobile smartphones (Liang & Chen, 2018). The authors further noted that there are significant organizational, technological, and financial costs associated with IoT adoption. The infrastructure needs high levels of availability, scalability, security, and dependability, all of which need a large amount of computer power. Consequently, some libraries are not equipped financially or technically to deploy IoT, and those that have some sort of IoT application face the risk of data breach and leak, which becomes a challenge for IoT-enabled smart libraries. Before libraries deploy IoT, they must consider challenging issues regarding privacy and security of users' data, as systems and networks involved in IoT applications are prone to hacking and data sharing with third parties (Uganya et al., 2021). Moreover, libraries are challenged with the high cost associated with investing in IoT technologies in terms of skilled manpower, money, and time (Khan et al., 2025). Other possible challenges in the application of IoT in libraries to include weak technological and technical design, lack of experience and skills, and difficulty in implementing training programs for beneficiaries (Ahmed & Abdulateef, 2022). These challenges differ across libraries, and must be addressed for libraries to successfully implement and optimize the potentials of IoT in libraries.

4. Conclusion

Libraries of all types are striving to maintain a place of relevance in the future amidst alternative information sources. They have adopted IoT in ensuring efficiency in information service delivery. The ideology behind the IoT is that physical things within the library can work together as a system with the aim of stimulating efficiency and effectiveness in library practices. Its application is capable of ensuring that libraries are sustainable, that is, they do not only fulfill their objectives in grandeur but also retain in them sufficient capacity to actualize future expectations of them.

Across the tripartite dimensions of sustainability, IoT application has proven to enhance the library's practice of information resource and service provision in an eco-friendly manner, taking into cognizance the social well-being of all stakeholders and ensuring that resources are efficiently utilized without future strain. Regardless of the immense benefits of its application, IoT, like most emerging technologies, experiences challenges in its infiltration and spread across the library system. Addressing these challenges will determine the success of its implementation and the extent to which IoT will enhance economic, social, and environmental sustainability in libraries.

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