

Robotic Technology, Artificial Intelligence and the 4IR Libraries

Current Topics in Library and Information Practice

Robotic Technology, Artificial Intelligence and the 4IR Libraries

Edited by

Adeyinka Tella and Omwoyo Bosire Onyancha

ISBN 978-3-11-117461-7

e-ISBN (PDF) 978-3-11-117698-7 e-ISBN (EPUB) 978-3-11-117754-0 ISSN 2191-2742

Library of Congress Control Number: 2024944104

Bibliographic information published by the Deutsche Nationalbibliothek The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available on the internet at <http://dnb.dnb.de>.

© 2025 Walter de Gruyter GmbH, Berlin/Boston, Genthiner Straße 13, 10785 Berlin Typesetting: Integra Software Services Pvt. Ltd.

Printing and binding: CPI books GmbH, Leck

www.degruyter.com

Questions about General Product Safety Regulation: productsafety@degruyterbrill.com

Contents

The Authors IX

Lorette Jacobs

Chapter 1

Internet of Things (IoT)-based Smart Libraries: Opportunities and Advances 1

Amos Orenyi Bajeh, Adeyinka Tella

Chapter 2

Internet of (Robotic) Things in Library System Automation 21

Tom Kwanya

Chapter 3

Enhancing the Findability of Library Information Resources Using the Internet of Things: A Kenyan Perspective 53

Olaronke O. Fagbola

Chapter 4

The Prospect of Blockchain Technology Adoption in Academic Libraries: An Overview 73

Rhodes Elias Mwageni and Robert Stalone Buwule

Chapter 5

The Assumptions of the Use of Artificial Intelligence Technologies in Robotics in Inclusively Engaged Academic Libraries in Sub Saharan Africa: A Literature Survey 95

Airen Edale Adetimirin and Oyedele Abimbola Ojeniyi

Chapter 6

Building Future Information Professionals for 4IR Libraries: Role of Library and Information Science Lecturers in Nigeria 111

Temidayo Oluwatosin Omotehinwa

Chapter 7

Artificial Intelligence and Libraries: The Possibilities in the 4IR 131

VI Contents

Robert Stalone Buwule and Stephen Mutula

Chapter 8

Inclination of Uganda University Libraries on Co-Driving the Fourth Industrial Revolution 145

Adeyinka Tella, Joseph. M. Ngoaketsi and Oluwatoyin Oluwayemi Obinyan

Chapter 9

Legal and Ethical Issues Associated with Adoption and Utilisation of Cloud Computing in Academic Libraries in Nigeria 165

Wilson Chukwunedum Ochonogor and Edwin Iroroeavwo Achugbue

Chapter 10

The Relevance of Cloud Computing and the Internet of Things for

Effective Information Service Delivery in Medical Libraries in Nigeria 197

Aderinola Ololade Dunmade, Uloma Doris Onuoha, and Adeyinka Tella

Chapter 11

Cyberethics and Cybersecurity in Universities in Developing Countries: A Literature Survey and Course Content Analysis from Library Instruction's Perspective 215

Musediq Tunji Bashorun, Kabir Muhammad Abubakar, Iro Sani Lawal, and Rafiat Bukola Bashorun

Chapter 12

Application of Big Data and Advanced Analytics in Future Librarianship 227

John Jackson Iwata

Chapter 13

Libraries in the Wake of the Fourth Industrial Revolution: A Portrait of Roles, Challenges, and the Prospects 249

Collence Takaingenhamo Chisita, Rexwhite Tega Enakrire, and Blessing Chiparausha

Chapter 14

The Changing Role of Librarians in the Age of Hypermedia Seduction: Reflection on the Researchers' Exposition 267

Contents VII

Dayo Reuben Aremu

Chapter 15

Machine Learning and Data Mining: An Overview for Emerging Trend in Fourth Industrial Revolution 287

Yusuf Ayideji Ajani, Ganiyu Ojo Adigun, Saheed Oyeniran, and Olufunke Abosede Ayeni

Chapter 16

The Fourth Industrial Revolution and the Relevance of its Technologies to Libraries 309

Adeyinka Tella

Chapter 17

Artificial Intelligence Humanoid Robots for Public Libraries Reference Services 343

Omwoyo Bosire Onyancha

Chapter 18

Data Science: A Systematic Review of the Concept Using Author-supplied Keywords 357

Petros Nhlovu Dlamini, Yusuf Ayodeji Ajani, and Ugonna Vivian Ailakhu

Chapter 19

The Prevalence of Digital Pedagogy for Delivering Library Instructions in the Era of the Fourth Industrial Revolution 379

Abdulmumin Isah, Mariam Oyinda Aborisade, and Stephen Mayowa Omolounnu

Chapter 20

Awareness and Usage Readiness of Artificial Intelligence in University Libraries in Kwara State, Nigeria 403

Adeyinka Tella and Ajani Yusuf Ayodeji

Chapter 21

Virtual/Augmented Reality Meeting Platforms: The Enablers of Librarians' Collaboration in 3D Virtual Environment 421

Index 447

The Authors

Kabir Muhammad Abubakar, Department of Library and Information Science, Faculty of Education, Umaru Musa Yar'adua University Katsina, Katsina State, Nigeria.

muhammad.kabir@umyu.edu.ng

Edwin Iroroeavwo Achugbue, Department of Library & Information Science, Faculty of Education, Delta State University, Abraka.

edwin12ng@gmail.com

Airen Edale Adetimirin, Department of Library, Archival and Information Studies, University of Ibadan, Ibadan, Nigeria.

aeadetimirin@gmail.com

Ganiyu Ojo Adigun, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria. adiganfolly@yahoo.com

Ugonna Vivian Ailakhu, Department of Library and Information Science Faculty of Education National Open University of Nigeria, Abuja, Nigeria.

vailakhu@noun.edu.ng

Yusuf Ayideji Ajani, Graduate Students Department of Library and Information Science, University of Ilorin, Nigeria.

trustusouph@gmail.com

Dayo Reuben Aremu, Department of Computer Science, Faculty of Communication, University of Ilorin, Ilorin.

Olufunke Abosedo Ayeni, Dept of Library and Information Science Federal Polytechnic, Offa. Kwara State, Nigeria.

bosfunke@gmail.com

Ajani Yusuf Ayodeji, Department of Library and Information Science, University of Ilorin, Ilorin, Nigeria.

trustusouph@gmail.com

Amos Orenyi Bajeh, Department of Computer Science, University of Ilorin, Ilorin, Nigeria. bajehamos@unilorin.edu.ng

Musediq Tunji Bashorun, Department of Library and Information Science, Faculty of Education, Umaru Musa Yar'adua University Katsina, Katsina State, Nigeria. musediq.bashorun@umyu.edu.ng

Rafiat Bukola Bashorun, The Polytechnic, Ibadan, Nigeria. rafiatabashorun@gmail.com

Robert Stalone Buwule, University Librarian, Mbarara University of Science and Technology. Dr. Robert Stalone Buwule is a University Librarian of Mbarara University of Science and

Technology. Previously he was a Senior Librarian at Kyambogo University (KyU) where he headed the Library ICT section. He obtained his doctorate from the University of KwaZulu Natal in South Africa. He holds a Master's of Information Science from Makerere University in Kampala, Uganda, and a

<https://doi.org/10.1515/9783111176987-203>

X The Authors

Master's of Information Technology at the University of Pretoria, South Africa. His research interests focus on the application of technological innovation, improving information access for SMEs, persons with disabilities, and empowerment of youth and other marginalized persons through information products and services. He has presented research papers at the Standing Conference of East, Central, and Southern African Librarians (SCECSAL), IFLA WLIC satellite conferences, IS and PROLISSA conferences.

rbuwule@must.ac.ug or burosta@gmail.com

Blessing Chiparausha, Bindura University of Science Education, Zimbabwe.

Collence Takaingenhamo Chisita, University of South Africa, Pretoria.

Petros Nhlovu Dlamini, Department of Information Studies, Faculty of Arts, University of Zululand.
DlaminiP@unizulu.ac.za

Aderinola Ololade Dunmade, Centre for Open and Distance Learning, University of Ilorin, PMB 1515, Ilorin, Nigeria.

Rexwhite Tega Enakrire, University of Johannesburg, South Africa.

Olaronke O. Fagbola, University of Ilorin, Nigeria.

Dr. Olaronke O. Fagbola, Ph.D., CLN, is a lecturer in the Department of Library and Information Science, University of Ilorin, Nigeria. She holds a doctorate in Library and Information Studies, Master degrees in Information Science and Master in Business Administration from the prestigious Universities of Ibadan and Lagos respectively and a Bachelor of Science degree in Education/ Biology from the Obafemi Awolowo University, Ile-Ife. Her research focuses on information management, users' studies, bibliometrics, and technology in academic libraries.

faith1931@yahoo.com or fagbola.oo@unilorin.edu.ng.

Abdulumumin Isah, Department of Library and Information Science, University of Ilorin.

John Jackson Iwata, Department of Knowledge Management, Moshi Co-operative University, Moshi-Kilimanjaro, Tanzania.

John Jackson Iwata is a teacher and library expert. He holds a Ph.D. in Information Studies of the University of KwaZulu-Natal, and both Master of Arts in Information Studies and Bachelor of Education in Arts of the University of Dar es Salaam. Besides lecturing and managing library collection, from 2010 to 2020 Mr. Iwata was involved in the management team of Moshi Co-operative University as Head of Periodicals Department, Deputy Director, and the Director of Co-operative Library and Archives. He was the first chairperson of the Steering Committee of establishing Cooperative Archives Centre at the same University in 2010. Also, he has been involved as a team leader in designing training programs in library and information sciences, and in developing some university guidelines and policies. Mr. Iwata is a former Postdoctoral Research Fellow of the University of KwaZulu-Natal, South Africa. During his postdoctoral studies, he assisted in the University Curriculum Transformation Project (UCDP) specifically on the Decolonization and Transformation of University's Education Curriculum in South Africa. His research areas include knowledge management (specifically management of indigenous knowledge), information literacy, and curriculum development.

iwata2j@gmail.com ORCID: <http://orcid.org/0000-0002-4491-650X>

The Authors XI

Lorette Jacobs, Department of Information Science, University of South Africa, Pretoria, South Africa.

ejacobl1@unisa.ac.za

Tom Kwanya, The Technical University of Kenya. tkwanya@tukenya.ac.ke

Iro Sani Lawal, Department of Library and Information Science, Faculty of Education, Umaru Musa Yar'adua University Katsina, Katsina State, Nigeria.

sani.lawal@umyu.edu.ng

Stephen Mayowa Omolounnu, Department of Library and Information Science, University of Ilorin

Stephen Mutula, University of Kwazulu Natal.

Rhodes Elias Mwageni, Director of Library Services, Kilimanjaro Christian Medical University College (KCMUCo).

(A Constituent College of Tumaini University Makumira)

Dr. Rhodes Elias Mwageni is a Director of Library Services at Kilimanjaro Christian Medical University College (KCMUCo) (a Constituent College of Tumaini University Makumira (TUMa) in Tanzania in East Africa. He completed his BA General (Hons) degree, Postgraduate Diploma in Education (PGDE), and MA in Information Studies at University of Dar es Salaam (in Tanzania), and his Ph.D. (Information studies) at

the University of KwaZulu Natal, Pietermaritzburg, in South Africa. His research interests include embracing reading culture as an attitude and behaviour, organizational behaviour, education, marketing of information services, reference services, digital library services, artificial intelligence technologies in robotics, and extensive experiences of research supervision at different levels.

rhodes.mwageni@kcmuco.ac.tz or rhodesmwageni@gmail.com

Joseph. M. Ngoaketsi, Department of Information Science, University of South Africa.
ngoakmj@unisa.ac.za

Wilson Chukwunedum Ochonogor, Department of Library & Information Science, Faculty of Education, Delta State University, Abraka.

wilsonchukwunedum@gmail.com

Oyedele Abimbola Ojeniyi, Central Bank of Nigeria-Centre for Economics and Finance, University of Ibadan, Ibadan, Nigeria.

deleojeniyi@yahoo.com

Oluwatoyin Oyeyemi Obinyan, The Library, Edo State University, Ekpoma, Nigeria.

Oluwatoyin Obinyan is the acting Head of the Electronic Library Department of Ambrose Alli University Library, Ekpoma Edo State Nigeria. She is a doctoral student at the University of Nigeria, Nsukka, with her areas of specialization including Information Literacy skills, Electronic resources management and use, ICT application to library processes, and Academic librarianship. obinyantoyin@gmail.com or obinyantoyin@aauekpoma.edu.ng

T. O. Omotehinwa, Department of Mathematics and Computer Science, Federal University of Health Sciences, Otukpo, P.M.B. 145, Nigeria.

Uloma Doris Onuoha, University Library, Adeleke University, Ede, Osun State, Nigeria.

XII The Authors

Omwoyo Bosire Onyancha, Department of Information Science, University of South Africa, PO Box 392 Unisa, 0003.

onyanob@unisa.ac.za

Saheed Oyeniran, Department of Educational Management, University of Ilorin, Nigeria.
saheed.oyeniran@gmail.com

Mariam Oyinda Aborisade, Department of Library and Information Science, Osun State University.

Adeyinka Tella, Department of Library and Information Science, University of Ilorin, Ilorin, Nigeria;
Department of Information Science, University of South Africa, Pretoria.

Adeyinka Tella is a Professor and Head of Department at the Department of Library and Information Science at the University of Ilorin in Nigeria and is currently a DISTINGUISHED PROFESSOR at the University of South Africa in Pretoria, South Africa. tellayinkaedu@yahoo.com or tellaa@unisa.ac.za or tella.a@unilorin.edu.ng

Olaronke O. Fagbola

Chapter 4

The Prospect of Blockchain Technology Adoption in Academic Libraries: An Overview

Abstract: Libraries of the twenty-first century are technology-driven. The Fourth Industrial Revolution (4IR) is gradually evolving, and the world of work is undergoing massive technological transformations, innovations, and advancements due to the adoption of cutting-edge advanced computing technologies such as artificial intelligence, cloud computing, big data analytic, the Internet of Things (IoT), and blockchain technology among others for the day to day management of business operations. Libraries, most importantly academic libraries, being the reservoirs / repository of knowledge, are no exception to this development. The hallmark of blockchain technology remains transparency, high-level accuracy, security, and support. Thus, its adoption and deployment for library operations and management would bring about far-reaching implications for the future of academic libraries by promoting high-level security, accuracy, support, and transparency.

Blockchain technology can find application in academic libraries for the creation of an enhanced metadata system, provision of unrestricted access to digital contents and print collection to all possible users in participating library systems, while managing risk to ensure that the privacy, and personal identity of each user(s) are secured, and protection of digital-first sale among others. In the long run, these would enhance the relevancy of academic libraries in the unfolding 4IR era. This chapter provides an overview of what blockchain technology is all about, its application, features, models, use, challenges, blockchain technology and libraries, and prospects of its applications in academic libraries. The purpose is to help the readers understand how the blockchain technology works, and benefits academic library operations.

Keywords: Academic library, Adoption, Blockchain, Prospect, Technology, Nigeria

Introduction

The Fourth Industrial Revolution (4IR) is gradually evolving, and the world of work is undergoing massive technological transformations and advancements due to the adoption of cutting-edge computing technologies such as artificial intel-

ligence, cloud computing, big data analytic, the Internet of Things (IoT), and blockchain technology among others in the day to day management of business operations. Most importantly, academic libraries, the reservoirs / repository of knowledge, are no exception to this development (Konappa, 2014, p. 1). Essentially, these significant developments in the field of computing technology created revolutionary changes in all fields of knowledge, fundamentally altered the way we live, work, and relate with one another; and created opportunities, and heralded the transformation of the entire systems of production, management, and governance among others (Fagbola et al., 2021, p. 1). The authors explained that the technological advancements led to massive infrastructural development; transformed initiatives and activities in the business environment; revolutionized the entire operational process in organizations, libraries inclusive, and the deployment of modern Information and Communication Technological ICT tools for a wide variety of tasks in every field of human endeavours.

Advancement in computing technology has radically altered human lives in ways that hitherto were unanticipated. One of the novel technological advancements ravaging the world of work is Blockchain technology. Blockchain technology is one of the most remarkable technological innovations of the twenty-first century and the foundation of modern-day cryptocurrencies (Kimani et al., 2020, p. 1). Blockchain technology is part of the broader Digital Ledger Technologies (DTL) family, a type of database where recorded data are shared and synchronized across a distributed network of computers or participants (Nascimento et al., 2019, p. 13). Also, the technology combines asymmetric (public key) encryption, distributed ledger, peer-to-peer (P2P), incentive theory, and innovative contract technologies (Wang et al., 2019, p. 45062).

Blockchain technology is just one of several evolving computing technologies compared to other technologies like the steam engine and the Internet that triggered previous industrial revolutions; it represents a shift away from the traditional trust agents and a move towards transparency (Niforos, 2019, p. 9). In addition, blockchain technology is an amalgamation of many techniques consisting of cryptography, algorithms, economic models, and mathematics, combining P2P networking and distributed consensus algorithms to solve the synchronization issues from the traditional distributed database (Joshi et al., 2018, p. 123).

Blockchain technology is a decentralized, transparent, traceable, and resistant platform, a new type of data structure, and digital information stored in a public database (Hasavari & Song, 2019, p. 159; Fuchs, 2019, p. 1). Though Benton and Radziwill (2017, p. 42) observed that blockchain technology enables the sharing and consuming of computing resources and delivering computing capabilities anytime, it may reduce information asymmetries between people, increase transparency, and ultimately help build trust between them and autonomous systems.

Furthermore, the blockchain technology is a decentralized, transparent, trace-able, and resistant platform, that enables the sharing and consuming of computing resources; and delivering computing capabilities anytime (Hasavari & Song, 2019, p. 159; Benton & Radziwill, 2017, p. 42). It is a new type of data structure and digital information stored in a public database; secures the integrity of a network, and essentially codifying the 'truth' and eliminating the need for 'trust'. However, it may reduce information asymmetries between people with increase transparency; ultimately, helping in building trust between the people and the autonomous systems (Fuchs, 2019, p. 1; Benton & Radziwill, 2017, p. 42).

Driving greater transparency and substantiating the accuracy of transaction data across the digital information ecosystem are the hallmarks of blockchain technology. Thus, the potential applications of this novel technology are practically endless. The technology can be used independently in various use-cases and markets, ranging from insurance, manufacturing, and finance, to supply chain management, education, and health (Sultan et al., 2018, p. 54). The authors stated further that it could find applications in industries that involved transactions and assets management. Also, blockchain has the potential to help minimize counter-party risk, reduce settlement times, improve contractual term performance, and increase transparency for regulatory reporting (Charteredaccountantanz.com, 2017, p. 2). However, Efanov and Roschin (2018, p. 119) warned that the technology is poised to disrupt many business models which rely on intermediaries (the crux of blockchain business applications) by facilitating the creation, management, and transfer of digital assets through automated validation rules, cryptographically verified rights and ownerships, and the validation of transactions without requiring intermediaries.

Libraries of the twenty-first century are technology-driven, and coupled with the development in Web technology which has created a friendlier, social, and fun environment for accessing, retrieving, sharing, and disseminating information to diverse users; libraries are consistently undergoing a paradigm shift through the digital transformation of their operations and services (Konappa, 2014, p. 1). Thus, academic libraries in particular, and libraries generally stand to benefit massively through the adoption and deployment of blockchain technology for library operations because blockchain is a decentralized, and distributed computing protocols designed to provide access to digital contents and ensure its integrity. For instance, academic libraries have a significant opportunity to use blockchain technology to advance privacy for users, increase collaboration, and transform the way they work with each others and their communities (Meth, 2020, p. 1). Furthermore, the transactions on the blockchain could ameliorate the need for documentation, duplication, third-party intervention, and remediation. Hence, it could revolutionize academic libraries and drive industry and econom-

ics because it is secure, fast, trustworthy, immutable, and provides transparent public and private solutions (Zubaydi et al., 2019, p. 3).

Indisputably, Fuchs (2019, p. 20) opined that the pace of global technological changes and development keeps accelerating; however, the adoption of blockchain technology will take time and likely will follow a trajectory similar to the Internet around the mid 1990s. He observed that although some benefits are realizable in the short term, it would take decades for blockchain's full potential to be reached.

Essentially, the blockchain technology is one of the pillars of the 4IR; an invisible enabler, unlike the Artificial Intelligence, IoT, and Big data analytics, among other more visible digital technologies. Arguably, libraries are not left out of the digital tsunami sweeping across every facets of human endeavour and activities. It is against this background, that this chapter examines the prospects of Blockchain technology adoption for library services; and as a game changer in the operations of academic libraries in Nigeria. More so, this chapter provides an insight on the Blockchain technology, its benefits and how academic libraries can leverage on the technology in upscaling library operations, enhance service delivery and reduce operational cost.

The Blockchain Technology: An Overview

The blockchain is a revolutionary and foundational technological innovation with tremendous potentials across different verticals vis-à-vis financial services, insurance, real estate, education, agriculture, manufacturing, healthcare, supply chain management, legal, government, and notary service, among others (Girish, 2018, p. 1). Blockchain is an emerging technology that offers the possibility of re-engineering economic models and enabling the creation of markets and products that were previously unavailable or unprofitable across emerging markets (Ben-jamin et al., 2019, p. 6). According to Kattwinkel and Rademacher (2020, p. 2), the concept of a blockchain system consists of a network containing a distributed and chronologically ordered transaction database for the manipulation and proof storage of linear data records. They explained that it enables a distributed consensus between untrusted participants and represents a continuously expanding open ledger. Equally, Zile and Strazdiņa (2018, p. 12) averred that blockchain technology is a system that performs accurate, and irreversible data transfer in a decentralized P2P network; creates a tamper-proof document and a distributed ownership record.

Blockchain describes a collection of complementary technologies; each of these elements has existed in some form for many years. However, blockchain

brings them together in a way that can result in significant benefits to network integrity, information security, and connectivity (Fuchs, 2019, p. 6). Similarly, Foote (2019, p. 4) averred that a blockchain is a distributed database shared by all distributed network members, allowing transaction data to be recorded quickly and audited without being altered or manipulated. Blockchain can deliver productivity gains to multiple industries, from the financial sector to energy markets, supply chains, education, health, intellectual property management, virtual firms, the public sector, and beyond (Niforos, 2019, p. 9).

Blockchains are structured to be public or permissioned / private, as determined by a given situation (Bacigalupo, 2020, p. 2). She explained further that critical to a blockchain's infrastructure are nodes (Computer Servers) which store a block of data comprising a blockchain, connected to other nodes with which they exchange the most current data and authenticate a block's legitimacy. Likewise, Fuchs (2019,

p. 6) averred that the building blocks vary. However, the most common include authentication, encryption, digital signature, and hashing.

The blockchain is a new method of securely storing and distributing information, creating trust through cryptographic operation by allowing parties to exchange value without the use of an intermediary securely, and making it technically possible to ensure the integrity of information and the process of exchanging it (Sultan et al., 2018, p.49. Fuchs, 2019, p. 4). It is a distributed database containing records of transactions shared among participating members, and each transaction is confirmed by the consensus of a majority of the members, making fraudulent transactions unable to pass collective confirmation (Efanov & Roschin, 2018, p. 119). Also, blockchain is a technology designed to focus on streamlining the proper flow of information in business networks, ensure the sharing of the correct information very quickly and rapidly in a manner that minimizes the amount of time that people have to find and correlate information across business networks (Hasavari & Song, 2019, p. 158). However, Charteredaccountantanz.com (2017, p. 3) cautioned that blockchain technology is a disruptive technology platform that uses cryptography, and a distributed messaging protocol to create shared ledgers among counterparties.

Furthermore, blockchain is digital, containing information about the sender and the receiver. Once created, information is tough to change (Efanov & Roschin, 2018, p. 119). Thus, the data is trustworthy because it is bound in a strict framework of rules and cryptographic keys, and only those with the correct key can access or modify the data. Also, Yaga et al. (2018, p. 1) remarked that the blockchain is tamper-evident and tamper-resistant digital ledgers implemented in a distributed fashion (without a central repository) and usually without a central authority (a bank, company, or government).

According to Zubaydi et al. (2019, p. 1), the blockchain can achieve and maintain data integrity in distributed systems due to the high level of security imple-

mented in the blockchain technology. Hence, the blockchain would not exist without computer networks such as the Internet because it is by way of networks that all the users of particular blockchain technology are linked, with the ledger distributed and maintained (Benton & Radziwill, 2017, p. 39).

Consequently on the above, the blockchain technology was heralded by the fusion of the multidisciplinary fields of software engineering, distributive computing, cryptographic science, and economic game theory as a technological building block, permitting applications from a broad swath of industries to take advantage of sharing, tracking, and auditing digital assets (Sultan et al., 2018, p. 54). Similarly, Hasavari and Song (2019, p. 58) noted that the technology is a comprehensive computer technologies application that combines encryption algorithms, P2P networks, distributed storage, consensus algorithm, and smart contracts. However, it has the power to disrupt existing economic and business models and may prove particularly valuable in emerging market economies (Niforos, 2019, p. 9).

Fuchs (2019, p. 1) averred that blockchain technology is a game-changer. It removes the need for an intermediary, thereby enabling a nearly frictionless exchange of value, much like the Internet has enabled a nearly frictionless exchange of information. Thus, the adoption and use of blockchain technology in the deployment of library products and services could be relevant not only for housing

electronic credentials, information tracking, and management, but also for transactions that require personal identification, peer review, democratic decision making or consensus, or solid provenance and audit trails.

Features of the Blockchain Technology

Blockchain is a unique technology that has provided new solutions to old problems, disrupted traditional business models, and helped us become efficient and productive (Charteredaccountantanz.com, 2017, p. 1); when added, transaction operations are recorded and cannot be altered. According to Joshi, Han, and Wang (2018, p. 143); Song (2019, p. 160), features that make Blockchain Technology unique include:

- Security: One of the advantages of a blockchain is keeping track, and securely verifying information. With blockchain technology, all transactions are time-stamped, (for example details about payment, a contract, transfer of ownership), and are linked publicly to a specific date and time, meaning that no one would be able to modify recorded and time-stamped information. Thus, making it beneficial for different parties to check when, and who made a specific transaction, or certify that data existed at a given time.

- Decentralization: This feature ensures that stored blockchains can be accessed, and copied by any node on the network. Thus, multiple and distributed nodes make it very difficult to target the majority simultaneously, and completely break down the whole network because blockchains run through a distributed network of participants who do not necessarily trust each other. Hence, the fact that there is no central point of failure, nor entity controlling the system creates a strong resilience for blockchain, and makes the system very difficult to attack.

- Immutable and tamper-resistant: A blockchain is a permanent record of transactions, and continuously growing data records (tamper-proof), making it extremely difficult to change or delete the record of transactions. This feature, in the long run creates trust in the transaction record because a newly added block cannot be removed.

- Transparency: Blockchain is an open file where any party can access and audit the entire transaction history, thus, creating provenance under which assets' life-times are monitored. The ledger or blockchain is accessible to all, making every modification visible to the participants, and almost impossible to make any changes unnoticed. Similarly, the non-repudiation and non-forgeability characteristics of blockchain guarantee that a unique and historical version of the records can be agreed upon, and shared among all the participants in a particular network or chain. Moreover, the public-private keys / cryptographic signatures ensure the integrity and authentication of transactions in that records in a blockchain are tamper-resistant. For example, in public / open blockchains, everyone with an Internet connection to the network has the same rights to access, and update the ledger according to the consensus mechanism; making all transactions transparent and visible, thereby increasing

audibility and trust in the network. However, in private or closed blockchains, access to the records can be restricted to specific participants.

- Smart contracts: This refers to a computer code running on top of a blockchain, containing a set of rules under which parties to that smart contract agree to interact (executable logic that generates new facts added to the ledger). Thus, if and when the pre-defined rules are followed, the agreement is automatically enforced. The smart contract code facilitates, verifies, and enforces the negotiation/performance of an agreement/transaction (Salim, 2019, p. 8). With smart contracts, blockchain technology can implement other decentralized services besides currency transactions, where trust is inbuilt based on blockchain intrinsic properties.

- Consensus driven: This mechanism (trust verification) works without using a central authority / an explicit trust-granting agent. Each block on the blockchain is verified independently via consensus models, which provide rules for validating a block and often use a scarce resource (computing power) to show proof that adequate efforts were made.

Evolution of the Blockchain Technology

Blockchain technology has undergone four phases of development, and the primary data structure exists as a linear linked list, linked with blocks, with each block containing information such as the hash of pre-block, the hash and address of the block, the information of transactions, and other helpful information (Efanov & Roschin, 2018, pp. 117–118; Hasavari & Song, 2019, p. 2; and Zubaydi et al., 2019, pp. 2–3). The phases include:

- a) Blockchain 1.0: This refers to the digital currency phase, the first generation of blockchain technology applications. The generation comprises of the underlying technology platform (mining, hashing, and the public ledger); the overlying protocol (transaction enabling software), and the digital currency (Bitcoin, Litecoin, Dogecoin, or other digital tokens/coins), which represent a store/transfer of value as well as provide value to the protocol.

- b) Blockchain 1.5: This phase is built upon existing blockchains by offering additional dependent layers and protocols, allowing for unique offerings and transfer of value. The phase comprises of:

- Name Coin (an experimental open-source technology that improves decentralization, security, censorship resistance, privacy, and speed of specific Internet infrastructure components) which provides distributed DNS.

- Coloured Coin (a method used to represent and manage real-world assets with the Bitcoin blockchain), Counterparty, and Omni can tag and track digital assets.

– File Coin (a blockchain-based technology that connects customers and data storage providers from around the world); and StorJ (an open-source cloud storage platform) provide distributed C.D.N. (content delivery network) with proof of bandwidth.

c) Blockchain 2.0: This digital economy phase refers to the wide range of economic and financial applications that exist beyond simple payments, transfers, and transactions. The phase is currently the most theoretical or pre-alpha state, but involves starting from the scratch and introducing turning-complete functionality. These include traditional banking instruments such as loans and mort-

gages, complex financial market instruments (stocks, bonds, futures, derivatives), legal instruments (titles, contracts, assets), and other property that can be monetized. For instance, Ethereum and Codius introduce autonomous applications (recently used by I.B.M. at the core of their new IoT platform, ADEPT). An example is the payment clearing system, while bank credit information systems can be the appropriate blockchain application scenarios.

d) Blockchain 3.0: This refers to the digital society phase where many applications do not involve money, currency, commerce, financial markets, or other economic activity. The phase comprises curated and private access / hybrid block-chains, as well as entry/exit points known and regulated, such as Ripple and Tembusu. The most promising application of blockchain technology is smart cities, which involve horizontally cumulative elements such as smart governance, smart economy, smart citizens, smart mobility, smart living, and the smart use of natural resources. Examples of such applications include art, health, science, identity, governance, education, public goods, agriculture, estate management, licensing offices, and various aspects of culture and communication.

Types of Blockchain Networks

Blockchain networks comprise of four different models. These models are named based on the system's degree of decentralization and the possibility for participants to access transaction validation rights. The model can be public, private, or hybrid, and the overall purpose of a blockchain will determine which is best (Sultan et al., 2018, p. 53; and Bacigalupo, 2020, p. 2). The identified types are as follows:

i. Public blockchain system: The public blockchains consist of open and publicly accessible networks decentralized in a P2P fashion. They have no single owner; transactions are transparent and read/written by any network participant(s). An example is Bitcoin.

ii. Private blockchain systems: These refer to smaller, limited membership, centralized networks controlled and operated by a single entity. The system is a closed network (invitation-only); data structure is not immutable, and only permissioned users can read/write/audit/delete, and validate transactions. A private blockchain system hardly shares transaction data, thus, losing the ability to adequately protect against manipulation. Additionally, it decreases the availability and failure tolerance of the stored data, enabling a single point of failure. However, private blockchains use

privileges to control who can read from and write to the blockchain. In the private blockchain system, consensus algorithms, and mining are not usually required as a single

entity has ownership and restrains block creation. Examples of private blockchain systems include those enterprises used to record asset transactions within a limited user base (restricted scope).

iii. Hybrid blockchain system: This refers to the consortium or federated blockchain system. These blockchains are public only to a privileged group (visualized as very small-scale public blockchains). Privileged servers control this system's consensus process, distributing copies among entitled participants across a limited participant base. Thus, the network is only partly decentralized.

iv. Permissioned blockchain system: The permissioned blockchain system is an extensive and distributed networks based on open-source code developed and maintained by the respective communities open, to participation. It is equally open to audit by anyone, once the system is built, thus, requiring permission to read or limit the parties that transact business.

Potential Application of Blockchain Technology

Blockchain technology is so pervasive that it has found application in virtually every sphere of human life. It has rapidly gained traction in the capital markets industry as one of the most exciting technological developments in recent history. According to Puthal et al. (2018, p. 7), the technology can revolutionize the security, stability, and transparency of needed networks provided it is applied appropriately and only if needed, meaning it is not a panacea for all security applications. Some of the areas in which the technology has found application, and use include, but are not limited to the following areas:

i. Blockchain as a marketplace: Blockchain platforms can be deployed directly to match buyer(s) and seller(s) in the marketplace, by allowing them to transact business through smart contracts such as in open Bazaar and Soma, with the technology enabling peer-to-peer market places with no governing authority, thus providing accessible and dis-intermediated trade. Also, blockchain technology is being touted as an enabler for next-generation online workforce marketplaces in the context of the gig economy that relies on independent contract workers, and freelancers for short-term engagements, and the shared economy where consumers increasingly become prosumers. In such instances, blockchain platforms can ensure that any central authority does not constrain service providers, thereby allowing them to extend flexible offerings; payment interactions and service transactions can function in a transparent environment. In all, as a marketplace enabler,

blockchains can be used to operationalize programmable asset ownership and money.

ii. Blockchain as a smart contract utility: Smart contracts are computer programs that automatically execute contract terms and manage smart properties. They are an emerging use case in this generation; data can be transformed faster than traditional contracts and are faster for execution. For instance, activities often managed by third-party central authorities can be mitigated to the blockchain instead of through dis-intermediating transactions. Also, blockchain start-ups such as R3 collaborate with banks and regulators to operationalize blockchains as a new operating system for financial markets. Thus, using a blockchain platform implies that each of the six elements is programmable, and by dis-intermediating these factors, blockchains can enable new services to come to market with cheaper transaction fees and faster execution. Examples include escrow, multi-party transactions, digital notarization, and time stamping (Joshi et al., 2018, p. 143).

iii. Blockchain technology in agriculture: The ability of blockchain technology to instantly record, validate, and share vast amounts of data could be a game-changer for the agricultural sector. The technology could improve food traceability, supply chain management, better pricing, and payment options (Simard & Tetreault, 2017, p.6).

iv. Blockchain as a development platform: The introduction of Blockchain as a Service (BaaS) platforms such as Microsoft's Azure, and IBM's Cloud provide an inexpensive environment for developers to rapidly prototype on-test blockchains before deploying to live ones. Other examples include Xage, a technology platform that enables secure sharing of data across industrial networks through Blockchain's tamper-proof ledgers, and Guardtime, technologies that offer blockchain-enabled data transaction verification. These BaaS solutions form the basis for programmable trust, ownership, and identity and facilitate enterprise blockchain applications and services (Sultan et al., 2018, p. 54).

v. Blockchains are a distributed ledger: This refers to a database that functions like a distributed network. Databases that spread across several computing devices (nodes) comprise blocks, and each block comprises a block header containing metadata about the block and block data containing a set of transactions and other related data. Thus, every block header (except for the very first block of the blockchain) contains a cryptographic link to the previous block's header, and each transaction involves one or more blockchain network users and a recording of what happened, signed digitally by the user who submitted the transaction (Yaga et al., 2018, p. 1).

vi. Blockchain in asset management: This entails transferring assets (server, computer / laptop, software, and services) securely within a business network. The blockchain offers shared ledger capability (complete visibility from end to end) into a business network. Consequently, the blockchain can be employed from serialization to being deployed on the floor, focusing only on five key events, i.e. manufacturing serialization of assets to initiate the Blockchain, receiving and validation of assets, asset capitalization, warranty activation, and installation of the asset (Puthal et al., 2018, p. 7).

vii. Blockchain in trusted-service application: The trusted-service application, sometimes referred to as Blockchain 2.0 comprises end-to-end functionality by facilitating highly specialized applications for any purpose imaginable. It is a more generalized use of blockchains that enables all types of

applications through a combination of programmable assets, trust, ownership, money, identity, and contracts.

viii. Blockchain in authentication and verification: Blockchain technology can authenticate personal information and profile pages in the form of blocks, and distribute them with blockchain to become a trusted reference point for identifying and verifying social network accounts. The process is made possible through the developers' updates of the characteristics of the platforms (Shorman & Allaymoun, 2019, p. 1).

ix. Blockchain in real estate: Often, transactions in real estate are cumbersome, opaque, and expensive, mainly because of the involvement of the various middlemen (agents, brokers, government, title companies, escrow companies, inspectors, appraisers, and notary public). Consequently, blockchain technology can speed up the real estate sector by reducing the need for paper-based records, tracking, verifying ownership and the accuracy of documents, and transferring property deeds. Also, the blockchain would enable properties anywhere to have a corresponding digital address comprising of tenancy, finance, legal, building performance, and physical attributes that convey perpetually and maintain all historical transactions (Puthal et al., 2018, p. 7; Joshi et al., 2018, p. 143).

x. Blockchain in education: The blockchain platform is also perfect for protecting, sharing, and authenticating of educational credentials. It would help reduce certificate falsification; promote confidentiality, security, and validity of certificates generally (Koko, 2020, p. 8).

xi. Blockchain in the financial service industry: Most banking institutions adopt Blockchain and advanced distributed ledger technologies for a wide range of functions, including trade settlements, payment processing, cross-border transactions, securities clearing, and syndicated loans. In addition, the anti-money

laundering (A.M.L.), and know your customer (KYC) rules are at a considerable cost to financial institutions and, in turn, customers; hence, the blockchain technology could automate current labor-intensive work (Fuchs, 2019, p. 13).

xii. Blockchain in the IoT: Blockchain technology can build IoT solutions to maintain a continuously growing list of cryptographically secured data records protected against alteration, and modification. For instance, an IoT connected (e.g. RFID) asset with sensitive location and temperature information moves along various points in a warehouse / smart home. This information could be updated on a blockchain, thus, permitting all involved parties to share data and the status of the package as it moves among different gatherings to guarantee the terms of an agreement are met (Puthal et al., 2018, p. 7).

xiii. Blockchain in healthcare: The global healthcare industry manages vast amounts of clinical and administrative data, from the pharmaceutical supply chain to patient medical records and claims management. Thus, accurate, accessible data are critical to improving clinical outcomes and reducing waste. The blockchain technology immutability, ability to connect currently siloed information, and serve as the "single source of truth" are vital enablers. The introduction of smart medical devices, from

personal fitness trackers to connected surgical suites, presents an entirely new ecosystem of information to mine, and the pool of data collected is growing exponentially.

xiv. Blockchain in governance: The ability of blockchain technology to provide a chronological, immutable, single source of truth makes it ideal for individual identities, property records, patents, and other primary data. There is enormous potential to use Blockchain to manage online voting for elections and more minor matters, and create genuine participatory democracy, giving everyone a direct say in the use of shared resources.

xv. Blockchain in supply chain auditing and management: Blockchain technology gives supply chain partners, and consumers a way to verify the origin of products and component materials. For example, “green” products are sourced from environmentally conscientious suppliers, the global supply chain for automotive recalls, and counterfeit airbags.

xvi. Blockchain in data security: With the blockchain technology trusted system, companies can share, store, and record sensitive data through a protected participant-visible and unchangeable network (Bacigalupo, 2020, p. 2).

xvii. Crowdfunding: Going beyond the model of Kickstarter and IndieGoGo to allow funders to participate in the management of projects they back with voting rights earned by their contribution.

Uses of Blockchain Technology

Increasingly, technology is finding applications in every sphere of human life. Blockchains can potentially change the basic framework of information storage and exchange by simplifying how computer networks connect and link data to a familiar subject (Fuchs, 2019, p. 10). Without doubt, the goal of blockchain technology is to create a decentralized environment. Some of the uses of blockchain technology, according to Foote (2019, p. 1); Fuchs (2019, p. 13); Joshi, Han, and Wang (2018, p. 143), include but are not limited to the following:

- a. Blockchain technology is helpful for different organizations wanting to communicate and cooperate.
- b. Blockchain Technology can significantly reduce the complexity of computer networks. For instance, new nodes can join the network and automatically have access to the same reference information. Complexity increases linearly, making the network far easier to scale.
- c. Blockchain technology offers transparency and has the potential to reduce legal disputes.
- d. They are used to forecast the changes on the entire approach to research, consulting, and analysis.
- e. Blockchain technology can create a transparent, permanent, public record of transactions and activities.
- f. Blockchain technology increases connectivity. Thus, it references vast amounts of data about a subject that can be tied together and yet simultaneously remain independent.
- g. The technology prevents the immutability of the recorded entries.

- h. Blockchain technology could be used in cybersecurity with verified data and encryption using advanced cryptography, thus, making it less prone to hacking and modifications without authorization.
- i. Blockchain technology is used in many financial service institutions to make business operations faster, more efficient, and secure.
- j. The technology can provide access to the banking and payment sector by providing financial services to billions of users worldwide without having access to traditional banking.
- k. Data distribution can use classical data distribution models: P2P (offering greater decentralization and better protection against closing the network) and client-server models.
- l. The technology can document the transaction in a permanent decentralized record, monitored securely, and transparently in supply chain management, thus, reducing time delays and human error significantly.
- m. It provides an extremely high level of security for transactions and data.

- n. Blockchain technology can execute smart contracts (programs that execute only) when specific conditions are in place.
- o. The technology promotes a real sharing economy, thereby completely cutting out intermediaries and letting individuals exchange value directly, without overhead or brokers. An example is Uber.
- p. Blockchain can be used in personal data management that might enable micro-payments, to accrue to users in exchange for access to their attention, and other personal information, while providing enhanced layers of personal control. Examples include platforms like Facebook and X (formerly Twitter), which profit by selling users' attention to advertisers.
- q. Blockchain technology can conduct background checks on education credentials and criminal records, as well as secure document storage, home deeds, auto titles, birth registries, and land registries.
- r. The technology can forecast the changes on the entire approach to research, consulting, and analysis.
- s. Blockchain technology can document transactions in a permanent decentralized record and thus, monitor supply chain management securely and transparently, significantly reducing time delays and human error.
- t. The technology can track donations in a secure, transparent, and verifiable way to make sure that the donated money reaches the intended beneficiary.
- u. Blockchain technology can be used in IoT to create a decentralized network of IoT devices that operates like public ledgers for many devices. These could help eliminate the need for a central location

to handle communication like updating software, managing bugs, and monitoring energy usage in the long run.

Undoubtedly, with this plethora of uses, the, blockchain technology makes it technically possible to create a person-centric society where data is consistently reliable, and securely organized around each individual. The Blockchain technology, therefore, is a technology that is most helpful in exchanging information, and other assets among several parties who may be unfamiliar or untrusted.

Challenges to the Adoption of Blockchain Technology

Indisputably, the potentials of Blockchain Technology application and use in many sectors have increasingly come to the fore. Though, its application is still in its embryonic stage as an emerging technology, however, the core technical bottlenecks remain unresolved, depending on the type of Blockchain. Some of the identified challenges to the all-pervasiveness of blockchain technology are:

- **Interoperability:** This refers to is the ability of the Blockchain to exchange and use information with other applications transparently (interface with other Software). This could constitute a challenge considering the fact that Software are updated on a regular basis, and are sometimes upgraded.
- **High energy consumption.**
- **Data privacy:** The protection of personal, sensitive/confidential data.
- **Regulatory uncertainties** over the formal status of blockchain applications are also causing extra ambiguity and risk for firms and other organizations either piloting blockchain or interested in its deployment.
- **Scability and Performance:** Scalability is the ability of Blockchain technology to perform, and support the growing amounts of data, handle increased work- loads while adding users, and removing them with minimal cost impact. This enhances the performance of the Software, data security, and a significant cost-saver for the organization in the long run. The inability of blockchain to do all these could pose a challenge to the operation of the organization.
- **Transparency:** In a public blockchain, transparency of data might pose a might be a problem when certain information is not meant to be publicly available or has to be altered later due to errors, inaccuracies, or other problems.

Blockchain Technology Adoption and Application in Nigeria

Blockchain technology is pervasive; it enables a broader impact within the community and around the globe (Alman & Hirsh, 2019, p. 1). In Nigeria, the introduction of blockchain technology started a couple of years back with Cryptocurrency – Bitcoins trading (online, digital payment systems based on P2P networking technology, and public-key cryptography). These systems allow users to exchange value in a trust-less setting. Transactions are semi-anonymous, irrevocable, and recorded in a distributed ledger that ensures all parties can agree that the transaction took place. With Blockchain's unique characteristics of transparency, and security, many other possible uses are emerging, in energy markets, digital identity, supply chain, manufacturing, agriculture, and financial services. For example, in blockchain is becoming a valuable tool revolutionizing the industry worldwide, decentralizing a patient's health history and tracking their pharmaceuticals.

Blockchain Technology and the Libraries

From time immemorial, libraries have been agents of transformation and the storehouse of knowledge along with collecting, processing, organizing, managing, storing, disseminating, and providing access to information and information resources in diverse formats. Today, varieties of technological innovations and solutions such as integrated library management software, artificial intelligence, robotics, IoT, drones, assistive technology, and RFID, amongst others, are deployed in the libraries' day-to-day management.

Libraries, are greatly benefiting from the massive digital transformations ravaging the world of work brought about by the unprecedented advancements in computing technologies. These innovative technologies have impacted the libraries positively in enhanced library operations, promoting effective service delivery, efficiency of staff, broader access to library patrons, enhanced inter-library cooperation, and a user-friendly environment, amongst other benefits. Consequently, adopting and deploying blockchain technology, one of the newly evolving computer technologies in academic libraries, could further enhance the library's outlook and operation, as witnessed in other sectors already deploying the technology due to its transparency, security, and immutability characteristics. Without mincing words, the presence of libraries in our societies supports and transforms human lives positively. Expectedly, as with other previous technological innovations, studies are already at the advanced stage in developed countries on the possibilities of libraries leveraging on the opportunities inherent in the adoption of the Blockchain technology into the library, the information profession, and information professionals generally. For instance, Hirsh and Alman (2019, p. 1) averred that blockchain technology has the potential for libraries to accomplish much more than housing electronic credentials. Furthermore, Meth (2020, p. 1) and Hontalas-Adams (2020, p. 3), Smith (2019, p.1), Brown (2018, p. 1), and Hoy (2017, pp. 276–277) all unanimously opined that blockchain technology is the best fit for academia and could have a potential place in libraries in various

ways such as:

- a. Metadata creation: The blockchain technology could create and build an enhanced metadata system for libraries and data centers to keep track of and protect digital-first sale rights and ownership, connect networks of libraries and universities, support community-based collection and borrowing, skill-

sharing programs, and P2P sharing of information resources, as well as facilitate partnerships across organizations.

b. Accessing digital contents: Blockchain could be used to provide unfettered access to digital content and print collections to all potential users in partici-

pating library systems while managing risk to ensure that each user's privacy and personal identity are secure.

c. Sovereign identity (S.S.I.): This blockchain application enables individuals or organizations to have sole ownership and control of their digital and analog identities. Thus, through the adoption by libraries, information literacy and digital inclusion efforts would be enhanced as users gain access to all resources in those libraries by creating their secure and private digital identity.

d. Security: The immutability feature of the blockchain technology would enhance the security of user records in libraries, document library acquisitions, and improve collections maintenance.

e. Unique collection: Applications of blockchain technology for special collections could allow for identifying and discovering unique holdings.

f. Scholarly records: blockchain technology could be adopted to manage the scholarly record by allowing researchers to record and time-stamp their ideas and disseminate knowledge.

g. Interlibrary loan: Blockchain technology could allow libraries to increase their services to include international inter-library loans.

h. Reaching the unreached potential library patrons: With the use of an interoperable blockchain-based system across all types of library systems and the use of a secure, verified digital identity by participating libraries to gain access to information, libraries could provide services to diverse communities of users (homeless, transient, immigrants, displaced, or away from their usual home base that may need all types of information resources that include support for literacy, community integration, new skill development, employment services, research, disaster relief, and entertainment) that they cannot obtain anywhere else; however, in most instances, these individuals cannot obtain a library card and are ineligible to take materials out of the library.

The Prospects of Blockchain Technology: Adoption and Application in Academic Libraries in Nigeria

Blockchain technology, without any doubt, is one of the significant advancements of computing technology. The extraordinary technological advances evolving daily, coupled with converging technologies, are making computing technology more efficient and user-friendly in the merging of the digital world with every business/orga-

nization and social interaction. Thus, the technology has great potential to transform the way academic libraries as custodians and store-houses of knowledge operate and disseminate authorized, tamper-free, proof resistant, and authentic information functions (Meth, 2020, p. 1; Shorman & Allaymoun, 2019, p. 9).

Equally, libraries have the mandate of gathering, collecting, processing, organizing, storing, preserving, sharing, and providing access to authoritative information; librarians, and information professionals are always on the cutting-edge of technologies to enhance quality service delivery for their users (Gujral et al., 2019, p. 79). Consequently, the ability of blockchain to store information in a distributed, tamper-free, and proof-resistant setting could make its adoption and application germane and of significant advantage in academic library operations (Shorman & Allaymoun, 2019, p. 9; Hasavari & Song, 2019, p. 158). Therefore, areas that the technology could find applications in the academic libraries include but are not limited to the following:

- i. Library services: Blockchain technology could facilitate many traditional library services like circulation, paying fines, and booking rooms, amongst others.
- ii. Verification: Blockchain technology could create time-stamped, verifiable versions of journal articles (a record) which other researchers can quickly verify whenever necessary.
- iii. Registration: Blockchain technology could aid program registration and the cataloging systems storing their information in blockchains, enhancing selective retrieval of information resources.
- iv. Inter-library loans: The adoption and application of blockchain technology in academic library operations could increase the services to include international inter-library loans and make library services available to unreached library users.
- v. Peer review process: Blockchain could be used in the peer-review process to set up the chain of custody of institutional repositories – the hallmark/core of academic libraries.
- vi. Identification: Information professionals could use blockchains to identify and locate the most recent and authentic version of the information.
- vii. Digital provenance: Blockchain could help establish digital provenance. Stampery is a digital notary that uses blockchain to create proof of provenance. This same methodology could apply to institutional repositories and archival databases.
- viii. Open access: The adoption and application of blockchain technology in the academic library could enhance scholarly publishing and credentialing (making information available that is the outcome of scientific research hitherto hidden and controlled within an institution so as to be open and freely distributed).

- ix. Universal library card: The decentralizing and transparent features of blockchain technology can help facilitate the development of a universal library card in an academic library with multiple branches.
- x. Security: Academic libraries with a presence on the social networking sites (Facebook, Twitter, LinkedIn, etc.) need not fear about the security and sanctity of their social media platforms because, with the use of blockchain, a safe environment conducive for library operations can be guaranteed since the technology can electronically authenticate and verify divergence of users on their platform.
- xi. Saves time: Blockchain is a technology designed to streamline the flow of information in business networks and ensure that the needed information is shared very easily and rapidly to minimize the time people have to find and correlate information across the business network.

Conclusion

The blockchain technology is exceedingly recognized and appraised due to its decentralized infrastructure and P2P nature. This could support a plethora of requirements in different areas and applications making the technology to be used successfully in a variety of areas. Conclusively, its adoption and application in academic library operations would go a long way in providing the library with a significant opportunity to advance their products and services to diverse users. In addition, it would increase collaboration, transform the way library personnel work and relate to one other and the user communities. Moreover, it would enhance privacy of transactions in academic libraries that operates a branch library system. Also, the libraries / librarians / and information professionals generally could regularly evaluate the blockchain opportunities and make the best use of this technology by keeping up to date.

References

- Bacigalupo, T. (2020). Maryland: A leader in embracing blockchain. *Today's General Counsel*, 16(4), 44–46. https://issuu.com/todaygc/docs/todaysgeneralcounsel_winter2020/46.
- Benjamin, M., Bishop, A., & Daibo, O. (Eds.). (2019). *Blockchain: Opportunities for private enterprises in emerging markets*. 2nd ed. <https://documents1.worldbank.org/curated/pt/260121548673898731/pdf/134063-WP-121278-2nd-edition-IFC-EMCompass-Blockchain-Report-PUBLIC.pdfPubppi>
- Benton, M. C., & Radziwill, N. M. (2017). Quality and innovation with blockchain technology. *New Technology*, 20(1), 36–44. <http://www.asq.org>.

Brown, J. L. (2018). Blockchain in the library: Researchers explore potential applications. <https://www.edsurge.com/news/2018-02-01-blockchain-in-the-library-researchers-explore-potential-applications>

Chartered Accountants Australia and New Zealand. (2017). The future of blockchain: Applications and implications of distributed ledger technology. <https://charteredaccountantanz.com/futureincwww.accenture.com>

Di Giuda, G.M., Pattini, G., Seghezzi, E., Schievano, M., Paleari, F. (2020). The construction contract execution through the integration of Blockchain Technology. In: Daniotti, B., Gianinetti, M., Della Torre, S. (Eds.). pp.27–36. Digital transformation of the design, construction and management processes of the built environment. Research for Development. Springer, Cham. https://doi.org/10.1007/978-3-030-33570-0_3.

Efanov, D., & Roschin, P. (2018). The all-pervasiveness of blockchain technology. *Procedia computer science*, 123, 116–121. <http://creativecommons.org/licenses/by-nc-nd/3.0/>

Fagbola, O. O., Atulomah, B.C. & Oladeji, T. I. (2021). Entrepreneurship and digital transformation: Leveraging on technological advantages in Nigeria. In A. Tella (Ed.). pp.205–235. ICT and entrepreneurship in information: Perspective from developing digital economies. Ess Ess Publications, New Delhi, India. <http://www.essess.net.in/details.jsp?b=751>.

Foot, K. D. (2019). Blockchain and artificial intelligence: Driving the fourth industrial revolution. <https://www.dataversity.net/blockchain-and-artificial-intelligence-driving-the-fourth-industrial-revolution/>

Fuchs, P. (2019). Blockchain: Everything you need to know about how this remarkable technology will impact you, your organization, and society. Mercer. <https://www.mmc.com/content/dam/mmc-web/insights/publications/2019/jan/gl-2019-blockchain-101-overview-mercer.pdf>

Girish, B. V. S. (2018). Blockchain technology: Concepts. https://www.sasken.com/sites/default/files/files/white_paper/Sasken%20-%20Whitepaper%20-%20Blockchain%20Technology.pdf

Gujral, G, Shivarama, J., & Choukimath, P. A. (2019). Perceptions and prospects of artificial intelligence technologies for academic libraries: An overview of global trends. 12th International CALIBER-2019 KIIT, Bhubaneswar, Odisha, November 28–30, INFLIBNET Centre, Gandhinagar, Gujarat, 79–80.

Hasavari, S., & Song, Y.T. (2019). A secure and scalable data source for emergency medical care using blockchain technology. *International Journal of Networked and Distributed Computing*, 7(4), 158–166. <https://doi.org/10.2991/ijndc.k.190917.001>.

Hirsh, S., & Alman, S. (2019). Blockchain and the future of libraries: An interview with Sandra Hirsh and Susan Alman. American Library Association. <http://www.ala.org/tools/article/future-libraries/blockchain-and-future-libraries-interview-sandra-hirsh-and-susan-alman>. Document ID: e8ab87d7-d6b6-40ae-9e10-40ee17b5f913

Hontalas-Adams, A. (2020). Blockchain in libraries: A new potential use for blockchain technology. <https://vocal.media/thechain/blockchain-in-libraries>

Hoy, M.B. (2017). An introduction to the blockchain and its implication for libraries. *MedicalReference Services Quarterly*, 36(3), 273–279. <http://doi.org/10.1080/02763869.2017.1332261>

Joshi, A. P., Han, M., & Wang, Y. (2018). A survey on security and privacy issues of blockchain technology.

Mathematical Foundations of Computing, 1(2), 121–147. <https://doi.org/10.3934/mfc.2018007>

Kattwinkel, O., & Rademacher, M. (2020). Technical fundamentals of blockchain systems. BRSU

Communication Report No. 1, 1–10. <https://doi.org/10.18418/978-3-96043-081-0>

Kimani, D., Adams, K., Attah-Boakye, R., Ullah, S., Frecknall-Hughe, J., & Kim, J. (2020). Blockchain, business and the fourth industrial revolution: Whence, whither, wherefore and how?.

Technological Forecasting and Social Change, 161, 120254. <https://doi.org/10.1016/j.techfore.2020.120254>.

Koko, T. Z. (2020). Certificate verification system based on blockchain technology. *University Journal of Creativity and Innovative Research*, 1(1), 6–10. <https://www.ucsbamaw.edu.mm>

Konappa, K. (2014). Use of electronic information resources in university libraries of tirupati (A.P.): An analytical study. *International Journal of Library and Information Science*, 6(1), 5–13. <https://doi.org/10.5897/IJLIS2013.0405>

Meth, M. (2020). Understanding blockchain: Opportunities for libraries. <https://americanlibrariesmagazine.org/2020/01/02/understanding-blockchain-libraries/>

Nascimento S. (ed), Pólvara A. (ed), Anderberg A., Andonova E., Bellia M., Calès L., Inamoratodos Santos A., Kounelis I., Nai Fovino I., Petracco Giudici M., Papanagiotou E., Sobolewski M., Rossetti F., Spirito L.. (2019)Blockchain now and tomorrow: Assessing multidimensional impacts of distributed ledger technologies: Executive summary, EUR 29813 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-08972-8,doi:10.2760/305417, JRC117255.

Niforos, M. (2019). Blockchain in development: A new mechanism of trust. In M. Benjamin, A. Bishop, & O. Daibo (Eds.). pp. 9 –15. *Blockchain: Opportunities for private enterprises in emerging markets*. 2nd edition. International Finance Corporation / World Bank Group. Washington, D.C. <https://documents1.worldbank.org/curated/pt/260121548673898731/pdf/134063-WPandexpanded-121278-2ndedition-IFC-EMCompass-Blockchain-Report-PUBLIC.pdf>.

Puthal, D., Nisha, S. M., Mohanty, S. P., Kougianos, E., & Das, G. (2018). Everything you wanted to know about the Blockchain. *IEEE Consumer Electronics Magazine*, 7(4): 6–14. <https://doi.org/10.1109/MCE.2018.2816299>

Salim, M.M. (2019). When intrusion detection meets blockchain technology. Seoul Tech UCSLab, 1–17. http://www.parkjonghyuk.net/lecture/2019-1st-lecture/blockchain/3_When%20intrusion%20detection%20meets%20Blockchain%20technology.pdf.

Shorman, S., & Allaymoun, M. (2019). Authentication and verification of social networking accounts using blockchain technology. *International Journal of Computer Science and Information Technology*, 11(6), 1–11.

Simard, C., & Tetreault, P.-F. (2017). How the agricultural industry can harvest the benefits of blockchain technology. <https://www.nortonrosefulbright.com/en/knowledge/publications/99438e54/how-the-agricultural-industry-can-harvest-the-benefits-of-blockchain-technology>.

Smith, C. (2019). Blockchain reaction: How library professionals are approaching blockchain technology and its potential impacts. *American Libraries Magazines*. Retrieved from <https://americanlibrariesmagazine.org/2019/03/01/library-blockchain-reaction/>.

Sultan, K., Ruhi, U., & Lakhani, R. (2018). Conceptualizing blockchains: Characteristics and applications. *Proceedings 11th International Association for Development of the Information Society (IADIS) International Conference on Information System*, M.B. Nunes; Isaias, P. & Powell, P. (Eds.). 49–57. <https://www.researchgate.net/publication/325464908>.

Wang, X., Zeng, P., Patterson, N., Jiang, F., & Doss, R. (2019). An improved authentication scheme for internet of vehicles based on blockchain technology. *IEEE Access*, 7: 45061–45071. <https://doi.org/10.1109/ACCESS-2-19.2909004>

Yaga, D., Mell, P., Roby, N., & Scarfone, K. (2018). Blockchain technology: Overview. National Institute of Standards and Technology Internal Report 8202. <https://doi.org/10.6028/NIST.IR.8202>

Zile, K., & Strazdiņa, R. (2018). Blockchain use: Cases and their feasibility. *Applied Computer System*, 23(1): 12–20. <https://doi.org/10.2478/acss-2018-0002>

Zubaydi, H. D., Chong, Y.-W., Ko, K. H., Sabri, M., & Karuppayah, S. (2019). A review on the role of blockchain technology in the healthcare domain. *Electronics*, 8. <https://doi.org/10.3390/electronics8060679> www.mdpi.com/journal/electronics