

Review

A Cross-Sectional Review of Blockchain in Thailand: Research Literature, Education Courses, and Industry Projects

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Abstract: Blockchain technology, a decentralized database that encourages collaboration, transparency, and security, is popular in Thailand, as seen from many practical projects. Nevertheless, information about Thailand's blockchain ecosystem is incomplete. We conducted literature reviews of research articles, education courses, and industry projects, to explore blockchain from the technology adoption flow including academic research, knowledge acquisition, and project implementation. Blockchain research articles were collected from the Scopus database, while projects and courses were retrieved from an internet search. After applying inclusion and exclusion criteria, a total of 13 research articles, 50 courses, and 54 industry projects, dated from 2016 to 2020, were included in our review. Based on an analysis with respect to trends, focuses, and characteristics in all three aspects, we found that blockchain technology in Thailand was in its infancy, but has been increasing in numbers and domain varieties. However, blockchain technology did not move towards the same direction for all aspects. Most research articles were found in government services, supply chain, and traceability domains; while most projects were in the financial domains. We offer possible explanations for this observation. This paper provides challenges and opportunities for the research community and involved parties in practical implementation.

Keywords: blockchain; review; blockchain research; blockchain projects; blockchain courses; cross-sectional review; Thailand



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1. Introduction and Background

Blockchain is a technology that stores all records of transactions in all member nodes in the network. The technology uses cryptography, and every node can verify all transactions in the network. Thus, the data is immutable and fraud-proof. Blockchain technology is therefore considered a traceable decentralized solution with high transparency.

A blockchain workflow has four main steps [1]. First, when a transaction occurs, a block is first generated for storing data. A block consists of two components: (1) a content of the transaction and (2) a header that includes a block ID, a timestamp, and a hash value. The hash value is a string calculated from the content by a cryptographic function and acts like a fingerprint to prevent content modification. Second, once the new block was created, other nodes—devices in the blockchain network—are notified about the new transactions. Third, all nodes perform a consensus mechanism. That is, all nodes must reach an agreement on the transactions to verify the authenticity of the new block. Last, the verified block is linked within the chain. Each block has the hash value of the previous block on the chain to prevent a tampering of history.

The blockchain can be categorized into three types based on permission of data access: public, private, and consortium blockchains. The public blockchain, such as Bitcoin [2] and Ethereum [3], allows everyone to make a transaction without the constraint of data access. Therefore, it is also called permissionless blockchain. A private blockchain, such as MultiChain [4], allows users with permission to access the blockchain network. The

consortium blockchain or federated blockchain, such as Hyperledger [5] and Corda [6], is the combination of the first two types. It only allows a group of users to access the data. Although consortium blockchain is a permissioned blockchain like the private blockchain, it is usually carried out by a collaboration of organizations within the same domain, such as the banking industry.

The topic of blockchain has gained great interest among techno-savvy individuals and communities in Thailand in recent years. Digital Government Development Agency (DGA) published a manual of blockchain application in government services in 2019 [1]. Collaboration projects among Thai banks has also been emerging on the news [7–9]. Nevertheless, blockchain is not yet well known by the general public. Its systematic literature reviews are also scarce. To the best of our knowledge, an ecosystem of blockchain technology in Thailand was recorded in the Bhumiratana’s Github repository [10] in 2018. Unfortunately, the repository was last updated within the same year.

Due to the above reasons, investors would have a difficult time trying to estimate a feasibility of implementing a blockchain project in Thailand. A quick and general search would yield a seemingly promising landscape: an assortment of activities, private sector collaborations, and research papers, all pointing towards a possibility of existing blockchain infrastructure in place and a pool of talents to handle the new technology, but in what capacity can these infrastructures serve? A general literature review would hardly suffice for providing answers. We see the need to thoroughly understand blockchain in Thailand in terms of a knowledge flow, from research to education, and finally, to implementation.

Therefore, a cross-sectional analysis of blockchain development was needed in order to obtain a snapshot of all-around current state of the blockchain as shown in Figure 1. On one end, blockchain research and blockchain courses supply resources. Research articles could show the resources for blockchain implementation. Courses of blockchain could show the capacity to produce potential users to utilize blockchain technology. On the other end, blockchain projects could provide a picture of the market demands of the technology. Such an end-to-end process of blockchain study within the three aspects is an interesting approach to capture the current state of technology adoption.

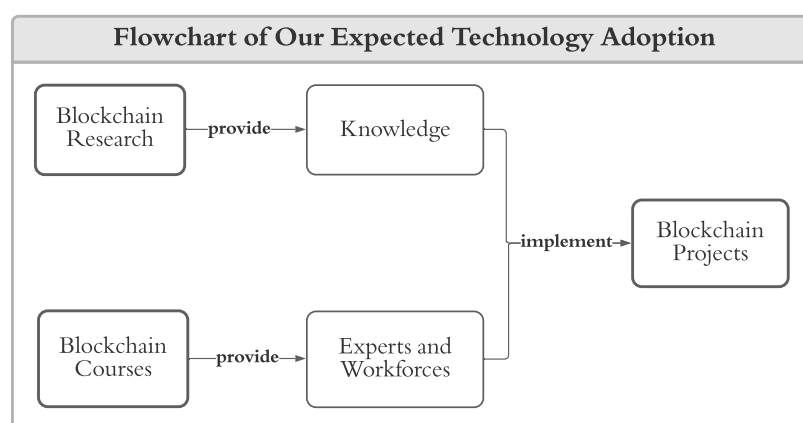


Figure 1. A flowchart of our expected technology adoption.

Most of the existing literature reviews studied blockchain on research papers, in order to capture the current state of blockchain technology and to derive a roadmap for future studies. For example, Casino et al. [11] explored 260 blockchain research articles, categorized them into ten application-oriented categories to show the current stage of each domain, and analyzed the limitations of blockchain technology in order to guide future research. However, the overview of blockchain technology was limited only to scientific research.

An attempt of the cross-sectional research of blockchain development was found in an article by Leible et al. [12], which studied blockchain possibilities to foster open science.

The authors made a comparison between the characteristics of blockchain and open science, and explored 35 research publications and 60 blockchain-based projects to understand current research situations. Data were collected from research publications, whitepapers, blogs, and search engines such as Google scholar, PLOS, CiteSeerX, Microsoft Academic Search, and Github. The authors categorized the projects into six groups based on their functionalities for open science. Most of the blockchain projects were found unstable. A few of them were inactive, cancelled, or disappeared. Despite a few inactive projects, some projects and literature had the potential to foster open science if they received some improvement. The authors also stated that blockchain development depends on “adoption rate of blockchain technology”, and “the number of users is a key factor.”

Few articles studied blockchain in education courses. To the best of our knowledge, we found only one literature studying the blockchain in academia. Themistocleous et al. [13] aimed to explore a current state of blockchain technology in academic education and to understand the blockchain course structures in Master of Science (MSc) degrees. They collected data from a web search for curriculum, an exploratory qualitative study on data of University of Nicosia, and an alumni survey. As a result, blockchain education was found to still be in an early stage. Most of them delivered only a basic of the technology, and a small number of universities provided a postgraduate program on blockchain. It can be seen that the number of talents in blockchain development were likely not to correspond to the high demands of blockchain technology, and the design of blockchain courses should receive more attention.

This paper explores an overview of blockchain development in academic research, knowledge acquisition, and project implementation. It aims to understand blockchain development from end to end as well as discover challenges and opportunities for further research in Thailand. To address this, research questions are proposed as follows: (1) how has blockchain developed in each aspect over time? (2) what are challenges and opportunities for blockchain research both in academic communities and business?

This paper contributes towards an understanding of blockchain technology in the perspective of technology adoption process. It provides potential research topics about blockchain development in Thailand. In regard to an analysis, this paper demonstrates the growing trends of the technology found in the blockchain-related platforms through three topics: (1) the relation of blockchain trends in academic research, project implementation, and knowledge acquisition, (2) an interest of blockchain technology in a large range of domains across aspects, and (3) a future direction of blockchain development through the challenges and opportunities found on Thailand landscape.

The remaining of the paper is arranged as follows. Section 2 presents the overall methodology of all the reviews. Sections 3–5 portray the results of the three aspects and basic analyses of the data. Section 6 discussed relative timelines, focuses, as well as the challenges and opportunities from the three aspects.

2. Methodology

In order to conduct an inclusive and reliable literature review search of blockchain-related subjects in Thailand, we adapt the systematic review methodology similar to that in Casino et al. [11]. The overall process of each aspect includes:

1. Identify objectives for the review as well as develop a protocol for data retrieval and analysis;
2. Locate data, select the data, and summarize data into a table; and
3. Report the results of the reviews.

2.1. Locating Data

Data in this paper was retrieved by two approaches (Figure 2). The first approach was a search on a scientific electronic database for research articles about blockchain. The second approach was an information search on internet to gather information for blockchain industry projects and education courses.

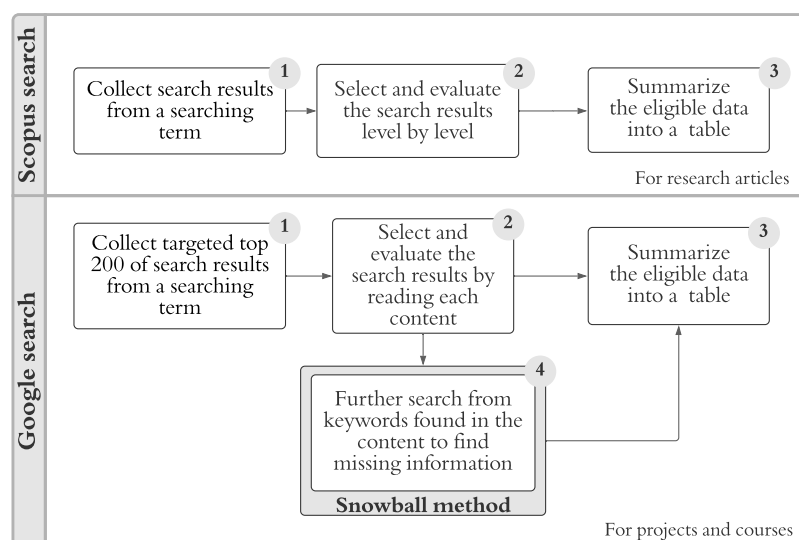


Figure 2. A workflow of data search.

2.1.1. Locating Data for Literature Reviews of Blockchain Research in Thailand

A literature search was conducted on 6 January 2021. Scopus was used as a main database where *TITLE-ABS-KEY((blockchain OR “block chain” OR Bitcoin OR ethereum) AND (Thailand OR Thai))* was applied as a search term. Using this search pattern, 23 articles, published between 2017 and 2020, were identified. Nevertheless, only 16 articles can be retrieved in a full-text article. Although all of the retrieved articles were not full-text, the basic information, such as titles, authors, published years, and abstracts, could be retrieved in a CSV format.

In addition, another search was conducted to compare the number of blockchain-related articles in Thailand in relation to the number of blockchain-related articles in the global. The second search was done in Scopus on 27 January 2021, with the search pattern *TITLE-ABS-KEY((blockchain OR “block chain” OR Bitcoin OR ethereum))*. According to this modified search pattern, 20,441 articles, published between 1968 and 2020, were found. It is good to note that *ethereum* has other meanings apart from blockchain architecture. As a result, some articles that were not related to blockchain appeared before 2008. To compare the number of articles within the same time frame (between 2017 and 2020), 18,734 articles were identified.

2.1.2. Locating Data for Literature Reviews of Blockchain Projects and Courses in Thailand

To identify blockchain industry projects and education courses in Thailand, the Google search engine was chosen as a retrieval platform because the database is easily accessible and consists of reliable sources such as official press websites, organization websites, and technology-oriented websites. The websites “techsauce” and “siamblockchain” were examples of technology-focused websites containing project information, while the websites “techtalkthai” and “mgronline” were examples of websites containing course information. A literature search without a clear scope of systematic search strategies could cause data redundancy and data insufficiency for analysis within the time limit. Thus, in order to avoid the mentioned problems, a targeted number of search results was set, and snowball method was adopted as follows (Figure 2):

1. Top 200 search results from Google were retrieved and recorded to prevent the change of search results due to search engine’s algorithm.
 - (a) On 9 December 2020, the results about projects were collected with three Thai words “โครงการ บล็อกเชน ประเทศไทย [Thailand blockchain projects]” as a search term.
 - (b) On 13 January 2021, data of blockchain courses in Thailand were collected with the following search pattern: “บล็อกเชน [blockchain] OR blockchain OR block

*chain OR บิทคอยน์ [bitcoin] OR bitcoin OR ethereum OR Cryptocurrency OR fintech
AND หลักสูตร [course] OR สอน [teaching] OR บรรยาย [lecture] OR สัมมนา [seminar] OR วิชา
[subject] ORอบรม [training]."*

2. A further search using *keywords* found in the contents of search results from the previous step (snowball method) was carried out to make the search scope more inclusive and detailed. Since search results in the first step were likely to be general, such as articles about blockchain concept, press releases showing a project progress, course advertisements, and news about courses, the details of projects retrieved in the previous step might not be adequate for analysis. The keywords could be a term relevant to either blockchain-oriented projects or courses, such as titles, stakeholders, and architectures.

In the end, we retrieved 145 search results from the search term about blockchain projects in Thailand and received additional 59 keywords for the snowball method. Regarding to the data for blockchain courses, 147 search results were found as a result of the search pattern.

2.2. Selection and Evaluation

The process of data selection started after data retrieval had been done. Table 1 shows inclusion and exclusion criteria.

The selection process of research articles was conducted in three levels: title screening, abstract screening, and full-text article reading. If the decision on the article's eligibility could not be made clearly, the article would have to undergo the selection in the next level as shown in Figure 3. For a research article to be eligible, it must show that its procedures involved Thais. It can be an article authored by at least one Thai researcher or an article that had a field research in Thailand. Further, the contents of articles must mainly presented blockchain development, application, or adoption.

To be included, project-based data must not present only the content about the basic ideas of blockchain. It must offer either a blockchain-based solution in a particular domain or a blockchain architecture design. Besides, the projects need to involve Thais or be implemented in Thailand (Thai people may be exposed to the technology).

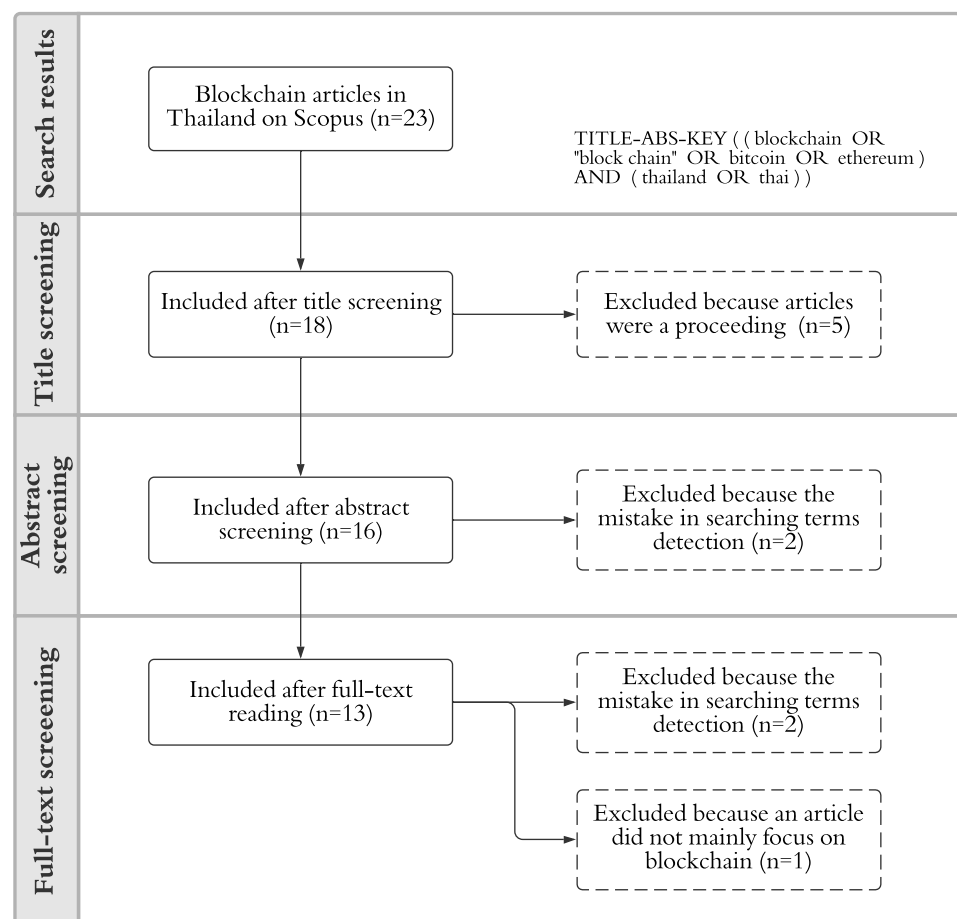
Similarly, eligible courses must be taught by Thai experts or had Thais as a part of the organizer. In addition, the eligible course-based data must not provide only materials about blockchain, such as books and articles, but also present the basic details of courses about blockchain, namely titles, objectives, and organizers. The eligible courses also include a workshop and a seminar.

The data sources of projects and courses should be trustable or supported by official entities, such as experts or credible organizations.

Any data meeting one of the exclusion criteria was excluded from the analysis, and the reasons behind the exclusion would be recorded. Most of the articles were excluded because they were in proceedings. On the other hand, the search results of projects and courses from the internet were mostly excluded due to duplicates. Any discrepancy in the eligibility of data was resolved through the authors' discussion.

Table 1. Inclusion and exclusion criteria.

Selection Criteria	Research Articles	Projects	Courses
Inclusion criteria	(1. At least one author is Thai OR 2. Having a field research in Thailand) AND 3. Contents of the articles mainly present about blockchain, such as its development, its acceptance, an application of digital currency, etc.	1. A project must have Thai people exposed to blockchain AND 2. A search result needs to show how blockchain can be applied in a particular industry either in theory or as a launched project AND 3. The data sources should be trustable or supported by experts.	1. A course must be organized by Thais. AND 2. A course could be a course, a workshop, or a seminar. AND 3. A search result has to show the basic details of courses about blockchain like titles, objectives, and organizers AND 4. The data sources should be trustable or supported by experts.
Exclusion criteria	1. No Thais involved in research OR 2. Research was not conducted in Thailand (excluding publishing) OR 3. Research used data in Thai, but Thais were not exposed to it OR 4. An article was found as a article listing page of a proceeding	1. The content must not be a duplicate. OR 2. The content is not just a general idea of blockchain	1. The content must not be a duplicate. OR 2. The content must not provide only materials about blockchain, such as books and articles

**Figure 3.** A flowchart of the research articles selection process.

2.3. Analysis

Details of eligible data were extracted and recorded. They were analyzed with respect to trends, focuses, and characteristics, to understand an overview of blockchain development.

3. A Systematic Review of Blockchain Research in Thailand

This section reviews research articles on blockchain applications in Thailand context. Twenty-three articles were identified from Scopus. After the selection and evaluation process, a total of 13 articles were included in the analysis.

3.1. Trend of Blockchain Research in Thailand

From 2017 to 2020, the number of blockchain research in Thailand was much smaller than the global ones, as shown in Figure 4. A total of 13 blockchain articles were published in Thailand, which is 0.07 percent of the number of worldwide blockchain articles. The number of blockchain research has been rising for three years, which corresponds to the growing tendency of the global ones.



Figure 4. A comparison of the number of blockchain-based articles between Thailand and worldwide from 2017 to 2020.

3.2. Focus of Blockchain Research in Thailand

The blockchain research in Thailand can be categorized into four domains: (1) government services, (2) supply chain and traceability, (3) finance, and (4) miscellany, as shown in Figure 5.

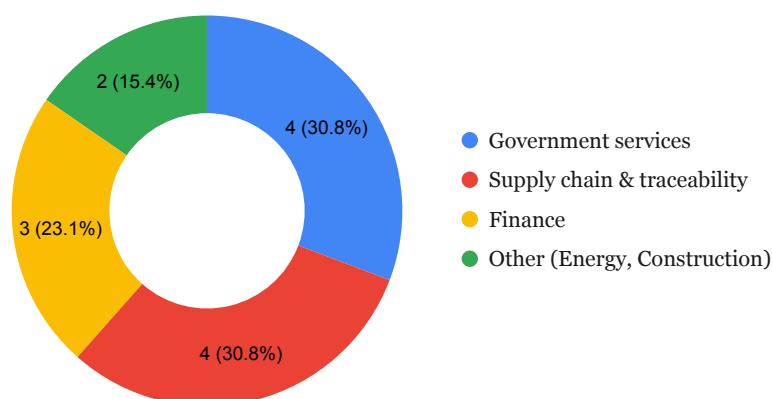


Figure 5. Domain portions of blockchain research in Thailand.

The research of blockchain in Thailand concentrated on blockchain's capabilities to tackle the problems of centralized government's performance, followed by the industry of supply chain and traceability. The research on government services focused on solving the problems caused by a centralized system, such as delay and complexity of government services [14–16], as well as the lack of transparency and credibility of Thai government [17].

The research on supply chain and traceability focused on how blockchain can enhance trust and transparency in food and agriculture, which are the main industries in Thailand [18,19]. Apart from the possibilities of blockchain applications in the domain of supply chain and traceability, success factors of blockchain implementation in this domain were also studied [20,21].

In addition to government services and supply chain, there were also research works in financial and other domains. Blockchain technology was initially in the spotlight due to its application in finance [20,22]. Contrarily, the number of blockchain research in the finance domain did not constitute a majority in Thailand. The existing articles in the financial domain were related to an application in accounting verification [23] and performance evaluations of bitcoin in investment [24,25]. Aside from the mentioned domains, there were one article about energy trade on a blockchain-based platform [26] and one article about the acceptance factors of blockchain in Thailand's construction industry [22] (Table 2).

Table 2. Articles categorized by domains and sub-domains.

Domains	Sub-Domains	Article Titles
Government services	Government services	- A practical national digital ID framework on blockchain (NIDBC) (2018)
		- Design of blockchain lottery for Thai government (2019)
		- Proof-of-Concept (PoC) of Land Mortgaging Process in Blockchain-based Land Registration System of Thailand (2020)
		- The prototype of thai blockchain-based voting system (2020)
Supply chain & traceability	Supply chain	- The acceptance of the application of blockchain technology in the supply chain process of the Thai automotive industry (2017)
		- Supply network design to address United Nations Sustainable Development Goals: A case study of blockchain implementation in Thai fish industry (2020)
	Traceability	- Blockchain Eco-System for Thai Insect Industry: A Smart Contract Conceptual Framework (2019)
		- Thai agriculture products traceability system using blockchain and Internet of Things (2019)
Finance	Accounting	- The development of accounting verification process affecting digital currency transactions using blockchain technology for small and medium business in Thailand (2018)
	Cryptocurrency	- Could Bitcoin enhance the portfolio performance? (2018)
		- Asymmetric correlation and hedging effectiveness of gold and cryptocurrencies: From pre-industrial to the 4th industrial revolution (2020)
		- A Business Model Guideline of Electricity Utility Systems Based on Blockchain Technology in Thailand: A Case Study of Consumers, Prosumers and SMEs (2020)
Other (Energy, Construction)	Energy	- A Business Model Guideline of Electricity Utility Systems Based on Blockchain Technology in Thailand: A Case Study of Consumers, Prosumers and SMEs (2020)
	Construction	- Understanding Stakeholders Needs for Using Blockchain Based Smart Contracts in Construction Industry of Thailand: Extended TAM Framework (2020)

Figure 6 portrays how diverse blockchain research in Thailand has become over the three-year period. In 2017, only a piece of blockchain-related research in supply chain and traceability industry [20] was found. A year later, the number of blockchain research increased, and research articles in finance and government services were present. The diversity of domains in blockchain research began to increase in 2020. Interestingly, the blockchain research in supply chain and traceability domain had been present from the start.

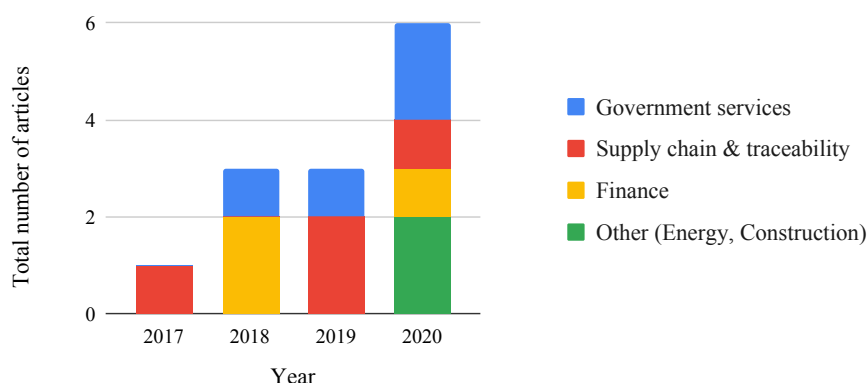


Figure 6. A trend of domains of blockchain research in Thailand between 2017 and 2020.

3.3. Characteristics of Blockchain Research in Thailand

The presentation of the research can be classified into three groups, which are (1) framework, (2) implementation guidelines, and (3) adoption. Each group had different focuses of topics, as shown in Figure 7.

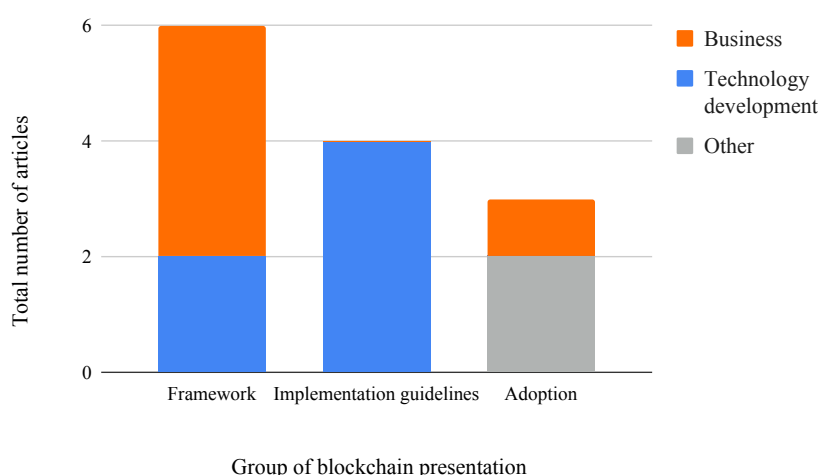


Figure 7. A portion of presentation of blockchain research in Thailand.

1. Framework of blockchain application

Research that presented frameworks of blockchain applications was found the most in the blockchain research in Thailand. This was a direct approach of blockchain research. However, most of the articles explained only featured characteristics of blockchain, such as decentralization, transparency, and high velocity. After that, they explained how these characteristics could solve problems of traditional systems in their domains. Some articles further presented frameworks with visualization showing the relation between stakeholders in networks. Some articles explained only how a blockchain system works in detail, but essential technical information for implementation was not found in this group of presentation. Thus, the objective of this group of articles mostly was business-oriented. Few articles presented a focus on technology development, but they had insufficient information for system implementation.

2. Blockchain implementation guidelines

Similar to the framework group of articles, this approach was a direct blockchain research. Articles in this group especially presented their architectures together with the software and types of blockchain they used. It was, thereby, possible to follow the proposed steps for an actual implementation. The group's aim was technology development rather than business. However, only few articles in Thailand included technical performance eval-

uation section, such as speed and security. Most of the articles only presented a framework with a prototype test.

3. Adoption of blockchain

This was an indirect approach of blockchain research. Examples of blockchain research papers in the adoption group are the following. An article studied about behavioral factors of stakeholders in a successful blockchain implementation in collaborative projects. Another article studied applications of products with blockchain as an infrastructure, such as, evaluating Bitcoin's performance in investment. Because this group of presentation did not deliver blockchain research directly, the focuses of these articles were mostly business application or other objectives apart from blockchain development. This group of presentation had the least number of research.

4. A Review of Blockchain Courses in Thailand

This section presents a systematic literature review of blockchain-related courses in Thailand. The courses could be offered by colleges, universities, technology-related associations, government organizations, companies, or individuals. After the process of selection and evaluation on 147 search results, there were 50 eligible courses for analysis.

4.1. Trends of Blockchain Courses in Thailand

4.1.1. A Trend of the Number of Blockchain Courses in Thailand

The first two courses related to blockchain, Seminar on Blockchain and Open API [27] and Seminar on Blockchain Technology and the Changes in Legal Services [28], began in 2016 as shown in Figure 8. The number of courses started rising in 2017 and has been increasing for three years. On January 2021, when the data was collected, there were already three blockchain courses: the 10th Fin-tech and Blockchain for Digital Transformation Course [29], Trading in Cryptocurrency Market and Understanding of Blockchain [30], and Blockchain Concept and Practical Use case for Management [31]. It could be said that blockchain technology in Thailand was in an early stage and was possibly prospected that blockchain will still be able to draw attention.

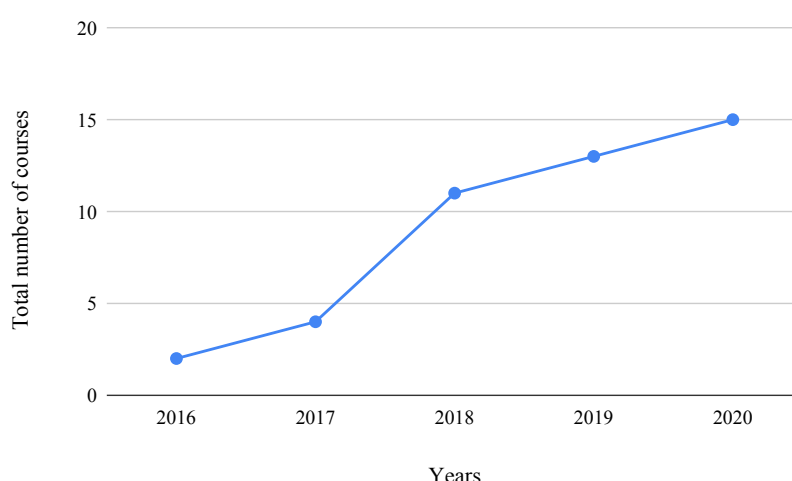


Figure 8. A trend of the number of blockchain courses in Thailand from 2016 to 2020.

4.1.2. A Trend of Instructional Mode from 2016 to 2020

The most used mode to deliver blockchain knowledge was an in-person lecture, as shown in Figure 9. In-person workshops of blockchain ranked second and dominated the instructional mode in 2019. Blended learning and online platforms, such as video and live streams, started to appear in 2018. Then, they were adopted even more in 2020. The adoption of online learning in 2020 might be higher because the social distancing regulation against COVID-19 pandemic was enforced in the end of 2019. Although the

online modes were adopted due to the pandemic, the majority of course delivery mode was still an in-person lecture. One possible reason of the popularity of in-person modes was that the public was not familiar with blockchain technology enough to trust and engage with the technology via online channels. It might also show that blockchain learners need an in-person lecture to understand the complexity of blockchain.

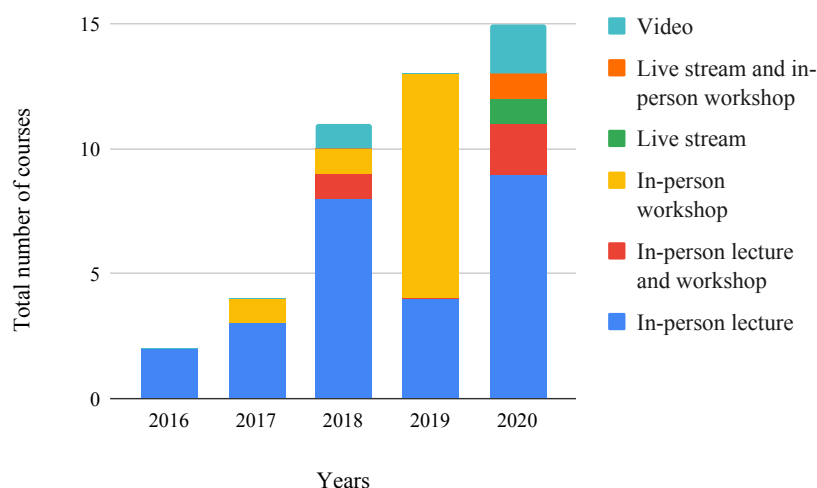


Figure 9. A trend of instructional modes from 2016 to 2020.

4.2. Focus of Blockchain Courses in Thailand

Objectives of blockchain courses in Thailand could be classified into 6 groups as shown in Table 3. The courses focused on introducing the basic concept of blockchain (45 courses out of 50 courses), followed by providing an understanding of cryptocurrency, how the technology disrupted the current business model, and ways to trade in the cryptocurrency market and to run the business, respectively. Technical skill training for blockchain technology development and experience sharing were less highlighted. To summarize, the blockchain courses in Thailand mainly covered blockchain concepts and its applications in general, together with its products like cryptocurrency. The courses with business-oriented purposes were produced to satisfy people's current needs, rather than the courses that aimed to develop technical skills for an implementation.

Table 3. A table showing the frequency of objectives in which each course targets.

Group of Objectives	Number of Courses
1. Understand the change of business models	25
2. Improve software programming skills related to blockchain softwares such as Ethereum, Hyperledger, etc.	17
3. Understand a concept of blockchain	45
4. Understand cryptocurrency and related topics	26
5. Understand ways to trade in cryptocurrency market and ways to run a business related to cryptocurrency	22
6. Share experiences about blockchain and cryptocurrency	16

4.3. Characteristics of Blockchain Courses in Thailand

4.3.1. Distribution of Blockchain Courses in Thailand by Duration

Blockchain course's duration could be divided into three groups. First, a short-term course is a course that ends within one day. Second, an intermediate-term course is a course that participants need to spend a few days to complete. Last, a long-term course is a course that takes approximately a week's time to complete. Examples of courses based on their durations could be seen in Table 4. The amount of time to complete a course on average

was considered very short. The average time duration of 50 blockchain courses was 10.7 h. Figure 10 shows that the majority of blockchain courses were short-term (assuming that an 8-h period can satisfy a one-day course). We believe that the limited time of the courses may be a result of some limitations, such as budget and management. In addition, the small amount of time corresponded to the simplicity of the course's contents (in Table 3). That is, most of the blockchain course's objectives in Thailand mainly aimed to present the basic idea of blockchain. The less time the course had, the less details of the blockchain concept could be delivered.

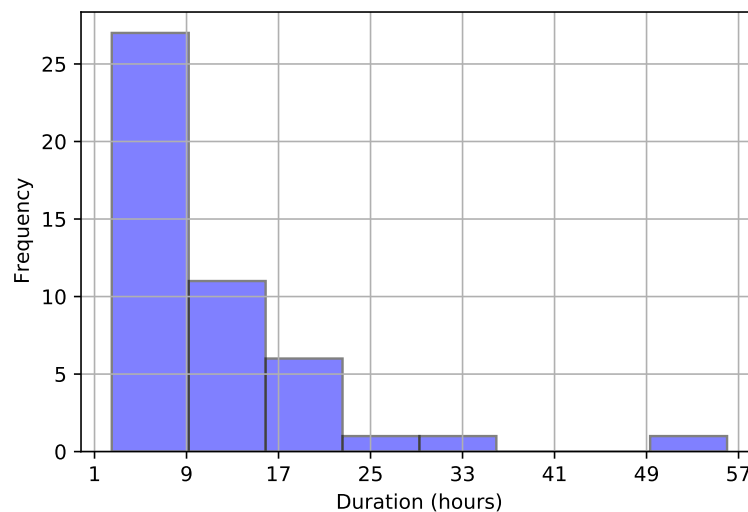


Figure 10. A histogram showing a distribution of course durations in Thailand.

4.3.2. Distribution of Blockchain Courses in Thailand by Instructors

There were a total of 110 blockchain instructors for the 50 eligible courses. However, only 19 instructors had conducted more than one course. That is only 17 percent of the number of all instructors. In other words, most of the instructors only conducted one course, as shown in Figure 11. The highest number of courses per instructor was eight. It was considered a small course-to-instructor ratio for the 3-year period. The frequency of courses per instructor could show that an expert in blockchain has not been distinctive yet in Thailand.

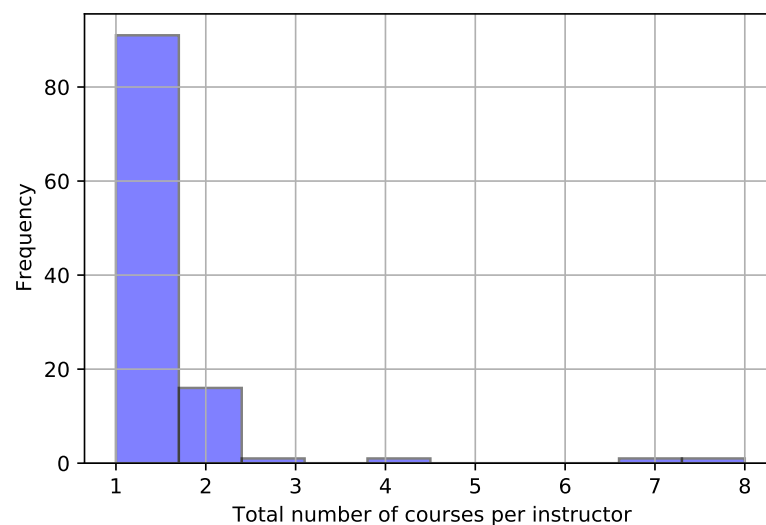


Figure 11. A histogram showing a frequency courses per instructor in Thailand.

Table 4. Examples of courses based on duration groups.

Course Titles	Objectives	Durations	Target Participants
An example of a short course:			
Blockchain and Bitcoin 101 [32–34] (7 March 2020 12:30–18:00)	to understand blockchain technology in details - to know the importance and benefits of cryptocurrency for our lives - to know how to trade cryptocurrency in markets	5.5 h.	For a beginner who is interested in blockchain technology, bitcoin investment, and cryptocurrency
An example of a medium-length course:			
“Blockchain: The Next Internet?": A workshop to get to know blockchain technology [35–38] (19–21 June 2017 9:00–17:00)	- participants will know and understand how blockchain technology operates both in theory and practice. - participants will have hands-on experience in developing an application on blockchain. - participants will join an experience-sharing session about blockchain from many experts and organizations that have developed applications on blockchain. - participants who are university lecturers will gain knowledge and experiences for their classes and will be able to train people to adapt to blockchain technology - to create a networking platform for people who are interested in blockchain development so that they can have a chance for cooperation, exchange, and learning from each other.	24 h.	- For people who are interested in blockchain technology and its applications, - For university lecturers who aim to develop a blockchain course - For IT specialists, IT lecturers, or business people who are interested in IT - Executives or strategic planners who follow the trend of new technology development
An example of a long course:			
“Geeks on the Block (Chain)” A Blockchain Camp for Developers [39] (7 September 2018– 2 November 2018, 7 days of instructions, 8 h per day)	- to enhance working efficiency and gain benefits of blockchain for your own business or your organization - to train a developer to be efficient in blockchain development - to understand the basic and concept of blockchain systems - to be able to create blockchain systems and understand the algorithms like Hyperledger and Ethereum. - to have a hands-on experience in doing projects and get reviewed project by project from mentors in business, user experiences, and technical operations after the course ends, participants will be able to utilize the knowledge of blockchain to run a business or provide values to their organizations	56 h.	For developers who - would like to be a blockchain developer - don't want to waste time undergoing trial and error - want a hands-on experience with experts in blockchain and a smart contract - would like to develop a solution for real-world problems would like to prove their programming skills and have an experience in public code review The developers needs to - have basic programming skills - be familiar with NodeJS and GO programming language - be familiar with Docker, Git, and Workflow

5. A Review of Blockchain Projects in Thailand

This section presents the results of a review of blockchain-related projects in Thailand. After the process of selection and evaluation, there were 54 finalists of the blockchain project to be analyzed.

5.1. Trend of Blockchain Projects in Thailand

The first two blockchain projects ([9,40–43]) in Thailand appeared in the press in 2016, as shown in Figure 12. There was a threefold increase of the total number of blockchain projects from 2016 to 2017. Blockchain implementation in Thailand skyrocketed since 2017 and slightly dropped in 2020. Note that a blockchain project normally takes more than 1 year. Thus, to inspect the trend of blockchain projects in Thailand, we considered the year that showed the first Thai-involved activity of a project in a press. There were three projects without dates.

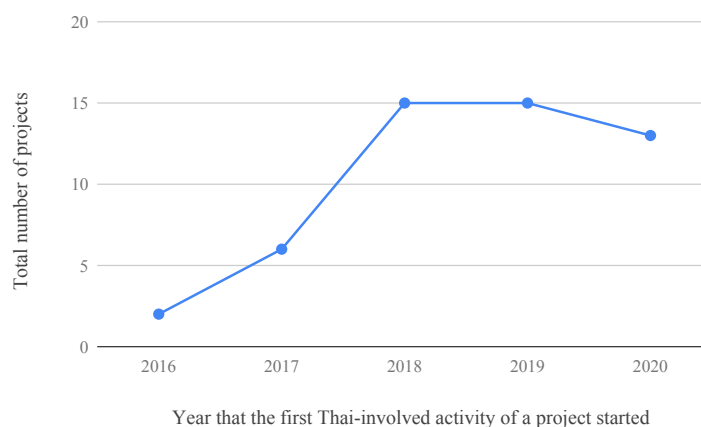


Figure 12. A trend of blockchain projects publicly known in Thailand.

Blockchain was employed in highly diverse industries. Not only had blockchain projects been increasing in numerosity, but domain variety also rose, as shown in Figure 13. For example, there were only financial projects in 2016. The project-domain ratio was 1. In 2017, besides finance, blockchain projects involved government services; trade, logistics, and supply chain; energy; and blockchain as a service. The ratio increased to 1.2. During 4 years, the most diverse years of blockchain project implementation were 2018 and 2019. Their project-domain ratios were 2.3. The figure also shows that financial projects of blockchain have adopted the technology from the start and increasingly utilized it over the years.

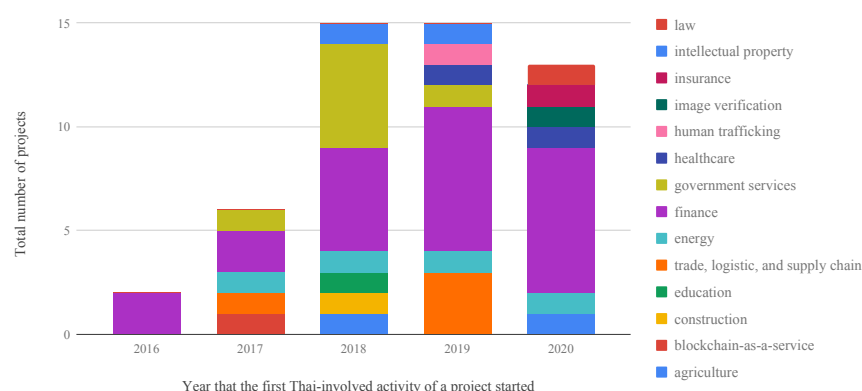


Figure 13. A trend of blockchain domain from 2016–2020.

5.2. Focus of Blockchain Projects in Thailand

There were 54 blockchain projects which can be categorized into 15 domains (Table 5). Financial applications take the largest portion of all blockchain applications (23 projects out of 54 projects), followed by government services; trade, logistics, supply chain; energy; and healthcare applications, respectively. We believe that a finance-oriented application becomes the largest portion of applications because the financial industry was one of the first industries disrupted by blockchain. The intensity of disruption which a domain faces could be one factor that affects blockchain development in Thailand.

Table 5. A table explaining domain classification.

Domains	Number of Projects	Percentage	Description
Finance	23	42.6	Actions relating finance e.g., letter of guarantee, letter of confirmation, domestic and international transfer, digital currency, bonds, and gold investment
Government services	8	14.8	Services delivered by a government e.g., tax refund, procurement, fee payment, NDID, identity verification, and voting
Trade, Logistic, Supply chain	4	7.4	Trade, logistics, procurement in supply chain industry, and financial transactions relating to trading
Energy	4	7.4	An exchange or trade of energy including an issue of renewable energy certificates
Healthcare	3	5.6	Medical information management such as medical history
Intellectual property	2	3.7	Intellectual property management including registration, copyright infringement protection, etc.
Agriculture	2	3.7	Agricultural traceability and commerce
Law	1	1.9	Applications relating to law such as case law management
Insurance	1	1.9	Applications relating to insurance
Image verification	1	1.9	Image storage and fraud detection of images
Human trafficking	1	1.9	Applications in human trafficking
Education	1	1.9	Applications for educational purposes such as educational document verification
Digital asset	1	1.9	Actions relating to digital assets
Construction	1	1.9	Applications in construction
Blockchain-as-a-service	1	1.9	A service that provides ready-to-use blockchain platform for users, not relevant to blockchain architecture design

5.3. Characteristics of Blockchain Project Implementation in Thailand

We investigated which types of stakeholders were involved in each domain of projects in order to understand blockchain project management in Thailand. A total of 220 stakeholders from 54 projects were classified into 4 types: banks, firms, government, and independent organizations. First, banks refer to financial institutions. Due to their large number, banks were considered one of the biggest stakeholder types. Second, firms refer to for-profit organizations. Third, government refers to any non-profit organization aiming for public benefit. Last, independent organizations refer to those organizations not governed by other parties. Examples of independent organizations include a university, an association, or an organization who took a neutral stand. As shown in Figure 14, blockchain projects in 9 out of 15 domains (attributing to 89 percent of all blockchain projects in Thailand) involved more than one type of stakeholders. The top two largest project domains, finance and government services, involved up to four types of stakeholders. It shows that various sectors were attracted to the blockchain technology. The biggest adopter of blockchain technology across domains in Thailand was the firms, whereas the banks are an important player in finance and government services.

A lot of stakeholders from various sectors were involved in blockchain project implementation in Thailand. Unlike a variety in types, the number of stakeholders per project was not very high. In Figure 15, most blockchain projects were conducted by a few stakeholders. It can show that the majority of blockchain projects in Thailand were small projects due to a small number of stakeholders. Only a financial project in the national scale took nearly 40 stakeholders from a collaboration of domestic and international financial institutes [44–48].

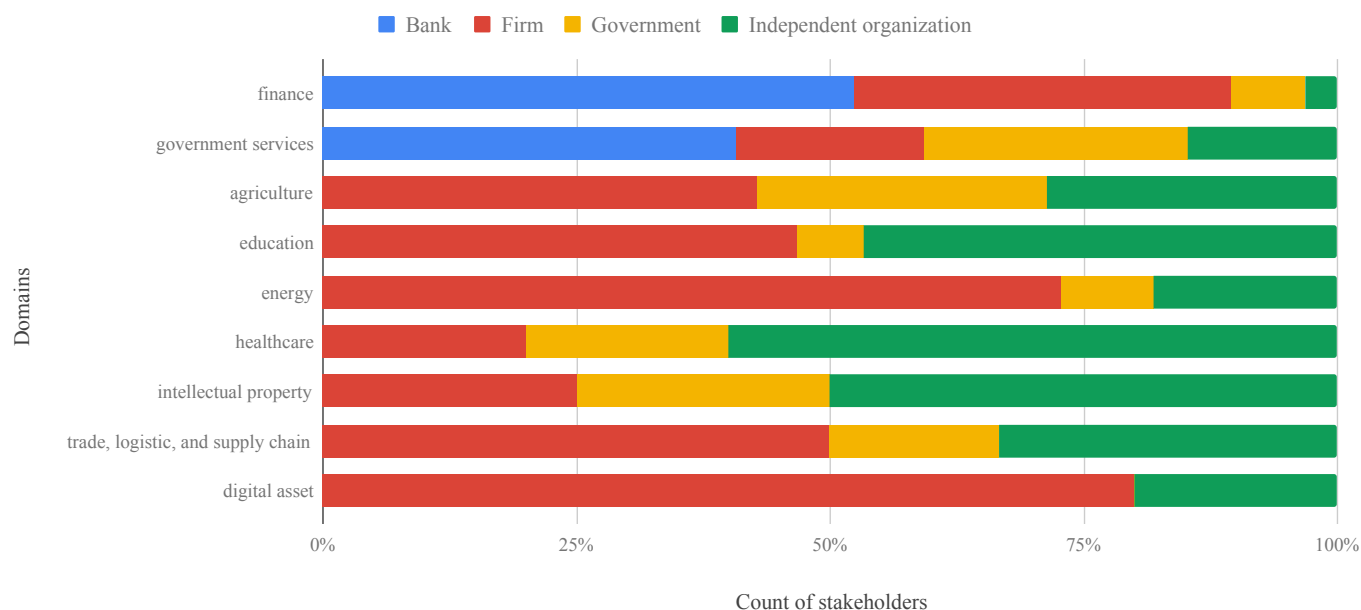


Figure 14. A distribution of agent types by domains.

Figure 16 shows top stakeholders of all blockchain projects. Krungthai Bank, a bank under Thai government, involved the most in blockchain project implementation in Thailand. Krungthai Bank's projects ranged from projects owned by the government, collaborative projects with Thailand's financial institutions, to its own projects. The projects owned by the government included E-credit Confirmation [49,50] and E-letter of Guarantee (e-LG) [49,51] with the Comptroller General's Department; VAT Refunds for Tourists with the Revenue Department and Thai Customs Department [52–56]; and Tax Refund Blockchain [57–60], License Renewal [57,58], and E-bank Guarantee [57,58] with the Excise Department. The collaborative projects were at a national scale that involved many banks, including other banks in Figure 16. Examples of collaborative projects include Inthanon project [61–66], Inthanon-LionRock project [36,61,67–69], DLT Scripless Bond project [70,71], and e-letter of guarantee service [44–48]. The Krungthai Bank also had their own projects like the remittance service with Shwe Bank [8,72] and identity verification for account opening by face recognition on Krungthai NEXT application [57].

Other banks—Kasikorn Bank, Krungsri Bank, and Siam Commercial Bank—were involved in the collaborative financial project called national digital id (NDID) project [73,74] aside from the mentioned collaborative projects. Moreover, they launched a few projects of their own. The Kasikorn Bank had K Connect-LG [75], bond selling [76,77], OriginCert API [40–42], and Visa B2B Connect [78–82]. Krungsri Bank presented Krungsri Blockchain's Interledger for real-time international funds transfer [7,83], Letter of Credit between Thailand and Japan [42,84], and process of documentation on the blockchain [42,85]. Siam Commercial Bank launched a project about international fund transfer between Thailand and Japan [9,42,43].

Aside from banks, IBM was also involved in the mentioned projects as a technology provider in Thailand. Examples of their projects included the OriginCert API and Visa B2B Connect of Kasikorn Bank, the documentation of Krungsri Bank, and collaborative projects like DLT Scripless Bond project and the e-letter of guarantee service. Besides, IBM participated in TradeLens project together with Maersk and Thailand Customs department [86–88].

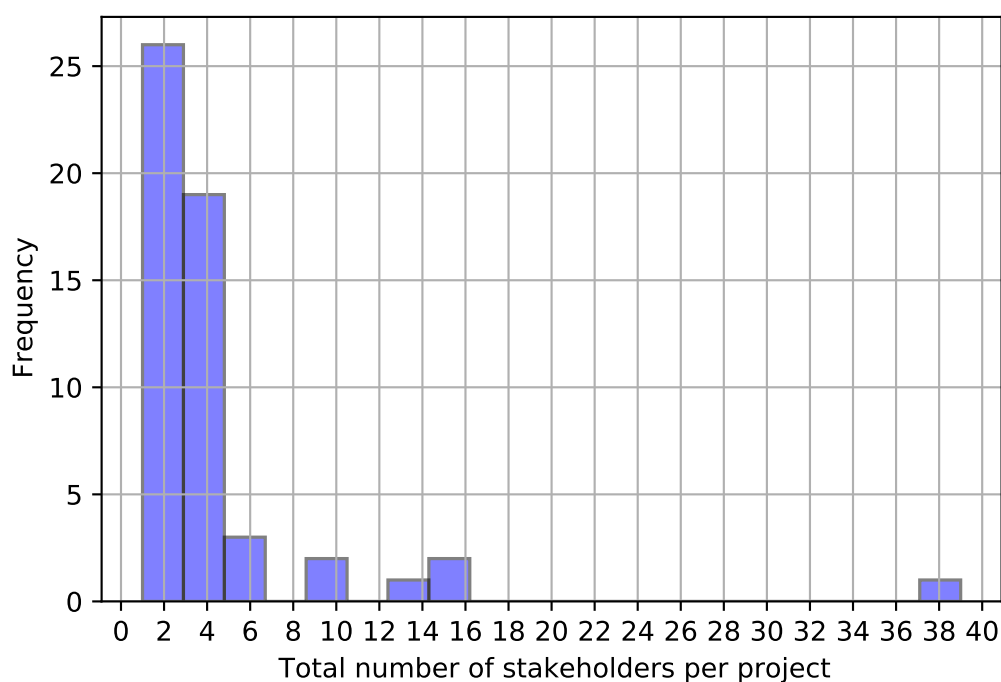


Figure 15. A histogram showing a distribution of stakeholders per blockchain project in Thailand.

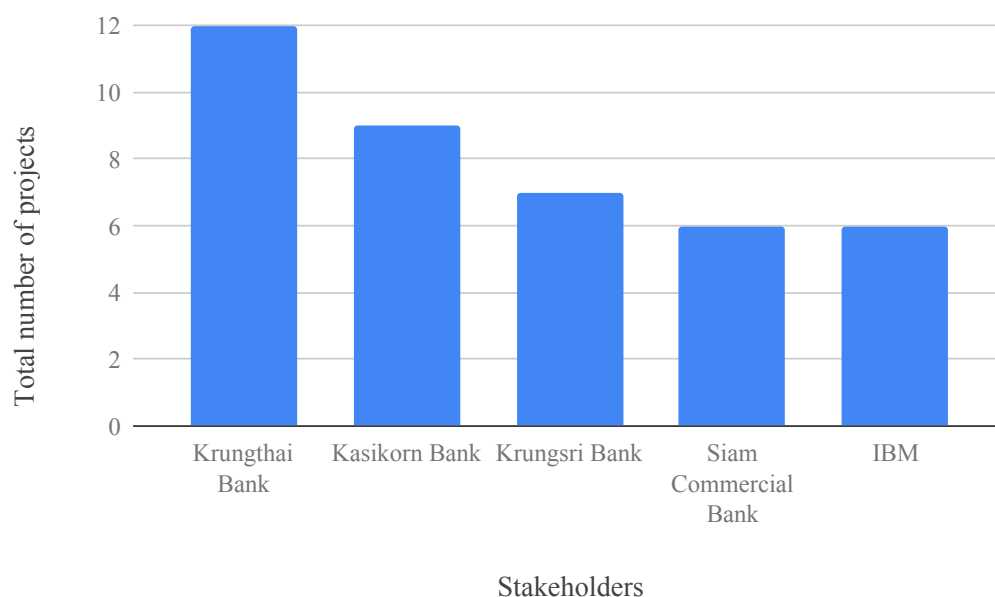


Figure 16. Top five stakeholders of blockchain projects in Thailand.

5.4. Generations of Blockchain and Blockchain Projects in Thailand

Blockchain has been classified into 4 generations according to their stages of evolution [89–91]. Blockchain 1.0 refers to digital currency applications, started with bitcoin in 2008. It enables decentralized consensus with the aim to reduce transaction cost. Blockchain 2.0, started around 2013, refers to smart contract applications, enabling additional services beyond digital currency applications. Blockchain 3.0, started around 2015, refers to decentralized applications (DApp). It enables a peer-to-peer network between different parties, lessening organizational boundaries. Blockchain 4.0 is emerging to apply the blockchain applications in wider industries, which started around 2018. It involves decentralized artificial intelligence (AI) to automate decision making. The classification of the four generations is a global aspect of blockchain evolution.

Most blockchain projects in Thailand belong to generation 2.0 and 3.0, and there is currently no project that could be classified as generation 4.0. Examples of generation 2.0 projects include an ICO portal project, Inthanon (Central Bank Digital Currency: CBDC), Lightnet (a cross-border remittance service), etc. Examples of generation 3.0 projects include B.VER (a blockchain solution for academic document verification), TradeLens (a joint project by Maersk and IBM to improve the efficiency and security of the shipping industry in global trade, in which The Customs Department of Thailand has joined), etc. We note that classifying a blockchain project to a blockchain generation between generation 2.0 and 3.0 is sometimes challenging, because the lack of details of the projects implementation, therefore, we are describing some example projects instead of providing categorization of all projects. However, we could summarize that the current generation of blockchain projects in Thailand is at most 3.0. We speculate that we might see some projects of blockchain 4.0 sometime soon, because both blockchain and artificial intelligence technology have been active areas of research and development by many Thai industries.

6. Discussion

6.1. Timeline and Trends

To see a blockchain trends across platforms, Figure 17 displays a gantt chart of events discovered in the review. The Y-axis shows the type of blockchain items and the identification number of (ID) of each blockchain. Each row represents one research article, course, or project. The X-axis shows the dates of the events from 2016 to the beginning of 2021. Each event has different colors based on the event types, as described in Table 6.

The cross-sectional timeline visualization shows that blockchain technology has appeared in Thailand landscape since 2016. Initially, it appeared in a project implementation in the beginning of 2016. Around the end of 2016, a blockchain course started. A year later, the first research article about blockchain was published. In other words, a behavior of blockchain technology in Thailand started with the project implementation before courses and research publications, which contrasts our believe of how technology adoption propagate from research and education to industry project as mentioned in Figure 1.

Although a lot of blockchain projects had been initiated during 2016–2020, only a few projects announced their terminations. For instance, the number of green dots, which indicate the start of a project, was significantly higher than the number of blue dots, which indicate the continuation of a project. Due to the unavailable update, it means that most blockchain projects in Thailand disappeared from the public eye.

In addition, according to the highest density of blockchain item events, it shows that blockchain became a growing interest during 2019. A lot of projects' progress were shown (blue dots), and many new projects started (green dots). Many courses were also present at that time.

The duration of blockchain project ranges from a one-time mention in the public to continuation of publicity for 3 years. There are many blockchain projects that has only one event (e.g., p3 and p4 in Figure 17). The lack of data does not ensure the lack of progress or continuity of the projects because the projects could continue without publicity. We could see that there are many experiments, and many disappear from the public eyes. However, there are also blockchain projects that span multiple years (e.g., p5 in Figure 17 started in 2017 and was still on-going in 2020). The on-going interests could indicate that such projects are suitable for blockchain implementations, needs publicity, and possibly needs the involvement from multiple parties, as discussed earlier about the number of stakeholders per project.

Table 6. A table of events and their descriptions.

Events	Descriptions
an article's publication date	The publication date of the research article.
a course's instruction dates	The dates that instructions occur. Some courses were one-day, while some spanned multiple consecutive dates. Some courses were in a series, offering the same lectures or workshops multiple times. In virtual courses, the dates are the announcement of the courses.
a project's start date	The first date of the project. Due to the incomplete information, this date could be the first time that a project was initiated. If the beginning of the project was not mentioned, the opening ceremony or the first press release will be considered. - Otherwise, the first time that a project was on the press will be used.
a project's updated date	A date that the project's information was updated to the public. This could be the date when an article was published, when an event was set up to show project's progress, or when a project that was mentioned in other project's articles.
a project's end date	The mark of the end of a project. A project could be announced success and conclude with a report.

6.2. Cross-Sectional Domains

Blockchain technology has been employed in many domains, as discussed in Sections 3.2, 4.2 and 5.2). For the research, blockchain technology was mostly found in articles related to government services, followed by supply chain and traceability. The government services included voting systems, lottery systems, land registration, and national digital identification (NDID). For the project, a financial domain was the majority. Similarly, blockchain courses mostly covered financial topics such as cryptocurrency, apart from the basic concept of blockchain that was introductory in most of the courses. It is noteworthy to mention that the blockchain courses and projects aimed at the same direction, whereas the blockchain research did not. It shows that, in Thailand, the blockchain in each aspect was not complementary as expected. The research was supposed to be a resource for financial project implementation; however, it focused on the government services as well as supply chain and traceability. Although blockchain courses mostly involved finance, few courses were a platform for fostering experts to execute the project. Instead, it seems to be providing more for the general public.

Three possible reasons of this situation are research applicability, business confidentiality, and bias in data collection of financial articles. First, there are a large number of research works on finance worldwide, and they are applicable for the financial blockchain project implementation in Thailand. Adopting compatible existing studies might be a more reasonable course of action than conducting a localized research, which costs time and resources. As a result, the research articles in finance were not a majority, unlike in projects and courses. Second, research in the financial domain in Thailand might not be able to be publicized due to the business confidentiality. Financial blockchain projects were mostly executed by banks and firms, as shown in Figure 14. Thus, the imbalance between the small number of research and the large number of projects and courses occurred. Last, collecting data on Google search engine, which is a platform dominated by advertisements, could bias the data collection. Since big projects like financial projects of banks and projects owned by government normally receive more spotlights than other domains with small stakeholders, the financial domain could easily outnumber the other domains in the analysis.



Figure 17. A visualization showing timelines of research articles, courses, and projects about blockchain in Thailand. Some courses and projects were excluded due to imprecise timeline.

6.3. Opportunities and Challenges

From the analysis of the trends, focuses, and characteristics in three aspects, we found that blockchain technology in Thailand has a lot of room for development.

Opportunities regarding trends arise as the number of blockchain-related works is still small. Recent studies deemed blockchain technology in Thailand as new [23] with a small number of research articles [20]. Even though the numbers are increasing, only 13 research articles, 50 courses, and 54 projects about blockchain technology were identified from 2017 to 2020. One possible reason for these modest numbers is the limited number of people who understand technology and experts who are able to execute the blockchain project implementation. This could be an opportunity for the authorities, event organizers, and educational institutes to increase the number of blockchain courses, especially for blockchain experts and in higher education. Establishing a degree related to blockchain should lead to an opportunity for possible novel research topics on blockchain and blockchain-based projects in Thailand.

Opportunities regarding focuses of each aspect arise from directions and gaps in specific domains. As discussed in Section 6.2, blockchain studies in Thailand aimed at different directions with courses and projects. It can be said that the project implementation in Thailand did not utilize domestic studies and missed a chance to tackle the explicit issues that blockchain technology was needed in Thailand. This could be an opportunity for developing blockchain projects that are based on the research findings in Thailand landscape. So, blockchain technology could be applied directly to the local problems and established an originality of blockchain use cases for the blockchain community in Thailand. Domain-specific studies on blockchain in Thailand also have a lot of room for further research. For example, blockchain research on energy trading was not clearly presented [26]; the study of applications of cryptocurrencies in investment risk management was limited [25]; and the research on stakeholders' acceptance and understanding towards blockchain was rarely found [22]. More diverse blockchain research is needed since the domain could affect different data management and design of blockchain.

Opportunities regarding characteristics of each aspect are varied. Blockchain studies mostly focused on a framework for blockchain applications, but rarely mentioned concrete instructions for the implementation. Furthermore, some blockchain-centric design and technology implementation frameworks, such as [21], might be too broad to cover the technical details of various types of collected data. As a result, there are opportunities for blockchain research in the technical presentation of articles, such as architecture design, and quantitative performance evaluation for the benefit of actual implementation. For blockchain courses, their main objectives mainly aimed to present the basic idea of blockchain within a short duration. Hence, there is an opportunity for longer courses with more in-depth knowledge. Unlike the studies and courses, opportunities regarding the characteristics of blockchain projects are not very clear. The biggest adopter of blockchain technology across domains in Thailand was banks, which is one reason that blockchain projects in Thailand mostly focused on financial domain. While we believe there is an opportunity for other entities to participate in blockchain projects, the participation could be difficult without sufficient local research works in a domain outside financial and blockchain experts to implement the projects.

In spite of the small number of blockchain-related works in Thailand, the existing works were sufficient to display challenges in many aspects as follows:

1. Stakeholders

Blockchain is considered a new technology, even in the academic sphere. Hence, it was likely that the rejection of the technology could happen from the stakeholders with limited understanding and exposure to blockchain. For instance, few fishermen, who were interviewed for a study of blockchain application in Thailand fishery, "seemed to be reluctant in providing direct answers about the fishing methods and records" [21]. The transparency characteristics that blockchain holds could cause a resistance when collecting the data. Thus, with the slow adaptation and negative attitudes towards blockchain, it

could be a challenge from stakeholders during the process of data collection for blockchain research and project implementation.

2. Traditional system integration

A lot of blockchain studies and projects presents blockchain as a solution for a centralized system with intermediary and errors in systems caused by human's mistakes. Nevertheless, the traditional system could not be replaced completely. For example, the result announcement of lottery system had to remain the traditional way and changing it was difficult [15]; voters had to go to voting sites for authentication before casting the vote on a blockchain-based platform [17]; and energy trading on blockchain platform still relied on government policies to support energy trading in every form [26]. It shows that blockchain applications were obstructed by the traditional approaches. Therefore, blockchain research could not be proved in respect to the abilities to deal with the middleman problems and could not show a decentralized system clearly.

3. Policies and regulations

Most of blockchain studies found outdated policies as an obstacle when planning to implement blockchain prototypes. For instance, blockchain might not disrupt some services of Department of Lands of Thailand because the services were governed by laws [16]. Moreover, current policies do not endorse the collaboration between the people who are interested in blockchain applications. Rungkaputi [23], for example, suggested that the authorities should develop specific accounting guidelines for SMEs in the financial industry. A challenge from policies and regulations today can be considered not only the challenge for blockchain application, but also a challenge for blockchain research in the implementation step.

6.4. Threats to Validity

Our paper has several limitations. First of all, the web search method brought biased data and problem of discrepancy to the process. Google search engine led to the collecting projects that were subjective to advertising purposes and were personalized by the algorithm. As a result, it might exclude a lot of small projects that could increase the variety of blockchain domains. The analysis of projects was dominated by financial projects of known banks. Further, the timelines of projects were quite incomplete since the data were from advertising contents of the projects on press. The detailed information of projects were rarely identified. In addition to the disadvantages of web search method, an abundance of search results were a duplicate. A lot of efforts were made to identify the original ones, and the duplicates decreased the number of unique projects that were supposed to be found. In the future, we will try to explore blockchain implementation in code-based platforms like Github repository to reduce the mentioned problems. Another limitation we found is an alternative meaning of *ethereum* during the search for blockchain-related research articles in the global scale. So, the comparison of blockchain research between Thailand and other countries was omitted.

7. Conclusions and Future Directions

This paper contains literature reviews of blockchain technology in Thailand based on three aspects: academic research, knowledge acquisition, and project implementation. We collected research articles from the Scopus scientific database, as well as data on courses and projects from the Google search engine. The data were analyzed based on trends, focuses, and characteristics in each aspect. The study revealed that blockchain technology on Thailand landscape initiated from the project implementation in 2016 rather than the research drive. The technology has increasingly drawn a lot of attentions and applied to various domains in each aspect. However, the technology in each aspect did not compliment each other like in the expected technology adoption flow. In addition, we found that blockchain technology in Thailand was still in an infancy stage because of the idleness of many projects, the lack of experts, and the popularity of in-person instructional mode.

This paper also proposes future research directions and ideas for applications. Due to the immaturity of the technology, there are a lot of rooms for research, courses, and project implementation. Especially for the research community, blockchain research in Thailand lacked the concrete prototype of the proposed framework and the performance evaluation of the application. Regarding the small number of courses, it was a chance to establish blockchain courses, especially technical focus, to increase users and workforce to the ecosystem of blockchain. Concerning the discrepancy between research focus and implementation focus, there were plenty of localized resources from academic research to be utilized to resolve the country's issues and generate the originality of blockchain use cases. However, we also found that blockchain research and implementation could not escape the challenges in regard to stakeholder's rejection, conflict with traditional systems, as well as unsupportive policies and regulations.

We believe that further development of blockchain in Thailand needs better integration between the three aspects and more collaboration between related parties, especially Thai government. Main directions could be summarized into 3 main points:

- Promote graduate-level or long-term professional courses about blockchain;
- Promote studies in more diverse research focuses and research areas as well as initiate research of Blockchain 4.0 in Thailand;
- Promote adoption of local research works into practical projects.

For future work, we would like to improve data collection from web searches to minimize the bias and maximize the chance to retrieve potential data. For instance, an interview with stakeholders may provide more credible insights. Github repository is another source to aggregate the aspect of project implementation in Thailand, regardless the scarce of public access. Besides, the future work could expand the scope of literature review regarding research articles by the improvement of searching terms. So, the landscape of blockchain research could be explored more widely and inclusively. Another interesting topic for future work is the difficulty to access blockchain-based projects in Thailand on internet. The difficulty could be evaluated by the number of times snowball method has been applied for a project. It may portray how Thai people perceived blockchain technology through media.

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