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What are the ICT infrastructure factors influencing the potential adoption of cryptocurrency in developing countries?

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Abstract

Adoption of cryptocurrency has been discussed by researchers since its introduction in 2009, but cryptocurrency remains on the fringe of the monetary system. Many researchers suggest that cryptocurrency has the potential to be adopted in developing countries where it does not have to compete with a strong and established financial system. This research examines the potential adoption for cryptocurrency in developing countries from the perspective of ICT infrastructure, attempting to analyse the connection between cryptocurrency and ICT infrastructure and to investigate ICT related factors that affect the adoption of cryptocurrency providing information on the previously unmapped territory. The research uses a systematic literature review methodology to identify and analyse research papers that provide information on the current state of ICT infrastructure and identify factors affecting the adoption of cryptocurrency. The research analysed 364 research papers and identified 53 research papers to contain relevant information on ICT infrastructure and cryptocurrencies. Quality analysis of research papers was used to extract and analyse information from the research papers. The findings identified four main factors affecting cryptocurrency adoption. Those are, a reliable supply of electricity, penetration of internet, availability of mobile networks and ownership of end-user devices. Analysis of current infrastructure indicates that current electricity penetration rates are still low and many communities do not have a reliable supply of electricity. The research found that mobile networks are the dominant form of network connection with 2G being the dominant technology, penetration of 3G networks that allow for mobile broadband is still low, but this is going to change in the near future due to investments into the infrastructure. Research also identified cryptocurrency attributes, literacy, mobile money competition and government support to be additional factors affecting acceptance of cryptocurrency. These conclusions point the way to further research with a more narrow focus on ICT infrastructure and other cryptocurrencies.

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Declaration

I declare that the work described in this dissertation is, except where otherwise stated, entirely my own work, and has not been submitted as an exercise for a degree at this or any other university. I further declare that this research has been carried out in full compliance with the ethical research requirements of the School of Computer Science and Statistics.

Signed: _____

Zdenek Linhart
29th of April 2019

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Abbreviations

2G	Second-generation mobile communication system
3G	Third-generation mobile communication system
5G	Fifth-generation mobile communication system (latest)
ATM	Automated Teller Machine (Cash Machine)
BS	Base Station
EMB	Electoral Management Body
Fiat Currency	A Government-issued currency
FinTech	A combination of words: Financial and Technology
GB	Gigabyte
GHz	GigaHertz, Giga means 10^9 , and Hertz is an oscillating frequency where Hz = 1 cycle per second
GSM	Global System for Mobile communications, protocols for second-generation (2G) mobile communication system
ICT	information and communication technology
IP	Internet Protocol
LTE	Short for 4G LTE – Fourth-generation mobile communication system - Long Term Evolution
MHz	MegaHertz, Mega means 10^6 , Hertz is an oscillating frequency where Hz = 1 cycle per second
SDR	Software Defined Radio
SIM	Subscriber Identification Module
UHF	Ultra High frequency in analogue television broadcasting
TCMO	Total cost of mobile ownership
tps	Transaction Per Second
Wi-Fi	Wireless Fidelity, A standards for short-range wireless data transmission (w: IEEE 802.11)

1. Introduction

1.1. Context of the Study

In most of the developed world, electronic banking is part of our everyday lives, billions of people use internet banking, online shopping or credit card payments on a daily basis. According to statista.com (2018), in 2018 the transaction value of global digital payments was over 3.4 trillion dollars. This massive volume of transactions is possible through sophisticated financial service sector made of commercial banks and financial service providers. These institutions provide financial custody and act as an intermediary in financial transactions. Despite its undeniable benefits, digital transactions provided by these intermediaries have several drawbacks for ordinary people, for example, loss of personal privacy, additional cost in the form of transaction fees, dependence on financial service providers to process their transactions or vulnerability during the financial crisis. By processing digital transactions, these providers can collect data about the spending habits of individuals as well as their whereabouts, something that is not possible when physical cash is used during the transaction.

An electronic alternative to fiat currency that exists solely in digital form is referred to as digital currency. In the Investopedia article, Frankenfield (2018) defines digital currency as a currency that has no physical representation, ownership of the currency, payments or transactions exist only in digital form. The idea of digital currency, or digital cash, was first introduced more than 30 years ago by David Chaum (1982) in his paper "Blind Signatures for Untraceable Payments". In the past, there were several attempts to create a digital currency, most notable of these digital currencies were DigiCash, Bit Gold, Hashcash or B-money (Lai and O'Day, 2018), but none of these digital currencies were widely adopted and did not survive to this day. It was not until the last decade when blockchain technology enabled the creation of a new form of digital currency that uses cryptography for security called cryptocurrency. First, and to this day the most popular cryptocurrency was Bitcoin launched in 2009, Bitcoin became successful and was soon followed by several other cryptocurrencies based on blockchain technology.

Since its introduction in 2009, cryptocurrency slowly gained the interest of the general public and institutions, however to this day cryptocurrency was not mass adopted for commerce and its use is mostly limited to either short- or long-term speculative investment. At this time cryptocurrency is mostly used in developed countries where it has to compete with well-functioning financial systems that slow its adoption, in contrast, developing countries are lacking such systems and could be potentially benefiting from cryptocurrency adoption. In 2017 the Bank of England conference in London, Christine Lagarde, the IMF Managing

Director supported the possibility of cryptocurrency use in developed countries. In her speech Lagarde stated:

“For instance, think of countries with weak institutions and unstable national currencies. Instead of adopting the currency of another country - such as the U.S. dollar - some of these economies might see a growing use of virtual currencies. Call it dollarization 2.0.” (Lagarde, 2017).

This suggests that there is potential for cryptocurrency to be adopted in developing countries and this research aims to explore this previously unmapped territory.

1.2. Background

1.2.1. Bitcoin & Blockchain

The first and, to this day, the most popular cryptocurrency is Bitcoin. At this moment, March 2019, Bitcoin has a market share of 50.3% with a market capitalisation of almost €64 billion ranking #1 on CoinMarketCap (2019). In their research, Corbet et al. (2019) identified Bitcoin as being a central topic of investigation in 74.3% of papers they analysed.

Bitcoin was created by the inventor of blockchain who is known only by his pseudonym Satoshi Nakamoto. In 2008 Nakamoto released a whitepaper which described fundamental principles of blockchain on which Bitcoin and other cryptocurrencies were created. In his paper “Bitcoin: A Peer-to-Peer Electronic Cash System”, Nakamoto (2008) proposed that current digital transactions require a trusted third party entity to process a digital transaction which can lead to trust issues. Since the 3rd party is responsible for mediating disputes and has to prevent double spending of digital funds, it both increase the cost of transactions and creates the need to collect additional personal data about both parties. Nakamoto also points out that the system does not allow for irreversible payments for non-reversible services. At that time, trust, cost and payment certainty issues in transactions could be solved only by using cash. Nakamoto solved this problem by creating distributed, and decentralised digital ledger called blockchain. In essence, blockchain is a digital ledger that keeps irreversible records of all transactions, the ledger is decentralised, meaning there is no central authority controlling the ledger, control is shared between several entities, and the ledger is distributed meaning it is not stored in one single location (Poenitzsch, 2018). Unlike in traditional centralised system, there is no need for a trusted third party for processing transactions and record keeping. In blockchain all processes are automated, cannot be reversed, trust is provided through an algorithm, and the ledger is stored in several locations (Market Business News, 2019).

1.2.2. Other Cryptocurrencies

The success of Bitcoin and blockchain led to the creation of many new cryptocurrencies, some trying to replicate the success of Bitcoin, others attempting to innovate or improve the underlying technology or offer new functionalities like smart contracts. Many new cryptocurrencies were created for a specific use, for example, to utilise small payments, speed up transactions, decrease transaction fees, provide complete anonymity, or fund start-ups. At this time, cryptocurrency portal Coinmarketcap.com lists over 2000 different cryptocurrencies. The first ten cryptocurrencies with the highest market capitalisation (market value) are Bitcoin, Ethereum, Ripple, Bitcoin Cash, EOS, Litecoin, Stellar, Tether, Tron and Bitcoin SV.

1.2.3. Proposed Cryptocurrency Advantages

At the moment there are over 2000 different cryptocurrencies in many variations, these differ in their characteristics, underlying technology or intent of use, the following traits are the most common traits recognised by analysts as cryptocurrency advantages.

Cryptocurrency has several benefits that could potentially make cryptocurrency a competitor to current financial services. Cryptocurrency is not only a medium transferring value, but it is also an ecosystem that can further develop in the future and introduce additional functionalities and react much faster to customer needs than traditional financial service providers. UK Banking Report released in 2015 recognised cryptocurrency as a potential risk to traditional banking, stating “*Bitcoin users can handle many of their daily payments needs themselves, without the need for interaction with banks, and avoiding the need to incur bank fees.*” (BBA, 2015).

One of the most important benefits of cryptocurrency is safety, the underlying technology of cryptocurrency, the blockchain, was designed with built-in security features and processes. Any security issue surrounding cryptocurrencies is linked to either trading platforms or individuals; this is further discussed in the next chapter. Blockchain uses cryptography and hashing to process transactions securely, transactions are irreversible, and it prevents double-spending of digital coins as they cannot be copied or faked (Rai *et al.*, 2018). Cryptocurrency is decentralised and distributed by design, the decentralisation makes it independent from any central authority and free from being affected by any monetary policies (Rey and Miles, 2014). Distribution protects cryptocurrency against a single point of failure, even if one part of the blockchain network is offline, the cryptocurrency network will keep processing transactions, unlike in centralised system (Bozic *et al.*, 2016). Cryptocurrency has an advantage of anonymity (or pseudo-anonymity), no personal data are exchanged in transactions only the addresses of the cryptocurrency wallets, the transaction itself remains fully transparent (Rai *et al.*, 2018).

Another advantage is transaction speed which is different for each cryptocurrency, but generally transactions are processed within minutes, regardless of location, this is a distinct advantage when used to send cryptocurrency to different countries, compared to cross-border transactions of fiat currencies between international banks, such transactions can take a number of days before the payment is cleared and processed. Not only are the transactions faster and more efficient, but also the cost of transactions is significantly lower (Gavril, 2017).

According to Kotane (2018), one of the advantages of cryptocurrency is its design to preserve value through a finite supply of coins that are gradually released into the system. Unlike the fiat currencies that are regulated by the local governments and can be devalued by inflation or simply by printing more money, cryptocurrency remains independent from such regulatory attempts.

Some cryptocurrencies, for example, Ethereum or Cardano, are part of a much larger decentralised platform that can run decentralised applications and smart contracts. Raval (2016) describes the decentralised application as a software application running on a decentralised network where each node acts independently, unlike distributed applications where one node instructs other nodes what to do. Decentralised applications achieve decentralised consensus, and if one node fails the application keeps operating unaffected because of node independency, this allows the application to eliminate the central point of failure. Developers of decentralised applications can avail the advantage of the decentralised platform that both the application and cryptocurrency use and easily integrate cryptocurrency into the application as a payment method. Smart Contracts can be described as “executable code that runs on the blockchain to facilitate, execute and enforce the terms of an agreement between untrusted parties” (Alharby and Moorse, 2017). According to Alharby & Moorse (2017), Smart Contracts are a form of digital rules that are automatically executed based on meeting predefined conditions. The main advantage of Smart Contracts is independence from a trusted third party, which makes transactions more secure, faster to process, less demanding on resources and thus resulting in lower transaction fees. Stark (2016) explains that Smart Contracts are not only executable code rules, but are also a form of a legal contract, a smart legal contract. Smart legal contracts could be used in future in financial instruments automating and simplifying process-intensive financial systems. Other examples of smart legal contracts use are in real estate, intellectual property, licencing agreements and possibly other areas.

1.2.4. Potential Cryptocurrency Disadvantages

Cryptocurrency is a relatively new medium of exchange with relatively low penetration into the population, in the 4th quarter of 2018 there were approximately 32 million blockchain wallets users registered (Statista.com, 2019a) which is less than 1% of the global

population. Cryptocurrency is yet to become mainstream, it is still in the stage of development, and some obstacles need to be overcome. The following disadvantages are recognised by analysts as some of the most significant disadvantages of cryptocurrencies.

Despite cryptocurrency being designed to preserve value through finite supply and gradual release of new coins, the spike in popularity of cryptocurrency led to the interest of speculators who trade cryptocurrency for profit. The result of using cryptocurrency for speculative trading rather than as payment method is high volatility when compared to fiat currency. Cryptocurrency value can fluctuate in the order of a few percentages per day. This extreme volatility makes cryptocurrency interesting for traders, but it makes it unsuitable for merchants to accept it as a payment method as they cannot be sure what the value will be the following day.

Current legislation is not ready for cryptocurrencies, and many countries do not recognise cryptocurrency as a legal tender. In the article reviewing legislation in 15 countries, Nelson (2018) discovered that the majority of countries are in the process of drafting regulations, with 2 countries currently banning cryptocurrency. This regulation uncertainty discourages investors interested in cryptocurrency and stalls further adoption. The need for new legislation is confirmed in another research stating *“the current legal framework is based on the centralized approach to money, payments, and financial services, and does not imply the existence of decentralized payment mechanisms”* (Nahorniak *et al.*, 2016).

Security surrounding cryptocurrency can be perceived as a disadvantage. Blockchain, an underlying technology of cryptocurrency, is secure by design and up to this day, there are no reports of blockchain being hacked or compromised. Although blockchain is considered highly secure, platforms facilitating storage and cryptocurrency exchanges have been compromised in the past, combined with irresponsible and insecure behaviour of individuals online resulted in a massive loss of cryptocurrencies due to theft. The Cryptocurrency Anti-Money Laundering Report for 2018 states that “in the first three quarters of 2018, \$927 million of cryptocurrency was stolen by hackers” (CipherTrace, 2019). In the article describing crypto hacks, Khatri (2018) explains that these hacks are conducted by professional hackers exploiting vulnerabilities on cryptocurrency exchanges and cryptocurrency wallets and through social engineering targeting individuals.

1.2.5. Developing Countries

The Cambridge dictionary defines the developing country as “a country with little industrial and economic activity and where people generally have low incomes” (Cambridge Dictionary, 2019). There is no strict definition of Developing country, International organisations like the United Nations (UN), World Bank or IMF have their own classification system to identify developing countries. Market Business News (2019) summarises the definition of developing country, as country with low economic development, low Human

Development Index (HDI), relatively low levels of access to safe drinking water, sanitation, education and health services, and relatively high level of corruption, pollution, violence and infectious diseases. Development of those countries is directly dependent on economic growth, without a growing economy, the country has no funds to make investments. Özşahin & Üçler (2017) identified corruption to be one of the obstacles to economic growth and development. In their study, they described how corruption leads to a reduction of investments, waste of natural resources, and inefficient distribution of finances and resources. Governments have no means to effectively collect taxes which is often compensated by increasing money supply leading to increasing inflation, which in turn undermines the national currency, devaluating savings, purchasing power and making the country unable to participate in international markets.

Developing countries are facing many challenges, and some of those challenges could be overcome by new technologies. Professor Sani Rodrik (2018) describes how technological leapfrogging could aid developing countries, namely the increase in usage of mobile phones. The prices of mobile phones have decreased to a level that makes them affordable even in developing countries. Mobile phones are providing communication capability without costly investments to landline infrastructure. The increase in mobile phone usage has a secondary effect of increased access to information and financial services even in very remote areas. According to a press release by The World Bank report (2015), between 2011 and 2014, the number of bank account users in developing countries increased by 11%, mostly through mobile banking and new technologies. The report further states that in those years “700 million people became account holders at banks, other financial institutions, or mobile money service providers” (The World Bank, 2015), dropping the number of unbanked by 20%. In his report, Howell (2016) explains in his article how new technologies are helping in healthcare, education or sanitation of drinking water.

1.3. Research Question

Developing countries have underdeveloped financial systems where only a small portion of the whole population has access to banking and other financial services. Infrastructure in the developing countries is underdeveloped with the exception of mobile phone infrastructure which can reach even remote areas. The need for affordable financial services and penetration of mobile phones make adoption of cryptocurrency in developing countries possible. The main focus of this research is to investigate the current state of infrastructure in developing countries and answer the following question:

What are the ICT infrastructure factors influencing the potential adoption of cryptocurrency in developing countries?

To help answer the main research question, this research will additionally aim to answer the following supporting questions:

- i) What is the current state of ICT infrastructure in developing countries?
- ii) What other factors are influencing the adoption of cryptocurrency in developing countries?

1.4. Research Beneficiaries

Main beneficiaries of this research are researchers and officials in developing countries who are responsible for the monetary policies of the country. Information in this paper can be of value to them when assessing whether cryptocurrency is worth implementing in their country and it will inform them about requirements for potential applications. Other beneficiaries of this research are creators of cryptocurrencies and developers of cryptocurrency applications, the research will provide them with information about possible limitations of ICT infrastructure. This research can also benefit researchers and educators, providing them with overarching information about the subject.

1.5. The scope of the Research and Assumptions

Many factors need to be met to adopt a cryptocurrency as a currency successfully. This research solely focuses on ICT technology, an underlying technological infrastructure. This research does not consider other important factors that need to be met for acceptance, for example, utility, political or legal.

This research is based on two assumptions, first being that the concept of cryptocurrency as a medium of exchange is viable and will be further developed. Second, citizens and governments in developing countries find benefits of cryptocurrencies appealing and would seriously consider adopting cryptocurrency as the main currency or at least as an alternative medium of exchange.

1.6. Value of this Research

The research aims to have an informative character, the focus is on identifying factors that are most important for successful adoption of cryptocurrency from the perspective of ICT infrastructure. The objective of this research is to search existing literature on the topic and summarise all findings into one comprehensive document. Research also aims to provide more information on the current state of ICT infrastructure in developing countries.

1.7. Structure of this research

Structure of this research is the following:

Chapter 2: Methodology – This chapter describes the methodological framework used in this research. It discusses the used research method, the approach taken in searching the literature, list locations and keywords used in the search and describe how the findings were catalogued.

Chapter 3: Literature Review – Literature identified as valuable to the research was reviewed in this chapter. Each source was rigorously evaluated summarising the key information.

Chapter 5: Finding and Analysis – In this chapter, all findings from the literature review were reviewed and critically analysed.

Chapter 5: Conclusion and Future Work – Final chapter present findings of the research and answer main and supporting research questions, discuss the limitations and assumptions of this research and identify areas for future research.

2. Methodology

2.1. Introduction

The main goal of this research is to find key factors that are influencing the successful adoption of cryptocurrency in developing countries and finding answers to supporting questions. This chapter describes the method used in the research, justification for the selected method, and how the information on the topic was searched, collected and analysed.

2.2. Research Method

Cryptocurrency and underlying blockchain technology are relatively new and innovative, the technology is still in its infancy going through development and continuous improvements that are yet to become accepted by the mainstream. As a result, the data and information about cryptocurrency are inconsistent, scarce and, in some cases, incomplete. This paper aims to conduct thorough research aiming to collect and analyse relevant data and portray a complete picture of the current state of the ICT infrastructure used by the cryptocurrency ecosystem with a focus on developing countries. Other researchers can then use the results as a baseline for further research.

The method identified as most suitable for this type of research is a Systematic Literature Review because it provides a framework on how to systematically analyse research papers

that are diverse in content from a qualitative perspective. Systematic literature review attempts “to collate all empirical evidence that fits pre-specified eligibility criteria in order to answer a specific research question” (Chandler *et al.*, 2017). Okoli and Schabram (2010) describe systematic literature review as a “journal-length article whose sole purpose is to review the literature in a field, without any primary data (that is, new or original) collected or analysed”. A literature review as defined by Fink (2005) is using systematic methodological procedures to locate and synthesise evidence from scientific studies to obtain an overview, it is explicit about the processes used during the research, comprehensive by examining all relevant sources and material and reproducible by other researchers. It creates a baseline, a theoretical background for ensuing research, provides a context of the research, or provide understanding on the topic. Systematic literature review, compared to the conventional literature review, is conducted in a more rigorous, systematic and critical manner with broader scope creating a standalone study or research. This research is exploratory qualitative research using secondary data and information collected by other researchers for analysis, to gain a better understanding of the topic and to draw conclusions.

Research methodology of this research is a synthesis of the approaches from the guide “A guide to Conducting a Systematic Literature Review of Information System Research” created by Okoli and Schabram (2010) and guide “What is a systematic literature review and how do I do one?” by Dr Andy Siddaway (2014). A systematic literature review is mostly used in health sciences and the guide by Okoli and Schabram (2010) was considered the best fit because of its focus on information systems. The methodology in this research does not follow every detail of the guide as it is intended for a doctoral dissertation that goes into much more depth than a master’s thesis, Dr Siddaway’s (2014) guide was used to ensure the work was completed at a level appropriate for master thesis.

The Systematic Literature Review guide follows a 4-stage concept: Planning, Selection, Extraction and Execution. Each stage is subdivided into steps that further details the research process as outlined in Table 1 - Steps of Research Methodology.

Table 1 - Steps of Research Methodology

Step	Stage
1. Purpose of the Literature Review	Planning
2. Protocol	Planning
3. Searching the Literature	Selection
4. Practical Screen	Selection
5. Quality Appraisal	Extraction
6. Findings and Analysis	Extraction
7. Writing a review - Conclusion	Execution

The following chapters describe in detail the steps of Selection, Extraction and Execution stages. The planning stage was already discussed in previous chapters. The first step of the planning stage, Purpose of the Literature Review, define the research questions and purpose of the research. The second step of the planning stage, Protocol, describe the Okoli and Schabram's (2010) protocol that is followed to conduct the research in this paper.

2.3. Searching the Literature

2.3.1. Approach

In the third step, Searching the Literature, databases that were used for the research were selected based on their focus and number of resources available, then to define keywords and search queries. Each of the queries was searched on every predefined electronic database using Advanced Search option, to further narrow down the search results, time and language limitation was applied to set a start and end date beyond which studies were not added to the research. At this stage, it was also established what referencing, and note taking system will be used to record search results. The search for resources did not end by the searching electronic databases, the reference section of each valid study was screened for additional sources that could be relevant to this research.

2.3.2. Search locations

The search was conducted solely on electronic resources, 2 academic research databases, ABI/Inform Global and IEEE Xplore. These sources cover peer-reviewed researches, papers and articles. An additional resource, Google Scholar, was added to the search resource to cover "grey literature", a non-peer reviewed sources, such as reports, dissertations, theses, conference literature and other. Traditional resources, books and paper journals, were omitted due to the nature of the research, researching emerging technology, and because currently, the majority of resources are accessible online or downloadable in digital form. Selected electronic sources were selected because of their focus and the number of covered papers. Together, sources cover topics related to technology, science, business and finance, all related to cryptocurrency to a certain extent. The sources together covered over 5 million peer-reviewed papers and studies and over 100 million (estimated) of non-peer reviewed studies from Google-Scholar, this amount was considered more than sufficient for this type of research. Information about the digital databases is listed in Table 2 - List of Digital Resources.

Table 2 - List of Digital Resources

Digital Resource	Focus	Coverage
ABI / Inform Global (2011-)	Business, Economics & Finance	Over 600,000 working papers
IEEE Xplore	Science and Technology	Over 4.5 million items
Google Scholar	Collection of multiple sources	Estimated over 100 million

2.3.3. Keywords

Selected keywords were based on the research question and the main theme of the research, using keywords *cryptocurrency*, *developed countries*, *infrastructure* and *ICT*. Additionally, each of these words has several different forms either in terms of plural/singular, verb/adjective, different ways of writing it (*cryptocurrency/crypto currency*) or there is a similar word with the same meaning (*developing/underdeveloped*). To assure relevant results, for each word that had additional forms, an asterisk (*) known as a wild card was used in combination with the root of the word or, the additional word was used. For a full list of the keywords used in the research refer to Table 3 - List of Keywords.

Table 3 - List of Keywords

Desired Search Word	Used Search Word	Additional Search Word
Cryptocurrency	Cryptocurrenc*	Crypto currenc*; (crypto-currenc*)
Developing country	Developing countr*	Underdeveloped; developing nation*;
Infrastructure	Infrastructur*	Infrastructures
ICT	ICT	

During the keyword testing, it was discovered that in all databases there was no difference in returned results between words “*Crypto currenc**” and “*crypto-currenc**”, all three database resources had a built-in functionality to substitute the space between words with dash and vice versa. Consequently, the keyword “*crypto-currenc**” was not added to search queries.

2.3.4. Search Queries

Searching keyword on its own would yield a large number of unrelated results, to narrow the search down keywords were combined into search queries. The query was created using the Boolean operator AND to combine 2 or more words and the Boolean operator OR to get results for at least one of the keywords from the query. Keywords that were made of 2 words (*crypto currency* or *developing country*) were put into brackets, the search engine

interprets such term as one word. All combinations of keywords are listed in Table 4 - List of Search Queries.

Out of 4 keywords, 2 were identified as common keywords specifying the desired domain of search referring to cryptocurrency and location (*Cryptocurrency* and *Developing country*), these 2 keywords were included in every search query. The other 2 words narrowed down the results to the specific interest of this study focusing on ICT and infrastructure.

The search was divided into two parts, following the logic of narrowing down results. Started by getting all results concerning cryptocurrency, narrowed down to results in developing countries. Within those results, the first search focused on papers containing keyword *ICT*, the second search focused on those containing the keyword *infrastructure*. Results for all queries were recorded into a table in Appendix 2 – Literature Review Search.

Table 4 - List of Search Queries

#	Search Query
1	("crypto currenc*" OR cryptocurrenc*) AND "developing countr*" AND infrastructur*
2	("crypto currenc*" OR cryptocurrenc*) AND "developing nation*" AND infrastructur*
3	("crypto currenc*" OR cryptocurrenc*) AND underdeveloped AND infrastructur*
4	("crypto currenc*" OR cryptocurrenc*) AND "developing countr*" AND ICT
5	("crypto currenc*" OR cryptocurrenc*) AND "developing nation*" AND ICT
6	("crypto currenc*" OR cryptocurrenc*) AND underdeveloped AND ICT

In Google Scholar it is not possible to combine phrase and prefix ("*Crypto currenc**"), Google Scholar interprets such query as the search for exact word located between brackets. Through testing, it was decided to create an additional set of keywords and queries for Google Scholar, where keywords and queries did not contain the wild card symbol (*). Variations of words were determined through the online word finding tool at <https://www.litscape.com> and cross-referenced with results from search results on the other 2 databases.

All keywords are listed Table 5 - List of Google Scholar, queries using those keywords are in Table 6 - List of Google Scholar Search Queries. The last query used on Google Scholar search combines all keywords to ensure that most of the relevant results were captured.

Table 5 - List of Google Scholar Keywords

Desired Search Word	Used Search Word
Cryptocurrency	cryptocurrency cryptocurrencies crypto-currency crypto-currencies
Developing country	developing country developing countries underdeveloped developing nation developing nations
Infrastructure	Infrastructure Infrastructures
ICT	ICT

Table 6 - List of Google Scholar Search Queries

#	Search Query
1	(cryptocurrency OR cryptocurrencies OR "crypto-currency" OR "crypto-currencies") AND ("developing country" OR "developing countries" OR underdeveloped OR "developing nation" OR "developing nation") AND infrastructure
2	(cryptocurrency OR cryptocurrencies OR "crypto-currency" OR "crypto-currencies") AND ("developing country" OR "developing countries" OR underdeveloped OR "developing nation" OR "developing nation") AND infrastructures
3	(cryptocurrency OR cryptocurrencies OR "crypto-currency" OR "crypto-currencies") AND ("developing country" OR "developing countries" OR underdeveloped OR "developing nation" OR "developing nation") AND ICT
4	(cryptocurrency OR cryptocurrencies OR "crypto-currency" OR "crypto-currencies") AND ("developing country" OR "developing countries" OR underdeveloped OR "developing nation" OR "developing nation") AND ICT
5.	(cryptocurrency OR cryptocurrencies OR "crypto-currency" OR "crypto-currencies") AND ("developing country" OR "developing countries" OR underdeveloped OR "developing nation" OR "developing nations") AND ICT AND (infrastructure OR infrastructures)

2.3.5. Search Limitations

Main Limitations

During the search, two main limitations were applied to narrow down the search, timeframe and language.

Electronic databases have the advantage of providing access to millions of papers and articles, with new ones being added practically every day as new researches are added. New articles could be added throughout this research as it is not possible to analyse and review articles that were released close to the day of submission of this paper. As a result, the search will be performed between a time frame setting the earliest and latest date the source will be accepted for revision. The earliest date was set to January 2009, a date when bitcoin was first released, marking the start of the first cryptocurrency and the point from which the cryptocurrencies were analysed, and new theories start to emerge. March 2019 was selected as the latest date for all searches, after this date no searches were performed as there would not be enough time to analyse them and add the information to this paper.

Since the majority of resources are published in the English language or are translated into English, it was decided not to search for sources in a foreign language. The time constraints creating this paper do not permit to spend the additional time required for translation of any source.

Additional Limitations

During the search in ABI/Inform resource, it was discovered that despite the specific filtering, the number of results was relatively high, approximately a couple of hundreds, while the number of relevant results was very low. Additional filtering was applied to specify *Source Type* to further improve and narrow down the results, selecting:

- Books
- Conference Papers & Proceedings
- Dissertations & Theses
- Reports
- Scholarly Journals
- Trade Journals
- Working Papers

One more additional limitation was applied to Google Scholar search; Google Scholar generally returned a much higher number of results compared to other databases due to its broader search and access to a higher number of resources. Throughout the search on Google Scholar, it was discovered that the relevancy of results was practically 0 beyond page 4; therefore a limitation was applied where no results were considered beyond page 5, yielding approximately 50 results per query which were then considered in practical screening.

All applied limitations, main and additional, are specified in Appendix 2 – Literature Review Search.

2.3.6. *Management of references*

Information about papers was recorded in reference management software Zotero. Zotero was used to categorise, and tag sources found during the search and to add additional information in the form of notes for each source, it also allowed to store methodically, manage, edit, import and export references. Each study found during the search had citation exported to Zotero as a new record, it was tagged with the name of the resource where it was found along with a date when it was found. Any useful information found during the screening of the study was recorded into notes associated with that record. Zotero was used to insert and edit citations during the creation of this document and at the end, it was used to generate a bibliography in Harvard referencing style.

2.3.7. *Supplemental search*

After the main search was completed, supplemental “backward” and “forward” search was carried out through the research to exhaust all options finding relevant sources. References of each valid source were examined for additional sources, doing a backward search. Moreover, in the case of Web of Science, a forward search was performed by screening papers that cited that particular source. Web of Science was the only source that showed which other research papers cited selected source.

2.4. **Practical Screen**

The fourth step, Practical Screen, filtered results from the search. Searching the databases returned a larger number of studies, the purpose of the practical screen was to identify studies that are suitable for the research and filter out unsuitable studies.

Studies were assessed based on meeting the following criteria:

- *Content:* Study was relevant to the topic
- *Language:* Study was in English
- *Field of Study:* Studies from fields of health science, biology or psychology were excluded
- *Date:* Study was released between January 2009 and March 2019

In practical screen studies were assessed based on their title, by reading the abstract and, in some unclear cases, the conclusion as well. Some studies appeared in more than one search query or resource database, to prevent duplicates, such studies were recorded only once.

2.5. **Quality Appraisal**

Quality Appraisal, the fifth step, assessed filtered studies in detail. Studies that passed the first practical screen were then screened a second time in the Quality Appraisal, conducting

more methodological screening. Each suitable study was read and assessed in 2 stages, in the first stage the relevance was assessed, the second stage assessed the quality of the research paper.

In the first stage, relevance was assessed, the content of the study had to be relevant with information and data adding value to the research. Studies that had their content considered not relevant to the research were excluded from the research. Studies passing the first stage advanced to the second stage.

Quality, the second stage of the assessment, was determined by rating the study in 5 categories using the scoring matrix. The scoring matrix was created to assess the quality of all papers in a unified and transparent manner. Categories assessed in the scoring were:

- Study Methodology
- Quality of Reporting
- Evidence
- Argumentation
- Research Objectiveness

Scoring matrix, presented in Table 7 - Quality Scoring Matrix, shows how each level of quality (*Strong, Moderate and Weak*) is worth a certain number of points.

Table 7 - Quality Scoring Matrix

Quality	Points
Strong	3
Moderate	2
Weak	1

The study was scored in each category, the average of all scores was calculated resulting in a *Quality Score*. The *Quality Score* was rounded to a whole number, and using the *Scoring Matrix* the *Overall Quality* was determined and recorded in Table 8 - Quality Assessment which is available in Appendix 2 – Literature Review Search Results. Example of quality scoring is in the Image 1 - Example of Quality Assessment below.

Study	Overall Quality	Study Methodology	Quality of Reporting	Evidence	Argumentation	Research Objectiveness	Quality Score (Average)
Maccari et al. (2018)	Moderate	2	3	2	3	2	2.4
Geetha and Girisha (2018)	Weak	1	1	2	1	2	1.4
...

Image 1 - Example of Quality Assessment

Studies that had *Overall Quality* determined as *Moderate* or *Strong* were included in the research, and their quality was considered during the research. Studies assessed as *Weak* in *Overall Quality* were excluded from the research.

Studies passing both stages were included in the research, studies that failed in one of the stages were removed from the pool of suitable studies, the study was recorded in Table 9 - Excluded Research Papers available in Appendix 2 – Literature Review Search Results and, in Zotero, the record of that study was moved to folder Excluded in Quality Appraisal.

While the quality evaluation was highly subjective, scoring is based on knowledge and experiences of the reviewer, recording the process of assessing relevance and quality aimed to make the selection process transparent.

2.6. Findings and Analysis

The research was qualitative in nature where the text and information were first reviewed, analysed and understood. Key information and themes were recorded in the form of summarising information, findings were organised and categorised. Extracted information from various papers was collated into separate categories, compared, any inconsistencies were highlighted, and findings were put into context and assessed.

In this part of the research it needs to be acknowledged that despite attempts to achieve a high degree of objectivity, the evaluations, findings and conclusions are the subjective views of the researcher.

During the planning of the methodology steps, a potential bias was recognised that could affect the findings in this stage. The researcher comes from a position of cryptocurrency optimist, as a result, additional effort was made to review all information more critically to counterweight this possible bias.

2.7. Writing a review - Conclusion

In the final seventh step of the research, all findings of the topic were discussed and summarised, any limitations, contradictions, gaps in the research or available data were considered. And finally, all information was evaluated, the research question was answered and recommendations for future research were made.

3. Searching the Literature

3.1. The Search

The literature was searched following the methodology in the previous chapter. The first search, practical screen, was performed on 3 main database resources, IEEE Xplore, ABI/Inform Global and Google Scholar using predefined search queries. The search returned 532 results, out of the 513 papers, 168 papers were identified as duplicates and removed from the practical screen list resulting in 364 papers eligible for the practical screen, results of search query without duplicates were recorded in Appendix 1 – Results of Search Queries. The practical screen assessed the remaining 364 papers based on 4 criteria defined in the methodology (content, language, field of study and date), out of 364 papers, 316 papers did not meet the criteria and were removed from the list, 43 studies were excluded from IEEE Xplore search, 82 studies were excluded from ABI/INFORM Global search and 191 studies from Google Scholar search. The remaining 38 papers were passed to quality appraisal analysis. In quality appraisal, papers were assessed on relevance and by the scoring matrix in 5 categories defined in the methodology (study methodology, quality of reporting, evidence, argumentation and research objectiveness). Out of 38 papers, 13 paper was identified to have no relevant information to the research and 2 papers were excluded for weak overall quality. The quality assessment was recorded in Table 8 - Quality Assessment and all removed papers with the reason for the removal were recorded into Table 9 - Excluded Research Papers, papers found during Backward/Forward Search were noted in Table 10 - Results of Backward/Forward Search, all tables are available in Appendix 2 – Literature Review Search Results.

3.2. Result of the Search

The final search result after practical screen, quality appraisal and backward/forward search was 53 papers. These papers were used for data extraction and analysis, and to draw conclusions in this research. The graphical representation of the selection process and the number of papers found in each stage, including the number of papers excluded, is depicted in the PRISMA diagram in Figure 1 – Diagram of the Search Process.

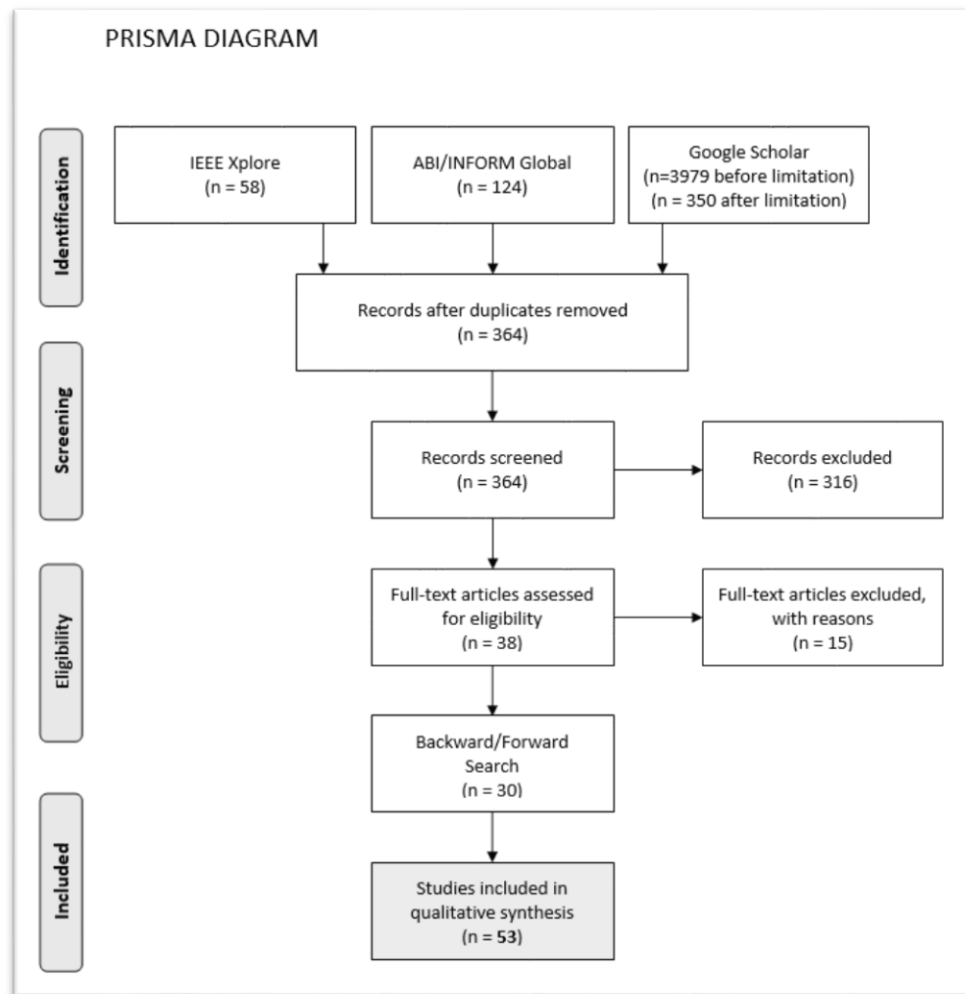


Figure 1 – Diagram of the Search Process

4. Findings and Analysis

This chapter reflects on findings, information was analysed and collated into categories and put into context. During the research, it became apparent that there are 3 main and 2 secondary themes discussed in the literature. These themes were:

- Physical Infrastructure
- Cryptocurrency and Blockchain Factors
- Human Factors
- Other Factors
 - Mobile Money
 - Government Support and Regulation

4.1. Physical Infrastructure

The infrastructure necessary to run any cryptocurrency is electricity and internet, in addition, this research identified mobile networks and end-user devices to be similarly important in developing countries.

4.1.1. Electricity

In developing countries, a reliable electricity supply is repeatedly discussed as a limitation in research papers and reports. Reliable electricity is key to ICT infrastructure or any digital device and any technology-based development. In the research investigating FinTech in Sub-Saharan Afrika, Yermack (2018) identified electrification to be one of the main obstacles to Fintech, the research found that as of 2016 the electrical penetration in sub-Saharan Africa was 39%. This is further supported by Lambrechts and Sinha (2018) who identified a reliable supply of electricity to be of the obstacles to utilising ICT technology in education in developing countries. Another research by Micheni and Murumba (2018) discussed how inadequate electricity grid is a complication when using ICT to run blockchain based electoral process in Kenya, they found electricity to be especially problematic in remote areas that have unstable supply and alternative sources may not provide continuous supply for an extended period of time. The Global Findex Database also identified reliable electricity and mobile networks to be important for financial inclusion *“Physical infrastructure - such as reliable electricity and mobile networks - is key. People will be less inclined to use digital payments if network outages or other technical problems undermine their dependability”* (Demirgüç-Kunt *et al.*, 2018).

To get a better understanding of electricity penetration levels, a supplement search was conducted, the findings show that nearly 1.1 billion people worldwide do not have access to electricity. The majority of people without access to electricity are residing in Sub-Saharan Africa and Developing Asia. In Africa, 590 million people, approximately 57%, without access to electricity are located in Sub-Saharan Africa. The majority of those without electricity live in rural areas, about 80%. In developing Asia, most of the population without electricity are located in India with 239 million, Pakistan 51 million and Bangladesh 51 million. In Southeast Asia, it is Indonesia with 23 million, and Philippines 11 million. (iea.org, 2017).

4.1.2. Internet Penetration

Cryptocurrency is an internet based technology, for widespread use of cryptocurrency and other internet-based technologies, penetration of the internet in developing countries is key. In the research investigating E-finance and Entrepreneurship in developing countries, Haddad (2018) identified poor internet penetration to affect the deployment of technologies necessary for electronic finance to increase financial inclusion. In their research Haddad

(2018) identified that as of 2016, Africa had the lowest number of internet users, particularly in Somalia, Guinea, Burundi, Eritrea and Brunei (Southeast Asia) where 98% of the population did not use the internet.

Research investigating Bitcoin as a financial solution for developing economies identified internet connectivity as a significant barrier to the adoption of Bitcoin. In the research Clegg (2014) examined the penetration of the internet in developing countries and discovered that as of 2012 internet penetration rates were 15.6% for Africa and 27.5% for Asia. This is confirmed by Yermack (2018), researching FinTech in Sub-Saharan Africa, in their research, the internet penetration is reaching 29% in Africa, and they describe internet penetration to be one of the factors affecting financial inclusion and FinTech development. Access to the internet was identified to play an important role by other researchers as well, Lambrechts and Sinha (2018) identified it necessary for utilising ICT technology in education and Nicholson (2017) for libraries to become instrumental for introduction of Bitcoin.

While the majority of the researches discussed the shortcomings of the lack of internet connectivity, research by Naboulsi & Naubert (2018), investigating Impact of digital currencies on economic development in Kenya, discussed how economic growth was impacted by investments into ICT infrastructure in Kenya, Ivory Coast, Nigeria, Ghana and South Africa. These countries are referred to as KINGS countries. In KINGS countries, internet connectivity and a growing number of internet subscribers are mentioned as one of the important contributors to economic growth in KINGS countries. GDP growth and the number of internet subscribers are recorded in Table 11 - KINGS countries (Ndemo and Weiss, 2016).

Supplemental search for updated data shows that as of March 2019, the penetration rate for Asia is 51.7%, for Africa 35.9% and the Middle East 65.8%. Both, Africa and Asia, remain below World Average of 56.3%. Penetration rates for all regions are depicted in Figure 2 - Internet World Penetrations Rates by Geographical Regions (internetworldstats.com, 2019). In terms of population, in Asia, out of 4.2bn people, 2.19 billion people (51.7%) has access to the internet leaving 2bn people without access. In Africa, out of 1.3bn people, approximately 474 million people (35.9 %) have access to the internet leaving 840 million people without access. In the Middle East, out of 258 million people, 170 million people (65.8%) has access to the internet, leaving 88 million people without access. Average total for the world, out of 7.7 billion people, 4.3 billion (56.3%) has access to the internet, leaving 3.4 billion with access (internetworldstats.com, 2019).

4.1.3. Mobile networks

Mobile networks were identified to be key to development and advancement in developing countries by the majority of papers. This is mainly caused by the current level of penetration

of mobile networks in developing countries and the potential it poses in providing an internet connection to the population, and by the success of the mobile payment system M-PESA (discussed later in this research).

Report by GSM Association (GSMA, 2018), *The Mobile Economy - Sub-Saharan Africa 2018*, review the state of the mobile network industry and present predictions on development in sub-Saharan Africa. According to the report, Mobile broadband in sub-Saharan Africa is still in development, the dominant form of connection is still 2G, by the end of 2017 over 90% of the population in sub-Saharan Africa was covered by the 2G network. Mobile broadband networks covered approximately 400 million people, 2/3 of the population. Current investments are focusing on 3G networks, the report identified two reasons, 3G networks support both older devices with voice and smartphones with data. The second reason is the availability of broadband spectrum. Operators prefer to invest in technology reusing current 900 MHz spectrum rather than wait for auctions for new spectrum used by LTE networks. The 3G connection is predicted to become a dominant connection in the region by 2025 with a 60% share. Investments into 4G networks are starting to appear in the region as well. Currently, there are 120 4G networks in the region including six new launched in 2018, 4G networks are predicted to reach 23% share by 2025.

Mobile broadband covers most of the urban areas, areas that are excluded from network coverage are rural areas, 20% of the population is scattered across 70% of the region. Such regions are often in areas with rough terrain, such areas require high investments into infrastructure while serving only a small segment of the population. Such areas are financially unattractive for mobile operators as the revenue is one-tenth of that in urban areas. The report presents possible solutions to this problem, infrastructure sharing, partnerships and government support. Infrastructure sharing allows several mobile operators to share the same network infrastructure while sharing the installation and running costs. A new type of sharing is passive infrastructure sharing where a network provider is using towers of independent companies. Partnerships represent a new business model becoming frequent between the mobile operator and other service providers like community-based networks, satellite service providers or solar electricity networks. Government support is essential to the development of sustainability of services, deployment of mobile networks into rural areas can be stimulated by offering a financial incentive or tax breaks. The report further predicts the growth of mobile broadband connections from the current 38% to 87% by 2025 and increases the ownership of smartphones from 250 million to 690 million by the year 2025. According to the report, MNT and Ericson signed a memorandum of understanding in 2017 on the development of 5G services in South Africa. A technology trial was recently conducted using 5G 28GHz millimetre-wave connection, connection was use-case trial for fixed wireless broadband (house to house connection), this connection is seen as an opportunity for urban areas,

addressing the last mile connection bringing broadband connection to households without the need for physical connection, similar approach is considered by Verizon in the US.

Research by Maccari et al. (2018) investigates 5G networks and their contribution to rural areas. According to the Maccari et al. (2018), 5G networks are seen as a communication layer for the Internet of Everything (IoE) and possible enabler for the proposed Internet of Every One (IoEO) connecting people, devices, and things. Researchers argue that currently, deployment of 5G in densely populated areas is on the brink of profitability, deploying 5G in rural and suburban areas, as suggested by GSMA (2018) report, is not profitable and is likely to increase the gap between connected (getting faster) and unconnected (getting nothing). Maccari et al. (2018) propose a short-term solution with long-lasting impact, focusing on connecting unconnected (estimate more than 50%), rather than increasing speed for those already connected. Proposed IoEO is “*set of low-cost technologies that make connectivity affordable for everyone and enlarge the number of connected people*” (Maccari et al., 2018) vertical integration implemented on open source software with openness in mind, while preserving End-to-End principle (network neutrality), providers connect everything, they do not discriminate certain services (vertical integration of services). According to the research, studies show that a substantial impact on the society was the introduction of DSL connectivity (always on, speed in the order of few Mbit/s). The most attainable effect with 4-8Mbit/s, the further increase has a negligible impact. Maccari et al. (2018) propose two types of low-cost networks, *Low-Cost Access Networks* and *Low-Cost Backhauling Networks*.

Low-Cost Access Network is based on previous generations of technologies that are increasingly becoming more affordable (2G, 3G or LTE base-stations, and Wi-Fi), unlike 5G network that is cutting edge technology with all new physical layer. There are two approaches to low-cost access networks. The first approach is to develop new open source software similar to OpenBTS, OpenBSC or OpenLTE (under development) and used current technologies replacing the back-end voice stack with IP stack or use Software Defined Radio (SDR) replacing traditional hardware radio components with a software solution. Using an SDR solution, a 3G base station can be bootstrapped for a few thousand Euro. Second approach use combination of main UHF backhauling network and local Wi-Fi access points, in a Wi-Fi, enabled smartphone a dedicated application is used for phone calls and text messages, a similar project was pioneered in Argentina by the Altermundi NGO.

Low-Cost Backhauling Networks is a solution that brings network connectivity to rural and remote areas in the form of community networks. Deployment of fibre cables in rural areas is very costly with many obstacles, for example, cost of roadworks, cost of crossing private land, cost of the technology and slow return on investment due to the low density of

population. Networks built by communities use affordable technologies to create backhaul network bringing connectivity to the area, such connectivity can be a mesh of long-distance Wi-Fi networks using directional antennas capable of connecting two devices and reaching distances of several kilometres. According to Maccari et al. (2018), 1 Gbit/s connection between 2 devices can be built for under €2000 cutting the cost significantly, when combined with meshing long-distance wireless networks, the community network can scale effectively and become robust.

Additionally, researchers propose using Blockchain-enabled mesh networking, a concept of a distributed wireless network that use blockchain to encourage and incentivise its participants. There are currently two projects, Althea and AMMBR, both working on blockchain based application that runs on a network node and negotiates peer-network participation. A price is negotiated between neighbouring nodes as *price per byte*, creating an incentive for a node to be an active participant on the network. The process is fully automated, it negotiates, monitor and reward accordingly. Projects are still in their early stages, but their goals are to foster cooperation and participation, encouraging for the creation of small service providers.

Proposed Low-Cost Access and Backhaul Networks does not push for new, and costly, research of new technology, but rather bootstrap existing affordable technologies to enable connection of areas and communities without any connection. Combination of those technologies allows for a connection that is limited but sufficient to enable the use of 3G applications. In some areas, mobile technologies do not exist, and community networks are the only option to get network connectivity.

In their research, Micheni and Murumba (2018) emphasised the importance of 3G mobile networks for the use of ICT and blockchain technology in elections. Mobile 3G network was identified as a required minimum for data transfer when connecting ICT equipment in remote areas where traditional ICT infrastructure is not available. Haddad et al. (2018) discuss the importance of advanced networks for FinTech solutions and services, in their research, they emphasise that current 2G networks, that are widespread in Africa are adequate for phone calls, text messages and mobile banking, but are not sufficient for modern FinTech applications. In their analysis, they found that Fintech startups depend on advanced technologies to roll out their services. Researchers argue that “the better the supporting infrastructure, the higher is the supply of Fintech startups” (Haddad *et al.*, 2018), concluding that establishing and supporting infrastructure is critical for the success of Fintech startups in developing countries.

4.1.4. End-user devices

The end-user devices, smartphones, were identified as an essential part of the infrastructure in developing countries, it represents a gateway for consumers to FinTech

services and other technologies. The report by GSMA (2018) discuss the affordability of such devices, in the report, the affordability was identified as a barrier affecting the penetration of mobile devices into the sub-Saharan region. The total cost of mobile ownership (TCMO) is used in the report as a metric to measure the total cost of owning a mobile headset. The TCMO involve the cost of the headset, activation and cost of the service (voice, SMS and Data). In sub-Saharan Africa, the TCMO for handset and 500MB of data is \$101, that represents %10 of average income, well above the target of %5 entry-level broadband services set by the UN Broadband Commission for digital development (broadbandcommission.org, 2015). The research conducted by GSMA suggest the TCMO in the region is heavily affected by taxes and fees, lowering those fees and taxes would help increase the number of devices in use resulting in higher use of the services and growth of the mobile sector.

4.2. Cryptocurrency and Blockchain Factors

Evaluated research papers differed in terms of discussing either cryptocurrency or blockchain, in this research both types of evaluations were considered in this research. Throughout the research, two main themes became apparent, focus on energy consumption and focus on transaction speed. Additionally, transaction fees were identified as a possible barrier to acceptance in developing countries.

In the research discussing distributed ledger technologies for developing Asia, Ferrarini et al. (2017) highlight power consumption to be a significant weakness of distributed ledger technology. In their research, they discovered that as of 2017, Bitcoin's network alone accounted for 0.09% of total world energy consumption. In a perspective, energy consumption needed for one transaction is equivalent to consumption of 7.55 US households per day. The claim is supported by the research of Santos and Chaczko (2018) who argue that blockchain technology currently requires too much energy for operation. As an example, they discuss the consumption of Bitcoin blockchain that reached up to 70 TWh in the Q2 of 2018 pointing out this is equivalent of yearly energy consumption of a small country like Austria or Chile. In terms of efficiency, the performance is dismal, Bitcoin blockchain process 3 transactions per second, compared to Visa reaching up to 24,000 transactions per second (Visa Inc., 2019). According to Bitcoin Energy Consumption Index (Digiconomist, 2019a), the consumption of Bitcoin blockchain decreased to 41 TWh in March 2019, the decrease in consumption is not enough when compared to Visa. Visa requires 151,000 KWh to process 100,000 transactions, where Bitcoin require 459 KWh to process only 1 transaction (Digiconomist, 2019a). Santos and Chaczko (2018) conclude, energy consumption used for computational power to run a blockchain is too high at the moment and, from the perspective of the developing country, could be even considered wasteful as such energy could be used more productively in supporting the community.

The power consumption and transaction speeds are evaluated by Arps (2018) who examine cryptocurrencies from the perspective of the long term sustainability. Arps (2018) compared 4 different cryptocurrencies (Bitcoin, Ethereum, Ripple & IOTA), among many attributes, Arps (2018) compared cryptocurrencies based on energy consumption, transaction cost and scalability, in his research Arps (2018) found the following:

Bitcoin (BTC) – Bitcoin uses mining to verify transactions and to generate new coins, in 2018, the energy consumption of Bitcoin required 73.12TW of energy, compared to VISA one transaction requires 4000 times more energy (order of magnitude estimation). Bitcoin network can process theoretically up to 7 transactions per second (tps), the transaction fee is set to 0.0001 BTC. Software upgrades, codename SegWit and Schnorr, of the Bitcoin protocol, can increase the transaction speed up to 19 tps. Bitcoin protocol did not receive any update yet due to several reasons (rapid growth, organisational problems and decentralised software clients) and community did not agree on upgrading to a Lightning protocol that could theoretically allow Bitcoin network to process 500tps.

Ethereum (ETH) – Ethereum cryptocurrency use mining to verify transactions and to generate new coins, Ethereum cryptocurrency runs on Ethereum blockchain that is also a platform for smart contracts, as of 2018, power consumption is estimated to 7.737 TWh (Deka, 2019). Less than Bitcoin, but still very high. Ethereum process 15 tps, with an average cost of \$0.27 per transaction. Ethereum plans to upgrade the network protocol in future, codename Plasma and Raiden, which will theoretically allow for 1 million of tps.

Ripple (XRP) – Unlike opensource Bitcoin and Ethereum, Ripple is a private cryptocurrency and does not use mining to verify transactions. As a result, power consumption is minimal, exact consumption is unclear as Ripple is running on a network of its partners, the consumption of Ripple is much lower than Bitcoin and Ethereum according to Ripple Labs. Inc. A transaction fee is set to 0.00001 XRP per transaction, Ripple process 1,500 tps and can theoretically reach up to 50,000 tps. Since Ripple is not open source, dedicated engineering team works on supporting and scaling the Ripple network.

IOTA (MIOTA) – IOTA cryptocurrency, similar to Ethereum, runs on OITA platform owned by IOTA foundation, OITA does not use mining to verify transactions, therefore power consumption is minimal. As of 2018, IOTA can process 500 - 800 tps, OITA does not require any transaction fees. Instead, minimum computing power is required to process the transaction.

Transaction fees were also mentioned in research by Lindman et al. (2017) discussing blockchain in the payment system. Lindman et al. (2017) suggest that as the blockchain based currencies are becoming mainstream, the cost structure becomes more important for wider adoption. An example was given using the credit card industry where the norm is charging fees to merchants and subsidise customers, this meant almost no cost for the

customers and help the proliferation of credit cards. High transaction fees of cryptocurrencies can deter the user from adopting cryptocurrencies in developing countries conclude Lindman et al. (2017).

Research by Yli-Huumo *et al.* (2016) examined the literature available on Bitcoin blockchain technology, identifying 4 challenges to adoption of Bitcoin - throughput, latency, size and bandwidth. Throughput refers to transaction speed, Bitcoin's transaction speed of 7 transactions per second is no match for transaction rate of Visa at approximately 2000 transactions per second, in order for bitcoin to become more adopted it needs to increase the number of transactions. Latency refers to how long it takes to process a Block of Bitcoins blockchain. Yli-Huumo et al. (2016) determined it takes approximately 10 minutes to process one block to assure transaction was a secure process and to prevent double spending, concluding if a greater utility is to be achieved, the block needs to be processed faster. Size of Bitcoin blockchain is constantly growing, as of February 2016, the size of Bitcoin blockchain was 50 GB and with each processed block. The bandwidth refers to a number of processed blocks, each Block of Bitcoins blockchain is 1 MB with an average number of 500 transactions per 1 block, and each block is created every 10 minutes (Antonopoulos, 2015). Yli-Huumo et al. (2016) point out that in order to process more transactions, the issue concerning size and relatively slow bandwidth need to be addressed.

Valente et al. (2018) investigate the possibility of Bitcoin becoming a future of payments compared to available payment methods. The paper evaluates Bitcoin from a financial perspective and discusses limitations that need to be overcome for Bitcoin or other cryptocurrencies to be comparable with current payment methods. One of the limitations identified in the paper is technology and infrastructure. Valente et al. (2018) compare transactions processed by Visa, PayPal and Bitcoin, pointing out that Bitcoin lacks in a number of transactions behind its opponents. For Visa and PayPal, the transaction rates range between 200 to 1600 transactions per second, where Bitcoin process in theory only 7 (in reality 3-4). Ethereum is estimated to process over 30 transactions per second and Litecoin between 50-60. Paper is concluding that in this area, Bitcoin and other reviewed cryptocurrencies cannot compete with current payment methods.

Part of FinTech in Sub-Saharan Africa research, Yermack (2018) analysed the use of cryptocurrencies in Sub-Saharan Africa countries and discovered that cryptocurrencies, as a form of payment, did not become popular yet. Africa hosts almost no Bitcoin nodes, Yermack (2018) reasons, despite that, there have been spikes in interest in Bitcoin during the military takeover in November 2017 in Zimbabwe, as a result, countries cryptocurrency exchange Golix observed 80% price increase of Bitcoin when compared to rest of the world. The spike in price was a result of the political turmoil in the country with an inability to access international markets and with lack of Internet connectivity. In such occasions,

cryptocurrencies are seen as safe heaven as seen in Venezuela or Cyprus, leading Yermack (2018) to the conclusion that rather than lack of demand, the infrastructure is the limiting factor.

Data collected by Global Cryptocurrency Benchmarking study by Hileman and Rauchs (2017) seem to support Yermack's research. The study provides data on several Bitcoin wallets, Bitcoin ATMs and cryptocurrency user share in developing regions, particularly in Africa and the Middle East, Asia-Pacific and Latin America. Africa and the Middle East, when compared to other developing regions, have the lowest share in all 3 categories, 6% of Bitcoin Wallets, less than 1% of Bitcoin ATMs and 4% cryptocurrency user share. All results are available in Table 12 - Global Cryptocurrency Benchmarking.

Contra to Yermack's (2018) findings, research by Naboulsi & Naubert (2018) investigating the impact of digital currencies in Kenya, gave an example of BitPesa, a foreign exchange platform. According to the research, BitPesa offers innovative services to customers in Kenya, Senegal, Uganda, Mozambique, Nigeria, Tanzania, UK, Luxemburg and Spain. The service is intended for customers who send money from European countries to Africa. BitPesa uses Bitcoin to transfer payments, customers transfer Bitcoin to BitPesa wallet, BitPesa then converts Bitcoin to Fiat currency and transfer it to customer's mobile wallet like M-PESA, making the transfer faster, transfer takes less than 2 hours, and cheaper, reducing the cost by nearly 75%, when compared to services like PayPal or Western Union. In their research Naboulsi & Naubert (2018) draw an example of sending \$662 (approximately £500) through BitPesa, PayPal and Western Union and compared fees for each transaction. In their comparison, they found that the most expensive was PayPal with \$36 (5.4%) transaction charge, \$26 (3.98%) charge by Western Union and least expensive BitPesa charging \$7.1 (1%). As of 2018 BitPesa handle on average \$10 million worth of transactions per month, but as the researcher discovered, the volatility of Bitcoin is a challenge for BitPesa.

Since some of the data in the researches were inconsistent or outdated, several supplement searches were conducted to get the latest data available. Search for current power consumption of Bitcoin network show that, as of February 2019, was 42 TWh, as a percentage of worldwide energy consumption the number increased to 0.25% (1 transaction equivalent to consumption of 13.71 of U.S. households/day) (Digiconomist, 2019a) in comparison, energy consumption of Ethereum was, as of February 2019, 7.1 TWh, 0.04% of worldwide energy consumption (1 transaction equivalent to consumption of 1.21 of U.S. households/day) (Digiconomist, 2019b). In 2016 the size of Bitcoin blockchain was 50GB as presented by Yli-Huumo *et al.* (2016), the supplemental search showed that current size of Bitcoin Blockchain 197 GB (2019) (Statista.com, 2019a). As of April 2019, the transaction fees of cryptocurrencies discussed in research by Arps (2018) are \$1.135 for Bitcoin, \$0.102

for Ethereum and \$0.0005 for Ripple (IOTA has 0 transaction fees), all fees are captured in the graph in Figure 3 - Cryptocurrency Transaction Fees. In their research Yermack (2018) stated that Africa has almost no Bitcoin nodes, supplemental search for current cryptocurrency mining map (bitnodes.earn.com, 2019) shows there are still almost none in Africa as can be seen in Figure 4 - Global Bitcoin Nodes Distribution (bitnodes.earn.com, 2019).

In the research by Naboulsi & Naubert (2018), the researchers gave an example of different charges between PayPal, Western Union and BitPesa. In the case of BitPesa, the example did not take into account the initial charge that has to be made in the initial exchange from fiat to Bitcoin before the transfer to BitPesa. The additional price cannot be determined as it depends on the Exchange fees, however that usually is not free.

4.3. Human Factors

Another important factor affecting the acceptance of cryptocurrencies in developing countries are human factors, namely literacy and education, and how human perceive cryptocurrencies and their readiness to accept it.

4.3.1. Human Perception and Readiness

Shahzad et al. (2018) conducted research focusing on adoption of cryptocurrencies among the people of mainland China. The study investigates the intentions to use Bitcoin among Chinese people through empirical research. In the study, Shahzad et al. (2018) were attempting to describe factors and what affect the adoption of cryptocracy Bitcoin and how they affect the intention of use of this new innovative technology. The study is also interesting from the point of view of the context, it is investigating the intention to use Bitcoin despite the unfavourable regulations. Since 2013 Chinese institutions and banks are prohibited from dealing with bitcoin (Yiyao and Changxin, 2013), and in 2018 Chinese government announced its intention to “block access to all domestic and foreign cryptocurrency exchanges and ICO websites.” (Seth, 2018), but despite these restrictions, the Bitcoin and other cryptocurrencies remained popular among Chinese people. The study focused on 4 factors:

- Awareness
- Perceived ease of use
- Perceived usefulness
- Perceived trustworthiness

Awareness: The study discovered that awareness is one of the main drivers of diffusion in innovative technologies. In the adoption process, the awareness provides information about the innovative technology, its implications in the transformation process and shapes

individuals decision. It is a crucial factor leading to understanding the technology and its benefits.

Perceived ease of use: The confidence in the ease of use was recognised in the study as another factor influencing acceptance of Bitcoin. Computer literacy eases the adoption of innovative technologies in the field of information technology. The ease of use was linked to user-friendliness and ease of access.

Perceived usefulness: The likelihood of adoption increases if the person believes that adopting new technology is going to have a positive impact and be beneficial to them. It was discovered that “perceived usefulness has a persistent impact on behavioural intention to use technology in future” (Shahzad *et al.*, 2018).

Perceived trustworthiness: Trust was identified as one of the critical factors in the acceptance of bitcoin. In their research, Huhtinen (2014) examines trust importance in adopting bitcoin, dividing it into two categories. Trust in the monetary system and trust in system functionality. The high volatility of price and legal uncertainty affect the perceived trustworthiness of the technology and affect the likelihood of adoption.

Shahzad (2018) conclude the research stating, it was proved that *“awareness, perceived ease of use, perceived usefulness, and perceived trustworthiness to have a significant positive association with the intention to use of Bitcoin”*. (Shahzad *et al.*, 2018)

Schlegel et al. (2018) examined blockchain technologies from the consumer’s perspective, identifying two limitations, technical proficiency and human behaviour. In their research, Schlegel et al. (2018), explain that technical proficiency is necessary to set up and use cryptocurrency. The process is complex and needs to be followed step by step to set up and process transactions of blockchain based currency. The process starts with installing the digital wallet and downloading entire blockchain set, after validation of blockchain a transaction can be made. The initial setup process can take hours and is not considered user-friendly, especially for consumers who are not computer proficient. Human behaviour limitation is described by Schlegel et al. (2018) to be related to how humans are used to dealing with money. Humans are not yet used to the concept of *“backing-up”* their money, the paper proposes humans will have to adjust their behaviour, habits and expectation. The irreversibility of the blockchain transaction calls for a higher degree of responsibility. Unlike in traditional bank, there is no customer support to help customers, the loss of private keys will result in loss of access to funds. The change in the behaviour, taking more responsibility and behave securely is necessary for the blockchain enabled environment.

4.3.2. Literacy and Education

Another human-related factor discussed in research papers is the level of literacy in developing countries. The GSMA (2018) report indicate a lack of digital literacy and low

education level, in general, is a barrier for further growth of the mobile sector. According to UNESCO, 85% of children in sub-Saharan Africa will not be able to achieve minimum proficiency levels in reading and mathematics by the time they finish lower secondary education, followed by Central and Southern Asia with 81%, lowest results among all world regions (uis.unesco.org, 2017). Education of computer skills is also limited, according to UNESCO (2015), only a few percents of primary and secondary schools have computer laboratories, for example, South Africa 26% in primary and 39% in secondary, Gambia 11% and 42%, Zambia 5% and 15%, Cameroon 1% and 33% or Niger 0% and 9%. To overcome the computer literacy gap, governments in the sub-Saharan region will have to invest in the education, improving the school's infrastructure and overall literacy.

The importance of literacy and education in developing countries is discussed by Lambrechts and Sinha (2018) who focus their research on decentralised education facilitated through ICT technology. Lambrecht and Sinha (2018) state "*Electronic commerce (e-commerce), big data, and social media are contributing to how business is conducted globally, but also require knowledge of the ICT sector, adaptive education, and most importantly, connectivity.*" The research identified several challenges affecting the diffusion and growth of the education system:

- Lack of physical ICT infrastructure and energy supply
- Shortage of qualified workers
- The absence of affordable quality education
- Low performance of financial markets
- High corruption rates
- Inequality, poverty, hunger and epidemics

In the research, technology was identified as a supporting structure supporting the educational process, allowing for further scaling as the demand grows. However, Lambrecht and Sinha (2018) point out that using technology for teaching in developing countries has some challenges and limitations, the technology requires skilled staff to maintain and operate ICT technology and implementation is costly especially for developing countries.

The need for staff educated in ICT disciplines is confirmed by Micheni and Murumba (2018) in their research of ICT role in the election process, researchers found that electoral management bodies (EMB) in Kenya often found challenging to attract and even retain skilled staff with ICT knowledge to set up and support ICT technology. The need is further confirmed by Nicholson (2017) who identified staffing and upkeep of library ICT hardware to be a challenge in the research concerning the introduction of Bitcoin in developing countries through libraries. Even Naboulsi and Neubert (2018) found literacy to be a

challenge for BitPesa in Africa, literacy was especially challenging for BitPesa in rural areas where the concept of Bitcoin, its benefits and how it can lower fees had to be first explained.

Although these human factors are not directly related to ICT infrastructure, evidence from the research show the need for population educated and knowledgeable of ICT technology is necessary for the development of ICT infrastructure, for further penetration of technologies and possible acceptance of cryptocurrencies.

4.4. Other Important Factors

During the review of research papers, it became apparent that other factors influence the acceptance of cryptocurrencies in developing countries, even though these are not directly linked to ICT infrastructure they were found necessary for acceptance in the context of developing countries. These factors are mobile money, government support and regulation. It is expected that other non-ICT factors could be identified by a search focused on social or economic themes.

4.4.1. Mobile Money

Since its introduction in 2009 in Kenya, mobile money thrived in the sub-Saharan region. As a result, many researchers focus on mobile money and how they transformed the region.

In the research investigating Bitcoin in developing countries, Clegg (2014) identified unstable banks in developing countries as one of the main obstacles to their development and overcoming poverty. Businesses find it difficult to get funds to grow the business and fund innovation, consumers to preserve their wealth in the form of savings they can rely upon or to start their business. As a result, alternative services like mobile money service provider M-PESA in Kenya gain popularity very fast. M-PESA, owned by mobile network operator Safaricom, is a service for small-value payments and fund storage accessible from a mobile phone. The service was introduced in 2007 and in only 4 years attracted over 9 million customers in Kenya, about 40% of the adult population. Clegg (2014) argues that one of the reasons for the popularity of M-PESA is how simple it is to set up an account, M-PESA account is directly linked to a persons mobile phone number, to open an account, a person registers their SIM card in one of the authorised M-PESA stores. Another reason for the popularity is the fee structure, M-PESA charge a flat fee of \$0.40 to transfer funds between M-PESA accounts, to withdraw funds under \$33 the cost is \$0.33 and balance query \$0.0013, M-PESA has no monthly fees for owning the account. The only revenue stream is through transaction fees, to incentivise its customers to use M-PESA to transact instead of using it to save funds, the transactions are limited to \$500. During the research, Clegg (2014) found an unexpected benefit of M-PESA, its positive effect on crime in terms of lowering thefts and pickpocketing, and empower women by allowing them to make savings without their husband's permission.

Report by Vodafone (2016) on M-PESA states that as of March 2016, M-PESA has reached 25.3 million customers in Africa, Asia and Europe. The report further gives an account of partnerships M-PESA secured with mobile operators MNT, TransferTo and Vodacom in sub-Saharan Africa to facilitate international fund transfers. M-PESA further secured partnerships with several government organisations to facilitate fund transfers, Ministry of Social Development in Lesotho, Ministry of Agriculture in Kenya, charity National Rural Livelihoods Mission and National Rural Health Mission in India. In the private sector, M-PESA now facilitates payments for eBay, TabCab, children's charity World Vision, air carrier LAM, Qatar Airways and KLM in Tanzania, and with solar electricity providers Off-Grid Electric, Mobisol and MKopa.

In the research FinTech in sub-Saharan Africa, Yermack (2018) describe M-PESA mobile payments as the most common type of digital payments in Africa with growing popularity in Haiti and Bangladesh. The success is a result of using the "LASIC" principle (Chuen *et al.*, n.d.), (L) low-profit margins, (A) light asset, (S) scalable, (I) innovative, and (C) compliance friendly. Yermack's (2018) analysis of M-PESA further show the service is expanding, but it failed to succeed in South Africa, the failure is attributed to the strong banking system and spread of smartphone technology that low-tech M-PESA could not compete with. As concluded by Buckley and Webster (2016) "M-Pesa leverages existing infrastructure to deliver the simplicity and accessibility required of FinTech offerings in developing countries".

In the research investigating FinTech in developing economies, Klasa (2018) looked at mobile money from the perspective of bank inclusion. According to their research, there are approximately 1.7 billion adults, about one-quarter of the world's population, unbanked. Klasa (2018) proposed a solution to this problem which might be mobile money, as mobile money operators now offer additional services, saving accounts, utility payments, payroll and even small loans. The number of customers and transactions is on the rise, between the years 2014 and 2017 the number of mobile accounts rose from 54% to 63% (Demirgüç-Kunt *et al.*, 2018). Globally, there are 866 million mobile money customers, who are on average transacting \$1.3 billion per day, that is equivalent to \$206 in 12 transactions per month (Pasti, 2019). In the research Klasa (2018) further states that mobile operators are in a better position compared to traditional banks, in their decision-making process they have access to a large amount of data about their users and therefore offer more suitable services.

The success of M-PESA is particularly interesting when put in the context of financial inclusion in developing countries. Research by Lumsden (2018) suggests a correlation between poverty and success of mobile money in developing countries with a premise that there is a demand for financial services and that government regulation favour mobile

money because no other financial services and low-cost payment systems are available. Lumsden (2018) present example from Jamaica, where the main limitations to opening bank accounts are lack of identity documentation where identification cards are not standardised, lack of an independently verified source of data to help verify customers, opportunity costs in the form of travel to/from the bank, waiting times in banks and security in general. Opening a bank account in Jamaica is difficult due to anti-money laundering regulations to prevent fraud. Another obstacle identified by Lumsden (2018) were high fees, traditionally associated with bank transactions in the developed countries, the researcher puts this in contrast with M-PESA where ease of opening the accounts, accessibility and low fees were identified as significant contributors to the success of the service. Research also lists countries where mobile money have seen explosive success compared to countries where it failed, presented in Table 13 - Mobile money success/fail countries (Lumsden, 2018). In all countries where mobile money succeeded, researchers identified a common denominator, government regulations. In countries that have seen the success of mobile money, the regulation was “loose” and in favour of mobile money, where the regulation was restrictive, the mobile money failed. In 7 of listed countries, regulators “required banks to take the lead in overseeing emerging mobile technology” Lumsden (2018) point out. Lumsden (2018) conclude that to improve the financial inclusion, developing countries have to take advantage of technological developments, drive the change from bottom up, where the population embrace the technology before any regulation from the top (legislators) is introduced. Governments need to listen to the demands of the population and favour service that will serve a larger segment of the population. Lumsden (2018) also suggests that the population need to be informed about the benefits of digital payments and to understand how physical money can be secure.

4.4.2. Government Support and Regulation

The need for government support in many areas of development was commonly discussed by several researches.

Lambrechts and Sinha (2018) state that ICT can drive education in developing countries, but governments need to support the development of ICT infrastructure. According to the GSMA (2018) report, government support is essential to the development of sustainability of services and deployment of mobile networks into rural areas, by offering a financial incentive or tax breaks. In the research concerning Blockchain electoral process, Micheni and Murumba (2018) discuss that ICT can help to facilitate the process, but without legal and regulatory support, ICT on its own is no guarantee of transparent elections. In the research by Ferrarini et al. (2017), that successful deployment of distributed ledger technologies can only be achieved with functioning government institutions, reforms and policy compliance. In KINGS countries, the government support of tech hubs, incubators

and innovation were described by Naboulsi and Neubert (2018) to be resulting in solid GDP growth and a growing number of mobile and internet subscribers. Further confirmed by Ndemo & Weiss (2016, p.59) stating “economic growth, entrepreneurial ecosystems, vibrant telecoms, tech infrastructure, and supportive policies - distinguish the KINGS economies from others on the continent.”

Government involvement in cryptocurrency regulation was emphasised by Schlegel et al. (2018) in their research discussing blockchain technologies from a user perspective. The researchers identified legal uncertainty as a significant limitation, two contrasting countries were compared in the research, Estonia and China. Estonia with its integration of blockchain for nation-wide services fully supported by the government, compared to restrictive China clamping down on Bitcoin and Cryptocurrency exchanges. The legal uncertainty is recognised in the paper as a severe limitation to the expansion of blockchain technology.

Contrary to other researches, the conference paper by Harris (2018) warned against government involvement in blockchain technologies in developing countries. Harris (2018) identified corruption as an incentive for governments to manipulate blockchain as one of the most significant risks to cryptocurrency in developing countries. According to Harris (2018), private centralised blockchains are in danger of manipulation in the form of reversed transactions, restricting access or rolling out updates that are not favourable for the users of the blockchain. In the case of public blockchains, Harris (2018) argue, governments in developing countries have control over the internet allowing them to restrict the access for miners and users and affect the performance blockchains and cryptocurrencies. The main benefit of some cryptocurrencies is privacy that can be compromised by governments tracking transactions, and with enough data, government entities can identify and track users.

Research by Broby and Baker (2018) offered a different perspective altogether, assessing the role of Central Banks in developing countries in accepting cryptocurrencies. According to Broby and Baker (2018), the main role of central banks is to ensure a reliable and solid financial system, sustain price stability, maintain electronic and physical payment system, issue the national currency and protect citizens from negative effects of the financial system. Protection of citizens from any adverse effects of cryptocurrencies is challenging. Cryptocurrencies lack fundamental value, an individual perception determines the value, it is impossible for Central banks to assure protection. Central banks protect against inflation through regulation of money supply, by increasing or removing money from the economy. With cryptocurrencies, such regulation is not possible as banks have no authority over the supply of cryptocurrencies, if cryptocurrencies are widely used they can negatively affect the economy of the country. Example from China and Venezuela show that cryptocurrencies can be used to bypass exchange control of capital and tax evasions. Broby

and Baker (2018) summarise set of approaches suggested by Bank of International Settlements:

- Information – Describing cryptocurrencies as dangerous and fraudulent
- Interpretation of existing regulation – Attempt of authorities to align cryptocurrencies with existing regulations
- Regulation of specific entities – Refer to the regulation of exchanges, merchants and intermediaries.
- Licenses – Issuing licences to exchanges to operate with the country
- Prohibition – Banning of cryptocurrency exchanges or acceptance by merchants

Broby and Baker (2018) warn against legalising cryptocurrency in developing countries where penetration of the technology is generally low and fewer citizens of developing countries understand the complexities surrounding cryptocurrencies and could potentially expose them to risks of misinformation and fraud. Due to the high valuation of cryptocurrency, the primary use of cryptocurrency is speculation, legalising the cryptocurrencies could be perceived as an encouragement to speculate, that is very dangerous in the context of Central Banks not having direct control over cryptocurrencies. Authors argue that “with the volatile nature of cryptocurrencies, any loss in value would lead to a crisis where individuals, as well as the financial system, lose money” and that could pose a risk to financial stability. Authors agree that the technology of cryptocurrencies and blockchain, can be beneficial in the future, however in their opinion, developing countries should evaluate all risks and if risks are more significant than benefits, banning cryptocurrencies is seen as the best approach. However, the authors argue that a better approach is to exercise control over cryptocurrencies in developing countries with periodical reviews and periodic changes to regulations.

5. Conclusions and Future Work

5.1. Introduction

The purpose of this thesis was to investigate the adoption of cryptocurrency in developing countries from the perspective of ICT infrastructure. This chapter answers the main and supporting research questions, and it discusses key findings and conclusions from the systematic literature review. Furthermore, limitations are discussed in this chapter and topics for future research are suggested.

5.2. Limitations of the Research

Due to cryptocurrency being relatively new to the monetary system, the amount of research papers discussing the practical use of cryptocurrency is low. During the research, it was discovered that no paper discussed the influence of infrastructure on cryptocurrency directly. The majority of papers, found during the systematic literature review, assessed infrastructure in developing countries in relation to other topics and discussed cryptocurrency only superficially. In most cases, these topics were mobile payments, FinTech, financial inclusion and blockchain based electoral process. Since cryptocurrency, and underlying blockchain technology, run on the same ICT infrastructure as other technologies, the findings in these papers were used to draw conclusions in this research.

The majority of papers that discussed cryptocurrency focused solely on one cryptocurrency - Bitcoin, this was attributed to the popularity of Bitcoin. Bitcoin was the very first cryptocurrency on the market, it was widely researched and remained the prevailing currency on the market. During the research, only one research paper was found to compare four different cryptocurrencies, Bitcoin, Ethereum, Ripple and IOTA. This lack of diversity in discussion limits the conclusions that can be drawn as there is less discussion of non-Bitcoin cryptocurrencies.

The second identified constraint was lack of papers discussing developing countries as a whole, the focus of the majority of papers was in a particular country or on sub-Saharan Africa region, only a few papers mentioned developing Asia or other countries. This focus of research papers was attributed to sub-Saharan Africa being the least developed region in the World, repeatedly scoring the lowest results in many international reports, and as a result, attracting researchers.

5.3. Answering the Research Questions

2.1.1 *The main research question*

What are the ICT infrastructure factors influencing the potential adoption of cryptocurrency in developing countries?

During the systematic review of available literature four factors influencing the adoption of cryptocurrency in developing countries were identified as:

- Reliable supply of electricity
- Penetration of internet
- Availability of mobile networks
- Ownership of end-user devices

Access to a reliable supply of electricity is essential for deployment and further development of any information technology-based service. Cryptocurrency cannot perform its function as

a monetary medium without consumers and merchants having a constant supply of electricity to power on their devices to process payments. In developing countries, this is particularly a concern in rural areas, where there is either limited or no supply of electricity. The need for a reliable source of electricity for the development of ICT supported services was highlighted in several reviewed researcher papers. Statistical information shows that two regions, sub-Saharan Africa and India, have most of their population without access to electricity. In sub-Saharan Africa alone nearly 57% of the population, approximately 590 million people, does not have access to electricity with 80% of people without access are estimated to live in rural areas. India was found to have the second largest share of people without access to electricity, accounting for 239 million people. Based on the reviewed data, access to reliable electricity was identified as being a severely limiting factor to not only the spread of cryptocurrency but also to the development of the whole regions. If cryptocurrency is ever to become widespread in developing countries, this limiting factor needs to be addressed first.

Another limiting factor identified as the main influence on the adoption of cryptocurrency in developing countries is access to the internet. It was discovered that the lowest penetration rates of the internet are in Africa with only 39.5% and Asia with 51%. For comparison, the World average penetration rate is 56.3% with North America and Europe reaching over 80% each. Many researchers described the lack of internet access to be a severe limitation to the development of ICT based services, investments and financial inclusion. This is true especially for blockchain and FinTech technologies which cryptocurrency is part of. An example from KINGS countries in Africa, where governments adopted the approach of prioritising investments into ICT technologies, show that such investments result in significant growth of the Internet and mobile subscribers leading to the growth of GDP and prosperity in these countries.

Availability of mobile networks was identified as another ICT factor affecting the adoption of cryptocurrency that is specific to developing countries. Lack of physical infrastructure in developing countries led to investments in mobile technology that provides connectivity to the population without the need for massive investments into physical infrastructure. Unlike physical connections, mobile networks do not require last mile connections (a connection between the provider and a household) and provide a reasonable return on investment for mobile network providers. As a result, developing countries have seen a boom in coverage of mobile networks in past years, in sub-Saharan Africa, the coverage of 2G network is over 90% of the population and 3G network reaching to 75% of the population. However, during the research, it was discovered that availability of mobile networks remains scarce in rural and remote areas, where the connection is available, it is usually only a 2G network which is not capable of mobile broadband that is necessary for FinTech applications and services, including cryptocurrencies. Mobile network providers continue to invest in the mobile

network infrastructure to increase coverage and introduce more mobile broadband connections. The research shows that mobile operators settled for older and proved 3G technology allowing them to reuse already acquired 900 MHz spectrum currently used for 2G connections, investing into newer technologies like 4G LTE or 5G is currently seen as not profitable and remains minimal. It is estimated that by 2025, 3G technology will reach 60% share of all connections, allowing for an increase in mobile broadband connections to 87% in the sub-Saharan region. Connecting remote areas is especially problematic as 20% of the population is scattered across 70% region, solution for disconnected communities could be community networks, these networks bootstrap existing affordable technologies using open source applications to provide connectivity to remote areas and serve the whole community. Unlike mobile service providers, community networks are not driven by profit, and the return of investment is not a primary concern. Community networks can provide much faster access to broadband than mobile networks for much lower prices.

Ownership of end-user devices is factor directly linked to the availability of mobile networks and penetration of the internet. Underdeveloped infrastructure and relatively good coverage of the population by mobile networks led to increasing the use of mobile devices in developing countries. The total cost of ownership of smartphone in developing countries reaches \$101 representing approximately 10% of average income in a developing country, a high price considering UN Broadband Commission target is set to 5% of average income. The price is a result of high taxes and fees and is a limiting factor to the penetration of mobile devices. In sub-Saharan Africa, the development of mobile networks is expected to drive the increase in ownership of smartphones devices rising from the current 250 million devices to 690 million in 2025. During the research, it was discovered that smartphones are seen by many researchers as an essential device enabling the development of services and for gaining access to FinTech application and other FinTech services. Unlike traditional mobile phones, basic smartphones have sufficient computational power to run applications, from the perspective of cryptocurrency, the smartphone can provide a gateway to cryptocurrency and related services and serve as a mobile wallet allowing the sending and receiving of payments. The level of smartphone penetration in developing countries is an important factor in the acceptance and utility of cryptocurrency.

2.2.1 Supporting Questions:

What is the current state of ICT infrastructure in developing countries?

The most important ICT infrastructure for deployment and operation of cryptocurrency were identified as a reliable supply of electricity and mobile networks. There are some limitations in this research regarding the ICT infrastructure, most of the collected data have regional character, for mobile networks, the data were available only for countries in sub-Saharan

Africa, and none of the research papers discussed landlines or physical broadband infrastructure.

Electricity is not strictly part of the ICT infrastructure, but it was included as it provides a supply of energy for ICT devices, without functioning electricity grid and reliable supply of electricity, all other ICT devices are inoperable. Worldwide there are nearly 1.1 billion people without access to electricity, and the majority of them are located in Sub-Saharan Africa and Developing Asia. Sub-Saharan Africa, data available only for the region, has 590 million people without access to electricity, the second highest number has India with 239 million people, Pakistan with 51 million, and Bangladesh with 51 million followed by Indonesia 23 with million and Philippines with 22 million. The electricity penetration is a significant obstacle to the development and adoption of modern technologies in developing countries, this is supported by findings in research papers where low penetration of electricity is often pointed out.

Mobile networks are the most common way to access IT services in developing countries, the predominant network connection 2G covering over 90% of the population. More modern 3G networks, capable of broadband connectivity, cover over 400 million people, about 60% of the population. Covering rural and remote areas remain challenging, especially in geographically hard to reach areas. Adoption of 4G LTE and 5G networks is slow, and mobile operators prefer to further invest in proved 3G technology that allows them to reuse already leased spectrum. Mobile networks are a vital enabler for mobile broadband connection, research suggests the coverage by 3G connection is insufficient, but that is believed to change in the near future due to investments into mobile networks.

What other factors are influencing the adoption of cryptocurrency in developing countries?

Other factors identified during the research to have an influence on cryptocurrencies in developing countries were:

- Attributes of cryptocurrencies
- Literacy
- Competition in the form of Mobile money
- Government support

These non-ICT infrastructure factors present an interesting avenue for future research as the initial results show the potential importance of these factors.

Cryptocurrency is still in its early stages of development, some of the attributes of cryptocurrency would have to change before it can become accepted as the main monetary payment method. Several research papers identified the energy consumption of the Bitcoin

blockchain network to be too high. The consumption of the Bitcoin network is driven by demand, at the moment the average consumption is reaching 41 TWh, but in 2018 the consumption was reaching up to 70 TWh, that is equivalent to the consumption of a small country. For comparison, Ethereum has an average consumption of 7.7TWh, cryptocurrency OITA and Ripple have reportedly negligible consumption when compared to Bitcoin. The energy consumption of the cryptocurrency is a factor that needs to be taken into account before the cryptocurrency is even considered for use, Bitcoin for example shows that energy consumption can reach levels that are untenable from long term perspective, the research also shows that consumption levels vary among cryptocurrencies. Another property of cryptocurrency that might become a factor affecting acceptance is the transaction speed. Bitcoins reported transaction speed is realistically between 3-4 tps, where Ethereum is reaching 15 tsp, OITA up to 800 tps and Ripple is capable of processing 1,500 tps. The transaction speeds vary among the cryptocurrencies and vary due to differences in the underlying blockchain technology. There are some upgrades planned for reviewed cryptocurrencies that could increase the transaction speeds, but those upgrades were not applied yet. The transaction speeds are often compared with Visa that is capable of processing up to 24,000 transactions per second. However, Visa is not the best example when developing countries are discussed. Visa is widely used in developed countries that have highly developed ICT infrastructure, high levels of financial inclusion and use of IT technology, furthermore transaction fees represent only a fraction of transferred funds and are usually absorbed by the merchant.

Literacy and knowledge of ICT systems were mentioned to be the main factor affecting the adoption of new technologies in developing countries, and it could also affect the adoption of cryptocurrency. Primary education is a concern especially in sub-Saharan Africa and Central and Southern Asia where UNESCO report 81-85% of children will not achieve minimum proficiency levels. Education in ICT disciplines is lacking with low numbers of computer classes in primary and secondary schools. Several reviewed researches also identified a lack of ICT skilled staff to be a challenge.

Another factor that could affect the acceptance of cryptocurrency is the popularity of mobile money in developing countries. Mobile money is well established among the population in developing countries, currently having a customer base of 866 million customers worldwide and transacting on average \$1.3 billion per day. The most established mobile money is M-PESA with customers in Africa, Asia and Europe. The popularity of mobile money is attributed to several reasons, it is easy to open an account, easy to use, affordable, is lightweight on the resources using SMS, requires only simple mobile phone and 2G network to operate. Mobile money has its limitations in the service offerings, but it is firmly established on the market and has proven its utility. In the example of M-PESA, the expansion continues with new services and partnerships, one such partnership is with

BitPesa. BitPesa allows expat workers to send funds to their home country directly to M-PESA accounts. Workers transfer Bitcoin to BitPesa account, BitPesa automatically transfers funds to the destination M-PESA account. The BitPesa process the transactions in less than 2 hours and at a much lower cost than its competitor, Western Union and PayPal which dominate the international money transfers for expat workers. BitPesa is a good example of the potential cryptocurrency has in developing countries and shows that cryptocurrency can provide an alternative to current services.

The research identified government support to be necessary for cryptocurrency acceptance and for the deployment of any new technology in developing countries. During the research it was discovered that one of the reasons for the success of mobile money is due to its support from the government, in countries where mobile money was not supported by government, the service failed. In many research papers, the role of the government was identified as important, if not essential. In the case of cryptocurrency acceptance, the same applies, without legislator's support, or at least neutral approach from legislators, the cryptocurrency adoption could be negatively affected and possibly fail. One research paper stands out in its recommendations, calling for more strict control of cryptocurrencies and possibly banning them to protect people from price speculation and possible loss of money.

2.3.1 Conclusion Summary

The essential ICT related factor to cryptocurrency adoption was identified to be a lack of electricity penetration, limiting the penetration of all other ICT technologies. In developing countries, over 1.1 billion people are still without access to electricity. Other limiting factors, penetration of internet and availability of mobile networks, are linked together. The penetration of the internet remains low in developing countries, sub-Saharan Africa and Asia regions remaining below the World average in internet penetration. Mobile networks are the most common way of providing internet connection in developing countries. Mobile operators actively invest in the mobile network, upgrading from current 2G networks to 3G enabling mobile broadband. The technology is not cutting edge technology, but it is proved and cost-effective, an essential attribute in developing countries. Another way to provide a connection to rural and remote areas are community networks, using bootstrapped technologies to provide connectivity. Ownership of mobile devices was identified as another factor, mobile devices play a vital role in developing countries as they are affordable and provide a gateway to the internet, cryptocurrency and other ICT based services. With the increasing levels of 3G coverage, the number of smart mobile devices is expected to grow.

The research also identified other non-ICT related factors that affect the adoption of cryptocurrency in developing countries. Attributes of cryptocurrency were identified as an important factor. The most discussed cryptocurrency, Bitcoin was determined to have high power consumption and slow transaction rates, the research identified other

cryptocurrencies that have higher transaction rates and consume less electricity, these have the potential to be more suitable for developing countries, but further research is necessary. Low literacy levels were identified as another factor, developing countries are lacking in basic literacy and computer education, leading to a shortage of ICT staff. Another significant factor is the competition of mobile money, especially M-PESA, a very successful mobile money widely used in developing countries. M-PESA is light on resources, cheap on transaction fees and widely accepted among the population. The last factor identified to be affecting the acceptance of cryptocurrency was government support. Government support is vital in accepting new technologies. The example from mobile money shows the acceptance of the technology could fail without the support of the local government.

5.4. Suggestions for Future Research

Most of the researches surrounding cryptocurrency and blockchain technology is investigating how these technologies can help in developing countries without concerning themselves with the question “Can these technologies be deployed in the first place?” This research identified some gaps in terms of physical infrastructure, an underlying physical layer of technology that is necessary for the deployment of any blockchain based technology. From the research it is clear there is a need for more practical research focusing on the current state of infrastructure and how can it be married with blockchain technology.

All of the research papers, except one, focused solely on Bitcoin. There are currently over 2,000 different cryptocurrencies each with its unique approach or utility. There is a need to examine different types of cryptocurrencies in future researches as Bitcoin is not the only cryptocurrency on the market. Bitcoin has its own set of limitations that might have been overcome by other cryptocurrencies, and there are possibly cryptocurrencies that would be more suitable for developing countries.

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Appendix 1 – Results of Search Queries

IEEE Xplore

Search: Full Text & Metadata

Publisher: ALL

Content Types: ALL

Timeframe: 2009-2019 (Present)

Source type: Books, Conference Papers & Proceedings; Dissertations & Theses; Reports; Scholarly Journals; Trade Journals; Working Papers

(actual search query in IEEE Xplore)

#	Search Terms	Results
1.	("crypto currenc*" OR cryptocurrenc*) AND "developing countr*" AND infrastructur* <i>((("crypto currenc*") OR cryptocurrenc*) AND "developing countr*") AND infrastructur*)</i>	26
2.	("crypto currenc*" OR cryptocurrenc*) AND "developing nation*" AND infrastructur* <i>((("crypto currenc*") OR cryptocurrenc*) AND "developing nation*") AND infrastructur*)</i>	3
3.	("crypto currenc*" OR cryptocurrenc*) AND underdeveloped AND infrastructur* <i>((("crypto currenc*") OR cryptocurrenc*) AND underdeveloped) AND infrastructur*)</i>	13
4.	("crypto currenc*" OR cryptocurrenc*) AND "developing countr*" AND ICT <i>((("crypto currenc*") OR cryptocurrenc*) AND "developing countr*") AND ICT)</i>	13
5.	("crypto currenc*" OR cryptocurrenc*) AND "developing nation*" AND ICT <i>((("crypto currenc*") OR cryptocurrenc*) AND "developing nation*") AND ICT)</i>	1
6.	("crypto currenc*" OR cryptocurrenc*) AND underdeveloped AND ICT <i>((("crypto currenc*") OR cryptocurrenc*) AND underdeveloped) AND ICT)</i>	2

ABI/INFORM Global

Search keyword in: Anywhere

Limit to: No Limit

Publication date: 01/2009 - 03/2019

Language: English

#	Search Terms	Results
7.	("cryptourrenc*" OR cryptocurrenc*) AND "developing countr*" AND infrastructur*	67
8.	("cryptourrenc*" OR cryptocurrenc*) AND "developing nation*" AND infrastructur*	20
9.	("cryptourrenc*" OR cryptocurrenc*) AND underdeveloped AND infrastructur*	17
10.	("cryptourrenc*" OR cryptocurrenc*) AND "developing countr*" AND ICT	14
11.	("cryptourrenc*" OR cryptocurrenc*) AND "developing nation*" AND ICT	4
12.	("cryptourrenc*" OR cryptocurrenc*) AND underdeveloped AND ICT	2

Google Scholar

Publication date: 2009 - 2019

#	Search Terms	Results
13.	(cryptocurrency OR cryptocurrencies OR "crypto-currency" OR "crypto-currencies") AND ("developing country" OR "developing countries") AND (infrastructure OR infrastructures)	1,330
14.	(cryptocurrency OR cryptocurrencies OR "crypto-currency" OR "crypto-currencies") AND ("developing nation" OR "developing nations") AND (infrastructure OR infrastructures)	207
15.	(cryptocurrency OR cryptocurrencies OR "crypto-currency" OR "crypto-currencies") AND underdeveloped AND (infrastructure OR infrastructures)	438
16.	(cryptocurrency OR cryptocurrencies OR "crypto-currency" OR "crypto-currencies") AND ("developing country" OR "developing countries") AND ITC	40
17.	(cryptocurrency OR cryptocurrencies OR "crypto-currency" OR "crypto-currencies") AND ("developing nation" OR "developing nations") AND ICT	272
18.	(cryptocurrency OR cryptocurrencies OR "crypto-currency" OR "crypto-currencies") AND underdeveloped AND ICT	112
19	(cryptocurrency OR cryptocurrencies OR "crypto-currency" OR "crypto-currencies") AND ("developing country" OR "developing countries" OR underdeveloped OR "developing nation" OR "developing nations") AND ICT AND (infrastructure OR infrastructures)	1580

Appendix 2 – Literature Review Search Results

Table 8 - Quality Assessment

Study	Overall Quality	Study Methodology	Quality of Reporting	Evidence	Argumentation	Research Objectiveness	Quality Score (Average)
Maccari et al. (2018)	Moderate	2	3	2	3	2	2.4
Geetha and Girisha (2018)	Weak	1	1	2	1	2	1.4
Shahzad et al. (2018)	Moderate	3	3	1	2	2	2.2
Naboulsi and Neubert (2018)	Strong	3	3	2	3	3	2.8
Schlegel et al. (2018)	Strong	3	3	3	3	3	3
Santos and Chaczko (2018)	Moderate	3	3	2	2	2	2.4
Valente et al. (2018)	Strong	3	3	2	2	3	2.6
Clegg (2014)	Strong	3	3	3	3	3	3
Broby and Baker (2018)	Moderate	2	3	2	1	2	2
Ferrarini et al. (2017)	Strong	3	3	3	3	3	3
Klasa (2018b)	Moderate	2	3	2	2	2	2.2
Klasa (2018a)	Moderate	2	3	1	2	2	2
Yermack (2018)	Strong	3	3	3	3	3	3
Lindman et al. (2017)	Moderate	2	3	1	2	2	2
Lambrechts and Sinha (2018)	Strong	3	3	2	3	2	2.6
Haddad and Hornuf (2018)	Strong	3	3	3	3	3	3
McGowan and Jaisinghani (2015)	Weak	1	2	1	2	1	1.4
Lumsden (2018)	Moderate	2	3	2	2	2	2.2
Nicholson (2017)	Moderate	1	2	1	3	2	1.8
Hileman and Rauchs, 2017	Strong	3	3	3	3	3	3
Harris (2018)	Moderate	2	2	2	3	2	2.2
Micheni and Murumba (2018)	Strong	3	3	2	3	3	2.8
Wang et al. (2019)	Strong	3	3	3	3	3	3
Arps (2018)	Strong	3	3	3	3	3	3
Haddad (2018)	Moderate	2	3	1	2	2	2

Table 9 - Excluded Research Papers

Resource	Author	Title	Reason for Exclusion
ABI/INFORM Global	Risius and Spohrer (2017)	A Blockchain Research Framework.	Not relevant to the research. The study has little focus on the infrastructure.
Google Scholar	Geetha and Girisha (2018)	A Conceptual Study on the Impact of BitCoins On the Indian Economy.	The study excluded based on quality. Study present overview of the information, it is not critical and does not go into detail.
IEEE Xplore	Xie et al. (2019)	A Survey of Blockchain Technology Applied to Smart Cities: Research Issues and Challenges.	Not relevant to the research. Study focus on the Cities solely from the perspective of service, but omits physical infrastructure
IEEE Xplore	Kshetri and Voas (2018)	Blockchain in Developing Countries.	Not relevant to the research. Study focus on Blockchain applications in developing countries. Paper too short.
Google Scholar	Modh et al. (2018)	Decentralized Way for Keeping Transactional Record.	Not relevant to the research. Paper discusses the application of blockchain in the banking system and how it will transform banking services.
Google Scholar	Ahishakiye et al. (2018)	Developing Countries and Blockchain Technology: Uganda's Perspective	Not relevant to the research. Paper discusses the benefits of blockchain and how Uganda committed to integrating it into their government and banking system.
ABI/INFORM Global	Doria and Fantacci (2018)	Evaluating complementary currencies: from the assessment of multiple social qualities to the discovery of a unique monetary sociality.	Not relevant to the research. Paper discusses the benefit and evaluation process of cryptocurrencies only from a monetary and sociological point of view
IEEE Xplore	Hurlburt (2016)	Might the Blockchain Outlive Bitcoin?	Not relevant to the research. Paper discusses the benefits of blockchain without a focus on infrastructure.
Google Scholar	Shrier et al. (2016)	Mobile Money & Payments: Technology Trends.	Not relevant to the research. Paper discusses the benefits of blockchain without a focus on infrastructure.
ABI/INFORM Global	Reijers and Coeckelbergh (2018)	The Blockchain as a Narrative Technology: Investigating the Social Ontology and Normative Configurations of Cryptocurrencies.	Not relevant to the research. Paper discusses blockchain from the perspective of sociological impact, the impact of infrastructure is mentioned, but not discussed in detail.
Google Scholar	McGowan and Jaisinghani (2015)	The End of Financial Marginalization Is in Sight: Here's the Roadmap.	The study excluded based on quality. The study does not reference the majority of its findings, the methodology is unclear.
ABI/INFORM Global	Angel et al. (2015)	The Ethics of Payments: Paper, Plastic, or Bitcoin?	Not relevant to the research. Paper discusses Payment methods including cryptocurrency, infrastructure is mentioned, but not discussed in detail.
Google Scholar	Darlington (2014)	<i>The Future of Bitcoin: Mapping the Global Adoption of World's Largest Cryptocurrency Through Benefit Analysis.</i>	Not relevant to the research. Paper discusses cryptocurrency, infrastructure is mentioned, but not discussed in detail.
ABI/INFORM Global	Antonio et al. (2014)	The Gender Digital Divide in Developing Countries.	Not relevant to the research. The study was excluded based on dates of the resource, the majority of the resources are 10 and more years old, the study was considered not up to date.
ABI/INFORM Global	Zamani and Giaglis (2018)	With a little help from the miners: distributed ledger technology and market disintermediation.	Not relevant to the research. The study focus on blockchain and cryptocurrency without taking into account ICT constrains

Table 10 - Results of Backward/Forward Search

Author	Name
Antonopoulos, A.M. (2015)	Mastering bitcoin.
Buckley, R.P., Webster, S. (2016)	FINTECH IN DEVELOPING COUNTRIES: CHARTING NEW CUSTOMER JOURNEYS
broadbandcommission.org (2015)	Broadband Targets for 2015.
Chaia, A., Dala, A., Golan, T., Gonzalez, M.J., Morduch, J., Schif, R. (2009)	Half the world is unbanked.
Chuen, D.K., Swee, G., Jinrui, Z. (2015)	Emergence of FinTech and the LASIC Principles.
Deka, C. (2019)	Ethereum [ETH] and BTC together stand 45th on the global map of energy consumption levels, says research.
Demirgüç-Kunt, A., Klapper, L., Singer, D., Ansar, S., Hess, J. (2018)	The Global Findex Database 2017: Measuring Financial Inclusion and the FinTech Revolution
disrupt-africa.com (2018)	Disrupt Africa.
Graham, L. (2017)	Bitcoin: Digital currency price falls on China ICO ban.
GSMA (2018)	The Mobile Economy Sub-Saharan Africa 2018.
ITU.int (2019)	ICT Facts and Figures 2017
uis.unesco.org (2015)	Information and Communication Technology (ICT) in Education in sub-Saharan Africa: A comparative analysis of basic e-readiness in schools.
Huhtinen, T.-P. (2014)	Bitcoin as a monetary system: Examining attention and attendance
iea.org (2017)	Energy Access Outlook 2017
Ndemo, B., Weiss, T. (2016)	Digital Kenya: An Entrepreneurial Revolution in the Making

Author	Name
Pasti, F. (2019)	State of the Industry Report on Mobile Money 2018.
Seth, S. (2018)	Is Bitcoin Banned in China?
The Economist (2016)	Mobile money in Africa: Promise and Perils
uis.unesco.org (2017)	More Than One-Half of Children and Adolescents Are Not Learning Worldwide
UN (2019)	UNITED NATIONS E-GOVERNMENT SURVEY 2018
Visa Inc. (2019)	Visa - Small Business Retail.
Vodafone (2016)	Vodafone M-Pesa reaches 25 million customers milestone
Yiyao, W., Changxin, G. (2013)	Banks not allowed to use Bitcoin.
Yli-Huumo, J., Ko, D., Choi, S., Park, S., Smolander, K. (2016)	Where Is Current Research on Blockchain Technology?
bitinfocharts.com (2019)	Avg. Transaction Fee chart - Bitcoin, Ethereum, Litecoin, Bitcoin Cash, XRP, Monero, Dash.
bitnodes.earn.com (2019)	Global Bitcoin nodes distribution.
Digiconomist (2019)	Ethereum Energy Consumption Index
digiconomist.net (2019)	Bitcoin Energy Consumption Index
internetworldstats.com (2019)	World Internet Users Statistics and 2019 World Population Stats
Statista.com (2019b)	Bitcoin blockchain size 2010-2019.

Appendix 3 – Figures & Tables

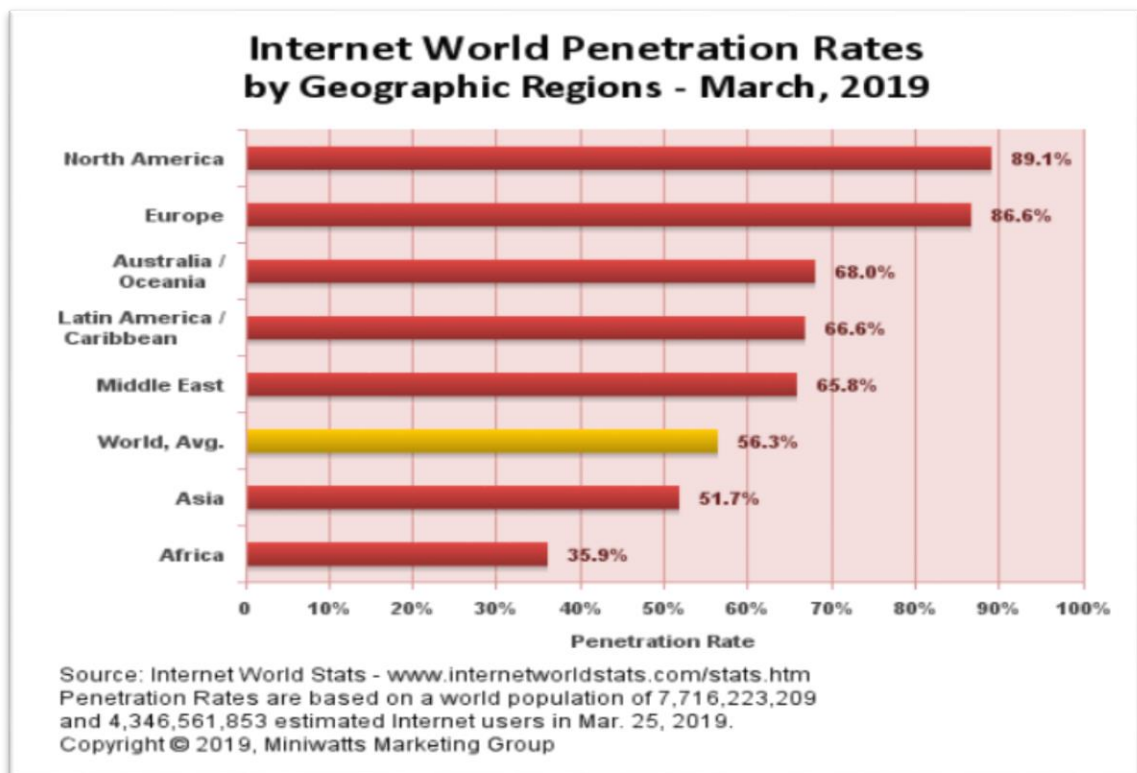


Figure 2 - Internet World Penetrations Rates by Geographical Regions (internetworldstats.com, 2019)

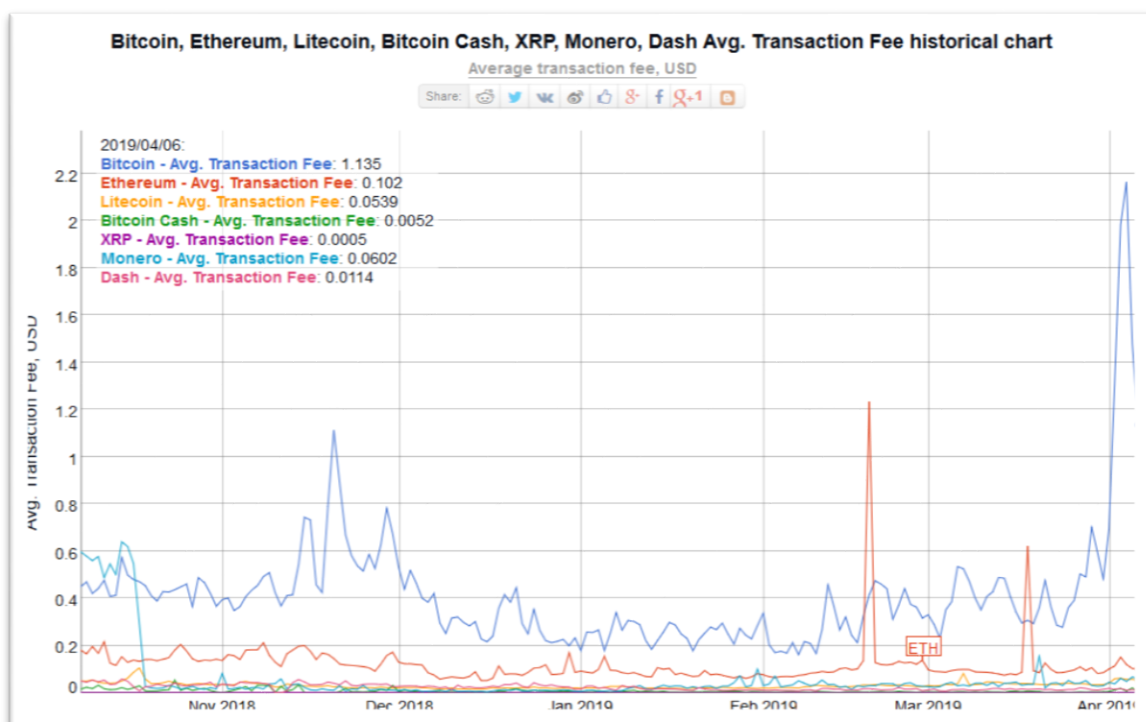


Figure 3 - Cryptocurrency Transaction Fees (digiconomist.net, 2019)

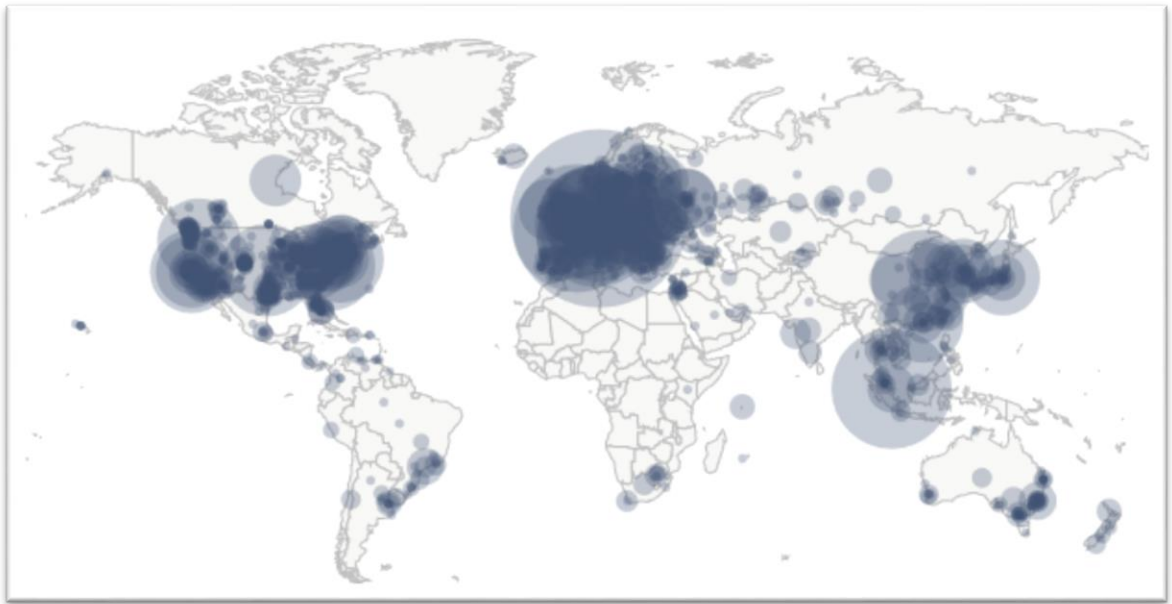


Figure 4 - Global Bitcoin Nodes Distribution (bitnodes.earn.com, 2019)

Table 11 - KINGS countries (Ndemo and Weiss, 2016)

Country	Population	GDP Growth (%)	Mobile Subscribers	Internet Subscribers
Kenya	44.35 M	5.7	32.3 M	16.2 M
IvoryCoast	20.32 M	8.7	17.9 M	5.6 M
Nigeria	173.6 M	5.4	133.2 M	70.3 M
Ghana	25.9 M	7.1	29.53 M	14.62 M
SouthAfrica	52.98 M	1.9	59.5 M	21.73 M

Table 12 - Global Cryptocurrency Benchmarking

	<i>Africa and the Middle East</i>	<i>Asia-Pacific</i>	<i>Latin America</i>
No. wallet users	6%	20%	13%
Bitcoin ATM share by region	<1%	5%	<1%
Cryptocurrency user share	4%	14%	38%

Table 13 - Mobile money success/fail countries (Lumsden, 2018)

The success of Mobile Money	Fail of Mobile Money
Bangladesh	Burkina Faso
Cote D'Ivoire	Haiti
Kenya	India
Rwanda	Indonesia
Somaliland	Madagascar
Tanzania	Mexico
Uganda	Nigeria
Zimbabwe	South Africa