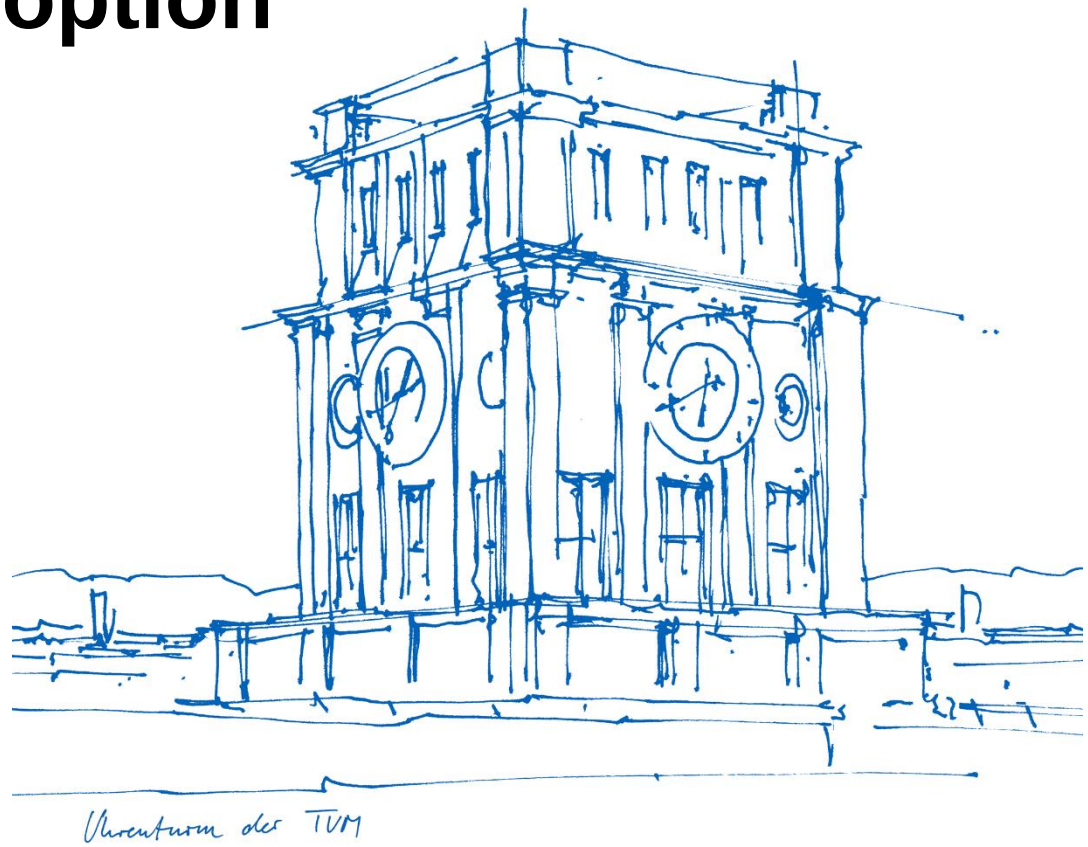
Chair for Strategy and Organization
TUM School of Management
Technical University of Munich

Master Thesis

Cryptocurrencies as Payment: An Overview and Analysis of Factors Driving Adoption

Results and Main Findings



Florian Knöchel

April 22, 2022

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Executive Summary

Methodology:
Building on the current research in the field of cryptocurrencies as payment, a qualitative analysis of existing cryptocurrencies was conducted through secondary data collection and three expert interviews to evaluate the factors of adoption in practice.

Approach and Results:
Cryptocurrencies are ranked according to various acceptance factors derived from existing literature and the most suitable ones for payments are identified.

- Solana is the best-suited payment cryptocurrency
- Tether is the best-ranked stablecoin

The payment process and critical entities such as payment gateways are included in the analysis fostering a complete understanding of the adoption procedure.

- Payment gateways, exchanges, and wallets all play a vital role in the ecosystem adaption and influence accepting venues, usability, and availability

Adoption factors that cryptocurrencies already satisfy are highlighted and aspects currently hindering adoption are thus inferred.

- Transaction speed and costs, throughput, and energy consumption match and outperform VISA. Security and volatility are also satisfied.
- Usability, acceptance, availability, knowledge, trust, and regulations are currently hindering mass adoption.

Cryptocurrencies and Stablecoins are poised for a future means of payment.

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About

This slide deck is part of the master's thesis "Cryptocurrency Payments: An Overview and Analysis of Factors Driving Adoption". The collected data is as of February 26, 2022.

The thesis was conducted at the TUM School of Management at the Chair of Strategy and Organization and supervised by Prof. Dr. Isabell M. Welpe.

Links:

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Notion Page

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Theory and Outline

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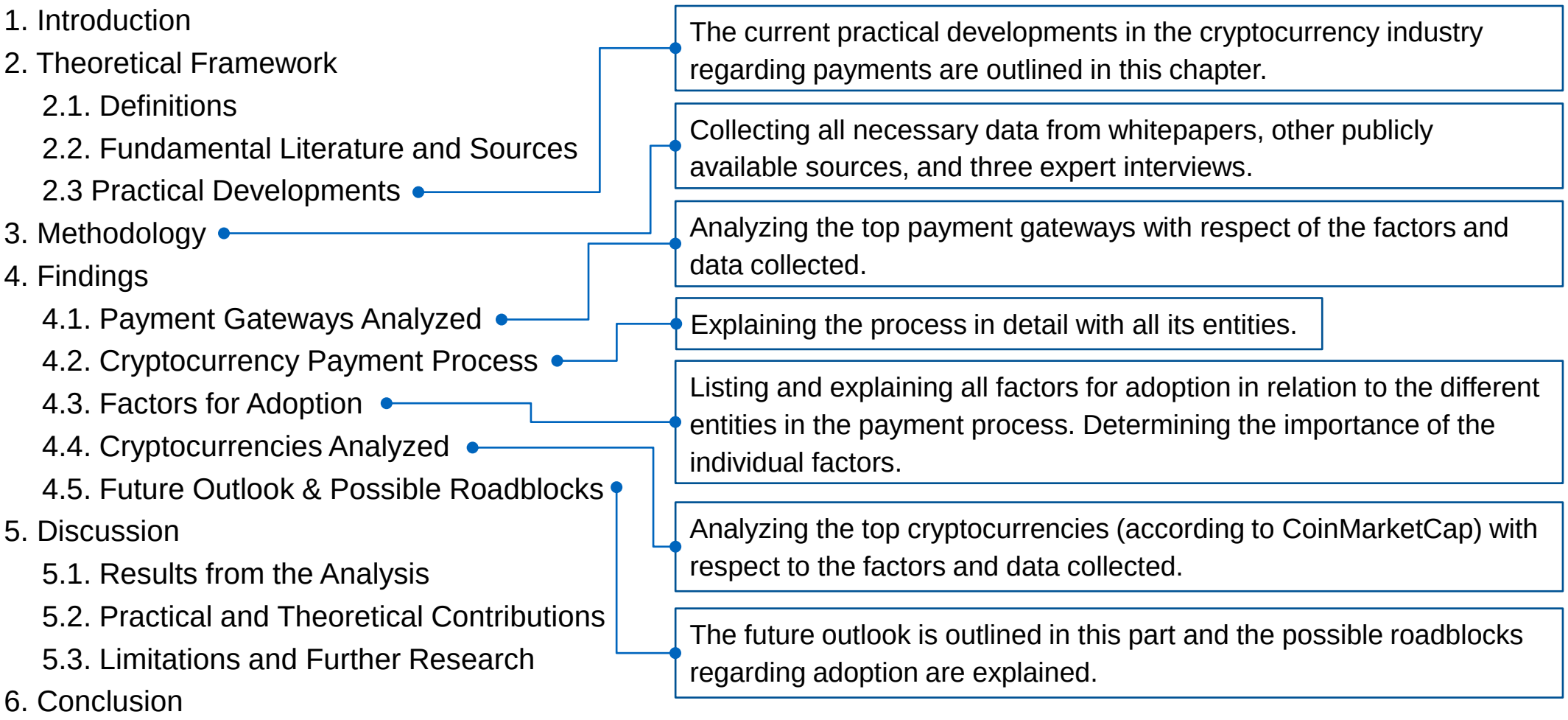
Sources in the following.

Outline of the Thesis and Main Topics



Need for Research and Main Research Question

Current Developments:

- El Salvador became the first country to allow Bitcoin as legal tender in 2021.
- 46 new venues start to accept cryptocurrencies weekly.
- Elon Musk announced that Tesla is accepting BTC as an official payment in February 2021, only to retract the payment option three months later due to environmental concerns.

Cryptocurrency payment has gained much traction in practice but has not received significant research attention yet.

Current State of Research:

- BTC was invented in 2009 by Nakamoto to establish a resilient and non-censorable electronic payment system.
- Today, several factors, such as transaction speed, are negatively affecting the possibility of BTC functioning as a suitable means of payment.
- Factors for adoption are manifold and different papers have researched them, but an overview of all factors is scarce.
- Most of the factors have not been analyzed regarding the suitable existing cryptocurrencies.
- Research on the functions of money suggests that cryptocurrencies cannot currently fulfill them completely.

Research Question

Which factors influence the adoption of cryptocurrency payments and what existing cryptocurrencies do fulfill these factors best?

Sources: Al-Amri et al., 2019; Ammous, 2018; Ante, 2020; Fama et al., 2019; Levulytė & Šapkauskienė, 2021; Nakamoto, 2008; Peters et al., 2015; Sabah, 2020; Saiedi et al., 2021.

Important Theoretical Concepts

Functions of Money 💵

The functions of money is a theoretical concept relevant for understanding the adoption of cryptocurrencies as a means of payment.

Money serves three primary functions:

- **medium of exchange**
- **unit of account**
- **store of value**

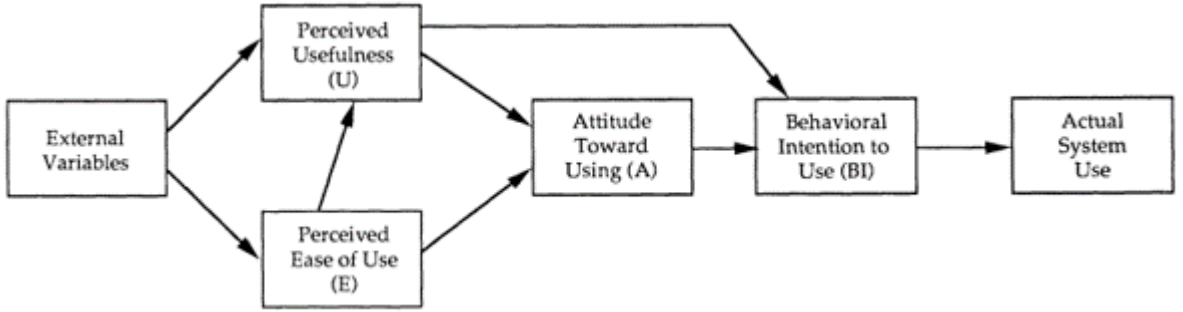
It is essential to satisfy all functions as this is the minimum requirement to become an adequate means of payment.

Cryptocurrencies already fulfill the function as a medium of exchange but **volatility** is impacting the other two aspects.

Stablecoins like UST, USDT, and DAI solve the volatility of cryptocurrencies and therefore satisfy all three main functions of money.

Stablecoins are explained on the next slide.

Technology Acceptance Model (TAM)



Adapted from "User Acceptance of Computer Technology: A Comparison of Two Theoretical Models," by F. D. Davis, R. P. Bagozzi, and P. R. Warshaw, 1989, *Management Science*, 35(8), 982-1003. (https://doi.org/10.1287/mnsc.35.8.982). Copyright 1989 by INFORMS.

The Technology Acceptance Model (TAM) is a theoretic model for users' acceptance and use of technology first proposed by Davis et al. (1989).

The TAM gives a theoretical foundation for why external variables, like ⚡Transaction Speed or 🔒Security, can influence perceived usefulness and ease of use and drive the adoption of a system.

Perceived usefulness is the extent to which an individual believes that adopting the system will enhance their performance.

Perceived ease of use is defined as individuals' belief that the system's adoption will be effortless.

Sources: Davis et al., 1989; Levulytė & Šapkauskienė, 2021; Nuryyev et al., 2021; Peters et al., 2015, Titov et al., 2021.

Cryptocurrency Basics

Cryptocurrencies are virtual assets based on a blockchain that is distributed over a peer-to-peer network to record transactions and ownership without an intermediary secured by cryptography, hence the name (own definition).

A **blockchain** is a growing list of transaction records called blocks, linked and secured through cryptography, each containing a timestamp, transaction data, and the previous block's hash (Narayanan et al., 2016; Nofer et al., 2017).

Cryptocurrency Types

Cryptocurrencies can be classified into either **coins** or **tokens**.

Coins are the native cryptocurrency of their blockchain. Notable examples are BTC, ETH, and DOGE.

Tokens depend on the blockchain of a coin and could not function without it. Blockchains such as Ethereum allow the development of cryptocurrencies utilizing the provided chain. Examples: ONE and MATIC.

Stablecoins are cryptocurrencies designed to remain at a stable market price. Most often they are pegged against the US Dollar. Examples: USDT and USDC.

Consensus Algorithm

A consensus algorithm is an underlying mechanism on the blockchain, secures it and gives integrity to the whole system by making compromising attacks too costly.
There are two main consensus algorithms:

Proof of Work secures the cryptocurrency with computational power. Through this resource, energy consumption can be very high, and throughput and transaction speed are limited.
Notable examples: BTC, ETH, and DOGE

Proof of Stake uses cryptocurrency ownership as a resource. As no computational puzzle needs to be solved, proof of stake tends to be more sustainable and faster.
Notable examples: ETH2*, DOT, and ADA

*Ethereum is upgrading from PoW to PoS.

Sources: Farell, 2015; Giudici et al., 2020; Li & Whinston, 2020; Narayanan et al., 2016; Nofer et al., 2017; Steinmetz et al., 2021.

Results

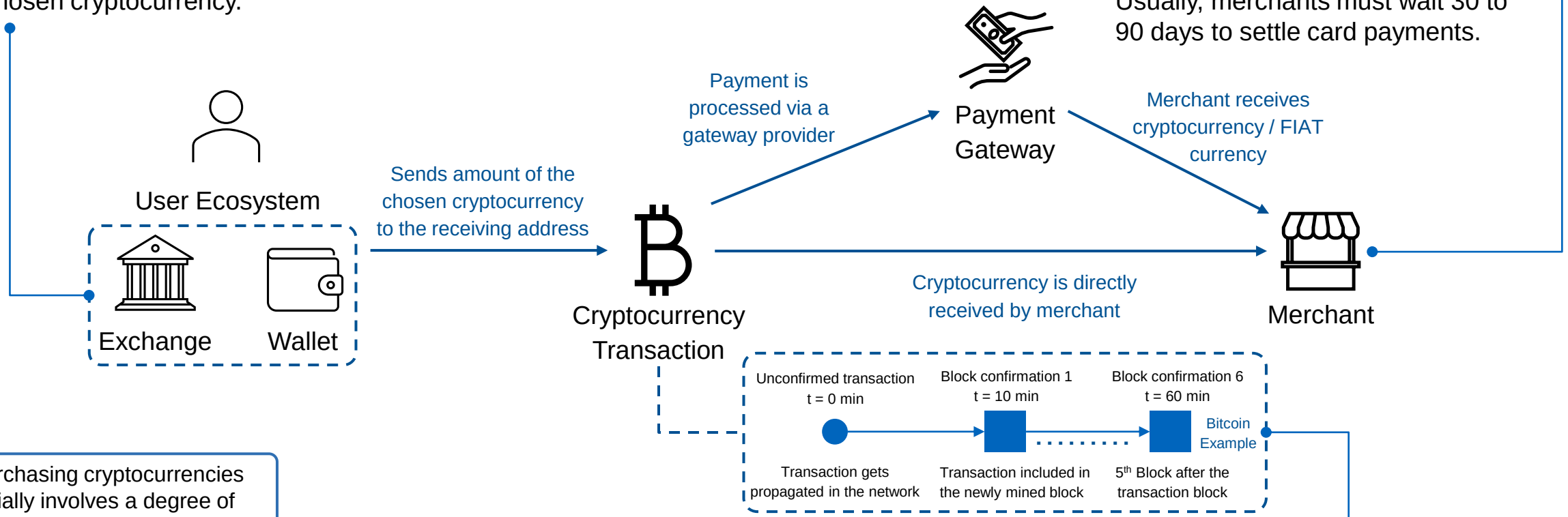
Source of Image: unsplash.com

Sources in the following.

Payment Process

Wallets and **exchanges** nowadays have similar functions. The process displays wallets, exchanges, and **users** as one ecosystem responsible for sending a specified amount of the chosen cryptocurrency.

Compared to VISA, cryptocurrency payments are almost instantly in the hands of the **merchant**. Usually, merchants must wait 30 to 90 days to settle card payments.



Purchasing cryptocurrencies initially involves a degree of complexity as consumers are unfamiliar with exchanges and wallets, hampering usability.

In the form of BTC, the first confirmation takes at least 10 minutes. As SOL has a blocktime of only 0.4 seconds, the first confirmation would be received much faster.

Source of Image: Own illustration [Florian Knöchel]

Sources: Arli et al., 2021; Hileman & Rauchs, 2017.

Wallets, Exchanges, and Payment Gateways are explained in more detail on the next slide.

Payment Gateways, Wallets, and Exchanges

Wallet

A **wallet** is a software used to securely store, send and receive cryptocurrencies by managing private and public key.

Popular examples include MetaMask and Trust Wallet.

Wallets provide a user interface to track the status of cryptocurrency holdings and automate certain functions such as estimating the transaction fee.

Exchange

Cryptocurrency **exchanges** enable anybody to get cryptocurrencies in exchange for FIAT money.

Popular examples are Binance, Coinbase, and FTX.

The boundaries between **wallets** and **exchanges** are increasingly blurred, with 52% of wallets surveyed by Hileman and Rauchs (2017) offering integrated exchange capabilities, while exchanges tend to provide integrated wallets.

Payment Gateway

Cryptocurrency **payment gateways** are payment processors enabling merchants to accept cryptocurrency payments easily. They act similar to credit card providers and offer services such as instantly converting cryptocurrencies into FIAT currencies and managing the vendor's wallet.

Most payment gateways are third-party solutions. But there are also open-sources solutions for merchants, such as BTCPay Server, omitting third-party reliance and fees.

The fees range from 0.4% to 1% for all third-party solutions.* Thus, all listed payment gateways are cheaper than VISA which charges between 1.43% and 2.4% in fees.

This fee difference is particularly relevant for merchants.

Deciding factors in achieving adoption for payment gateways are integrations and plugins for e-commerce players like Shopify, WordPress, APIs, the number of supported cryptocurrencies, and point of sales standardization.

Popular Examples: Coinbase Commerce, Coingate, and BitPay

*9 payment gateways and one open-source solution were examined.

Sources: Hileman & Rauchs, 2017; Johnson, 2020.

Factors for Adoption

The **factors driving** the **adoption** of cryptocurrencies payments identified by the academic community **are manifold**. Volatility, Transaction Cost, and Security are the most frequently mentioned factors.

The factor Sustainability is not mentioned concerning payments in the literature but is nevertheless added because of rising concerns about the energy consumption of cryptocurrencies.

All of the factors with a ranking coefficient are used in the following cryptocurrency ranking and will be explained in detail there.

Trust, Knowledge, and Regulations are not included as the choice of cryptocurrency does not directly influence them.

Users will not use cryptocurrencies if they do not understand them. In El Salvador, the adoption is high among people who understand the underlying technology.

Trust is also vital, as demonstrated by the hacking attacks on Mt. Gox in 2014, which severely affected trust and led many people to refrain from using cryptocurrencies. Trust is essential for users to switch to a new form of payment.

Regulations like in El Salvador, where BTC is now a legal tender, might play a key role in the adoption.

Factor	Number of Sources	Interview Score		Ranking Coefficient
		M	Mdn	
Volatility	15	1.67	1	2
Transaction Cost	11	2.00	2	2
Security	10	1.00	1	1
Transaction Speed	8	2.00	2	2
Accepting Venues	8	2.67	3	2[a]
Ease of Use	8	2.67	3	2[a]
Trust	7	2.33	3	
Knowledge	7	2.00	2	
Regulations	6	2.33	2	
Availability	4	2.67	3	3
Decentralization	3	0.67	1	1
Throughput	2	1.67	2	2
Supporters	2	0.67	0	0
Current Success	2	1.00	1	1
Sustainability	0	1.00	1	1

The interview score is retrieved from the conducted interviews. The ranking coefficient is evaluated based on the other columns and used in the cryptocurrency ranking. Both range from 0 to 3.
[a] Reduced for the ranking as not all aspects of these factors are measurable.

Cryptocurrency Ranking

This ranking comprises all 29 sample cryptocurrencies ranked according to the factors for adoption. Points are awarded from 1 (poor) to 5 (excellent) in all categories and multiplied by the respective ranking coefficient for the final ranking. As stablecoins rely on the blockchain of other cryptocurrencies, they are ranked separately

USDT takes the top spot in the stablecoin ranking. The top 4 are all available on the best-rated Solana Blockchain.

SOL takes the top spot in the cryptocurrency ranking. According to the factors analyzed, Solana scored the most points and is thus the blockchain best suited for payments. Solana is leading in all technical factors, lagging others only in availability and acceptance.

FTM and ETH2 share second place with 67 points. Ethereum 2.0 combines the points of one of the most established cryptocurrencies with the technical superiority of PoS over PoW regarding payments. It should be noted that Ethereum 2.0 is still under development.

BTC ranks 14th with the overall best current success and ecosystem acceptance in terms of availability and accepting venues but falls behind from a technical perspective.

Stablecoins:

Symbol	Name	Type	Points[a]	Best Blockchain[b]	Points[c]	Ranking
USDT	Tether	FIAT	22	57 (SOL)	79	1
USDC	USD Coin	FIAT	21	57 (SOL)	78	2
DAI	Dai	Crypto	18	57 (SOL)	75	3
UST	TerraUSD	Algorithmic	15	57 (SOL)	72	4
BUSD	Binance USD	FIAT	15	38 (ETH)	53	5

[a] Stablecoin points. [b] Points of the best scoring supported blockchain. [c] Points summed up.

Cryptocurrencies (without Stablecoins):

Symbol	Name	Consensus	Points	Ranking
SOL	Solana	Proof of History	71	1
FTM	Fantom	PoS	67	2
ETH2	Ethereum 2.0	PoS	67	2
AVAX	Avalanche	PoS	64	4
XRP	XRP	XRP Consensus	63	5
DOT	Polkadot	PoS	63	5
ALGO	Algorand	PoS	63	5
.....	.....	.....	...	...

Success, Security & Decentralization

Only the top-scoring cryptocurrencies in each category are displayed.

The **current success** of a cryptocurrency is measured by market capitalization, the transaction volume, the number of estimated users, and two third-party ratings. These metrics are related to the availability and accepting venues, which generally describe current ecosystem adaptation. All metrics indicate the levels of trust in a cryptocurrency and therefore confer legitimacy.

BTC and ETH are the two most successful cryptocurrencies. USDT also acquires maximum points for having the highest transaction volume.

BTC, ADA, ETH2, SOL, and LUNA are the most **secure** cryptocurrencies. All of them require an investment of at least 10 billion euros for a successful 51% attack, making an attack by a single entity almost impossible.

BTC, ADA, ETH2, and ETH are the most decentralized cryptocurrencies. The **decentralization** of a cryptocurrency influences security and creates trust.

Current Success:

Symbol	Marketcap	Volume (24h)	Users[a]	FCAS	TokenInsight	Points
BTC	666,077	16,019	40,923	A-	AA	5
ETH	302,698	11,931	175,000	B+	A	5
USDT	70,596	43,457	4,108		B	5
BNB	55,414	1,215	5,871	B+	BBB	4
USDC	47,287	3,287	1,394		A	4

Marketcap and volume are in millions of euros, the number of users in thousands.
[a] Estimated number of users is derived from the number of wallet addresses.

Security and Decentralization:

Symbol	Consensus	Staked Value	Hash Rate	Points[a]	Nodes[b]	Points[c]
BTC	PoW		153.97 EH/s	5	15,282	5
ETH	PoW[d]		1.06 PH/s[d]	4	2,532	5
ETH2	PoS	25,226,762,357€		5	339,000	5
ADA	PoS	20,341,880,754€		5	3,180	5
SOL	Proof of History	34,403,190,409€		5	1,000	4
LUNA	dPoS	26,605,518,088€		5	130	3

[a] Points for security. [b] Number of active validators or miners. [c] Points for decentralization.
[d] ASIC-resistant algorithm, which results in a lower hash rate for similar security.

Sources: Arli et al., 2021; Farell, 2015; Kwaasteniet, 2018; Marella et al., 2020.

Transaction Costs, Speed & Throughput

Transaction costs and throughput are two essential factors for a cryptocurrency that vary widely across the sample. VISA has a transaction fee of 1.43% - 2.4%, operates at 1,700 transactions per second (TPS), and requires a speed of 2.4 seconds.

Outside of BTC and ETH, cryptocurrencies are cheap. SOL and FTM both outperform VISA in terms of transaction fees and throughput.

The **European Central Bank** estimates a throughput requirement of at least 10,000 TPS to settle any transaction denominated in Euro.

Measuring the **speed** of a cryptocurrency for a single transaction is done via blocktime marking the lowest possible transaction time on a blockchain. Time to finality multiplies the blocktime with the number of confirmations but can be understood as an upper limit decreasing over time.

SOL has the fasted blocktime with 0.4 seconds out of all examined cryptocurrencies. ATOM, EOS, and FTM all achieve speeds of 1 second or below.

Transaction Costs & Throughput:

Symbol	Average Transaction Fee ($)	Points[a]	Throughput (TPS)	Points[b]
SOL	0.00025	5	50,000	5
AVAX	0.000004	5	4,500	4
CRO	0.0002	5	50,000*	4
NEAR	0.00001	5	100,000*	4
FTM	0.0000001	5	25,000	5
EOS	none	5	4,000	4

[a] Points for transaction fees. [b] Points for throughput. * Development TPS goal.

Transaction Speed:

Symbol	Block Time (s)	Recom. Confirmations[a]	Time to Finality (s)	Points
SOL	0.4	15	6	5
ATOM	1	1	1	5
FTM	1	1	1	5
EOS	0.5	1	1	5
ONE	2	1	2	4

[a] Recommended number of confirmations from Kraken or Coinbase.

Sources: Alzahrani & Daim, 2019; European Central Bank, 2021; Hairudin et al., 2020.

Usability, Availability & Acceptance

Many factors influence the usability of a cryptocurrency. One of the directly influencing factors is the **wallet**. The **usability** of one particular wallet for a particular cryptocurrency cannot be measured easily. **Mobile wallets** are essential for usability. **Native wallets** can offer additional capabilities.

All examined cryptocurrencies have a mobile and desktop wallet option. A few of them differentiate themselves with a native wallet like LUNA. Therefore, the usability in terms of wallets does not differ a lot between cryptocurrencies.

The **availability** and **number of accepting venues** are critical factors in the adoption. Both factors heavily influence whether people or stores accept payments with cryptocurrency. Better availability makes it easier for people to purchase cryptocurrencies. At the same time, a higher number of accepting venues helps with the network effect.

BTC, ETH, LTC, and BCH all have over 40 direct Euro or US Dollar pairs and are therefore the most available cryptocurrencies. BTC and LTC are the two most accepted coins regarding the examined payment gateways.

Usability:

Symbol	Number of Wallets	Mobile	Desktop	Native	Points
BTC	12	yes	yes	yes	5
ETH	40	yes	yes		5
BNB	8	yes	yes	yes	5
USDC	20	yes	yes		5
LUNA	6	yes	yes	yes	5

NEAR offers the advantage of human-readable wallet addresses instead of a public key hash. This results in a more straightforward user experience.

Availability and Acceptance:

Symbol	Markets	FIAT Markets[a]	Points[b]	Accepting Payment Gateways[c]	Points[d]
BTC	9,186	>40	5	10	5
ETH	5,524	>40	5	7	4
DOGE	452	32	4	7	4
LTC	736	>40	5	9	5
BCH	572	>40	5	8	4

[a] Number of US Dollar and Euro markets. [b] Points for availability. [c] Accepting payment gateways from the sample of 10. [d] Points for accepting venues.

Sources: Baur et al., 2015; Giudici et al., 2020; Kwaasteniet, 2018; PWC, 2015.

Sustainability

The **environmental sustainability** of a cryptocurrency can be measured by its energy consumption and the hardware required for validating or mining.

A lot of specialized, short-lived, and non-repurposable mining hardware is used for most **PoW** cryptocurrencies, such as BTC. This causes substantial electronic waste, including heavy metals and toxic chemicals, which is a significant environmental burden.

In general, **PoS**-based cryptocurrencies consume less energy and require less sophisticated, repurposable hardware than their **PoW** counterpart leading to better **sustainability**.

VISA consumes 0.00358 kilowatt-hours per transaction.

SOL, FTM, and XLM have the lowest energy consumption and also outperform VISA in this regard.

ALGO even pledges to be a sustainable carbon-negative blockchain.

Sustainability:

Symbol	Consensus	Energy Consumption[a]	Hardware Requirements	Points
BTC	PoW	707	Extensive	1
ETH	PoW	62.56	Medium[b]	2
DOGE	PoW	565.57	High	1
ETH2	PoS	0.00286	low	5
XRP	XRP Consensus	0.0079	low	5
AVAX	PoS	0.00476	low	5
SOL	Proof of History	0.000166	low	5
ALGO	PoS	0.00534	low	5
XLM	Stellar Consensus	0.00022	low	5
FTM	PoS	0.00000301	low	5

[a] Energy consumption estimation in kWh per transaction. [b] ASIC-resistant algorithm.

PoW cryptocurrencies consume massive amounts of energy compared to their **PoS** counterpart. BTC total energy consumption matches whole countries like Portugal.

Sources: Gallersdörfer et al., 2020; Vries, 2018.

Outlook and Conclusions

Source of Image: unsplash.com

Sources in the following.

Future Outlook and Current Roadblocks

Current Roadblocks

- **Usability** is a crucial factor for adoption.
- Payments with cryptocurrencies must be as easy as existing solutions such as Apple Pay, which has not yet been achieved.
- Handling private keys and recovery passwords impacts the user experience, and there is still room for improvement to reduce switching costs.
- Also, the process of initially attaining cryptocurrencies entails complexity.
- Other factors hindering the adoption in their current state are **Knowledge**, **Accepting Venues**, and **Availability**.
- The number of accepting venues and the availability need to increase to compete with the likes of VISA.
- Knowledge of cryptocurrencies needs to be spread further.

Future Outlook

- However, the **benefits already outweigh the switching costs** in countries like El Salvador or Turkey where adoption is high.
- In general, all interview participants see a continued increase in the adoption of cryptocurrency payments as there is a need to make worldwide payments more accessible, faster, and cheaper.
- Especially stablecoins like USDC could see an increase in adoption as they are easy to grasp and are not volatile.
- The market is evolving fast, and the benefits seem to be more significant than the current obstacles.

All technical challenges for the adoption as payment **are already solved**, including the scalability problem, but current roadblocks are regulatory and usability questions and switching incentives rather than technical challenges.

With all trends pointing in the right direction and set to continue, **cryptocurrencies and**, in particular, **stablecoins seem predestined for future use as a means of payment**.

Contributions and Further Research

Main Contributions

This work shows through the analysis of cryptocurrencies, that the most frequently mentioned and researched factors like **Transaction Speed** and **Volatility** are solved.

Therefore, the cryptocurrency payments research field should focus on other factors when studying adoption. **Usability**, **Knowledge**, **Trust**, **Availability**, **Regulations** and **Accepting Venues** are the current roadblocks for adoption and pose exciting research areas. Especially a study comprising all these aspects would be beneficial.

The **functions of money are fulfilled by cryptocurrencies** when factoring stablecoins into the discussion.

Practical Contributions

Relevant factors for each entity are highlighted, offering practical opportunities for improvement for cryptocurrency companies to enhance their adaptation and gain a competitive advantage:

- Cryptocurrency companies need to spread **Knowledge**, increase **Availability**, and most importantly enhance **Usability**.

The advantages for **users** and **merchants** are also outlined:

- **Users** get access to a non-volatile and less inflationary means of payment which is a benefit for some countries.
- **Merchants** have to pay fewer fees, get their money quicker, and can offer customers a new payment method.

Further Research Areas

- Products that benefit from cryptocurrency payments (e.g. gaming transactions because of the low Transaction Cost of cryptocurrencies)
- In-depth research on wallets and how they can improve Usability.
- Specific research on the merchant side.
- Considering the sustainability of cryptocurrencies as a factor in payment adoption would be a novel approach.
- Factors for adoption might differ completely or have distinct importance levels across different countries or have distinct. Comparing the adoption of countries could lead to insightful results.

End

Source of Image: unsplash.com

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