Hedera Hashgraph – How a Disruptive Player Gains Traction in an Emerging Market Space, a Mixed Methods Study

Carlos Boden

Dissertation written under the supervision of Professor Peter Rajsingh PhD

Dissertation submitted in partial fulfilment of requirements for the MSc in Management: Strategy & Entrepreneurship, at the Universidade Católica Portuguesa, 03.04.2021

Abstract

Title: Hedera Hashgraph – How a Disruptive Player Gains Traction in an Emerging Market Space, a Mixed Methods Study

Carlos Boden

Hedera Hashgraph (HH) is a Distributed Ledger Technology offering an alternative to Blockchain. However, success of an innovation is determined by multivariant factors, not just technological superiority. This study relies on perspectives from management theory to discuss how an innovation potentially gains traction in a fast-moving, emerging market space. We conducted semi-structured expert interviews to determine competitive advantage (CA) of HH, scenario planning, and a user-survey to check if user perceptions were in line with results from the expert interviews. Various sources of CA were detected. We concluded that a strategic management perspective suggests that HH has the potential to displace the reigning incumbent. At the same time, uncertainty and the surprise are important variables also in the mix.

Keywords: Distributed Ledger Technology, Ethereum, Hedera Hashgraph, Blockchain, Directed Acyclic Graph, Market Potential, Competitive Advantage

Resumo

Título: Hedera Hashgraph - Como é que um agente disruptivo ganha tracção num espaço de mercado emergente, um Estudo de Métodos Mistos

Carlos Boden

Hedera Hashgraph (HH) é uma Tecnologia de Distributed Ledger (DLT) que oferece uma alternativa à Blockchain. No entanto, o sucesso de uma inovação é determinado por um leque variado de factores, para além da superioridade tecnológica. Este estudo conta com perspectivas de teoria administrativa para argumentar como uma inovação potencialmente ganha tracção num espaço de mercado emergente e dinâmico. Realizámos entrevistas semi-estruturadas a especialistas para determinar a vantagem competitiva (CA) do HH, planeamento de cenários, e um inquérito a utilizadores para verificar se as percepções dos utilizadores estavam em linha com os resultados das entrevistas aos especialistas. Várias fontes de CA foram detectadas. Concluímos que uma perspectiva de gestão estratégica sugere que o HH tem potencial para destronar o actual incumbente. Ao mesmo tempo, outras variáveis importantes estão também em jogo, como a incerteza e a surpresa.

Palavras-chave: Distributed Ledger Technology, Ethereum, Hedera Hashgraph, Blockchain, Gráfico Acíclico Direccionado, Potencial de Mercado, Vantagem Competitiva

Acknowledgements

I would like to express my deepest gratitude to Prof. Peter V. Rajsingh for the guidance, expert knowledge, and time invested in this dissertation. His continuous support and dedication were critical for the outcome.

I am thankful to all the experts who willingly gave up their valuable time to be interviewed. They provided their experience and knowledge, which added decisive insights to this thesis. Thank you, Alexandra Khasirdzheva, Bryan Zhen Zhang, David Hanson, David Tawil, Dominik Myczkowski, Evan McFarwell, Igor Mikhalalev, Jason Nagi, Kevin Spur, Leemon Baird, Lou Kerner, Mance Harmon, Nicola Attico, Paul Rapino, Paulo Cardoso do Amaral, Riyad Carey, Steven Alexander Kok, and Wes Geisenberger

I extend my gratitude to all people who have been influential in my journey, both as a student and a person. There's a piece of all of them in this project.

To Elizabeth Erchova and Till Lojewski for the collaborative inspiration during my first project that included Distributed Ledger Technology as part of a solution design which awoke deeper interest in this transformative digital phenomenon.

To Juliane Geus for the ongoing motivation, emotional support, and the possibility to challenge ideas, friendship, and love during the research process.

To my parents, Bernadette and Arno, for their caring, selflessness, sympathy, and love. I am eternally grateful for the way they raised me and serve as role models.

Thank you.

Carlos Boden

Table of Contents

List of Figures

List of Tables

List of Abbreviations

ABFT – Asynchronous Byzantinous Fault Tollerance

BFT – Byzantinous Fault Tollerance

BGP – Byzantine General's Problem

CA – Competitive Advantage

DAG – Directed Acyclic Graph

DC – Dynamic Capabilities

DeFi – Decentralized Finance

DDoS – Distributed denial of Service Attack

DI – Disruptive Innovation

DLT – Distributed Ledger Technology

EVM – Ethereum Virtual Machine

FMA – First Mover Advantage

HH – Hedera Hashgraph

IDT – Innovation Diffusion Theory

MBV – Market Based View

NFT – Non Fungible Token

PoS – Prove of Stake

PoW – Prove of Work

SMA – Second Mover Advantage

TAM – Technology Aceptance Model

TPS – Transactions per Second

WTP – Willingness to Pay

1. Introduction

Distributed Ledger Technology (DLT) has been gaining attention and importance since described by Satoshi Nakamoto (2008) and implemented as Bitcoin in 2009. Based on peer-to-peer networks and a hashing consensus algorithm, crypto assets and tokens have gained prominence (Nathan et al., 2021). DLTs provide transparency and accountability, independent of any central point of failure or system owner. Use cases in financial services, supply chains, platform technologies, intellectual property, etc., can be implemented (Treiblmaier and Clohessy, 2020) which also position DLT as the infrastructure layer of Web 3.0 (Allaire et al., 2021). Thus, DLT needs to be seen as a technology innovation and not just an asset class.

As the dominant DLT architecture, Blockchain's market size was USD 1.57 Billion in 2018, expected to grow up to USD 162.84 Billion by 2027 (Statista, 2020). Overall, there is increasing trust and market traction for DLTs.

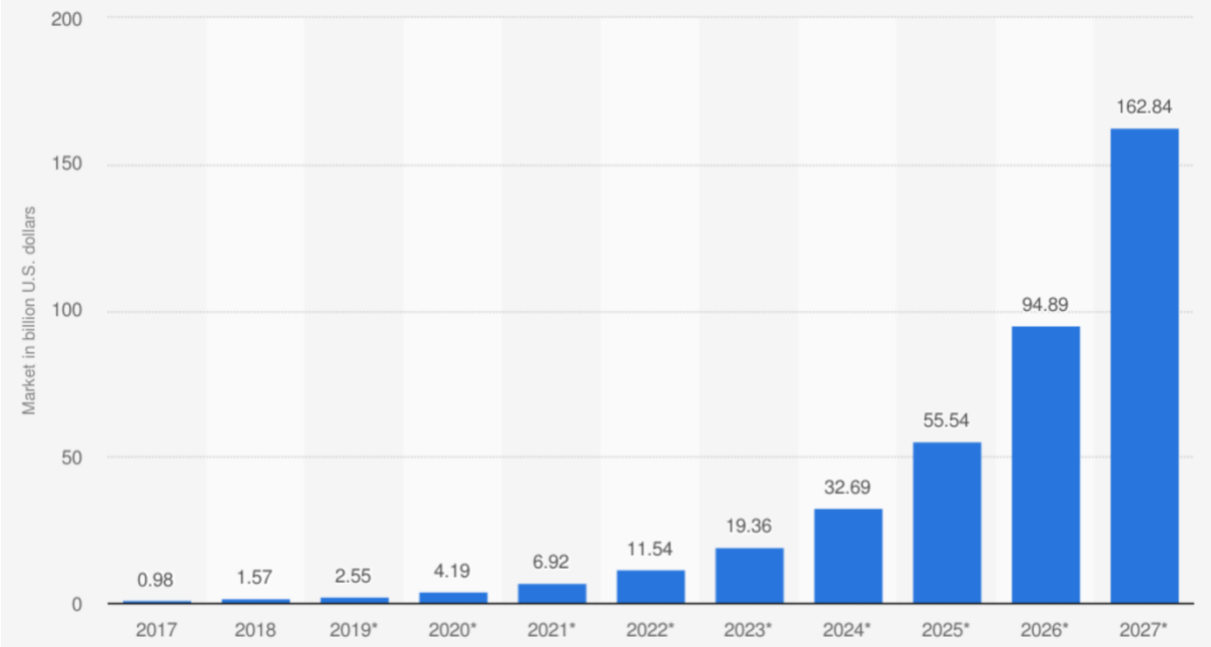

Figure 1: Size of the Blockchain technology market size worldwide from 2017 to 2027 (Statista, 2020)

But the history of disruptive technologies shows that first movers are not necessarily winners in an industry over the longer term (Christensen, 1997). This point is evident considering companies which used to dominate the internet at its inception. AOL, Yahoo, Myspace, Netscape, etc., lost their preeminent positions as second (or third) generation companies displaced them. This is consonant with theories such as Schumpeter's notion of creative destruction (Schumpeter, 2014 [1942]), Christenson's conception of how disruptors beat

incumbents (Christensen, 1997), and the fact that Amazon, Facebook and Google are today's behemoths of the Internet. Similarly, first generation Blockchain comes with significant disadvantages that limit its ability to scale suggesting that new winners could also prevail in the DLT sector. The following are limiting factors which serve as impediments for first generation Blockchain DLT (Buterin, 2013):

- High need for computational power that is leading to high energy consumption
- High transaction time and cost
- Limited throughput (3 transactions per second (TPS))

These factors limit the growth-potential and traction of first mover DLTs. Moreover, these DLTs are vulnerable to 51% attacks (Zhang and Lee, 2020) which also compromises security, one of the three pillars of the so-called Blockchain trilemma – decentralized, scalable, and secure – whereby enhancing one factor comes at the expense of others.

These limitations open space for other ledger designs and players. One of these, with increasing use cases associated with it, is Hedera Hashgraph (HH). Its architecture as a Directed Acyclic Graph (DAG) and gossip-about-gossip consensus algorithm mitigates issues associated with Blockchain, addressing problems mentioned above and facilitating new market opportunities. HH's technological efficiencies are enablers that could eventually bring DAGs to the mass market. However, superior products do not always prevail, despite technological advantages, as seen with various prior business examples such as Sony Betamax and VHS, or the Apple operating system versus Microsoft (Cusumano et al., 1992).

This dissertation explores HH's potential in the DLT space. Is it a disruptor with the capacity to become a dominant player? Which factors promote this new technology gaining traction; and how will the digital ledger landscape develop? Management theory allows us to assess the potential ascent of HH, its relationship to incumbents and its potential to be successful, from different angles.

The rest of this work is organized as follows: Section 2 describes the DLT space and potentially applicable management theory to serve as a foundation. Section 3 illustrates the methodology applied. Section 4 presents the results, which are discussed in section 5. This section also points out limitations and areas for further research. Section 6 concludes the research.

2. Literature Review

In this chapter we review the current state of the DLT landscape from its emergence in 2008 and discuss relevant managerial theory.

2.1. Failure of Hierarchies and Emergence of Decentralized networks

The Global Financial Crisis of 2008 caused significant levels of distrust in the social, political, and economic systems (Roth, 2009). Public confidence, especially towards financial institutions, decreased (Figure 2).

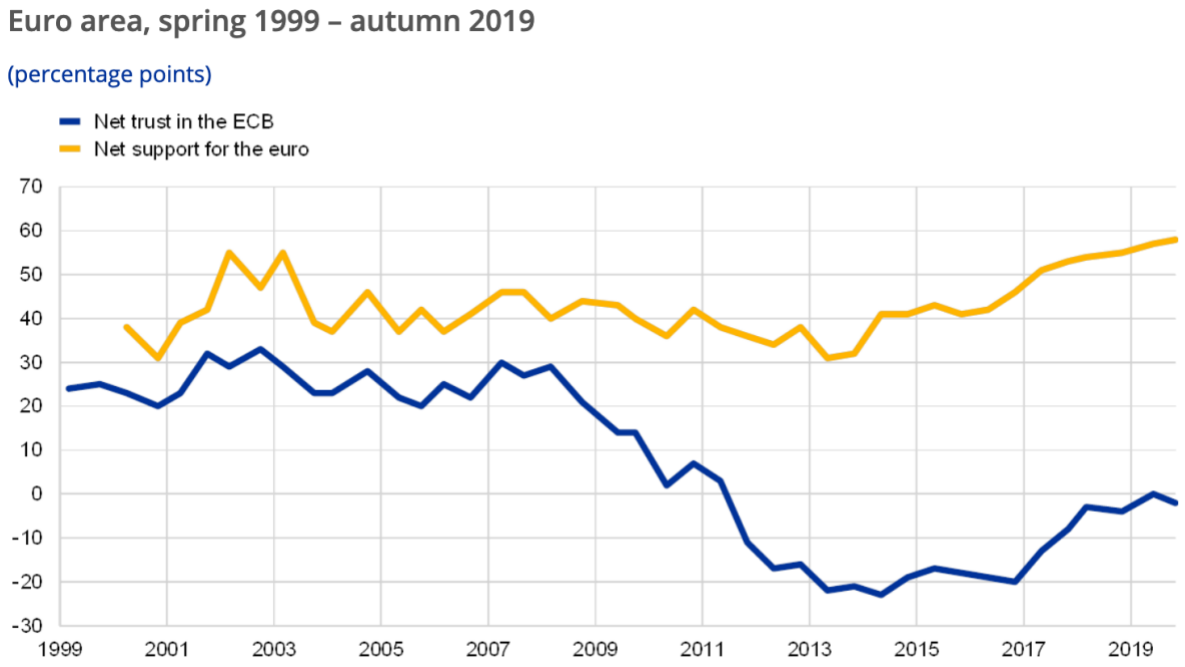

Figure 2: Trust in the ECB (European Central Bank, 2020)

Shortly after the collapse of Lehmann Brothers in mid-September 2008, Bitcoin was first proposed with the publication of a Whitepaper by its anonymous creator, Satoshi Nakamoto (2008). The promise of DLT – cutting out the middle man, democratizing access with lower transaction fees by peer to peer transactions independent of institutions – matched frustration with the financial system and lack of trust in central coordination (Allaire et al., 2021).

2.2. The Problem of Trust

From its early days, computer science has grappled with the problems of trustworthy security and how to enable reliable systems. In this context, trust refers to a system's ability to deliver stable results even if parts of the system fail or are malicious. This implies that to be trusted, systems need to be "fault tolerant" in adversarial environments (Rauchs et al., 2018).

In their seminal work, Lamport, Shostak and Pease (1982), analogize this issue to the Byzantine Generals' Problem (BGP): Generals of a Byzantine army need to develop a common strategy of either attacking or retreating in concert. They communicate across long distances and there is a chance that some of the messengers or generals are traitors, transmitting faulty messages which loyal generals have no means of distinguishing. The mathematical proof asserts that unless at least two-thirds of generals are loyal, establishing trust is impossible and no trustworthy and meaningful consensus can be reached (Lamport et al., 1982). However, so long as messages cannot be forged, the system can tolerate some fraction of bad actors (Lamport el al., 1982). This illustrates that "[r]eliable computer systems must handle malfunctioning components that give conflicting information to different parts of the system" (Lamport el al., 1982).

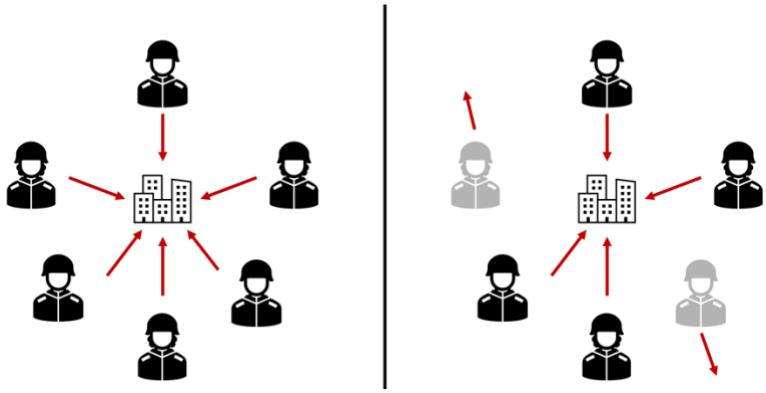

Figure 3: Byzantine Generals' Problem, Failure of Consensus

Byzantine-Fault-Tolerance (BFT) thus refers to a system's resistance to failure pertaining to the BGP. BFT occurs when at least two-thirds of nodes are reliable in settings where messages are falsifiable by number of unreliable nodes but cannot be forged, a matter achieved, for example, via digital signature procedures. Therefore, systems built on algorithms resistant to failures are BFT (Castro and Liscov, 2002).

BFT assumes that nodes can communicate with each other, and messages can be sent between them within a finite timeframe. If a system can reach consensus, even in the absence or the indefinite delay[1] of messages between nodes, it exhibits Asynchronous Byzantine Fault Tolerantce (ABFT). ABFT hinges on the assumption that at any point in time, a message from at least one reliable node can be delivered to the others (Baird et al., 2020). Therefore, ABFT is the *highest security standard* a system can obtain, even if communication lines between nodes

[1] For instance, this might occur due to Distributed Denial of Service (DDoS)-attacks which prevents nodes from performing tasks accurately.

are controlled by attackers, such as when there are firewalls or DDoS Attacks. In the context of decentralized networks, separated nodes need to reach consensus about the veracity of submitted transactions, their timing, and order (Baird et al., 2020).

2.3. Distributed Ledger Technology

BFT algorithms are used to avoid systematic failures in safety relevant systems like Airplane Information Management Systems, enabling them to achieve resilience (Driscoll and Hoyme, 1993). Fault-tolerant reliability is critical in settings where physical integrity needs to be guaranteed, such as to keep a plane flying safely, even if some aspects of the system fail. Since the Bitcoin Whitepaper (Nakamoto, 2008), systems solving the BGP have become increasingly important for establishing decentralized consensus without a single point of truth. And Blockchain is the first multiparty consensus system solving the BGP and is the most prominent example of DLT (Buterin, 2013).

Since the DLT field is young and rapidly evolving, a plethora of sometimes inconsistent terminology has developed. Rauchs et al. (2018) are among the first to provide a holistic definition of DLTs. Their work synthesizes all significant previous definitions and will therefore serve as a standard moving forward.

As a subset of distributed systems, DLTs are multiparty systems storing data and enabling participants to prove the validity of shared data. They have independent nodes exhibiting the same behavior as in the BGP, which is to say there may be some malicious actors. However, they generate trust without central coordination, ownership, or data storage. In this sense, they can be seen as "consensus-machines" (Rauchs et al., 2018) where the ability to maintain data integrity in an adversarial environment distinguishes them from traditional distributed databases. Thus, the performance of the system itself is guaranteed within BFT, whereas the reliability of users is not. Consequently, trust is delegated to the systems' end-users. For example, a customer purchasing a good in a marketplace still needs to trust the vendor sending the good, even if the payment system itself is trustless[2] (Rauchs et al., 2018).

Furthermore, permissioned and permissionless DLTs must be distinguished. In permissionless DLTs, anyone can participate as a node in consensus finding whereas in permissioned DLTs only approved agents act as nodes (Rauchs et al., 2018).

[2] Participants involved do not need to trust each other or a third party as the system is immutable and transparent.

In sum, DLTs typically have four major properties (Rauchs et al., 2018):

- Transparency is established based on a shared record, which can only be collectively edited;
- Trust in the record is created by a consensus mechanism;
- The ledger on which every party can validate transactions and the state of the system serves as a single source of truth;
- Records are immutable, since DLT systems are tamper-resistant and transparent.

Another property often mentioned is anonymity. From these properties, Rauchs et al. (2018) synthesize the following definition:

> "A DLT system is a system of electronic records that enables a network of independent participants to establish a consensus around the authoritative ordering of cryptographically-validated ('signed') transactions. These records are made persistent by replicating the data across multiple nodes, and tamper-evident by linking them by cryptographic hashes. The shared result of the reconciliation/consensus process - the 'ledger' - serves as the authoritative version for these records."

While characteristics of a particular Distributed Ledger may vary depending on the specific technology facilitating transactions, fundamentally all DLTs share the same technological key-components, which they blend in different ways (El Ioini and Pahl, 2018). Thus, DLTs typically have a consensus mechanism, key cryptography, and distributed peer to peer networks.

2.3.1. Bitcoin

Bitcoin established a permissionless ledger achieving BFT and conceptualized as a "purely peer-to-peer version of electronic cash" (Nakamoto, 2008). As such, the protocol focuses on solving the so-called double spend problem[3]. This is achieved with a Blockchain hashing consensus algorithm that establishes cryptographic and consensus-based proof of transactions through a time stamp. Being a pure crypto currency, this consensus algorithm cannot be used as a base layer for other tokens or applications.

[3]As digital files *per se* can be duplicated, malicious actors may manipulate a system to spend digital coins twice. DLT systems need to be resistant to this issue. In the case of Blockchain-based DLT, double spending would lead to a fork where the longer chain is accepted and the shorter one rejected.

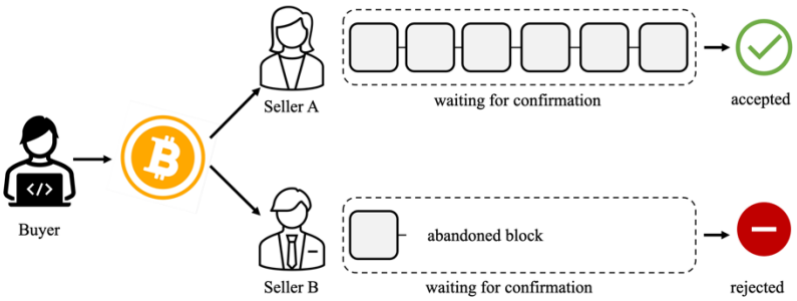

Figure 4: Double Spending Problem Bitcoin in the Case of a Purchase with Bitcoin

So, the basic idea of Blockchain is ordering all transactions in blocks or so-called hashes in a chain. Every hash contains the transaction and a reference to the previous hashes. This impedes tampering, since changes of a hash invalidate all following hashes (Nakamoto, 2008).

The process of the Bitcoin ledger works as follows: If a participant wants to transfer a Bitcoin or fraction thereof, a new transaction is triggered by digitally signing the previous transfer's transaction and adding the recipient's public key illustrated in Figure 5 (Nakamoto, 2008).

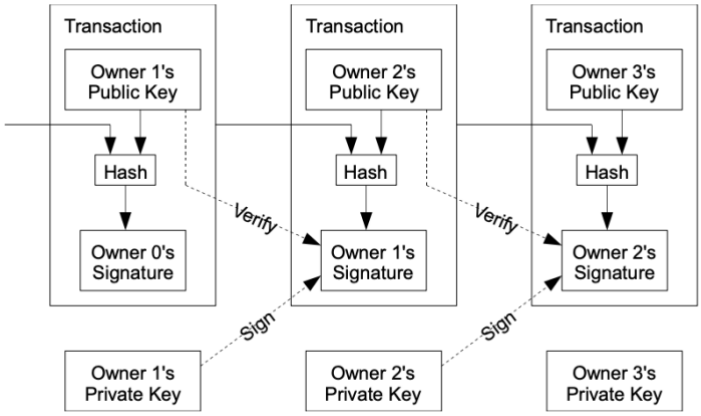

Figure 5: Transaction Blockchain (Nakamoto, 2008)

The transaction is sent to a distributed timestamp server run by the network of nodes, which verifies it by creating the next block including the information that was sent. The first block to be finished (timestamped) broadcasts it to the network. This distributed timestamp uses a Proof-of-Work (PoW) consensus algorithm whereby participating nodes (miners) work on a complex algebraic puzzle that can only be solved by trial and error. The miner who finds the solution gains the right to timestamp a transaction, and the block is added to the chain, as seen in Figure 6. It cannot be changed without redoing the work. In this sense, the process is a voting mechanism in which 1 CPU equals 1 vote. It solves the BGP as all participating nodes reach consensus via a majority decision so double spending is avoided. As soon as the block is broadcast, the other nodes validate it by working on top of that block only if it is the longest

chain and thus corresponds to the first transaction made. So long as honest nodes control most of the CPU capacity, it is possible to verify transactions by building on the longest chain. In theory this means malicious attacks can only occur if attackers control >50% of the computational power (Nakamoto, 2008).

Figure 6: Adding a Block to the Blockchain (Buterin, 2013)

Nodes are incentivized to contribute CPU power for PoW to the network by being rewarded in the form of new tokens (Nakamoto, 2008).

This design comes with downsides. The technology, and in particular the PoW protocol, require high storage capabilities and consumes substantial levels of computational power leading to scalability issues (Buterin, 2013; Zhang and Lee, 2020). High computational power limits throughput to 3-7 transactions per second and storage needs likely lead to centralization which may pose security issues (Buterin, 2013). Apart from these practical issues, scholars have identified other weaknesses: First, Bitcoin is not Turing-complete[4]. This means that it is a closed system that does not allow developers to build on it, limiting the tech to only one use-case (Buterin, 2013). Second, it does not have the full functionality of a decentralized database since the system has no access to Blockchain data (Buterin, 2013; Zhang and Lee, 2020). This leads to a "lack of state" where a system is stateful if designed to remember preceding events or user interactions. For Bitcoin, coins are either spent or not. Thus, Bitcoin is value blind – in its use-case as electronic cash, other kinds of transactions are not possible without hacks (Buterin, 2013). There is also no way to determine which transaction came first as only the first block finished by a node will be accepted, which leads to a lack of consensus finality (Buterin, 2013).

[4] Universal programmability, which allows multiple use-cases being built on a system.

Finally, orphan blocks[5] remain as forks in the chain, which compromises the consensus process (Buterin, 2013).

As the Bitcoin protocol *per se* is not static, changes and improvements are possible. Developers fix bugs and deliver updates but the decision process of implementing changes is neither built into the protocol nor clearly defined off-chain (Nabilou, 2021; Rauchs et al., 2018). Hence, governance is anarchic and relies on power dynamics of stakeholders in the Bitcoin network (Nabilou, 2021). In practice this results in centralization of influence regarding governance (Rauchs et al., 2018). Moreover, decision making is not transparent, hard to predict, and reaching consensus over changes is difficult. The practical controversies surrounding this are comprehensively documented by Bier (2021).

2.3.2. Ethereum and Ethereum 2.0

Ethereum was presented by Vitalik Buterin in 2013 and published in 2015 as the next iteration of Blockchain technology. Based on an adjusted system architecture and, most importantly, an integrative Turing-complete programming language, Ethereum overcomes many of Bitcoin's constraints. This enables developers to build their own coins, tokens, applications and contracts using Ethereum DLT as a base layer. Ethereum facilitates smart contracts and decentralized applications, which allow use-cases such as decentralized autonomous organizations. (Buterin, 2013).

But as Ethereum is still based on a Blockchain using a PoW consensus algorithm, the problems remain: Consensus is probabilistic[6], which means it cannot be proven mathematically and even if the technology is more efficient, it still has scalability and security issues (Buterin, 2013). This makes it a proof-of-concept for complex use-cases but not suitable for mass market implementation.

To improve the ledger, the Ethereum Foundation is currently working on several updates to shift to Proof-of-Stake (PoS). Just like PoW, PoS algorithms require the node to solve mathematical problems to create new blocks. In the case of PoS, the key to solving the puzzle is the stake of coins owned by the node. In this system, one coin multiplied by one time-period of ownership equals one vote. This protocol uses a fraction of the computational power needed for PoW as CPUs are not needed to power consensus. Moreover, anyone owning coins is able

[5] A block that was finished second and when nodes did not add more blocks on is called an orphan block. They are valid blocks that do not become part of the main chain and thus are not accepted transactions.
[6] The probability of a transaction being legitimate increases with the length of the chain built on top of it but is never 100%.

to participate as a node which prevents centralization and increases security (Zhang and Lee, 2020).

As announced on Ethereum's website, the first step – the Beacon Chain, a PoS based Blockchain network – has already gone live. This PoS-based Blockchain will be merged with the existing network, shifting Ethereum to PoS in 2022 under the name Ethereum 2.0 (Ethereum Foundation, 2020). Ethereum 2.0 solves significant problems, but issues associated with the Blockchain data structure remain.

Ethereum's governance model is more hierarchical than Bitcoin, enabling suchn an expansive overhaul, even though Ethereum lacks formalized standards (Rauchs et al., 2018). The decision-making process is dominated by Vitalik Buterin and the Ethereum Foundation (Rauchs et al., 2018). The development roadmap is largely determined by the Ethereum Foundation, a self-elected governance body. This makes decision-making more predictable and effective, but not more transparent.

2.3.3. Hedera Hashgraph

HH is a newer iteration of DLT. First presented in 2016 by Leemon Baird, it was released in 2017 as Swirlds Hashgraph, a private ledger and, since 2018, has been running the public Hedera Hashgraph Ledger. HH is significantly different from DLTs presented previously. It is a DAG data structure (Figure 7), rather than a Blockchain, and entails a "gossip-about-gossip protocol" and a virtual voting algorithm enabling quick consensus (Baird, 2016a).

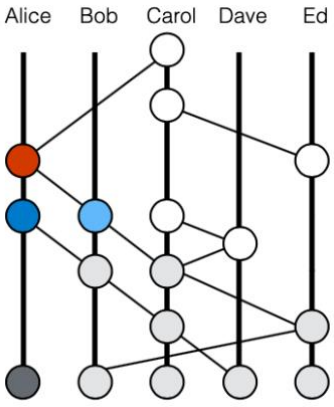

Figure 7: Hashgraph DAG Data Structure (Baird, 2016a)

HH's consensus protocol can abstractly be displayed as hashes aligned in rows, each representing a node (Figure 7). The vertices delineate communication between users that takes the form of creating and submitting a new event to other nodes (Baird, 2016a):

1. A new transaction is communicated to the network by randomly sending it to another node (Figure 7 red);
2. When they receive new information, nodes g*ossip* about an event, randomly choosing others to whom they communicate their state of the ledger (Figure 7 Bob to Alice, grey to blue).

An Event consists of 4 information parts: The hash created by the node for sending the event (Figure 7red); the previous event created by the node (Figure 7 dark blue); the event created by the node sending the event that caused the gossip (Figure 7 light blue); and a timestamp indicating when the event was created (Baird, 2016a).

Randomly spreading information about transactions and gossip (gossip-about-gossip) allows for "exponential diffusion of information" (El Ioini and Pahl, 2018). Moreover, every user not only knows what other users are doing but also what they know. This enables running a consensus algorithm based on virtual voting without collecting other users' votes, as these can simply be calculated with the information about their state of knowledge and their stake representing the weight of the vote (Baird, 2016a).

This technical approach brings substantial improvements to the DLT landscape (Baird, 2016b; El Ioini and Pahl, 2018). First, it creates fairness in the sense of timing as the consensus time, the median of the timestamp in the event, and the time all nodes received it are added to each transaction. Transactions can be ordered by these timestamps and no individual can make changes to them. Second, the technology is DDoS resistant. Since consensus is calculated virtually, it can be created even if some nodes are disconnected from the network. Moreover, the technology is 100% efficient as no orphan blocks are mined. Further, the gossip-about-gossip protocol enables substantial increases in the transaction rate, as throughput per second is only limited by bandwidth. In terms of fault tolerance regarding security, Hashgraph achieves the highest level of ABFT. The technology is further able to establish a clear, mathematically verifiable consensus which includes an exact time when consensus is reached.

However, for many there is one major disadvantage associated with HH – its level of decentralization. For now, the ledger is not run in a permissionless system (Baird et al., 2020), meaning not everyone can participate in the network by hosting a node. Governance is formalized and thus not anarchic with the network of nodes currently being run determined by the a Governing Council consisting of well-known tier one corporations and institutions (Baird et al., 2020). Not being fully decentralized in the sense of a permissionless ledger, and having

a closed governing body, poses potential trust issues for the traditionally libertarian DLT community given being suspicious of private institutions.

Yet, in theory the network could run permission-less (Baird, 2016b) and according to its roadmap and Whitepaper, Hedera is planning to progressively decentralize the network, moving towards a permissionless network (Hedera Hashgraph, LLC, 2020, 2022a). A major step towards decentralization was taken in January 2022 with open sourcing of HH's source code (Baird and Harmon, 2022; Pirkpatrick, 2022). Moreover, community nodes[7] are planned to be introduced - first permissioned in the second half of 2022 (Hedera Hashgraph, LLC, 2022a), and later permissionless (Hedera Hashgraph, LLC, 2020).

From a governance perspective, there is a pre-defined decision-making process. The up to 39 council members, democratically make decisions relating to the platform (Baird et al., 2020). Council members have term limits, are spread across industries and geographies, and consist of highly reputable firms (Baird et al., 2020) which also obviates concentrations of power.

2.4. Comparison of considered DLTs

Technologically speaking, DAG-based DLTs are superior to Blockchain DLTs with higher performance pertaining to better average block time, no confirmation delays, *de minimis* failure probability, and higher TPS (Cao et al., 2020). The following table summarizes DLTs based on a structured review of White Papers and websites, specialized blogs and forums, as well as academic sources.

[7] Nodes not hosted by Governing Council members

Table 1: Properties of common DLT protocols

	Bitcoin	Ethereum	Eth2.0	Hashgraph
Data structure	Blockchain	Blockchain	Blockchain	DAG
Consensus algorithm	PoW	PoW	PoS	Virtual voting (weighted votes by stake)
Consensus	Probabilistic	Probabilistic	Absolute (at check-points)	Absolute (time stamped)
Turing complete	No	Yes	Yes	Yes
Coding languages supported	-	Solidity	eWASM	Java, Java Script; Go, Shell
Maximum TPS	7	12	100.000 (with sharding)*	10.000 (without sharding)
Average energy consumption per transaction in 2022 (kWh)	2258,49	238,22	0,004*	0,0002
Average latency (min)	10	3	average 14 (w/ finality)	<0:03 (w/ finality)
Security	34% BFT attack and 51% attack possible	34% BFT attack and 51% attack possible	34% BFT attack and 51% attack prevented by burning stake	34% BFT attack possible but malicious node known
Fault tolerance	BFT	BFT	BFT	ABFT
Maximum transaction fee in 2021 ($)	62,79	71,72	Unknown	0,0001 (set)
Ledger typology	Permissionless (by miners)	Permissionless (by miners)	Permissionless (by users with >32ETH)	Permissioned (by governing council)
Degree of decentralization	Natural centralization (energy and mining equipment cost)	Natural centralization (energy and mining equipment cost)	Natural centralization (stake rewards)	Limited but decentralized
Governance	Anarchic	Hierarchic (anarchy guided by the foundation)	Hierarchic (anarchy guided by the foundation)	Democratic (by council)
Copyright	Open source	Open source	Open source	Open source
Maturity	Implemented	Implemented	Partly implemented	Implemented
Mass market feasability	No	No	Potentially	Yes

*estimate

2.5. Native Tokens

DLT systems have so-called native tokens, the primary digital assets which are endogenous to the system. They are the center of a system's economic design, typically used to align incentives, pay transaction fees, and motivate contribution to the network via mining (Rauchs et al., 2018). Using and participating in a DLT system requires owning the respective native tokens. Tokens, thus, are the driver of the DLT economy like oil is for the industrial economy. The value of tokens can theoretically be used to infer the relevance of a protocol's ecosystem and *vice versa*. In fact, tokens are subject to considerable noise and price volatility from speculation, as illustrated by the market cap of meme-coins[8] like DOGE.

[8] Retail investors' term for a token not backed by any project but based on hype.

Although we identified constant iterative improvements of DLTs by new players entering the field, prices do not necessarily reflect technical advantages. Regardless of technical limitations, Bitcoin is still the leader in the DLT space measured by its market cap whereas HBAR, Hedera Hashgraph's native token, has a market cap that is relatively insignificant as shown in Figure 8: Market Capitalization Native Token since 2013 (coinmarketcap.com)

Figure 8: Market Capitalization Native Token since 2013 (coinmarketcap.com)

2.6. Who will prevail?

There are many examples of technologically superior products. The extent to which firms monetizing these technologies have profited, however, varies greatly. The presumed technological superiority of HH does not guarantee its widespread dissemination, adoption, or whether it will eventually prevail in the DLT ecosystem, as the example of VHS illustrates in another technology domain (Cusumano et al., 1992). And while Ethereum has the advantage of being the "first mover", the example of Facebook replacing Myspace (Feng et al., 2020) prominently illustrates that success and competitive advantage depend on various endogenous and exogenous factors. As these examples show, development of the DLT landscape is not dependent on only one criterion – superior technology – but on multivariate factors.

Successful technology adoption is contingent upon practical superiority, along with how the technology is managed and marketed. Moreover external factors such as features of the market, user perceptions, or larger socio-economic trends are highly relevant (Christensen, 2001).

There are multiple strategies that enable firms to succeed, but these always need to be adjusted in light of particular conditions of the time (Christensen, 2001). To predict how the DLT landscape will evolve, this section elaborates on different scholars' perspectives on adoption of new technologies and summarizes key takeaways from the literature. Theories regarding

competitive advantage (CA), disruptive innovation, innovation diffusion and models dealing with user acceptance are reviewed.

Taking the firm and management-focused perspective, the most common arguments for how to prevail in an industry are illustrated in the theory of CA, first proposed by Michael Porter (Porter, 1998; Furrer et al., 2008). According to Porter's market based view (MBV), an organization with particular firm-level attributes can acquire and sustain CA against competitors by positioning itself within an industry as a cost leader or a value proposition differentiator (Porter, 1998). The concept of CA has been picked up by many scholars who built upon this theory.

The MBV regarding CA evolved into the Resource Based View (RBV) advanced by Barney (1991) which proposed that competitive advantage traces to a firm's distinct and idiosyncratic resources. RBV assumes resources are heterogeneous and immobile and if they have the right attributes, namely being "valuable, […] rare[, in]imitable, and [non-]substitut[able]" (Barney, 1991), they allow firms to acquire and sustain competitive advantage.

While RBV is static, a more recent view of CA focuses on firms in changing environments. Dynamic capabilities (DC) was first described by Teece et al. (1997) and recently summarized by Barreto (2010). According to the latter, a DC is "a firm's potential to systematically solve problems, formed by its propensity to sense opportunities and threats, to make timely and market-oriented decisions, and to change its resource base." These capabilities, adapted in the face of dynamic changes, promote a firm's competitive adventage (Teece et al., 1997).

The aforementioned theories dealing with CA on a general level are either market or firm-based views, while this research is mainly concirned with an innovation phenomenon. Moving further, theories dealing with CA arrising from innovation will be considered.

Indeed, innovation can be a source of competitive advantage (Porter, 1985) and Christensen (1997) claims that innovation has the potential to change industries and cause market leaders to fail. So-called disruptive innovation (DI) initially gains traction only with niche early adopters rather than immediately becoming part of the mainstream market. But as DI performs better, adoption expands and opens a new market, because the disruption creates a new and novel paradigm. Over time, DI appeals to the mainstream customer base and DI causes incumbents to lose market share to disruptors. Building on Christensen, Schmidt and Druehl (2008) introduced a framework to assess the potential impact of an innovation. They based their

work on assessing the market, product attributes, and potential segments buying the product. These potential segments are mapped to four types of innovation ("sustaining innovation[,] disruptive innovation[,] new market disruption[,] low-end disruption" (Schmidt and Druehl, 2008)), to explain how innovation takes hold and gains market traction.

Taking a marketing strategic perspective, the timing of market entry of an innovation is a significant source of competitive advantage and the success of a company (Gal-Or, 1985; Hoppe and Lehmann-Grube, 2001; Kerin et al., 1992; Tran et al., 2012). Depending on certain specifics, in some cases a first mover advantage (FMA) is the key determinant while in other instances a second mover advantage (SMA) is more significant. For IT-enabled platforms, Feng et al. (2020) investigated conditions under which FMA or SMA occur. They identified the length of the market growth phase and demand window as well as the improvement rate of the two players as determinants of FMA or SMA.

For any innovation to gain traction, the underlying technology needs to be acepted by users. To assess this, the technology aceptance model (TAM) (Davis, 1989) has become a key conceptual tool (Marangunić and Granić, 2015; Taherdoost, 2018). In this model Davis specified the causal relationships as seen in Figure 9 that lead to the use or rejection of a specific technology. According to him perceived usefulness and ease of use contour potential users' attitudes towards use of a product which leads to actual use.

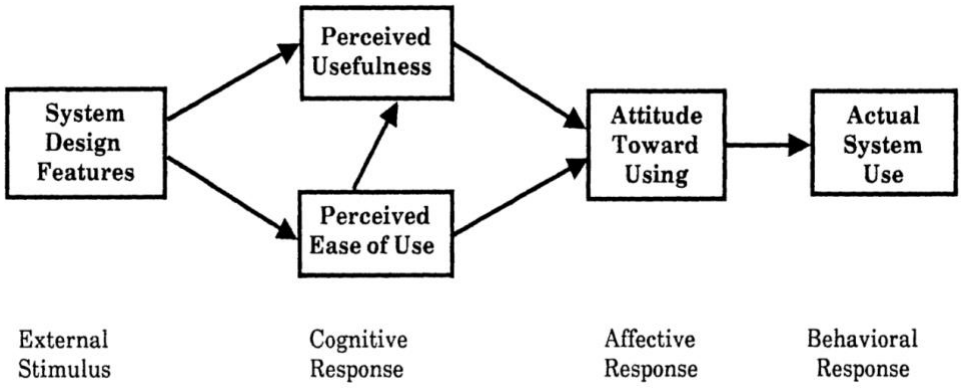

Figure 9: TAM (Davis, 1989)

Another commonly used theory predicting adoption of technical innovation is Rogers (1983 [1962]) Innovation Diffusion Theory (IDT). According to Rogers, improvements in quality as adoption of a product or service develops over time, can be described by an s-curve, with inflection points that trigger exponential growth.

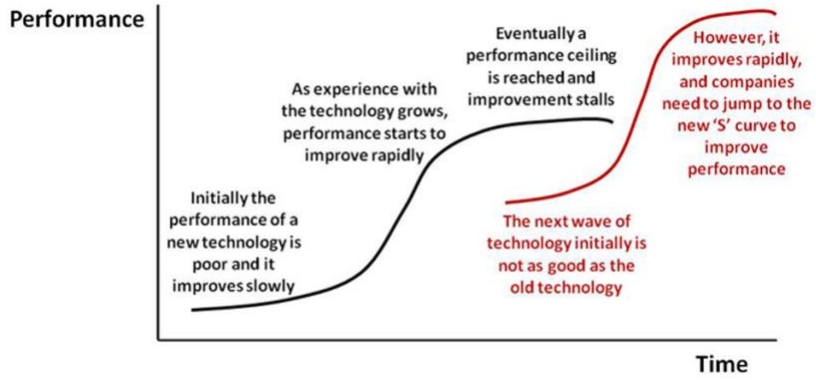

Figure 10: Innovation Diffusion (Rogers, 1983[1962])

This theory argues that potential users' beliefs about an innovation lead to adoption or rejection. Moreover, IDT identifies five characteristics of an innovation: compatibility, relative advantage, complexity, trialability, and observability. But according to Tornatzky and Klein (1982) only compatibility, relative advantage and complexity are drivers of adoption. Based on this, Lou and Li (2017) propose the following integration of TAM and IDT specifically to assess adoption of Blockchain technology, which we treat as a synonym for DLT. The model includes the major determinants shown in Figure 11.

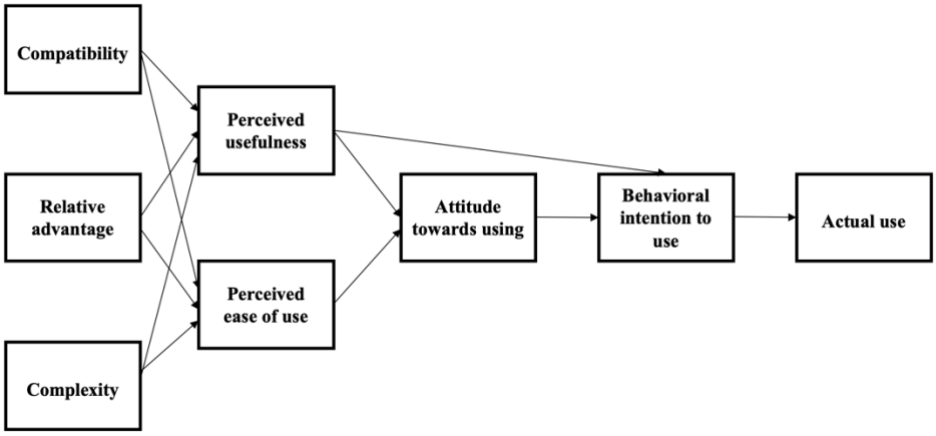

Figure 11: Integrated Acceptance Model (Lou and Li, 2017)

2.7. Contribution

The overall DLT market is growing significantly with constant improvements and iterations of the DLT concept by new market entrants – first Ethereum and now Hedera. While Bitcoin can be seen as a proof-of-concept for DLTs, the technological characteristics of HH allow for mass adoption and multiple new use cases. However, this technical superiority and potential, for now, are not reflected in the market cap of the native token.

Management theory provides tools that allow us to discuss the ascent of new market entrants from different angles and their relationship to incumbents. Despite the potential of the technology, illustrated in Table 1 and interest and investment in this fast-moving new market, no study fully assessing a new entrant's (HH) potential has been performed. This work aims to close this gap.

3. Methodology

Exploring developments in the DLT market entails considering a complex system where multivariate factors play a role. To cover the most important perspectives on the research question and draw more robust conclusions we took a three-step approach in a mixed method study, combining qualitative and quantitative approaches (Johnson and Onwuegbuzie, 2004). To assess if **Hedera Hashgraph is a disruptor with the capacity to become a dominant player**, potential user acceptance, CA, and external factors were evaluated. These three factors animate the discussion in the next two chapters.

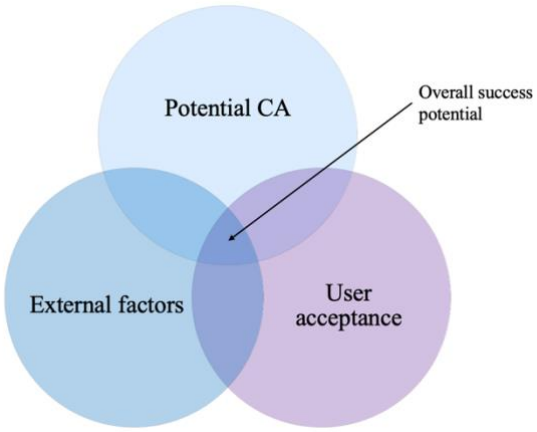

Figure 12: Perspectives of applied approach

For each of the three areas of research, the results are analyzed, interpreted and in a later step, merged by means of triangulation. (Denzin, 2009, pp. 297–313; Denzin and Lincoln, 2018, pp. 761–791). An overview of the applied frameworks, methods and data sources is depicted in Figure 13, summarizing the research approach.

The competitive landscape within the DLT market is very dynamic with players entering and subsequently leaving the market both quickly and frequently. Thus, comparing HH to an established incumbent is appropriate. Because Bitcoin is limited to being a digital currency, the frameworks and methods focus on comparing HH to Ethereum.

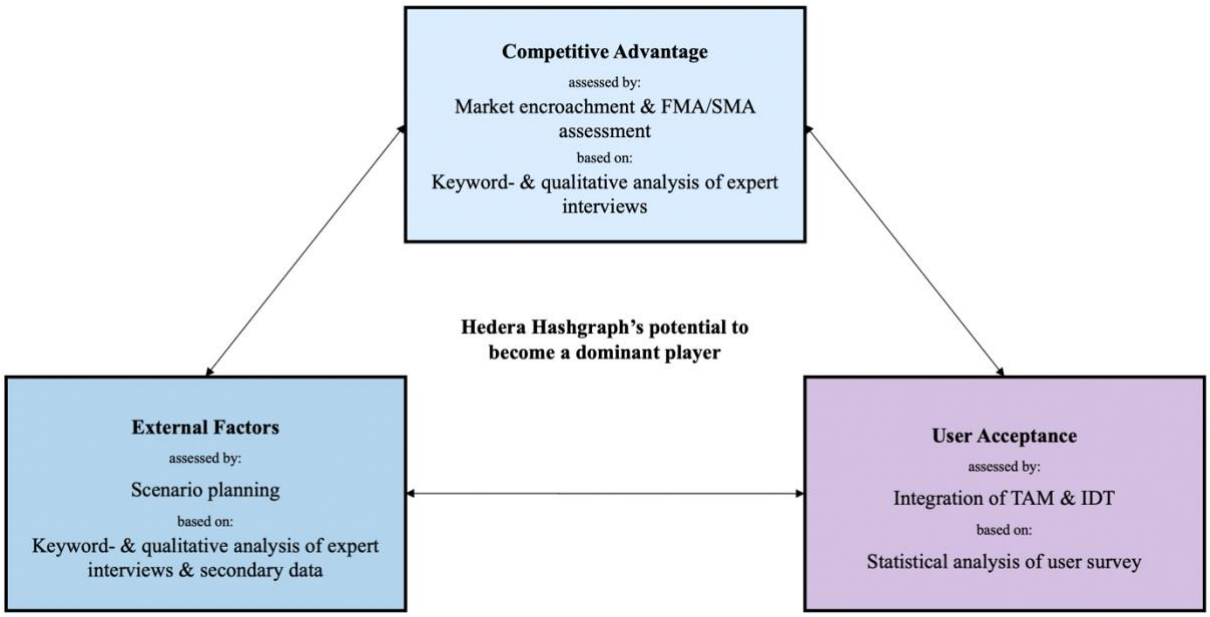

Figure 13: Scope, Framework and Approach and Data Source of Methods for Triangulation

We are fully aware that uncertainty is a major factor limiting predictability. The research approach was designed to address this issue in the most meaningful way possible. Approaches and measures used were specifically selected to work under uncertainty. Quantitative results were avoided since numbers, at best, approximate reality in the face of uncertainty. We strived to present a coherent qualitative description of the future by surveying the space from multiple points of view. Nevertheless, predictions that follow can only be considered approximations based upon efforts to determine the most plausible future developments.

3.1. Data Collection

Because of the complexity and novelty of the topic, qualitative data gathered in semi-structured expert interviews were the main data source. To achieve a wide range of perspectives and survey the full scope of the topic, experts from a variety of backgrounds ranging from management, law, and policy making, to computer science were interviewed. Interviews were structured in two phases. First, representatives of academia, public and private institutions, investors, CEOs of DLT-related companies, and Hedera users were interviewed. Second, C-level executives of Hedera and the HBAR Foundation, and a Hedera Governing Council member were interviewed to understand Hedera from the inside and confront management with insights gained from earlier interviews. A total of **18 experts** from different backgrounds and roles constituted the interview cohort.

Table 2: List of Experts including Roles and Fields

Interviewee	Position	Field
Bryan Zhen Zhang	Co-Founder and Executive Director, Cambridge Center for Alternative Finance, Judge Business School	Academia
Paulo Cardoso do Amaral	Professor, Católica SBE: DeFi, Blockchain, Entrepreneurship	Academia
David Hanson	Founder & CEO, Ultra.io	Entrepreneur (Protocol)
Dominik Myczkowski	Co-Founder and CEO Tokapi, Co-Founder Crypto Skills Academy, Ethereum Node Hosting	Entrepreneur (NFT)
Paul Rapino	Head of Growth, Global Blockchain Business Council	Industry association
Riyad Carey	Policy Analyst, Global Blockchin Business Council	Industry association
Lou Kerner	Partner, Blockchain Coinvestors	Investment
David T. Tawil	Co-Founder and President, Prochain Capital	Investment
Jason Nagi	Head of FinTech Practice, Offit Kurman	Law
Kevin Spur	Academic Advisorfor Blockchain Topics, German Bundestag	Politics
Igor Mikhalalev	Director (Global Topic Lead Emerging Technologies), BCG	Management consulting
Steven Alexander Kok	Associate Director (Global Topic Lead Blockchain & DLT), BCG	Management consulting
Alexandra Khasirdzheva	Vice President Strategy, Cointelegraph Consulting	Technological consulting
Evan McFarwell	Author "Blockchain Wars", Consultant, Definity	Technological consulting
Nicola Attico	Innovation and Strategy Officer, Service Now	Hedera user, Governing Council Member
Wes Geisenberger	Vice President, HBAR Foundation (Sustainability & ESG)	Insider
Mance Harmon	Co-Founder and CEO Hedera Hashgraph	Insider
Leemon Baird	Co-Founder and Chief Scientist Hedera Hashgraph	Insider

Interview guidelines focused on the state of the DLT market, HH's main advantages, fields of improvement, and its potential to solve key issues. Questions were iteratively adjusted to incorporate insights gained during the research process. For example, questions were modified to leverage interviewees' specialized expertise, although there were core questions addressed to most experts. Responses were summarized and quantified in a keyword analysis shown in the Appendix. A keyword was recognized if it surpassed a certain threshold. Results were summarized and interpreted for each question separately.

In addition to qualitative data from the interview process, a survey investigated whether actual users' opinions were in line with experts' points of view. Survey data and subsequent statistical analysis supported and complemented conclusions drawn from the interviews. The objective was not to conduct a stand-alone empirical analysis, but to find out if general trends observed in the data were broadly in line with major points and observations made by experts. For this purpose, data on perception of and trust in HH, user demographics, and drivers for investment in DLTs were collected. This information was then used to examine if users and non-users of

HH differ in key attitudes according to TAM criteria (complexity, competitive advantage, and compatibility).

Survey questions were multiple-choice or asked for a rating using a 10-point Likert scale. There were four questions intended to improve sample representativeness. Individuals were asked if they invested in DLT, were involved in projects using DLT or were familiar with HH or HBAR. If respondents indicated that none of these statements were true, their responses were not included based on respondents' knowledge being insufficient to reliably answer questions. This led to a final sample size of N = 121. For statistical analysis based on the integration of TAM and IDT, only respondents involved in projects utilizing DLT were considered since the term "user" here refers to teams building a certain protocol.

To reach qualified participants, the survey was shared in social media and messenger channels (Reddit, Telegram, Discord) specifically dealing with certain DLTs. To ensure unbiased selection, the survey was randomly posted to over 25 channels, including those of the top 5 DLTs by market cap, and only 2 of these focused on Hedera related topics.

3.2. Potential Competitive Advantage

First, we explored **if HH has CA**. Relevant theories dealing with new technology as a source of CA were applied. As the majority of DLT protocols are not managed in the classic context of a firm, firm-based strategic perspectives like MBV, RBV and DC were considered unfit as main frameworks. An innovation and product-based approach was selected instead to assess potential HH CA.

3.2.1. Disruptive Innovation Theory

Christensen's (1997) framework was used to assess if HH is a disruptive innovation, analyzing its type of market encroachment using Schmidt and Druehl's (2008) framework. First, market segments and primary attributes of DLT were identified with keyword analyses from expert interviews. Segments mentioned by two or more experts and the four most frequently mentioned attributes were recognized. Next, the market segments' willingness to pay (WTP) for each attribute was assessed based on identified criteria. In the third step, we assessed which segments would likely use HH over time based on WTP for certain attributes. This segmentation allowed us to determine the type of market encroachment. Lastly, the encroachment type was mapped to the type of innovation in accordance with Christensen (1997).

3.2.2. Potential Second Mover Advantage

We assessed SMA (Gal-Or, 1985; Hoppe and Lehmann-Grube, 2001; Tran et al., 2012) as a source of CA, arising from market entry timing of HH's rollout. Feng et al. (2020) define characteristics for platform products as first "the presence of network-effects[,] lock in-effects, and [...] marginal product costs",second as a revenue model that "earns sustained revenue from the same user base over time" and third as a "fast speed of technological innovation." These perfectly match the qualities of DLTs, so this framework was used to determine FMA or SMA.

For cases in which market entry time is exogenously defined, as is the case for Ethereum and HH (ie., the point of market maturity of the protocols equals their market entry time) (Interview: Baird), Feng et al. (2020) identify the rate of quality improvement of second movers and the length of the demand window of the growth phase as determinants of FMA or SMA. To assess the growth phase and demand window, the mean of expert opinions of the time frames was calculated. The quality improvement rate was qualitatively developed by confronting Hedera executives with shortcomings compared to Ethereum that were identified in the keyword analysis of expert interviews. The answers were validated by analyzing company resources.

3.3. Scenario Planning of External Factors

Second, we **explored factors not inherent in the technology** to assess if HH might be able to improve its market position. Since this part of the analysis deals with uncertainty, ongoing discussions in academia about decision making under conditions of uncertainty (Kelsey and Quiggin, 1992) were followed. Uncertainty here describes circumstances where it is impossible to gather and include all relevant information. Accordingly, a qualitative, non-additive measure associated with Potential Surprise Theory of Shackle (1949) as proposed by Basili and Zappia (2009) was used instead of Bayesian probabilities. This method is considered more appropriate for thinking about the future given conditions of uncertainty and that unexpected events can and do occur. The constructive approach of scenario planning (SP) corresponding to Schoemaker (1995) was applied to find the most plausible development trajectory for HH in the DLT market. This approach is congruent with Shackle's 'Potential Surprise Theory' and well-suited for addressing the presence of high uncertainty (Derbyshire, 2017).

The aim of the SP was to determine if Hedera is likely to become a dominant player in the DLT space considering the likely development of external factors. As the DLT sector is young, rising attention further speeds up dynamics associated with the space. Thus, a time horizon of 5 years, equivalent to the current life span of HH was set. Selecting an appropriate measure is difficult

since the market cap of native tokens is full of noise. Thus, only the tendency of gaining a valuation comparable to its competitor, Ethereum, was chosen for the scope of the SP.

To identify the scenario with the least potential surprise (Shackle, 1949), factors influencing HH's position relative to the incumbent Ethereum were identified. This was done by noting the frequency of keywords in the expert interviews and via market observations. These factors were either categorized as trends or unknowns, depending on the degree of Potential Surprise associated with future development of each factor.

The identified unknowns were then plotted into a correlation matrix, and four learning scenarios were constructed: A top scenario, an all-optimistic scenario, a baseline scenario, and an all-adverse scenario.

These learning scenario profiles were analyzed by the probability of "yes" answers, to be checked for internal consistency based on the correlation matrix.

Building on knowledge gained from the learning scenarios, a profile for a scenario with the least Potential Surprise was developed for the development of HH's market position relative to Ethereum, based on the likely evolution of relevant external factors.

3.4. Potential User Acceptance

In interviews, experts concurred that the DLT space is currently shifting from merely "investment driven exploration" (Interview: Kok) towards firms and institutions recognizing DLT as a significant technology tool. Thus, DLT has reached a level of maturity where it "enables new business models" (Interview: Hanson) and "gives them competitive advantage" (Baird, 2022). The main growth driver for the DLT market and protocols will thus be adoption for real use-cases. Hence, user acceptance will be a major determinant of a protocol's growth potential. For this purpose, user sentiment was explored. A large number of studies identified the TAM (Davis, 1989) as a suitable tool to assess user acceptance (Marangunić and Granić, 2015). But as the DLT space is a unique sector with properties differentiating it from regular technologies, Lou and Li's (2017) integration of TAM and IDT (Rogers, 1983) was the framework for **determining if HH will be accepted by users on a greater scale**. It was used to check if user dynamics are similar to predictions of the TAM and if user perceptions of HH would generate acceptance.

4. Analysis & Results

4.1. Potential Competitive Advantage

4.1.1. Disruptive Innovation

In the following, the expert interview results are displayed along Schmidt and Druehl's (2008) 3 step approach to define HH's type of market encroachment. The segments of the DLT market identified by the experts (Appendix 3), including upcoming ones, and primary attributes of DLT protocols are shown in Table 3.

Table 3: Market Segments & Attributes of DLT Protocols based on Keyword Analysis

Market Segments	Attributes DLT
Decentralized Finance (DeFi)	Transaction cost
Enterprise	Degree of decentralization
Non-Fungible Token (NFT)	Time in the market
Gaming (upcoming)	Technological data
Digital Assets	
Metaverse (future)	

As Schmidt and Druehl's framework includes the assessment of importance relative to cost - WTP - the first determined attribute "transaction cost" is covered by assessing the other attributes WTP. Figure 14 - Figure 16 show the idealized WTP for each attribute by market segment, assessed based on the criteria shown in Table 4 and explained as follows:

Table 4: Basis of Assessment of the WTP for each Attribute

Attributes DLT	Basis of Assessment
Degree of decentralization	Roots in the anarchistic/libertarian Blockchain community
Time in the market	Need for prove over time
Technological data	Transaction volume

Since DLT is a young market there are still no benchmarks for best practices and, due to high complexity, many actors do not fully understand the mathematical foundations of protocols. Flaws are mainly revealed through successful malicious attacks or other scandals. Time in the market is treated as a proxy for quality and security, one of the most important reasons for trusting a protocol. Hence, when a ledger is taken to represent value correlated with time in the

market, there is higher WTP. This particularly applies to digital assets, DeFi and NFTs. HH has been in the market since 2018 and is one life span younger than the incumbent, Ethereum, and accordingly was perceived as inferior by 50% of the experts.

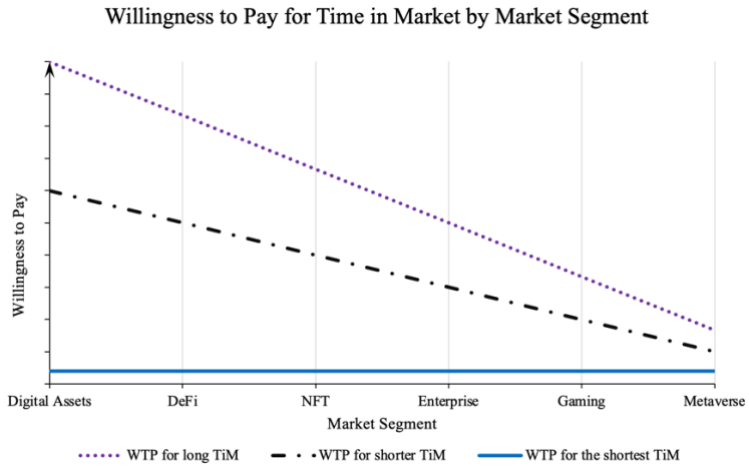

Figure 14: WTP for Time in the Market by Market Segment

The interviews also revealed that the degree of decentralization is valued most by Blockchain traditionalists, tracing their roots to the early days of the anarcho-libertarian crypto community. A philisophical premise of Nakamoto's (2008) work is equal access to participate in the network as a core principle of decentralization. Thus, only a permissionless ledger is considered decentralized, even if the legacy permissionless PoW protocols, like Bitcoin and Ethereum, have aspects of centralization and are not fully transparent with respect to governance as shown in Table 1. Consequently, market segments with stronger roots in the early community value this attribute more which is also associated with higher WTP.

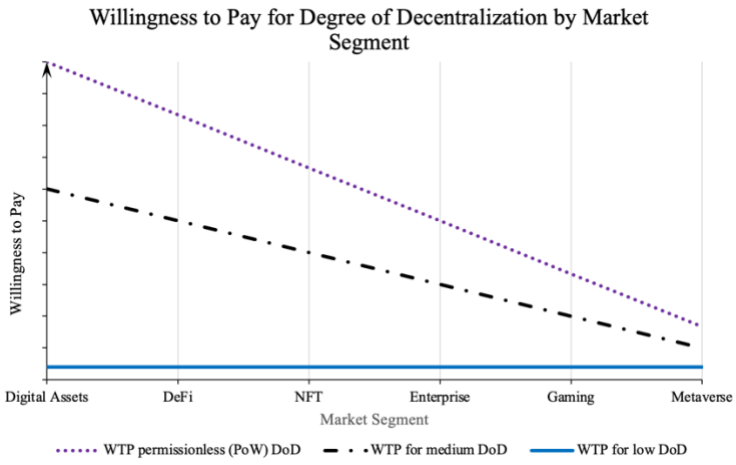

Figure 15: WTP for Degree of Decentralization by Market Segment

Speed and efficiency of a protocol lead to scalability. This becomes increasingly important with increasing transaction volume needed for use-cases. Thus, higher transaction volume in a market segment equates to higher WTP, as experts stated. Experts further proposed that for large parts of the enterprise sector, and for gaming and the metaverse, speed and scalability are crucial for a user experience compatible with centralized applications. This would not be possible building on Ethereum as clearly shown by the values identified in Table 1.

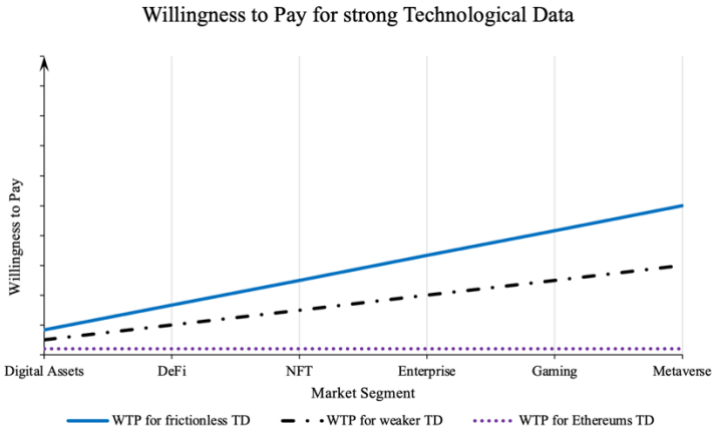

Figure 16: WTP for strong Technological Data

Becoming proven over time is less important for these segments, as there are no older protocols with speed and scalability. The same applies to the degree of decentralization (permissionless ledger) according to Hanson. As these are still in their infacy, the first to actually adopt DLTs is the enterprise sector as reflected in current use-cases (Hedera Hashgraph, LLC, 2022b). When interviewed, Harmon stated that Hedera focuses on enterprise users. This segment will be the main driver for HH's growth in the near future according to experts (85%). With increasing time in the market, which potentially will not be associated with hacks or malicious attacks as HH is ABFT, and with decentralization proceeding as announced in Hedera's (2022a) roadmap and affirmed by founder and CTO Baird, HH will be an increasingly winning option for market segments seeking these attributes. As HH's transaction fees are significantly lower than Ethereum and its technical features are superior, HH will likely take market share from Ethereum. This development is already observable with the first NFT projects launched on HH (Geisenberger, 2022; Hedera Hashgraph, LLC, 2022b) and projects shifting from Ethereum to HH (Interview: Baird). In effect, rising traction for Ethereum and HH is likely as seen in Figure 17.

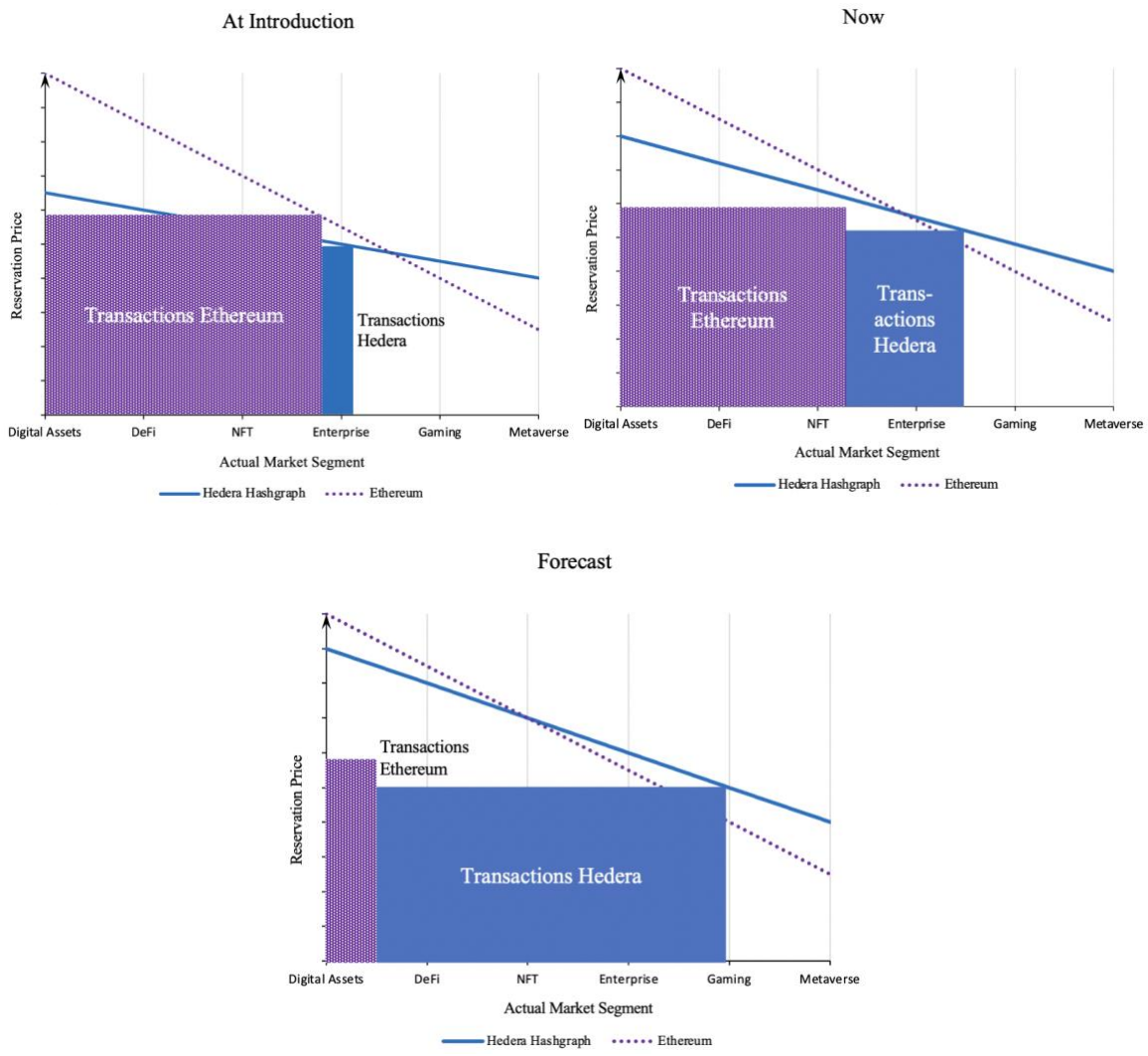

Figure 17: Development of Transactions per Market Segment (Hedera & Ethereum)

Summing this up, using Schmidt and Druehl's (2008) encroachment framework, HH "open[ed] up a fringe market, [is] encroaching on the low end of [Ethereum's] market [and is about to] defus[e] upward towards the high end". Thus, HH represents "low-end encroachment of the fringe-market type" which maps to a disruptive innovation as Christensen (1997) defines it. HH has CA arising from its associated innovative qualities.

4.1.2. Potential Second Mover Advantage

Analysing HH's market entry timing relying on Feng et al. (2020) and expert interviews yielded the following perspectives.

According to all experts not directly connected to Hedera or the HBAR Foundation, HH's overall quality does not exceed Ethereum's. Thus, SMA for Hedera versus Ethereum would only occur if HH's quality improvement rate, market growth phase and demand window were sufficiently large.

Regarding the length of the growth phase and the demand window for DLTs, experts were optimistic, considering mainstream market adoption to begin in the near future. The estimated mean of an expected period of strong growth is 10 years, while the demand window was estimated to be unlimited by 92% of the experts. A third of the experts tied the demand window to conditions like detected flaws. Overall, it is reasonable to anticipate that conditions for these two determinants are satisfied.

When considering the overall quality of the two protocols, experts mentioned shortcomings in terms of the degree of decentralization (29%), the small community size and the limited number of developers (64%) building apps on top of HH as main shortcomings of Hedera when compared to Ethereum. These were recognized by Hedera management and concrete measures to address them are already taken (Interviews: Geisenberger, Baird, Harmon). As mentioned in the previous subsection, decentralization is in progress. The latter two issues are based on awareness and thus strongly connected to Hedera's shorter time in the market. Regarding community size, CEO Harmon stated that management was aware of this issue. He explained Hedera's marketing focus as being on the number of use-cases rather than on retail investors who represent the largest part of protocol communities.

Hedera has lately shifted marketing efforts towards building awareness among retail investors. The number of developers is also a focus for Hedera since its rollout. This is reflected in its support of mainstream coding languages like Java Script (Interview: Geisenberger). These efforts were bolstered by measures like the recent open sourcing of the code and adding service extensions like the Ethereum Virtual Machine (EVM) compatible with smart contracts 2.0 (Interviews: Baird, Geisenberger, Harmon). Furthermore, the independent HBAR Foundation was founded and 10,7 billion HBARs[9] were allocated for ecosystem development (Hedera Hashgraph, LLC, 2021). With Hedera already focusing on issues brought up by observers, improvements regarding these metrics can be expected. Moreover, Hedera's overall quality improvement rate is high due to its clearer and effective governance model and more centralized management of the code base. This is reflected in the frequency of extensions and updates associated with HH compared to Ethereum, whose migration to PoS is continuously being postponed.

[9] About 2 billion USD at the time of allocation

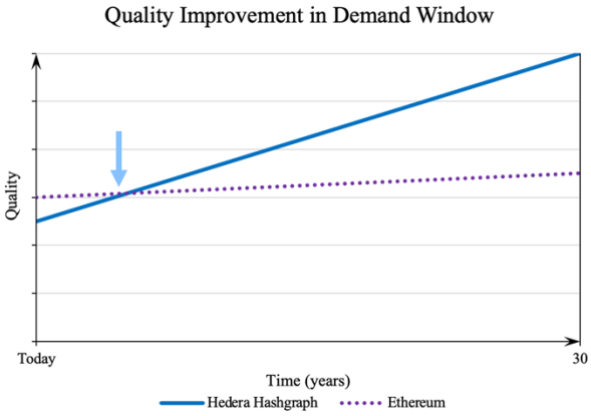

Figure 18: Ethereum & Hedera Hashgraph Quality Development over the Time

For this reason, a quality development trajectory pertaining to the two protocols as shown above is likely. This suggests that HH quality may surpass Ethereum and that SMA is more likely for HH than FMA.

Both models applied suggest that **Hedera Hashgraph has discernible CA over Ethereum**. Consequently, management theory implies a positive development of HH relative to Ethereum.

4.2. Scenario Planning of External Factors

The basis for SP were trends and unknowns identified in the keyword analysis of expert interviews and secondary data. These are shown in Table 5.

Table 5: Trends & Unknowns in Effecting Hedera's Development in the DLT Market

Knowlege Status	No.	Key Trend/Uncertainty	Effect (if yes)
Trend	T1	Regulators recognize the importance of DLT and set clear guidelines for the space, regulating the application layer of DLT as an asset class.	+
Trend	T2	The overall DLT market will grow.	+
Trend	T3	DLT adoption will first be driven by existing institutions as these already have a large user base. Later new institutions with new use-cases will drive adoption.	+
Trend	T4	Interoperability and crosscomposability of protocols will increase.	+
Trend	T5	Overall awareness of Hedera Hashgraph will increase.	+
Trend	T6	Ethereum's switch to PoS will sucessfully be completed, which increases its scalability.	-
Trend	T7	The DLT market will grow into a multichain, oligopolistic landscape in which protocols are topic specific ecosystems.	0
Trend	T8	Institutional investment will increase.	0
UNKNOWN	U1	Will the war in Ukraine end quickly and restore a favourable environment for investment in new technologies?	+
UNKNOWN	U2	Will the speed of digitalization keep up after the pandemic ends?	+
UNKNOWN	U3	Will the differentiating benefits of finality of consensus and/or ABFT of Hedera Hashgraph be recognized and deemed important by potential clients?	+
UNKNOWN	U4	Will no new DLT protocols with comparable or better hard facts than Hedera Hashgraph enter the market and become established?	+
UNKNOWN	U5	Will the number of use-cases of Hedera Hashgraph increase?	+
UNKNOWN	U6	Will a Hashgraph Hype occur?	+
UNKNOWN	U7	Will successful malicious attacks on Hedera Hashgraph be avoided?	+
UNKNOWN	U8	Will Ethereum's gas fees remain at uncompetitively high levels after the change towards PoS?	+

The correlation matrix of unknowns is visible in Table 6. The learning scenarios can be seen in Table 7, and are focused on potential developments of unknowns. Trends, by definition, are constant for all scenarios.

Table 6: Correlation Matrix of Uncertainties Occurrence

	U1	U2	U3	U4	U5	U6	U7	U8
U1	x	+	0	-	+	0	0	0
U2	x	x	+	-	+	0	0	0
U3	x	x	x	-	+	+	0	0
U4	x	x	x	x	+	+	+	-
U5	x	x	x	x	x	+	+	+
U6	x	x	x	x	x	x	+	+
U7	x	x	x	x	x	x	x	0
U8	x	x	x	x	x	x	x	x

Almost all the unknowns are positively correlated or neutral. Only U4 is negatively correlated to other unknowns, suggesting that developments favorable for Hedera will likely encourage new market entrants.

Table 7: Learning Scenarios

Scenario Type	Scenario Name	Scenario
Top	**Hedera Monopoly**	Excluded from consideration becuase of Trends (T7, T8).
Optimistic	**Hashgraph in the Top 5**	The Ukraine conflict has been settled quickly, which restored a favorable environment for investment in emerging technologies (U1) while the high speed of digitalization has kept up. (U2). Potential HH clients are deeming differentiating benefits of Hedera (ABFT and the finality of consensus) important (U3) while Ethereum's transaction fees (gas fees) have stayed at uncompetitively high levels despite its change towards PoS (U8). New market entrants have not entered (U4). Moreover, malicious attacks on Hedera Hashgraph have been prevented (U7). A Hedera Hype is occuring (U6), which drives further investment and adoption (U5). HH's importance in the space based on traction, HBAR market capitalization and expert perception increased significantly. Hedera has disrupted the DLT space and is one of the top three protocols.
Base Line	**Hashgraph on Pause**	The Ukraine conflict has been settled quickly which restored a favorable environment for investment in new technologies (U1) while the high speed of digitalization has kept up (U2). Potential HH clients started valuing differentiating benefits ABFT and finality of consensus (U3). This encourages new DLT protocols with comparable hard facts like Hederas to enter and establish in the market (U4), increasing competition. As Ethereum's change towards PoS drastically lowered the transaction fees of Ethereum (U8) competition is high. There have been no major successful malicious attacks on HH (U7) but as no Hype is favoring potential customers' and investors' attention (U6), use-cases are only slowly increasing (U5) and Hedera is not able to prevail in the highly competitive market. HH remains in the bottom half of top 50 protocols.
Adverse	**Hashgraph Wipe Out**	The Ukraine war expanded which detains firms' and institutions' investment in new technologies (U1). The trend of increasing digitalization caused by the pandemic has inverted (U2). This leads to a stagnation of adoption of DLT in Hederas core segment. Potential Hedera clients do not recognize the importance of ABFT or finality of consensus (U3) and new protocols with even stronger hard facts than HH have entered the market and established themselves (U4). This increases competition in the already stagnating segment. Moreover, malicious attacks on HH have repeatedly been successful (U7) which leads to HH use-cases decreasing (U5) as users lost value locked. Negative publicity is hitting Hedera Hashgraph (U6) while Ethereum's transaction fees have decreased as result of the change towards PoS (U8), strengthening its position as an incumbent. HH is going out of business as consequence of a traction falling towards zero.

The internal consistency of the learning scenario was analyzed based on the correlations identified. Therefore, the profiles of learning scenarios were plotted by the probability of "yes" answers in Figure 19.

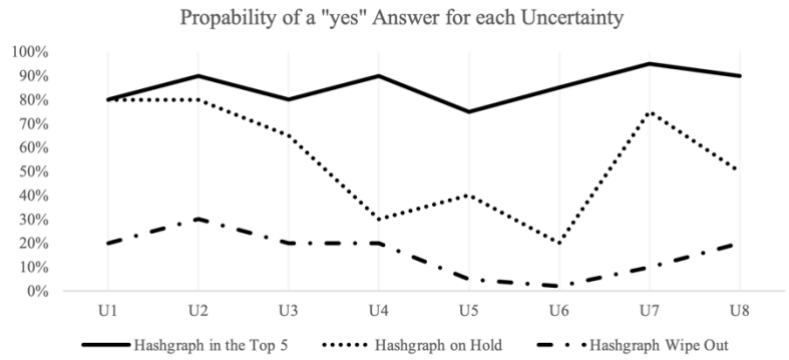

Figure 19: Profiles of Learning Scenarios

Because of the negative correlation of U4 with U1, U2, U3 and U8 revealed in Table 6, the optimistic and pessimistic learning scenarios were not internally consistent and thus hold large Potential Surprise. Building on these learnings, a scenario for a least surprising event was developed.

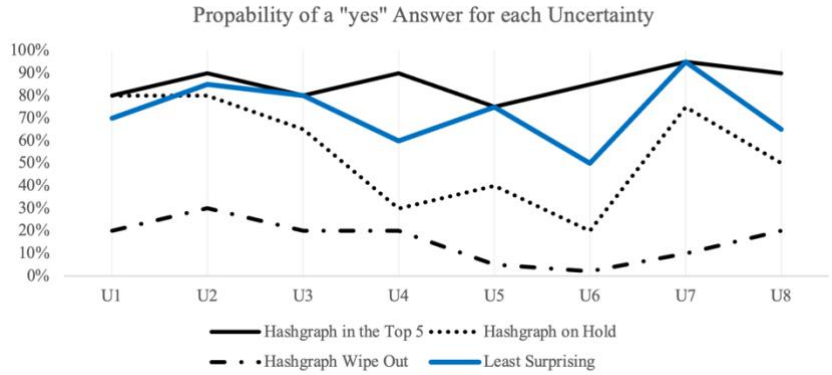

Figure 20: Profile of the Least Surprising Scenario

This profile set the frame for the final least surprising scenario formulated below. All trends and unknowns were included in this scenario.

Least Surprising Scenario for HH Development in the DLT Space based on External Factors

The Ukraine conflict was settled within less than a year. This short-term uncertainty did not stop institutions and the private sector firms from investing in emerging technologies (U1). The high speed of digitalization persists (U2), and these developments drive the adoption of DLT for real world use-cases in the enterprise sector which leads to growth in HH's target segment (T3). Law makers set a clearer framework for DLT (T1) which creates an environment allowing institutional investment (T8) to focus on Hedera for large allocations, as its security standard and focus on compliance with regulation is attractive. Potential HH clients started valuing the differentiated benefits of Hedera (ABFT and the finality of consensus) (U3) which allow HH to prevail in large parts of the newly emerging sectors of the market. Ethereum's transaction fees (gas fees) have been way lower since the change to PoS (T6) (about 5$) but still remain uncompetitively high as Hedera has transaction fees of less than 1$ (U8). This encourages a small number of new market entrants (U4). But as Hedera has FMA, rapidly building a comparable governance model is almost impossible for second movers, so new market entrants cannot gain substantial traction in the growing market (T2). These developments lead to many new use-cases for HH (U5). These further increase as interoperability (T4) decreases network and lock in effects that were giving advantages to incumbents. Moreover, there are no successful malicious attacks on HH (U7) as the system is ABFT which prevents DDoS attacks. Moreover, despite technical decentralization the majority of voting power is still held by the governing council that was instituted to ensure a rules-based system and who has no interest in falsifying the ledger. A Hedera 'Hype' has not occurred yet and token market caps remain unpredictable and random, but Hedera's use-cases are growing and becoming more prominent (U6). This allows Hedera to gain further awareness (T5) regardless of hype. HH's importance in the space based on traction, the HBAR market capitalization, and expert perceptions is increasing. With its focus on real world use-cases, exponential growth has just started. Hedera is in the first phase of disrupting the DLT space and is one of the top ten protocols with a promising future. HH developing into one of 5 oligopolistic (T7) players in the DLT space, beyond the period under review, would not be surprising.

Based upon Scenario Planning, **positive development of HH in the DLT market space can be assumed.**

4.3. Potential User Acceptance

To support the conclusions drawn from the interview process, survey data were collected and analyzed, with the goal of obtaining an indication whether users are likely to accept HH as a technology. For this purpose, users' perceptions of three key factors predicting technology adoption according to the TAM – complexity, relative advantage, and compatibility – were compared to that of non-users using a t-test. To obtain a broader understanding of the general sentiment towards HH among potential users, descriptive statistics measuring opinion, trust and investment were analyzed as well.

Table 8: Results T-Test by User

	Mean	Mean (User)	Mean (Non-User)	Difference
Complexity	6,1945	6,1	6,3125	-0,2125
Compatibility	6,9474	7,9333	5,8519	2,0815*
Relative Adventage	9,1389	10	8,0625	1,9375***

*10% significance level, **5% significance level, ***1% significance level

Table 8 reports mean levels of the three main predictors of technology acceptance for HH usage, as well as the difference between both groups. Overall, the data support the predictions of Lou and Lis' (2017) model: Hedera users[10] are significantly more likely to perceive a high relative advantage of HH over other protocols, significantly more likely to perceive HH as compatible and perceive HH to be less complex than non-users. However, the difference in perceived complexity observed between the two groups is not statistically significant and thus very likely zero, at least in the sample collected. There are two potential explanations for this. First, insignificant results very likely occurred due to the small sample size, which generally makes it hard to draw conclusions for the general population. Second, DLT protocols in general are complex, especially when compared to traditional software, which may explain high levels of overall perceived complexity. Since no data on the perceived complexity of other protocols was collected, HH is not necessarily perceived to be more complex than other DLTs and we cannot rule out the possibility that people are referring to the complexity of DLT in general.

It is important to note, that overall levels of perceived compatibility and relative advantage were high – even among non-users of the technology – and that users of the technology, without exception, rated the relative advantage of HH with a perfect 10. These observations underscore the favorable image HH has in the developer community.

Table 9: Result T-Test Trust by User

	Mean	Mean (User)	Mean (Non-User)	Difference
Trust	8,5417	9,7	7,0938	2,6063***

*10% significance level, **5% significance level, ***1% significance level

The impression of positive sentiment towards HH is even more solid when considering the results reported in Tables 9 and 10. Table 9 reports the average level of trust in HH by usage status. Unsurprisingly, users exhibit significantly higher levels of trust in the technology and its management. However, the level of trust is fairly high even among non-users. A similar picture emerges when comparing average levels of trust between those who invest in HBAR and those

[10] Participants in the survey that indicated to be involved in projects facilitating DLT and whose teams are already using Hedera Hashgraph

who do not (Table 10): The difference is slightly larger, but non-investors still, on average, indicated their trust in the technology on the upper half of the scale.

Table 10: Result T-Test Trust by HBAR-Investor

	Mean	Mean (HBAR-Inv.)	Mean (Non-HBAR-Inv.)	Difference
Trust	8,5844	9,0759	6,0513	3,0246***

*10% significance level, **5% significance level, ***1% significance level

Another important indicator of potential users' and investors' conviction concerning HH was the high number of people aware of the technology who also indicated an investment in it. 73,3% of individuals in the sample indicated they knew Hedera and of those, over 81% further indicated owning HBAR. This metric illustrates that once an investor becomes aware of HBAR, they are very likely to invest in it. By far the most important reason cited for investment in any token by respondents was "solid use case" followed by "trustworthy management". From this one can reasonably assume that HH's use case appeals to people quickly. **Thus, both potential users and retail investors appear to recognize Hedera's benefits and appear to accept the technology.**

5. Triangulation & Discussion

To converge the results, we first summarized the studies to integrate our findings.

5.1. Integration of Findings

Table 11 provides an overview of the research conducted. The individual conclusions are consistent and suggest a positive development of HH relative to the incumbent, Ethereum.

Table 11: Triangulation of Research

Scope	**Competitive adventage**	**External factors**	**User acceptance**
Objective	Determine CA inherent in Hedera Hashgraph	Determine if Hedera is going to be a dominant player in the DLT market based on external factors	Determine if Hedera Hashgraph will be accepted by developers
Theoretical basis	Theory of disruptive innovation (Christensen, 1997), SMA (Gal-Or, 1985; Hoppe and Lehmann-Grube, 2001; Tran et al., 2012)	(Basili and Zappia, 2009), Potential Surprise Theory (Shackle, 1949)	TAM (Davis, 1989), IDT (Rogers, 1983 [1962])
Framework	Type of market encroachment (Schmidt and Druehl, 2008), determine SMA in case of platfomrs (Feng et al., 2020)	Scenario planning (Schoemaker, 1995)	Integration of TAM and IDT (Lou and Li, 2017)
Research sesign	Keyword & qualitative analysis	Keyword & qualitative analysis	Statistical analysis
Data source	Company resources, expert interviews	Secondary data, expert interviews	User survey
Results	Hedera first is adopted by the enterprisen sector and diffuses upward: low-end encroachment. SMA is more likely than FMA as Hederas qualityimprovement rate is higher than Ethereums and the growth phase and demand window of DLT are large.	The scenario with the least potential surprise includes Hedera as one of the Top 10 protocolls.	The observed dynamics are in line with the model. Users and non-users rate relative adventage of Hedera high. The majority of respondants that know Hedera own the native token HBAR.
Additional insights gained	The largest hurdle for Hedera is ecosystem size and awareness (only 23% of non insider experts answered with a clear yes); Hedera knows ist community and is quick in reacting to user needs; The degree of decentralization is subject of discussion.	Ther are factors that are out of controll that may beneficial or adversely effect Hedera Hashgraphs development. Hype and noise in the DLT space, yet unclear regulatory framework.	As soon an as people were in contact with Hedera Hashgraph trust and acceptance is high.
Conclusion	Hedera Hasgraph is a disruptive innovation and in the concrete case SMA applies. Thus Hedera got discernible CA.	External factors are favouring Hederas development in the DLT market. Hederas market position is likely to increase.	There is a positive sentiment towards Hedera both among potential and actual users and retail investors. User acceptance appears likely.

All **individual results and conclusions support the hypothesis that HH is a disruptor with the capacity to become a dominant player**. But only an integrated consideration of all results and insights gathered allows us to draw comprehensive conclusions. In addition to results, insights gathered are included in Table 11.

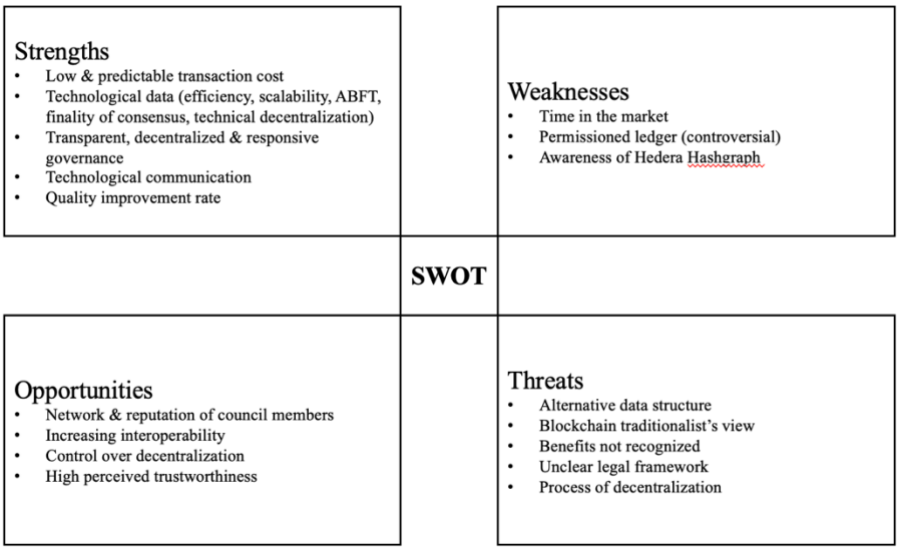

Figure 21: Summary of Findings SWOT Hedera

To blend the core findings, learnings gathered in the overall research process are summarized in Figure 21. Key points are the basis for the following discussion.

5.2. Discussion

HH's potential for success is rooted in superior technology. The non-Blockchain based architecture and the internal voting algorithm enable technological performance that is not possible with traditional PoW Blockchains and only partially possible with PoS Blockchains. HH technology ensures scalability and allows for low transaction costs, while offering the unique features of ABFT and immediate finality of consensus. Baird claimed that HH solves the Blockchain trilemma of security, decentralization, and scalability while Harmon framed it as the sweet-spot in the trilemma. Scalability already applies for several HH use-cases and while security may be correct from a mathematical perspective, the market will be the ultimate test and arbiter of success.

Beyond technological superiority, HH thus far has also been skillfully led. The flaws and problems associated with Generations One and Two of Blockchain protocols on a business level have been recognized and tackled by Hedera. HH provides stability in an essentially unstable space, illustrated by the low HBAR token volatility and the transaction fees fixed to a price in US Dollar. HH also represents an entity "similar to them to do business with" for firms and other institutions (Interview: Harmon). The Governing Council, consisting of well-known brands, provides a tangible face for an abstract service and is trusted as the survey results showed. Moreover, this governing body, combined with a clearly defined set of rules including no-forking, enables transparent and democratic governance. This model is way more responsive

and predictable than governance associated with Bitcoin and Ethereum. All of the foregoing, therefore, suggest SMA for HH.

Improvements over the first and second-generation protocols are specifically valued by users applying DLT to enterprise level real-world use-cases. HH is expanding its foothold starting in this segment, reflected by the first NFT projects in HH, all of which illustrate low-end encroachment by a Disruptive Innovation.

These positive developments are furthered by HH's good connection to customers and developers. HH is learning from community feedback and, because of the effective governance model, provides regular extensions and updates. This is illustrated by the recently released EVM compatible smart contracts 2.0 or the open sourcing of the code demanded by developers. This is in line with DC and is another source of CA. Shortcomings raised by experts were all already known by HH management with concrete plans to tackle them.

Despite criticism of HH for not being decentralized, when it comes to the number of actors controlling the network, HH technically is more decentralized than large PoW networks that suffer from natural centralization. Still, Hedera is responsive to the community's demands and has taken measures towards fully decentralizing the network. This process is necessary and needed to be taken seriously, although it comes with risks for HH. That is why Hedera is not taking these steps prematurely and has adopted intermediate stages, like permissioned community nodes, which would allow for pauses and realigning.

Community growth on the other hand is more straight forward. It is needed by all stakeholders. Harmon (2022) conceded that focus will be readjusted to promote broader awareness and ecosystem development. Hedera's communication capabilities are strong and perceptions of HH generally positive. As HH reaches wider audiences in the DLT space, acceptance can be assumed based on the user surveys results. Thus, general user acceptance will not limit HH's growth and with large investments, like 10.7 billion HBAR allocated to the HBAR Foundation, coupled with Hedera's strong communication skills, ecosystem and community growth are only a matter of time.

No concrete external factors were detected that would prevent HH from gaining significant market traction. Thus, Hederas development mainly depends on the handling of shortcomings discussed above while continuing to promote use case development.

Hedera is building a complex system, which is internally and externally consistent, and not only a technical product. This process is being managed well. Even though (Baird, 2022) described Hedera as DLT "for everyone", there is a clear focus on business applications. With a stable offering in a market which still has dubious players, HH is likely to be a protocol that succeeds.

Even though there are factors that are unknown unknowns, **HH can be assessed as a disruptor with the capacity to become a dominant player.** That HH develops into one of the significant DLT protocols in an oligopolistic market is its most likely evolution.

5.3. Implications

The following section outlines implications for different groups of stakeholders.

The results reaffirm HH's strategic orientation. This implies a trajectory towards success. However, uncertainties identified in the scenario planning should be monitored. Low-end encroachment should be actively pursued by further strengthening HH's position in the identified core segment and, in the next step, shifting focus upwards in the market. For potential users, HH is a good choice as the protocol is likely to expand and the ecosystem will grow.

HH clearly provides a scalable technical solution that is easy to access as mainstream coding languages are supported. Paired with its transparent governance and multiple use cases, HH is likely to acquire and sustain CA in the DLT space.

5.4. Limitations

Research of this kind suffers heavily from uncertainty. Even though appropriate methods were chosen, results can still not be considered accurate nor fully generalizable (Moore et al., 2006). An emerging market domain is further plagued by unpredictable events like hype or macro scenarios, making it impossible to account for all relevant factors in a complex system.

Analysis of the user survey was limited by the small sample size that did not allow for more in-depth analysis and generalizability. Moreover, the data was cross sectional and did not reflect developments over time which could offer important insights. Furthermore, the survey design did not allow us to compare user perceptions of HH with the one of other protocols. Lastly, self-selection bias needs to be assumed. Although we strived for even spread of the survey across protocol communities, biases associated with survey participants cannot be precluded. As DLT protocols communities are very focused on championing a specific protocol, many users reject and are dismissive of alternatives.

In addition, network-effects, as one of the major determinants for using a system, were not considered or isolated. An analysis of time series community data could cover another important perspective.

Expert predictions of complex systems outcomes, like population development, stock market data or, technological evolution according to Moore et al. (2006) are amazingly bad. The expert interviews need to be considered in light of this, along with the fact that experts express biases, and the small sample size is not necessarily representative.

Lastly this work considered HH's development relative to the incumbent, Ethereum. Other protocols or overall market development were not considered. Alternative protocols, however, are currently influencing overall market development.

5.5. Further Research

There are three main fields for further research. The first is conducting more in depth DLT user research. More detailed studies with a larger sample focusing on the relationship between degrees of decentralization and perception of DLT protocols could be conducted. Expanding the variables associated with adoption and weighting them would also be useful. Moreover, the actual influence of network and lock-in effects, and the development of DLTs is fertile ground for further exploration.

Expanding the relationship between specific DLT governing models and market success based on Dynamic Capabilities is also interesting. Lastly the explicit determinants of DLT protocols that render them mass market mature would be worth exploring from a technical and managerial perspective. Further drivers and hurdles for mass adoption could be determined.

6. Conclusion

This research assessed if HH is a disruptor with the capacity to become a dominant player in the DLT space. We used a multi-method approach analyzing the question from three different perspectives. We found that Hedera will most likely obtain a strong market position.

HH offers a DLT alternative different from the predominant Blockchain design. From a technical perspective, HH enables higher efficiency, speed, and scalability (TPS) and comes with the unique features of ABFT and immediate finality of consensus. The potential for adoption and success of an innovation in the market, however, depends on many factors and not just technological superiority. This dissertation relied on three perspectives that were

applied and triangulated. The assessment of HH was conducted in the relation to the incumbent, Ethereum.

Potential CA was determined based on Disruptive Innovation theory and market analysis of entry timing. Based on low-end market encroachment, disruptive innovation, SMA and CA were held to exist for HH. Dynamic capabilities based on the governance model were also detected. Hence, a strategic management perspective suggests HH's future success. External factors influencing HH's market position were included in scenario planning and a least surprising scenario was posited to infer an increasing market position of HH relative to the incumbent, Ethereum. Furthermore, user acceptance was determined based on statistical analysis of user-survey results. The latter implied user acceptance of HH. Consequently, all three perspectives taken in aggregate pointed towards positive development of HH vis-à-vis incumbents. We concluded that development of HH will continue apace as a significant protocol in an oligopolistic market.

This study is significant as it considers developments in DLT from a novel perspective. Thus far, discussions of DLT protocols and their potential in academia have mainly taken a computer science perspective. Success, however, is determined by multivariant factors. This study brings new thinking to the fore including the vocabulary of management theory and applies concepts from scholarship on innovation and strategy to the DLT market. Hopefully, this work contributes to stronger understanding of DLTs as a transformative, digital phenomenon and helps overcome naysayers who view the space with skepticism and incredulity.

Bibliography

Allaire, J., Bankman-Fried, S., Brooks, B.P., Cascarilla, C., Dixon, D., Haas, A.J., 2021. Digital Assets and the Future of Finance: Understanding the Challenges and Benefits of Financial Innovation in the United States. US Congress Hearing, Washington.

Baird, L., 2016a. The Swirlds Hashgraph Consensus Algorythm: Fair, Fast, Byzantine Fault Tolerance (White Paper No. SWIRLDS-TR-2016-01). swirlds.com, posted on the internet.

Baird, L., 2016b. Overview of Swirlds Hashgraph (White Paper). swirlds.com, posted on the internet.

Baird, L., Harmon, M., 2022. Open Source, Decentralization and Shared Worlds. https://www.youtube.com/watch?v=IeeyPPymlmI (accessed 04.02.2022)

Baird, L., Harmon, M., Madsen, P., 2020. Hedera: A Public Hashgraph Network & Governing Council (White Paper). Hedera Hashgraph, LLC.

Barney, J., 1991. Firm Resources and Sustained Competitive Advantage. Journal of Management 17, 99–120. https://doi.org/10.1177/014920639101700108

Barreto, I., 2010. Dynamic Capabilities: A Review of Past Research and an Agenda for the Future. Journal of Management 36, 256–280. https://doi.org/10.1177/0149206309350776

Basili, M., Zappia, C., 2009. Shackle and Modern Decision Theory. Metroeconomica 60, 245–282. https://doi.org/10.1111/j.1467-999X.2008.00333.x

Bier, J., 2021. The Blocksize War: the battle for control over Bitcoin's protocol rules.

Buterin, V., 2013. Etherium White Paper: A Next Generation of Smart Contracts & Decentralized Applications (White Papoer). ethereum.org, posted on the internet.

Cao, B., Zhang, Z., Feng, D., Zhang, S., Zhang, L., Peng, M., Li, Y., 2020. Performance analysis and comparison of PoW, PoS and DAG based blockchains. Digital Communications and Networks 6, 480–485. https://doi.org/10.1016/j.dcan.2019.12.001

Castro, M., Liscov, B., 2002. Practical Byzantine Fault Tolerance and Proactive Recovery. ACM Transactions on Computer Systems 20, 398–461.

Christensen, C.M., 2001. The Past and Future of Competitive Advantage. MIT Sloan Management Review 42, 105–109.

Christensen, C.M., 1997. The innovator's dilemma: when new technologies cause great firms to fail, The Management of Innovation and Change Series. Harvard Business School Press, Boston, Mass.

Cusumano, M., Mylonadis, Y., Rosenbloom, R., 1992. Strategic Manouvering and Mass-Market Dynamics: The Triumph of VHS Over Betamax.

Davis, F., 1989. The Technology Acceptance Model: TAM. University of Michigan, Michigan.

Denzin, N.K., 2009. The Research Act: A Theoretical Introduction to Sociological Methods. Aldine Transaction, New Brunswick, NJ.

Denzin, N.K., Lincoln, Y.S. (Eds.), 2018. The SAGE Handbook of Qualitative Research, Fifth edition. ed. SAGE, Los Angeles London New Delhi Singapore Washington DC Melbourne.

Derbyshire, J., 2017. Potential Surprise Theory as a Theoretical Foundation for Scenario Planning. Technological Forecasting and Social Change 124, 77–87. https://doi.org/10.1016/j.techfore.2016.05.008

Driscoll, K., Hoyme, K., 1993. SAFEbus. IEEE AES Systems Magazine March 1993.

El Ioini, N., Pahl, C., 2018. A Review of Distributed Ledger Technologies, in: Panetto, H., Debruyne, C., Proper, H.A., Ardagna, C.A., Roman, D., Meersman, R. (Eds.), On the Move to Meaningful Internet Systems. OTM 2018 Conferences. Springer International Publishing, Cham, pp. 277–288. https://doi.org/10.1007/978-3-030-02671-4_16

Ethereum Foundation, 2020. The ETH2 Upgrades: Upgrading Ethereum to radical new heights. ethereum.org. URL https://ethereum.org/en/eth2/ (accessed 10.19.21).

European Central Bank, 2020. Economic and monetary developments (No. 4 / 2020), Economic Bulletin. Frankfurt am Main.

Feng, H., Jiang, Z., Li, M., Feng, N., 2020. First- or Second-Mover Advantage? The Case of IT-Enabled Platform Markets. MISQ 44, 1107–1141. https://doi.org/10.25300/MISQ/2020/15273)

Furrer, O., Thomas, H., Goussevskaia, A., 2008. The Structure and Evolution of the Strategic Management Field: A Content Analysis of 26 Years of Strategic Management Research. Int J Management Reviews 10, 1–23. https://doi.org/10.1111/j.1468-2370.2007.00217.x

Gal-Or, E., 1985. First Mover and Second Mover Advantages. International Economic Review 26, 649. https://doi.org/10.2307/2526710

Hedera Hashgraph, LLC, 2022a. Hedera Hashgraph Roadmap. Hedera.com. URL https://hedera.com/roadmap (accessed 3.11.22).

Hedera Hashgraph, LLC, 2022b. Decentralized on Hedera. URL https://hedera.com/users (accessed 3.16.22).

Hedera Hashgraph, LLC, 2021. Hedera Governing Council to Allocate $5 Billion in HBAR to Independent Foundation and Ecosystem Development Initiatives. URL https://hedera.com/blog/hedera-governing-council-to-allocate-5-billion-in-hbar-to-independent-foundation-and-ecosystem-development-initiatives (accessed 3.24.22).

Hedera Hashgraph, LLC, 2020. HBAR Economics Whitepaper.

Hoppe, H.C., Lehmann-Grube, U., 2001. Second-Mover Advantages in Dynamic Quality Competition. J Economics Management Strategy 10, 419–433. https://doi.org/10.1111/j.1430-9134.2001.00419.x

Johnson, R.B., Onwuegbuzie, A.J., 2004. Mixed Methods Research: A Research Paradigm Whose Time Has Come. Educational Researcher 33, 14–26. https://doi.org/10.3102/0013189X033007014

Kelsey, D., Quiggin, J., 1992. THEORIES OF CHOICE UNDER IGNORANCE AND UNCERTAINTY. J Economic Surveys 6, 133–153. https://doi.org/10.1111/j.1467-6419.1992.tb00148.x

Kerin, R.A., Varadarajan, P.R., Peterson, R.A., 1992. First-Mover Advantage: A Synthesis, Conceptual Framework, and Research Propositions. Journal of Marketing 56, 33. https://doi.org/10.2307/1251985

Lamport, L., Shostak, R., Pease, M., 1982. The Byzantine Generals Problem. ACM Transactions on Programming Languages and System 4, 382–401.

Lou, A.T.F., Li, E.Y., 2017. Integrating Innovation Diffusion Theory and the Technology Acceptance Model: The adoption of blockchain technology from business managers' perspective, in: AIS Electronic Library (AISeL). Presented at the International Conference on Electronic Business.

Marangunić, N., Granić, A., 2015. Technology Acceptance Model: A Literature Review from 1986 to 2013. Univ Access Inf Soc 14, 81–95. https://doi.org/10.1007/s10209-014-0348-1

Moore, D.A., Tetlock, P.E., Tanlu, L., Bazerman, M.H., 2006. Conflicts Of Interest and the Case Of Auditor Independence: Moral Seduction And Strategic Issue Cycling. AMR 31, 10–29. https://doi.org/10.5465/amr.2006.19379621

Nabilou, H., 2021. Bitcoin Governance as a Decentralized Financial Market Infrastructure. Stanford Journal of Blockchain Law & Policy.

Nakamoto, S., 2008. Bitcoin: A Peer-to-Peer Electronic Cash System (White Papoer). bitcoin.org, posted on the internet.

Nathan, A., Lipton Galbraith, G., Grimberg, J., 2021. Crypto: A New Asset Class? Goldman Sachs Global Investment Research.

Pirkpatrick, D., 2022. Hedera Will Open-Source Its Hashgraph Code to 'Capitalize on Growing Demand for Public DLT.' Dallas Innovates.

Porter, M.E., 1998. Competitive advantage: creating and sustaining superior performance: with a new introduction, 1st Free Press ed. ed. Free Press, New York.

Porter, M.E., 1985. Technology and Competitive Advantage. Journal of Business Strategy 5, 60–78. https://doi.org/10.1108/eb039075

Rauchs, M., Glidden, A., Gordon, B., Pieters, G., et al., 2018. Distributed Ledger Technology Systems a Conceptual Framework. Cambridge Center for Alternative Finance, Cambridge.

Rogers, E.M., 1983. Diffusion of innovations, 3rd ed. ed. Free Press; Collier Macmillan, New York : London.

Roth, F., 2009. The effect of the financial crisis on systemic trust. Intereconomics 44, 203–208. https://doi.org/10.1007/s10272-009-0296-9

Schmidt, G.M., Druehl, C.T., 2008. When Is a Disruptive Innovation Disruptive? J Product Innovation Man 25, 347–369. https://doi.org/10.1111/j.1540-5885.2008.00306.x

Schoemaker, P.J.H., 1995. Scenario planning: a tool for strategic thinking. MITSloan Management Review 28, 117. https://doi.org/10.1016/0024-6301(95)91604-0

Schumpeter, J.A., Swedberg, Richard, 2014. Capitalism, socialism, and democracy.

Shackle, G.L.S., 1949. A Non-Additive Measure of Uncertainty. The Review of Economic Studies 17, 70. https://doi.org/10.2307/2295790

Statista, 2020. Size of the Blockchain Technology Market Worldwide from 2018 to 2025. Statista.com. URL https://www.statista.com/statistics/647231/worldwide-blockchain-technology-market-size/

Taherdoost, H., 2018. A Review of Technology Acceptance and Adoption Models and Theories. Procedia Manufacturing 22, 960–967. https://doi.org/10.1016/j.promfg.2018.03.137

Teece, D.J., Pisano, G., Shuen, A., 1997. Dynamic capabilities and strategic management. Strat. Mgmt. J. 18, 509–533. https://doi.org/10.1002/(SICI)1097-0266(199708)18:7<509::AID-SMJ882>3.0.CO;2-Z

Tornatzky, L.G., Klein, K.G., 1982. Innovation Characteristics and Innovation Adoption-Implementation: A meta-analysis of findings. IEEE Transactions on Engineering Management EM-29, 28–45.

Tran, V.D., Sibley, D.S., Wilkie, S., 2012. Second Mover Advantage and Entry Timing: Second Mover Advantage and Entry Timing. J Ind Econ 60, 517–535. https://doi.org/10.1111/j.1467-6451.2012.00490.x

Treiblmaier, H., Clohessy, T. (Eds.), 2020. Blockchain and Distributed Ledger Technology Use cases: applications and lessons learned, Progress in IS. Springer, Cham, Switzerland.

Zhang, S., Lee, J.-H., 2020. Analysis of the Main Consensus Protocols of Blockchain. ICT Express 6, 93–97.

Appendices

List of Appendices

The main quantifiable results from the expert interviews are below. Since questions were aligned to the interviewees' specific expertise, not all questions were answered by all experts. The individual tables are ordered by the analysis applied.

The tables contain the main insights from each expert. The lower columns of the charts show a summary of the keyword analysis: number of answers, thresholds set for the keyword analysis, keyword mentions and the results.

Appendix A: Keyword Analysis: General Topics

Interviewee	Knowlege HH	Definition of a "decentralized" network	Is there a "gold standard" of DLT?	Important factors for a protocols adaption	HH Cons are KO criterion
Dominik Myczkowski	Aware	Public; permissionless	Ethereum, but that will change		Blockchain purists
Paulo Cardoso do Amaral	Yes		No		
Evan McFarwell	Aware	Permissionless	Ethereum, but that will change	Ease of programmability	Blockchain purists
David Hanson	Aware	More than 4 partys in controll	No, there are generations of Blockchain	Utility	DeFi
Kevin Spur	No, but DAG	Decentral ≠ anarchistic	No	Specialization in one use-case, publicity	
Bryan Zhen Zhang	No		No, will depend on regulation	Use-cases	
Lou Kerner	Investor		Bitcoin	Network effects	Blockchain purists
Riyad Carey	Yes		No, too many trade-offs	scalability/transaction cost; degree of decentralization; network effects	Blockchain purists
Jason Nagi	No		No, there are generations of Blockchain	Transaction cost; speed; decentralization; interoparability	
David T. Tawil	No		No, the market will decide	Network effekts; scalabilty	
Paul Rapino	Yes		No, gaps in taxonomy and standardization still big	Taxonomy; economics; use-cases	
Igor Mikhalalev	Aware	Decentralized governance is most important	No, there are generations of Blockchain	Network effects (traction; capital, integrations, support)	
Steven Alexander Kok	Aware		No, there still is no player with scalability and operational maturity.	Network effects (developer); scalability	
Alexandra Khasirdzheva	Aware		No, it depends on the application.	Network effects; scalability	
Nicola Attico	Insider	Decentral ≠ anarchistic	No		
Wes Geisenberger	Insider	Decentral ≠ anarchistic	Hedera		
Leemon Baird	Insider	Decentral ≠ anarchistic	Hedera		
Mance Harmon	Insider	Decentral ≠ anarchistic	Hedera	Enterprise adoption and retail investors acceptance	
No. of answers	18	9	18	13	5
Threshold		>2		>2	>2
Keywords mentioned	6 aware; 4 no; 4 insider; 3 yes; 1 investor	2 permissionless; 5 decentral ≠ anarchistic	13 No; 2 ETH (for now); 3 Hedera	6 Network effects; 3 use-cases; 3 scalability; 2 decentralization	4 Blockchain purists
Result	Only 23% of experts without connection to Hedera were educated about the protocol	The majority of experts percieves permissioned DLT as decentralized.	So far there is no "gold standard" for DLT.	Network effects, the use-cases buildt on a protocol and its scalability are most important for adoption	Blockchain purists (80%)

Appendix B: Keyword Analysis: CA – General

Interviewee	Main Pros HH	Main Cons HH	Potential to solve cons
Dominik Myczkowski	Reputation of governing council members; technological data (speed); transaction fees	Degree of decentralization; not established; time in market	
Paulo Cardoso do Amaral	technological data	Community; time in the market	
Evan McFarwell	technological data (scalability); synergies with governing council memberns & their reputation	Not backed by internet community; degree of decentralization	
David Hanson		Alternative technology to BC, time in the market (only PoC)	
Kevin Spur	technological data (high scalability); low transaction fees	Small community & developer pool; degree of decentralization	
Lou Kerner	Quick governance; technological data; low transaction fees; understandable technology; proven concept	Small community & developer pool	
Riyad Carey	Transaction cost; technological data (scalability; energy use)	Time in the market; not established; small community & developer pool	Yes, they need to build up a community and survive
Jason Nagi	Technological data	Small community & developer pool	
Paul Rapino	Governance model; developer relation; technological data	Small community & developer pool	Yes, good relationship Management
Igor Mikhalalev	Technological data (Efficiency; speed); low transaction cost	Small community; time in the market; alternative technology to BC	
Steven Alexander Kok	Technological data	Uscases are very initial in nature	
Nicola Attico	Good communication; governing model; technological data; transaction fees; focus on use-cases; finality of consensus; business model; degree of decentralization	Degree of decentralization (for commercial and financial space)	Yes, the reoadmap to decentralization is set, the communication and support allows community growth
Wes Geisenberger	Technological hardfacts; built-in fairness; govering model	None	Yes, Hederas community is of high quality and growing; the roadmap for decentralization is set.
Leemon Baird	Transparen governance; technological data (scalability, ABFT, energy use); transaction cost		Yes, the roadmap to decentralization is set, marketing effort shifted, steps developer aceptance are taken
Mance Harmon	Technological hardfacts (scalability, ABFT, stability); governing model	Community size (retail investors)	Yes, the roadmap to decentralization is set, marketing effort shifted, steps developer aceptance are taken
No. of answers	14	14	6
Threshold	>2	>3	
Keywords mentioned	14 technological data; 7 governance; 4 low fees	9 community & 5 developer; 5 time in the market; 4 degree of decentralization	6 Yes because of: good relationship management, growing community, roadmap to dencentralization; 2 comes with time in market
Result	Pros arise from superior technology (100%) and the concept of the governing council (50%).	Main cons are the small community (64%) and developer pool size (36%), the short time in the market (36%) just as the design as permissioned ledger (25%).	100% Hedera will be able to tackle the main cons.

Appendix C: Keyword Analysis: CA – Disruptive Innovation

Interviewee	DLT market segments	Most important properties of DL	Market segments that decide for HH	HH users = first-time DLT users?
Dominik Myczkowski		Time in the market; transaction cost; stability		
Paulo Cardoso do Amaral		Time in the market; degree of decentralization	Enterprise	
Evan McFarwell	Finance; NFT; games; metaverse; smartcontracts; enterprise; web3.0	Time in the market, open source; standards; atomicity	Enterprise	
David Hanson	Finance; NFT; games; metaverse; smartcontracts; enterprise	Depend on usecase	Enterprise	
Kevin Spur	Enterprise DLT; digital assets; finance (DeFi), NFT, DAOs	Degree of decentralization; security; technological data	Enterprise; digital assets	
Bryan Zhen Zhang	Finance (DeFi), NFT, digital assets			
Lou Kerner			Enterprise	
Riyad Carey	Enterprise; finance; gaming; art; metaverse; asset tokenisation	Transaction cost; degree of decentralization; developers community; technological data	Enterprise (low transaction fees)	Yes
Jason Nagi	Art; gaming; digital assets; digital payments; securities; Web3.0; Finance (DeFi)	Transaction cost; stabile value; interoperability; compliance		
David T. Tawil	NFT; gaming; digital assets; digital payments	Transaction cost; technological data		
Paul Rapino	Enterprise; finance; consumer goods	Degree of decentralization; technological data; security; transparency; trust	Enterprise	
Igor Mikhalalev	Finance (DeFi); metaverse; enterprise	community; marketing; functionality; quality of governance; technological data	Digital payments (high TPS)	
Steven Alexander Kok	Finance (FinTech) and other DLT applicatons need to be seperated	Technological data; access to developer; usability; governance; economics	DLT	
Alexandra Khasirdzheva	Finance (DeFi); enterprise; NFT; gaming; digital assets; metaverse			
Nicola Attico		Technological hardfacts; stability; focus on use-cases	Enterprise	Yes
Wes Geisenberger			Early adopers: enterprise, NFT, sustainability	Yes
Leemon Baird		Technological hardfacts; governance	Hedera is for everyone; Enterprise; NFT	Yes
Mance Harmon		Security; stability; governance	Enterprise	Yes
No. of answers	11	14	13	5
Threshold	>2 (Art as part of NFTs)	Top 4 (insider excluded)	>2	
Keywords mentioned	10 Finance (DeFi); 7 Enterprise; 8 NFT; 5 Metaverse; 6 Digital Assets; 3 Gaming;	4 transaction cost; 4 degree of decentralization; 3 time in market; 7 technological data	11 Enterprise; 2 NFT	5 Yes
Result	DeFi; Enterprise; NFT; Gaming; Digital Assets; Metaverse	Transaction cost; degree of decentralization; time in the market as proove for security; technological data (scalability, speed)	Enterprise (85%) DLT is the segment that most likely decides for Hedera Hashgraph	Yes (100%)

Appendix D: Keyword Analysis: CA – SMA

Interviewee	Agree with*	market growth of DLT market (years)	Demand window of DLT
Dominik Myczkowski	No	As long new use-cases are developed, not in close future	Unlimited
Paulo Cardoso do Amaral	No		
Evan McFarwell	Depends on the usecase	20+	30 years
David Hanson		As long new use-cases are developed, not in close future	Unlimited
Kevin Spur	No	10+; then slowing down	Unlimited
Bryan Zhen Zhang		10+ (asssumption: structural change)	Unlimited; if adapted by the mainstream market
Lou Kerner	No	10+; growth with lots of noise for	Unlimited
Riyad Carey	No	10+; growth in segments	Unlimited
Jason Nagi		10+; mass adaption is just starting	Unlimited
David T. Tawil		5+	Unlimited; if no flaws are coming up
Paul Rapino		10+	Unlimited; if no flaws are coming up
Steven Alexander Kok		At the moment it is investment driven exploration no organic growth; if no mass market use-cases growth stops with investment	Unlimited; if mass market maturity and -use-cases are reached the demand window will be open
Alexandra Khasirdzheva		10+; exponential	Unlimited
Nicola Attico	Depends on the usecase; for enterprise they are ideal		
Wes Geisenberger	Yes		
Leemon Baird	Yes		
Mance Harmon	Yes		
No. Of answers	10	12	12
Threshold		Mean of quantified answers	
Top Keywords	5 No; 2 depends on usecase; 3 Yes	7 10+; 1 20+; 1 5+; 4	11 unlimited; 1 30; 4 tied to condition
Result	For now Hedera Hashgraph still has shortcomings compared to main incumbant in the market ETH. 50% percieve HH inferior.	10 years	Based on experts statements I assume a demand window of at least 20 years.

*Would you agree with the following statement "At this point Hedeara Hashgraph has a higher overall quality than Ethereum?

Appendix E: Keyword Analysis: SP

Interviewee	Development in the market - Will incumbents be replaced	Factors that are effecting the overall DLT space	Expected regulatory developments
Dominik Myczkowski	Incumbents will stay	increasing digitalization driven by the pandemic	
Evan McFarwell		Standardization, regulatory framework, economic experiments	
David Hanson	Protocolls will develop as topic specific ecosystems, oligopolistic market	Investments in ecosystems will be reinvested in community what leads to utility that benefits the overall space	
Kevin Spur		Integration in regulatory framework increases institutional investment, adaption of the DAO concept, growth NFT, DeFi &enterprise Blockchain	Increasingly embadded in regulatory frameworks; taxation oriented on stock taxation (low as location compeet)
Bryan Zhen Zhang	N/A	Trends of: crosscomposability, institutionalization, private issued stabile coins, asset tokenization	Regulation appears on the application layer; DeFi is going to be regulated as banks; Regulators are increalingly building competence; Coordination between regulators gets closer.
Lou Kerner	N/A	The development as infrastructure layer of the metaverse; intercomposability -> exponential development	
Riyad Carey	Regulations tend to favour incumbants but new players will be coming up; oligopolistic market	NFTs taking the topic mainstream; excitement about metaverse	Now: focus is on consumer protection, anti money laundering, know your customer; next: taxes; Focus: application layer; increasing
Jason Nagi	ETH and BTC are goin to stay, new protocols will come up; oligopolistic market	Regulation	The frame is increasingly getting tighter, governments want to control money
David T. Tawil	BTC will stay ETH will be replaced by one of the new players; it will be a oligopolistic multi system world	Opensource, interoperability, intercomposability are increasing speed of innovation; Quantum computing breaking the blockchain is the bigest threat	Increasing; countries differentiate by level of control
Paul Rapino	Oligopolistic market	Regulation; pandemic increased need; investments in protocols; political climate in majour countries	1st: regulating the marketplaces; 2nd: definition & interpretation; Now: regulators are defining POV, business needs clarity; increasing
Igor Mikhalalev	Hard for incumbents to keep up with innovation becuase of lobying of miners; N/A	Decentralized governance; turning away from PoS; increasing scalability; interoperability; enterprise blockchain turning permissionless; use-cases besides digital assets; work with regulators	
Steven Alexander Kok		High investments; crypto matures and will offer more complx services; eventual emergance of CBDC; Consensus as a service models;	
Alexandra Khasirdzheva	ETH and BTC are goin to stay, new protocols will come up; oligopolistic market	Geopolitical changes that could drive adoption	Varies over geography; increasing
Leemon Baird	Oligopolistic market; Ethereum & Bitcoin might stay.	Regulation	
Mance Harmon	Oligopolistic market; Ethereum & Bitcoin might stay.	Regulation	KYK for node operators;
No. of answers Threshold	12	15 >1	8 >1
Top Keywords	8 oligopolistic; 1 Ethereum replaced; 5 Ethereum & Bitcoin will not be replaced; 3 N/A	7 regulation; 4 investment; 4 hype topics like NFT & metaverse taking the topic mainstream; 4 interoperability & composability & standardization; 2 pandemic speeding up digitalization; 2 politics	6 increas; 2 application layer & transition points regulated
Conclusion	Multi chain oligopolistic market	Proceeding regulation; investment; hype topics like NFT & metaverse taking the topic mainstream; politics; increasing interoperability & composability; pandemic drives digitalization	Regulation is proceeding, application layer & transition points are center of regulators interest. Short term effects on the protocoll layer will be negligible