Technological challenges and business opportunities: state of the art and future trajectories

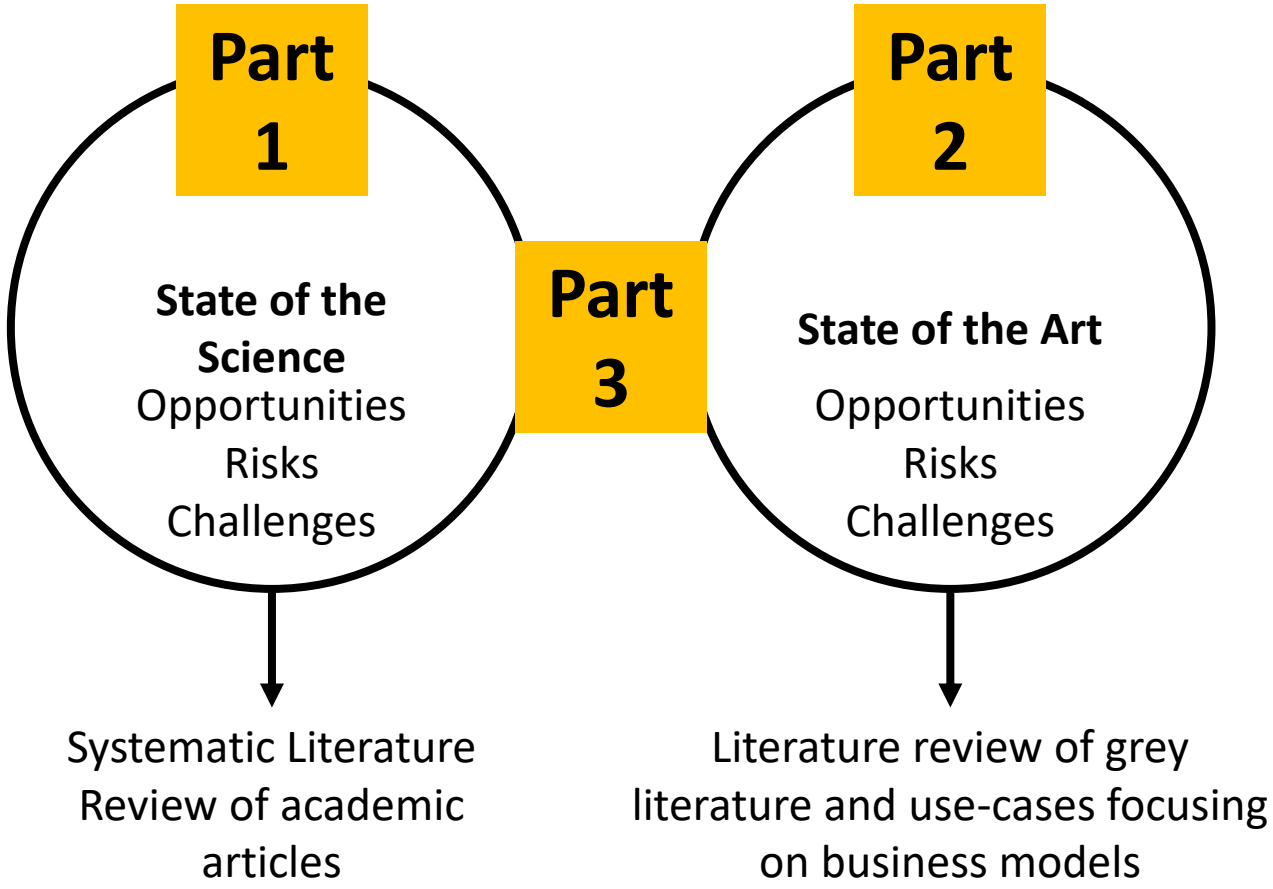
Final Workshop

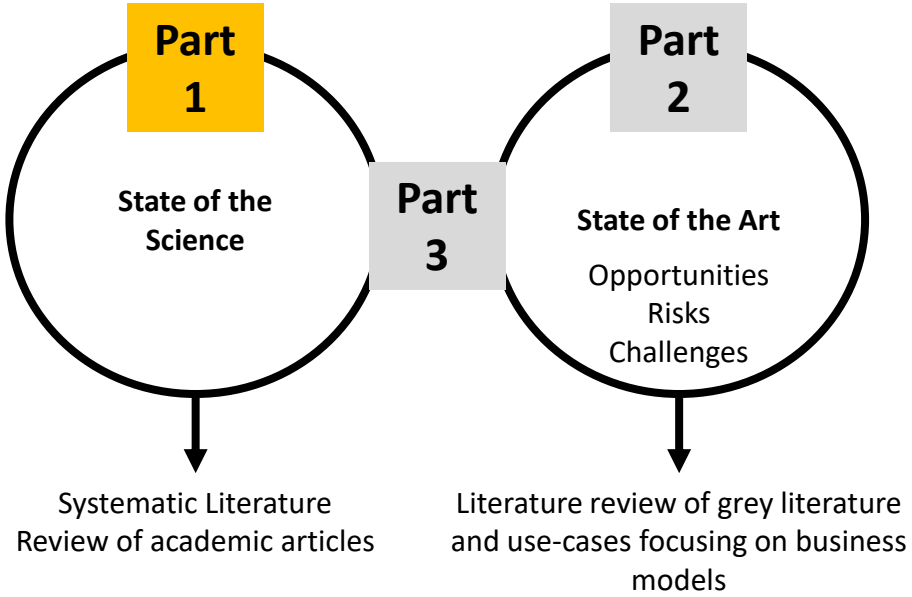
Kharlamov, A.A.; Motsi, I; Yeung, K.

Nov 2019

University of Birmingham

Approach


Part 1
State of the Science
Opportunities
Risks
Challenges
Part 3
Part 2
State of the Art
Opportunities
Risks
Challenges
Systematic Literature Review of academic articles
Literature review of grey literature and use-cases focusing on business models



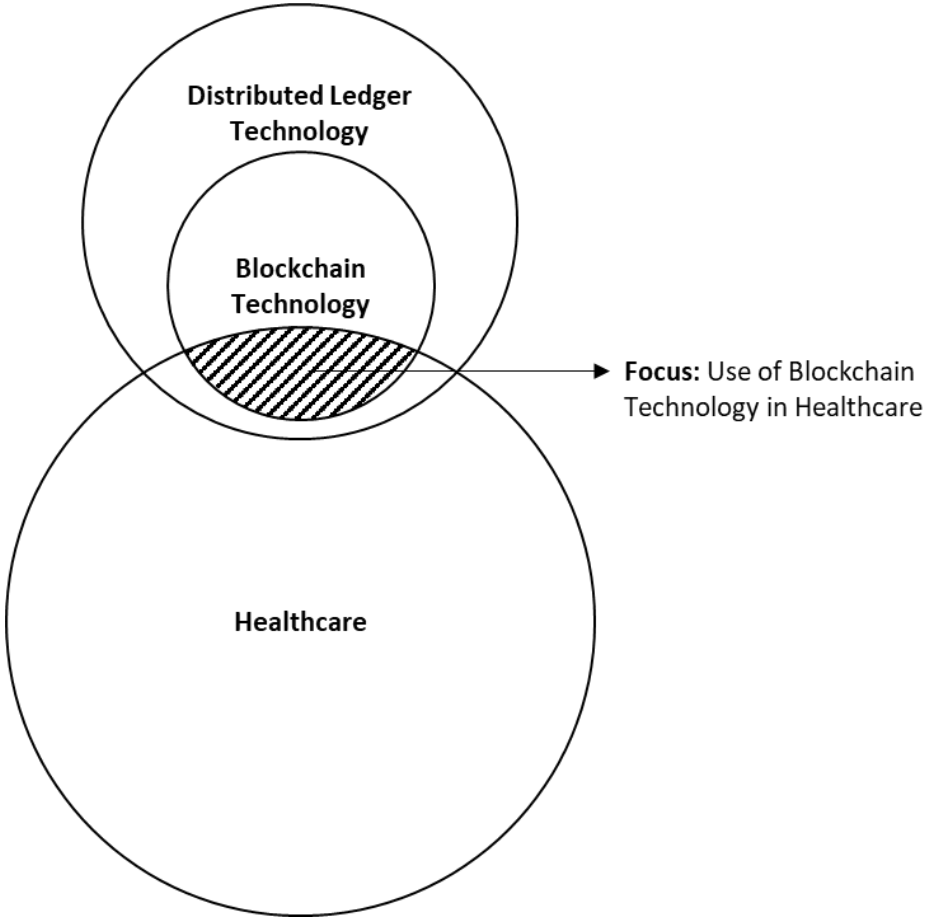
State of the Science

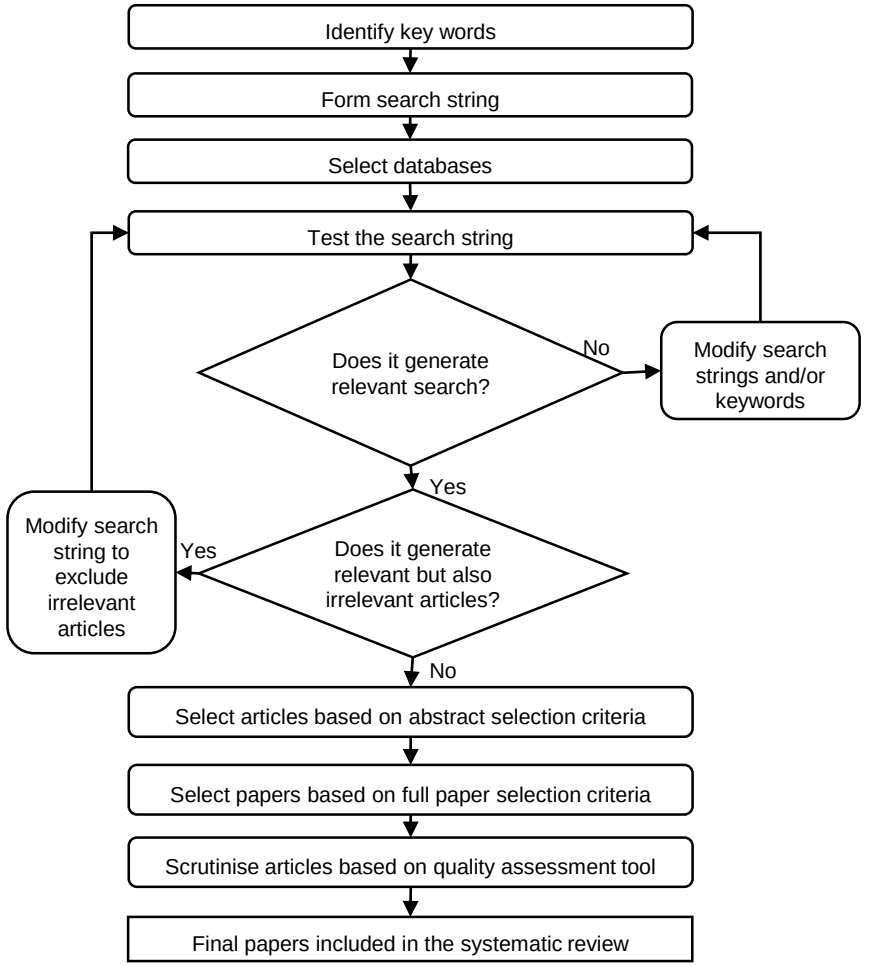
Academic Literature: Systematic Literature Review

Systematic literature review methodology

- Core SLR question:
  - *What are the (a) technical and (b) organizational* (i) ***benefits*** and ***opportunities*** as well as (ii) ***challenges, issues*** *and* ***concerns*** *that arise in blockchain for healthcare technologies?*
- *Sub-questions*
  - What are the **problems** that Blockchain technology is claimed to solve in healthcare?
  - What are the **opportunities** of utilising blockchain in healthcare?
  - What are the **risks** of utilising blockchain in healthcare?
  - What are the nature and range of **challenges** of utilising blockchain in healthcare that have previously been identified?

Scope & Search Strategy





Strings & Source & Quality control

Strings

Field	Keywords	Query
Blockchain Technology	Blockchain(s) Block chain Distributed Ledger	(blockchain* OR "block chain" OR (distributed AND ledger))
Healthcare	Health(care); Medicine; Medical; Medic; Care Patient	(*health* OR *medic* OR *clinic* OR *care OR patient*)

Database

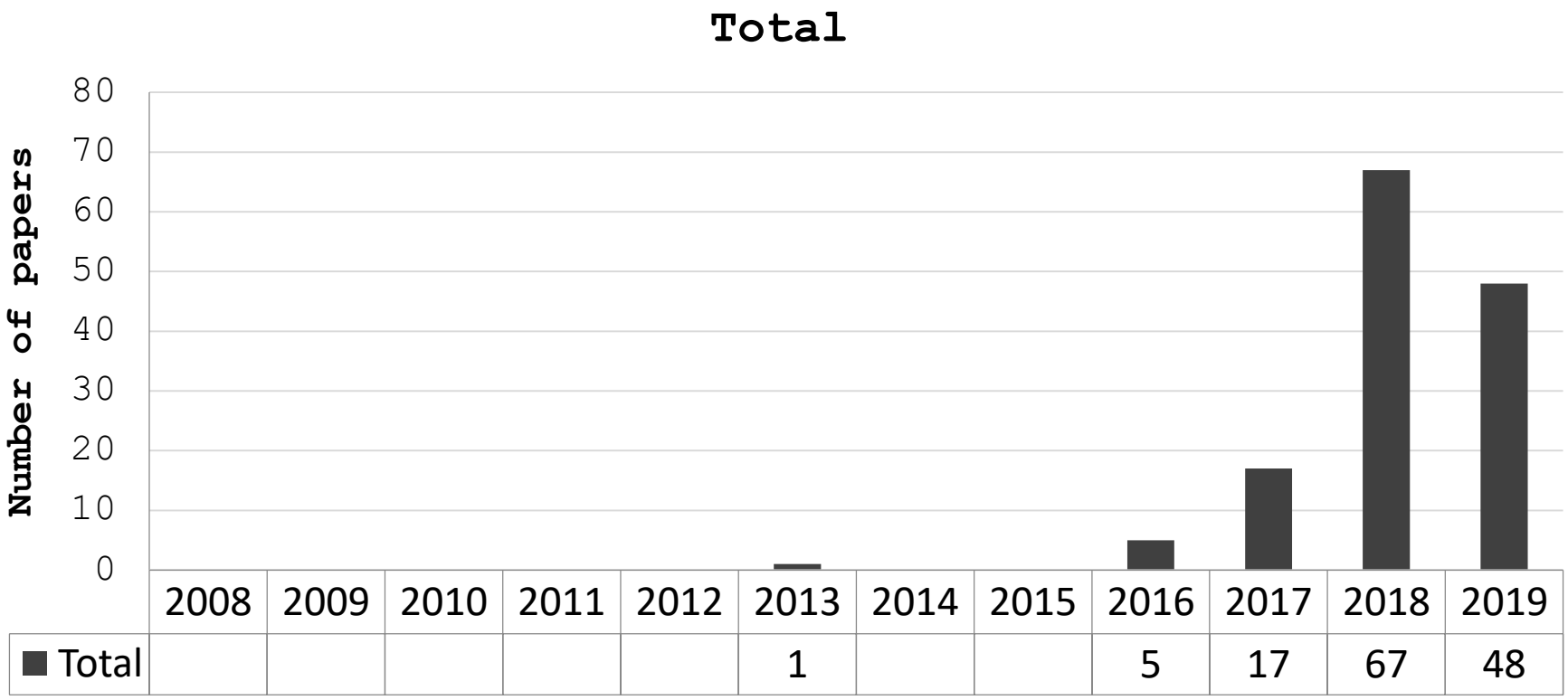
Scopus®

Quality control:

Academic Journal Guide 2018
Scopus CiteScore 2017
Impact Factors (InCites Journal Citation Reports 2017)
SJR 2018 score

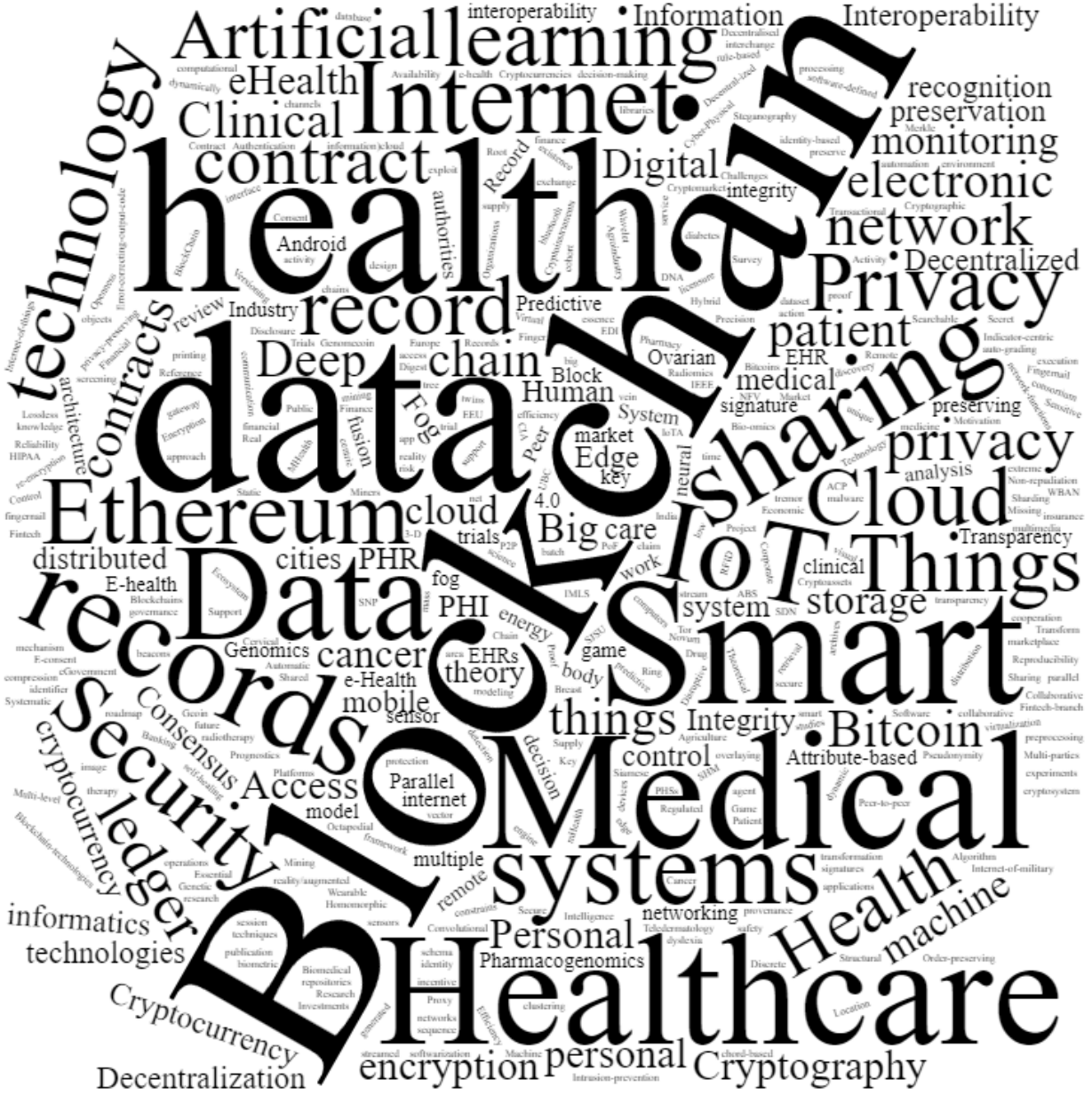
Sources:
AJG2018: https://charteredabs.org/academic-journal-guide-2018/
Scopus CiteScore: https://www.scopus.com/sources
InCites Journal Citation Reports: https://jcr.clarivate.com/
SJR Score: https://www.scimagojr.com/journalrank.php

Publication trends



Raw 145 articles as of June of 2019 → 133 after controlling for duplicates and quality

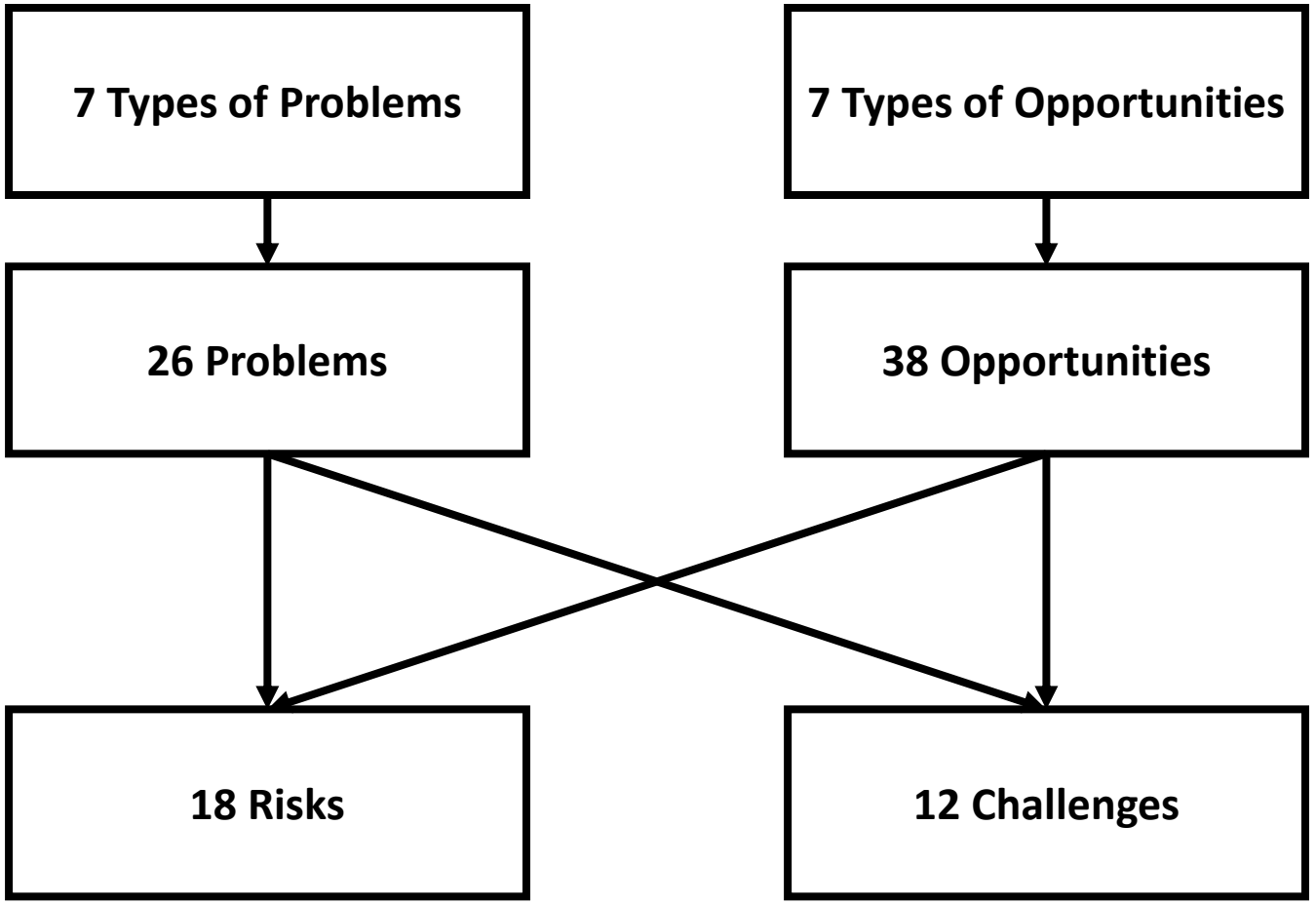
Keyword overview



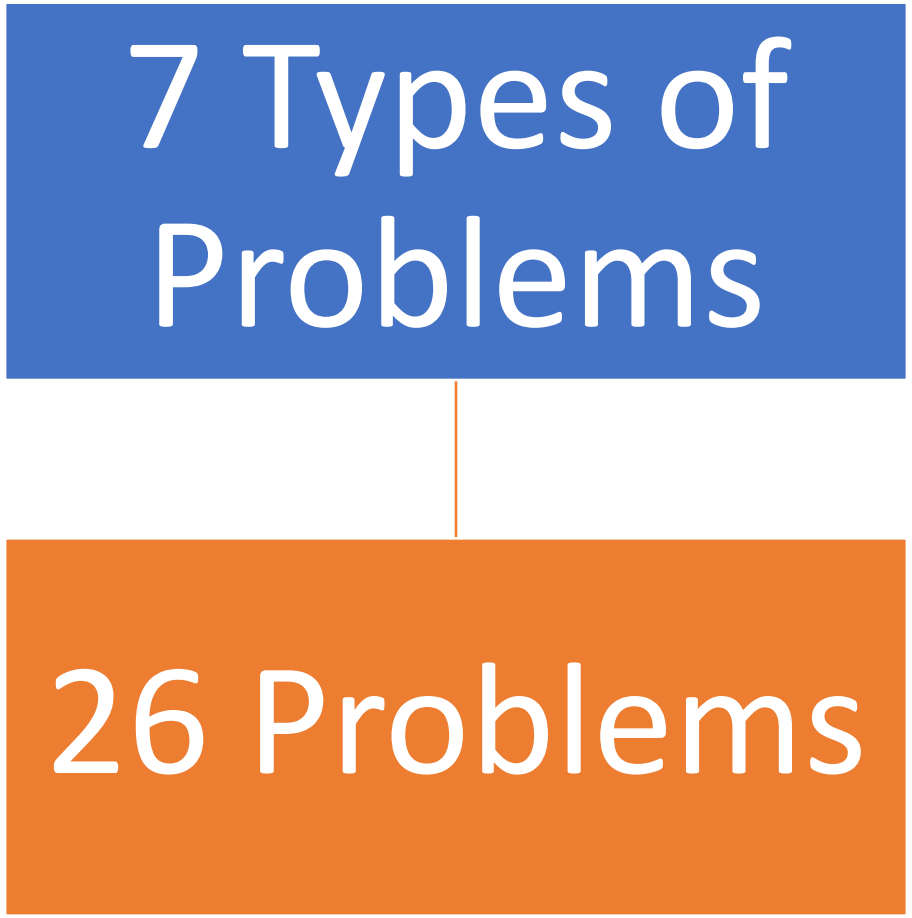
Keyword overview

Keyword	#		Keyword	#		Keyword	#		Keyword	#
Blockchain	76		Cloud	8		Decentralization	4		Human	3
data	28		information	7		Digital	4		work	3
health	24		healthcare	7		storage	4		Edge	3
blockchain	21		Artificial	7		machine	4		care	3
Smart	17		contract	7		eHealth	4		PHI	3
Healthcare	16		Health	7		Access	4		Fog	3
computing	16		intelligence	6		cancer	4			
Medical	16		Bitcoin	6		cloud	4			
Data	13		privacy	6		Personal	4			
records	12		network	6		Integrity	3			
sharing	11		ledger	6		PHR	3			
IoT	11		Cryptocurrency	6		Decentralized	3			
management	10		Cryptography	5		preservation	3			
Internet	10		contracts	5		technologies	3			
security	10		Clinical	5		informatics	3			
systems	10		patient	5		distributed	3			
Electronic	9		things	5		recognition	3			
learning	9		chain	5		Information	3			
Ethereum	9		Deep	5		Interoperability	3			
Security	9		Big	5		medical	3			
Distributed	8		electronic	5		control	3			
technology	8		monitoring	4		mobile	3			
Privacy	8		encryption	4		system	3			
record	8		Consensus	4		theory	3			
Things	8		personal	4		cities	3			

Base Framework



Opportunities of blockchain in healthcare



Types healthcare problems

- Data problems
- Security, Safety and Trust problems
- Computing and Sensing problems
- Service Delivery problems (including quality and efficiency)
- Integrity and Verification problems
- Financing problems
- Health-related Fraud and Corruption

Data problems

- **data sharing** (89% of our pool of research papers discuss this problem);
- **patient data security** (mentioned in 72% of papers);
- **patient data privacy** (discussed in 69% of papers);
- **data dredging** also known as “data phishing” when large volumes of data are being analysed to find relationships without having any a priori testable hypotheses (described in 9% of papers);
- **missing data** (appears in 9% of papers);
- **patient data integration problem** (included in 2% of papers).

Security, Safety and Trust problems

- **trust** issues between different actors (patients, practitioners, etc.) within the healthcare system as well as between actors and the system itself (discussed in 69% of all analysed papers);
- **security of the healthcare** system for various actors is another commonly mentioned issue (appears in 66% of all analysed papers);
- establishing **secure communication links** between actors and organizations within the healthcare system is another important problems (reviewed in 1% of papers).

Computing and Sensing problems

- **unbalanced computational requirements** (reviewed in 11% of papers);
- **mobile computing issues** (reported in 8% of papers);
- **wireless sensing and IoT technology** (represented in 1% of papers).

Service Delivery

- **e-health delivery, organisation, and scaling** (outlined in 13% of papers);
- **decision support systems for various types of healthcare actors** (featured in 7% of papers);
- **drug-testing, certification and offering** (depicted in 4% of papers).

Integrity and Verification problems

- **reliability and credibility of medical and other healthcare-related studies** (detailed in 48% of papers);
- **selective publication of studies and study results** (pictured in 9% of papers);
- **outcomes switching** problem in the medical as well as healthcare-related research and testing (exemplified in 8% of papers);
- **study systematization** problem related to difficulties in organizing and systematizing medical and healthcare-related knowledge (discussed in 7% of papers);
- **transparency of the patient consent** problem (mentioned in 3% of papers);
- **patient consent traceability** problem (depicted in 3% of papers);
- **verification of (health practitioner) qualifications** (appears in 2% of papers).

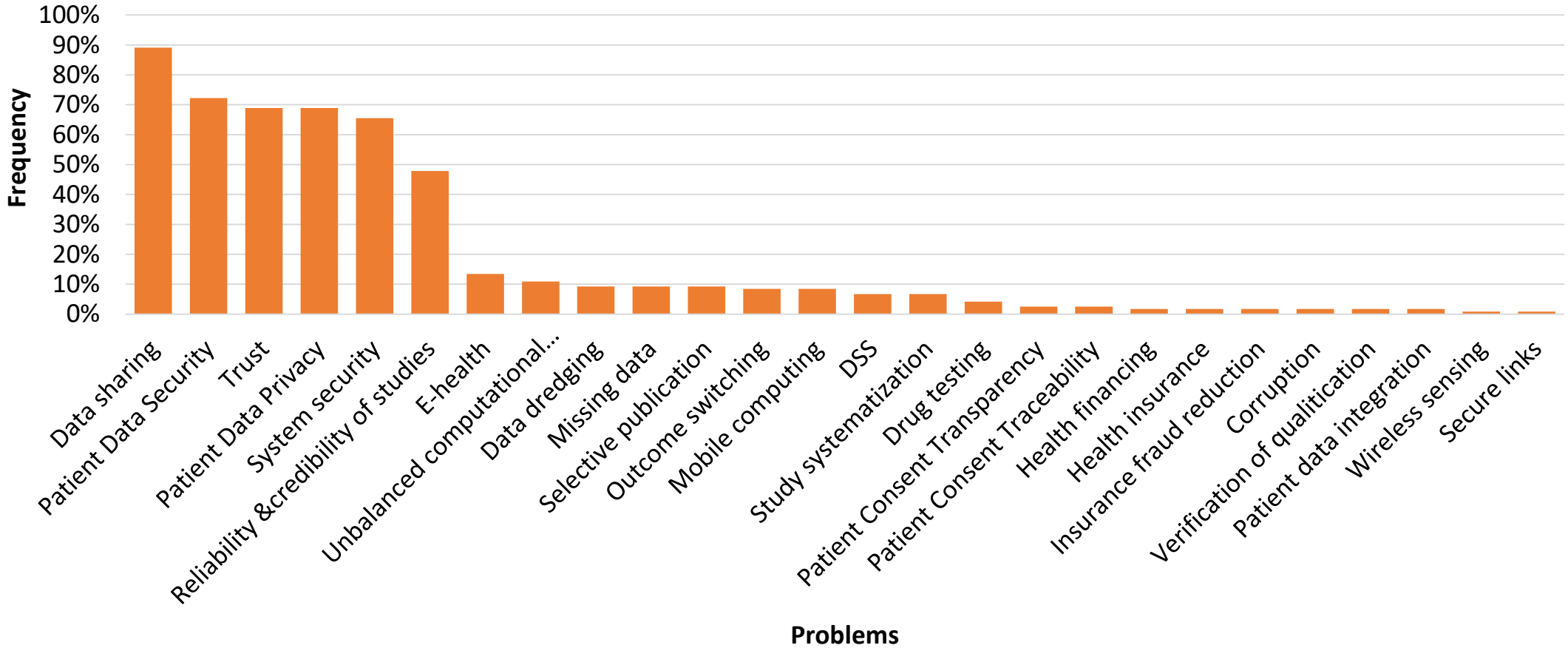
Financing problems

- **healthcare financing** (specified in 2% of papers)
- **health insurance** issues (mentioned in 2% of papers).

Health-related Fraud and Corruption

- **corruption** and related issues (described in 2% of papers)
- **healthcare insurance fraud** (illustrated in 2% of papers)

Healthcare Blockchain problems and importance



Opportunities of blockchain in healthcare

Types of opportunities

- Trust, security and control opportunities
- Opportunities to facilitate and enhance patient-centricity
- Data storage, sharing and co-ordination(?) opportunities
- Data harmonization, integration and interoperability opportunities
- Ecosystem and market creation opportunities
- Healthcare service provision opportunities
- Cost management and financial opportunities

Trust, security and control opportunities are featured in 37% of the analysed papers

- **data security and operability** (8% of studies);
- **distributed network control over records** (7% of studies);
- **traceability and authenticity of patient records** (4% of studies);
- **increased accountability and scalability** (4% of studies);
- **data ownership and security** (3% of studies);
- **increased security and reduced fraud and corruption in healthcare** (3% of studies);
- **transparency of data sharing** (2% of studies);
- **comprehensive history of healthcare and studies** (2% of studies);
- **data provenance, auditing, and control for shared medical data in cloud repositories among big data entities** (1% of studies);
- **increased trust due to better control procedures** (1% of studies);
- **quick verification and document delivery** (1% of studies); and
- **traceability of medical and healthcare-related data** (1% of studies).

Patient-centric opportunities appear in 23% of analysed papers

- **empowering patients to own, control, and share their data** (6% of studies);
- **master patient indices for data operations** (5% of studies);
- **patient-centric care** (5% of studies);
- **smart and personalized healthcare provision** (3% of studies);
- **increased patient satisfaction** (2% of studies); and
- **patient data control through ability to organize, store, and share streams of data effectively and reliably** (2% of studies).

Data storage, sharing and organisation opportunities are discussed in 18% of analysed papers

- **longitudinal patient records accumulation and storage** (8% of studies);
- **effective access and data sharing and archiving** (3% of studies);
- **efficient and secure information storage and sharing** (2% of studies);
- **distributed medical data management** (2% of studies);
- **efficient data sharing through public, private and hybrid ledgers** (1% of studies);
- **immutable trial history records provision** (1% of studies); and
- **efficient data storage and oversight** (1% of studies).

Data harmonization, integration and interoperability opportunities cover 10% of all analysed papers

- **data harmonization** (5% of studies);
- **patient data integration** (3% of studies);
- **harmonization of data systems** (1% of studies);
- **homogenizing data schema** (1% of studies).

Ecosystem and market creation opportunities are mentioned in 6% of papers

- **digital healthcare ecosystem provision** (3% of studies);
- **health records' management** (2% of studies); and
- **the opportunity for open markets for healthcare data that drive discovery, research and innovation** (1% of studies)

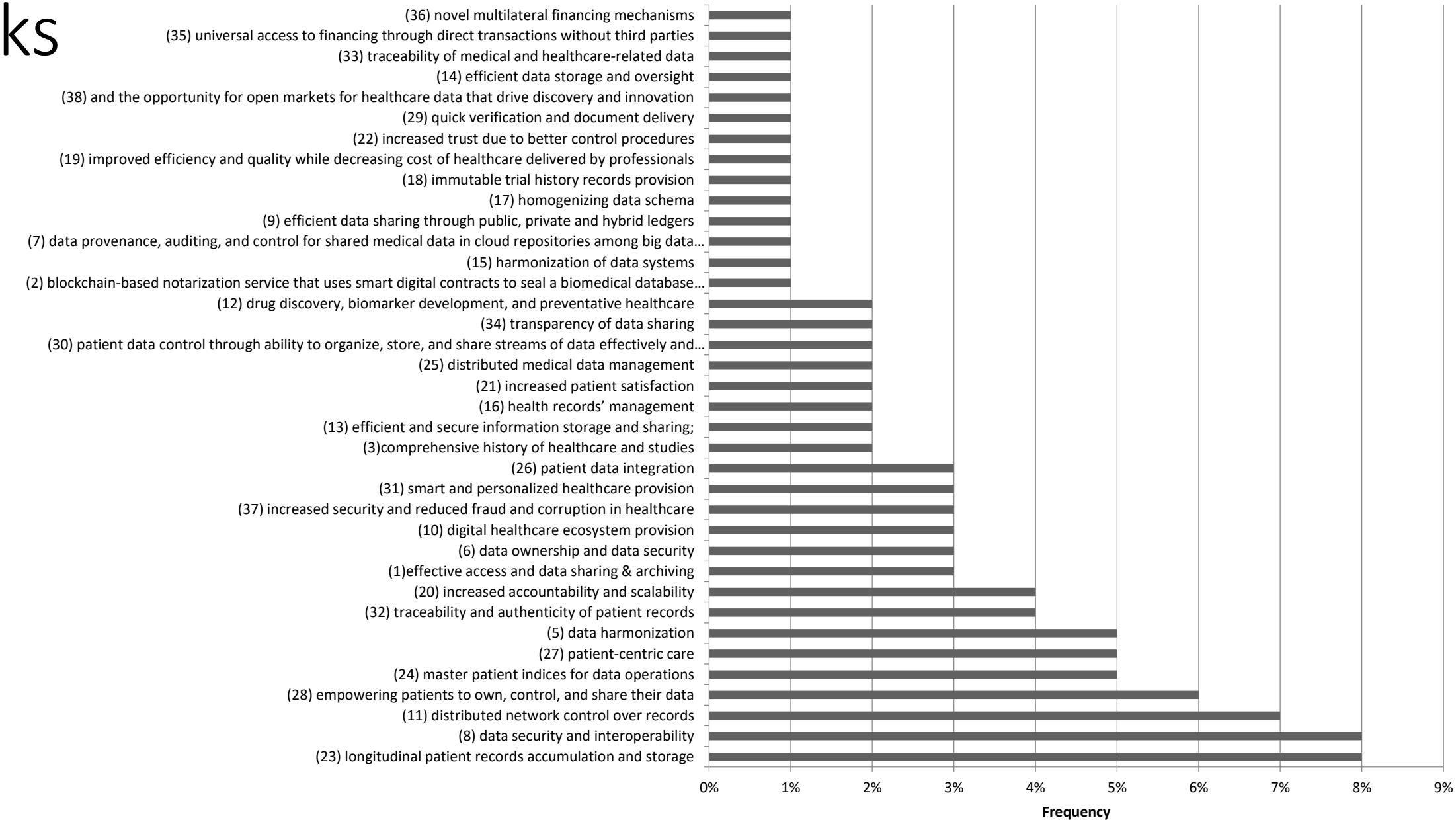
Healthcare service provision opportunities a featured in 3% of analysed papers

- **drug discovery, biomarker development, and preventative healthcare** (2% of studies);
- **blockchain-based notarization service that uses smart digital contracts to seal a biomedical database query and the respective results** (1% of studies).

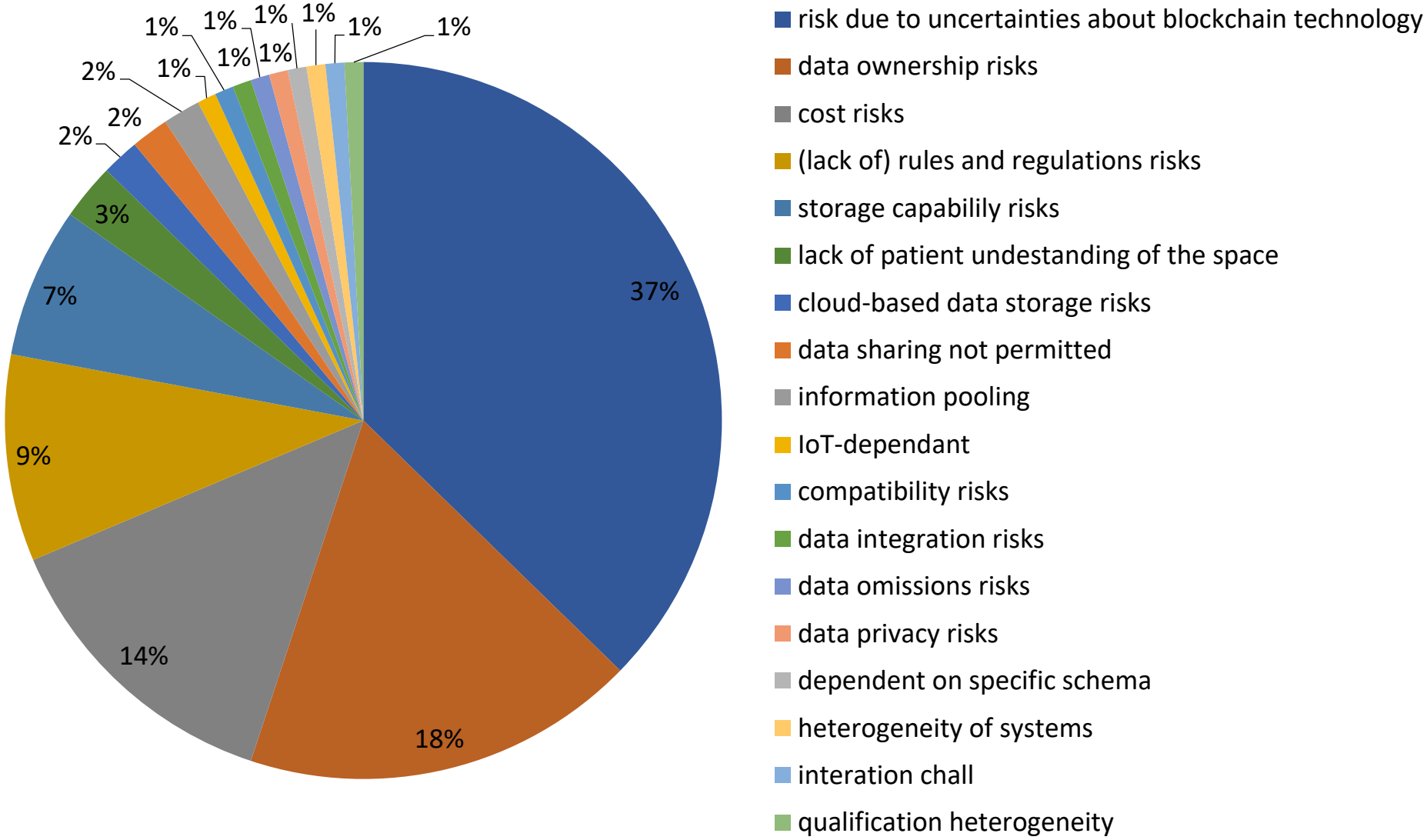
Cost management and financial opportunities are described in 3% of analysed papers

- **improved efficiency and quality while decreasing cost of healthcare delivered by professionals** (1% of studies);
- **universal access to financing through direct transactions without third parties** (1% of studies) and
- **novel multilateral financing mechanisms** (1% of studies).

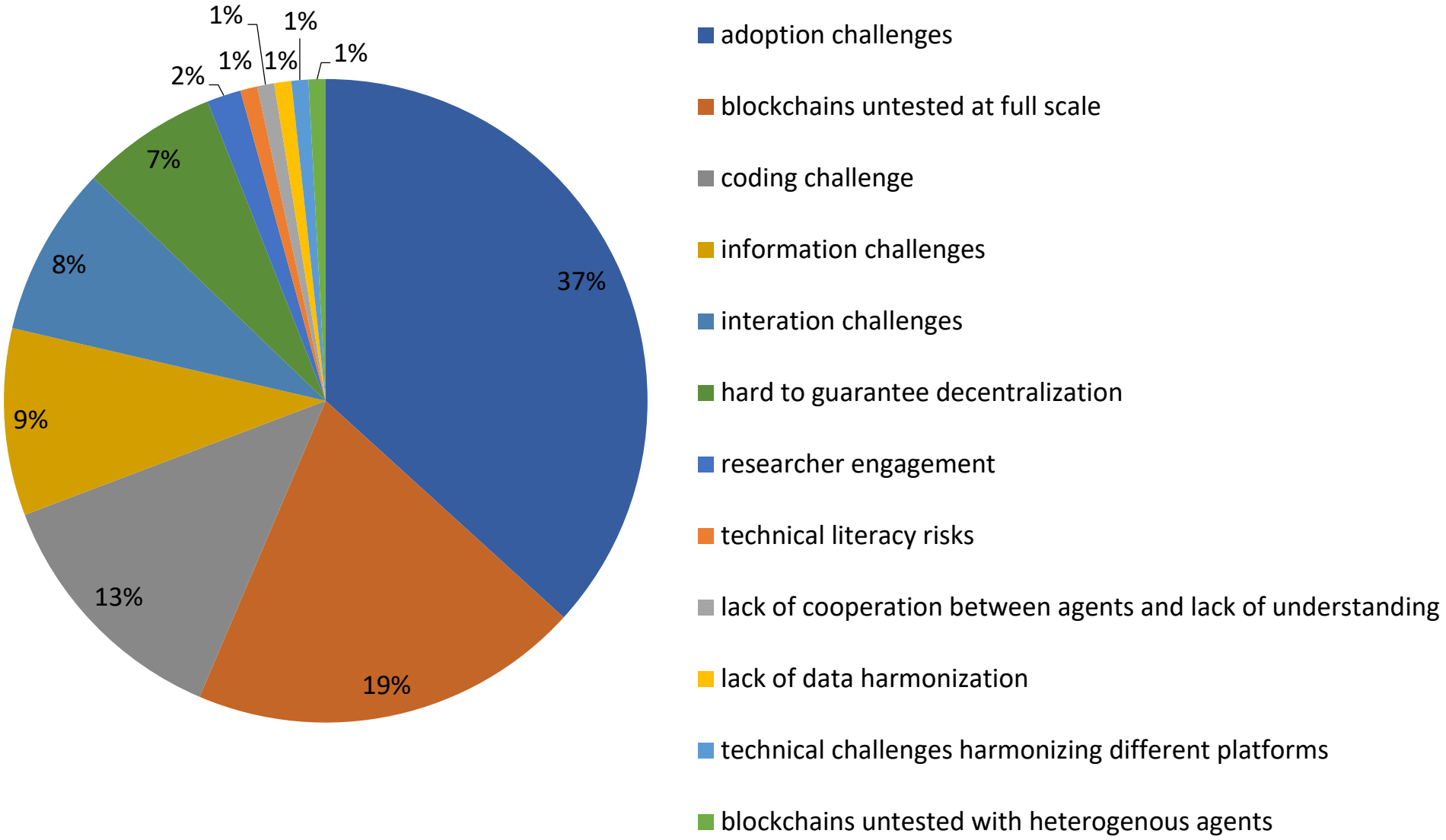
Risks


(36) novel multilateral financing mechanisms
(35) universal access to financing through direct transactions without third parties
(33) traceability of medical and healthcare-related data
(14) efficient data storage and oversight
(38) and the opportunity for open markets for healthcare data that drive discovery and innovation
(29) quick verification and document delivery
(22) increased trust due to better control procedures
(19) improved efficiency and quality while decreasing cost of healthcare delivered by professionals
(18) immutable trial history records provision
(17) homogenizing data schema
(9) efficient data sharing through public, private and hybrid ledgers
(7) data provenance, auditing, and control for shared medical data in cloud repositories among big data…
(15) harmonization of data systems
(2) blockchain-based notarization service that uses smart digital contracts to seal a biomedical database…
(12) drug discovery, biomarker development, and preventative healthcare
(34) transparency of data sharing
(30) patient data control through ability to organize, store, and share streams of data effectively and…
(25) distributed medical data management
(21) increased patient satisfaction
(16) health records' management
(13) efficient and secure information storage and sharing;
(3)comprehensive history of healthcare and studies
(26) patient data integration
(31) smart and personalized healthcare provision
(37) increased security and reduced fraud and corruption in healthcare
(10) digital healthcare ecosystem provision
(6) data ownership and data security
(1)effective access and data sharing & archiving
(20) increased accountability and scalability
(32) traceability and authenticity of patient records
(5) data harmonization
(27) patient-centric care
(24) master patient indices for data operations
(28) empowering patients to own, control, and share their data
(11) distributed network control over records
(8) data security and interoperability
(23) longitudinal patient records accumulation and storage
0%
1%
2%
3%
4%
5%
6%
7%
8%
9%
Frequency

Risks affecting blockchains for healthcare



Healthcare Blockchain Challenges



Types of blockchains

- *Permissionless* vs *Permissioned* blockchains
- *Public* vs *Private* (or *managed)*
  - While it is in principle possible to have a *permissionless* private chain, most of them are *permissioned*.
  - *Hybrid* blockchains run on a combination of public and private principles.
  - Usually in hybrid blockchains, individual transactions are ran instantaneously within private chains, yet, when further verification of the transaction is required, public chain mechanisms are used
- Majority of blockchain application for healthcare proposed in the literature have hybrid structures

Discussion

- There is a wide range of opportunities
- The whole Blockchain system may then be potentially affected by 18 major risks and suffer from 12 primary challenges.

Conclusions

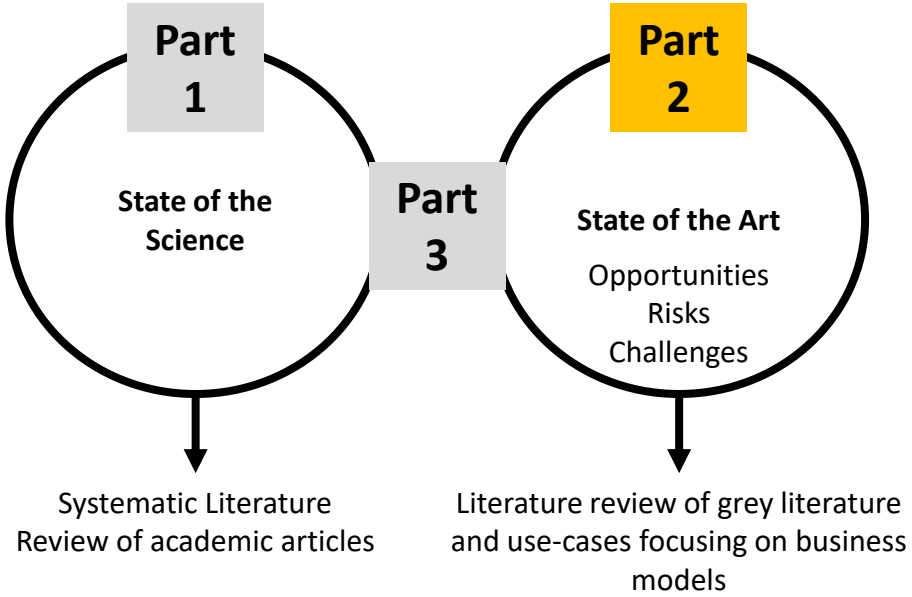
- blockchains may be instrumental in solving important problems such as:
  - data sharing, patient data security and strengthening trust in the healthcare provision systems.
- Lack of adoption and understanding of the technology by the stakeholders in the healthcare system
- Uncertainties associated with the use of the blockchain technology have not yet been given sufficient attention to support effective and beneficial implementations.

Blockchain as a panacea from all existing healthcare problems?

- Nope
- Should be treated as a useful tool, capable of contributing to many important and useful solutions, which may significantly improve patient wellbeing and simplify the tasks of the healthcare professionals.
- <u>This tool is not a must-use tool.</u>
  - Before implementing blockchain solutions, it is extremely important to engage into a comprehensive cost-benefit analysis and carefully understand the opportunities and risks which a specific technology implementation may bring to a specific context. This context-dependency often goes overlooked as blockchain and other AI-solutions often become hype buzz-words in many industries.

SLR Limitations & Mitigation

- despite careful quality appraisal and strict selection process used in our systematic literature review, individual claims are assumed as evidence
- This leads to the assumption that if multiple sources make the same claim, that claim is then representative of reality which may or may not be the case .
- Naturally, this risk is minor as we use scientific papers from peer-referees journals, where multiple reviews usually ensure quality control.



State of the Art

Grey Literature: Focus on Business Models

Grey Literature Sample

Business model

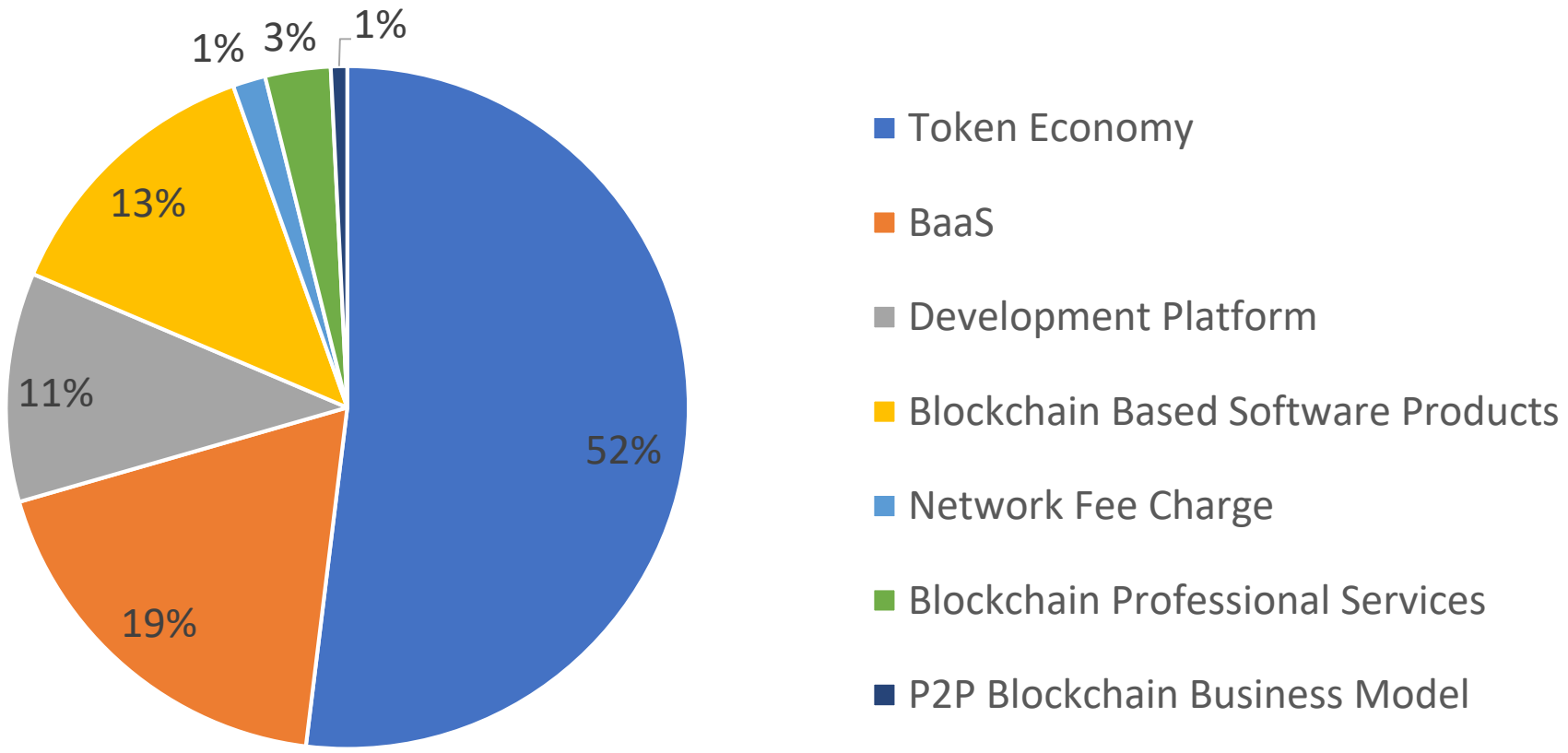
- *"a business model describes the value logic of an organization in terms of how it creates and captures customer value..."*
- Regulation of any technological and business ecosystem requires understanding of the logic behind the **value generation process**
- **Value is not the same as economic worth**
- **Value is realised in *use*** and this depends on the context of the application of the good or service

Value depends on context!

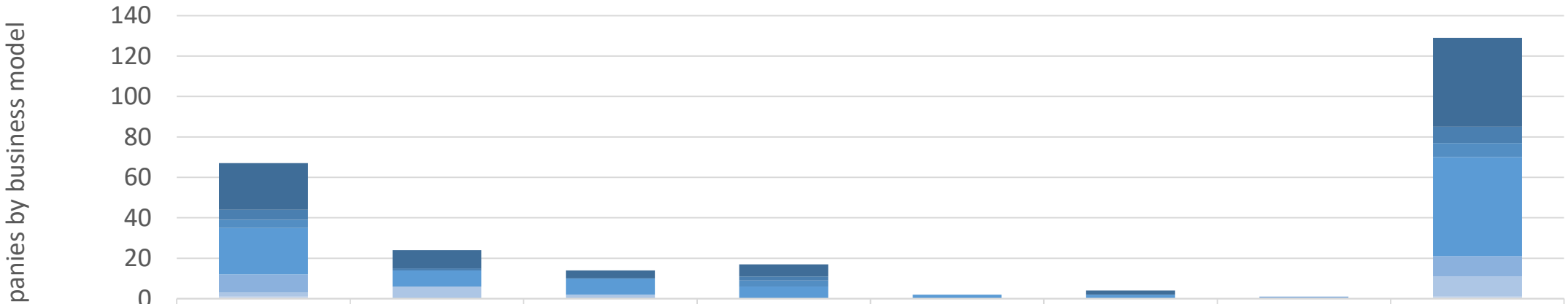
Summary of business models

Type	Blockchain Business Model	Summary
1	Token Economy	Utility tokens are the main “currency” which allow to perform transactions and incentivize all agents within the system.
2	Blockchain as a Service	BaaS generates an ecosystem for the benefit of various stakeholders making use of the blockchain technology.
3	Development Platforms	Blockchain technology stack are provided to stakeholders via this business model.
4	Blockchain Based Software Products	Blockchain solutions are developed by one set of agents in the system for sale to another set of agents
5	Network Fee Charge	In this model, blockchain users and stakeholders are changed a network fee, which allows to monetize the system.
6	Blockchain Professional Services	This model supports provisions of various professional services (auditing, development, etc.)
7	P2P Blockchain Business Model	Peer-to-peer model create direct markets where peer stakeholders engage in direct exchanges.

Healthcare Blockchains by Business Model Type

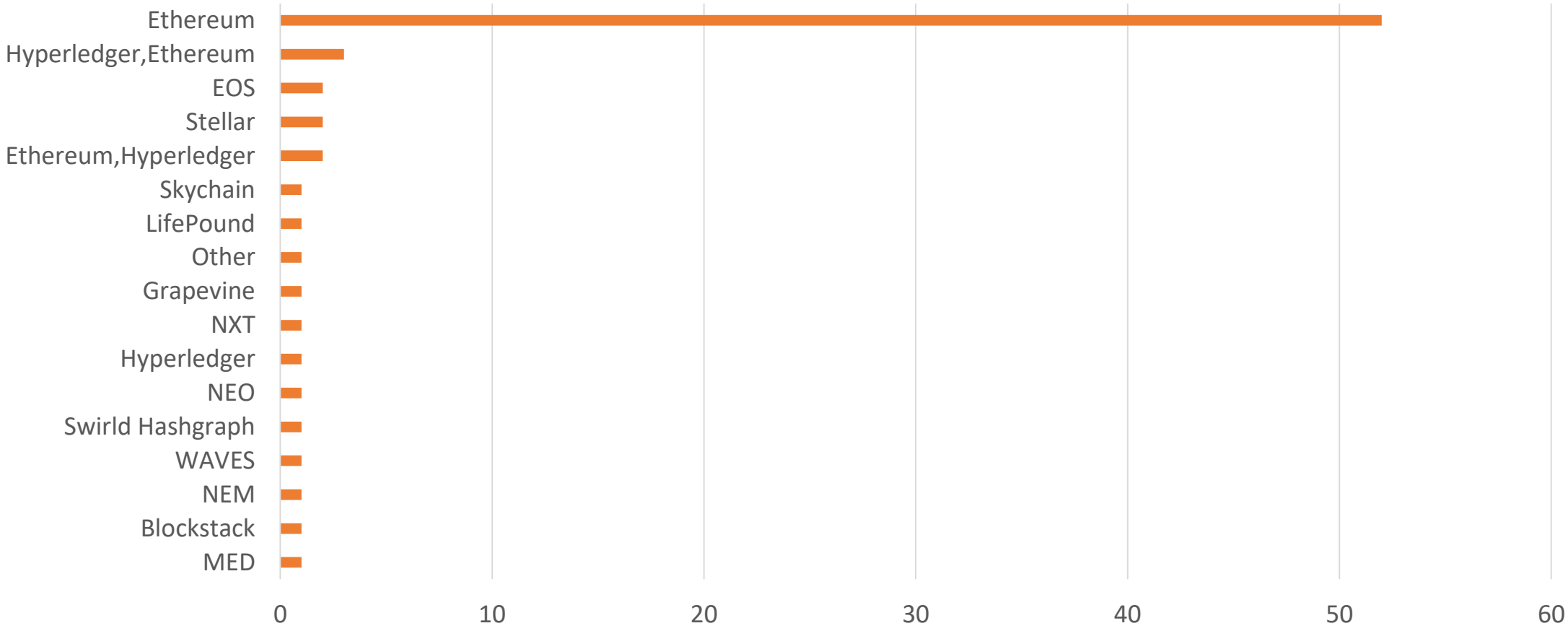


Healthcare Blockchains by Business Model Type and Maturity

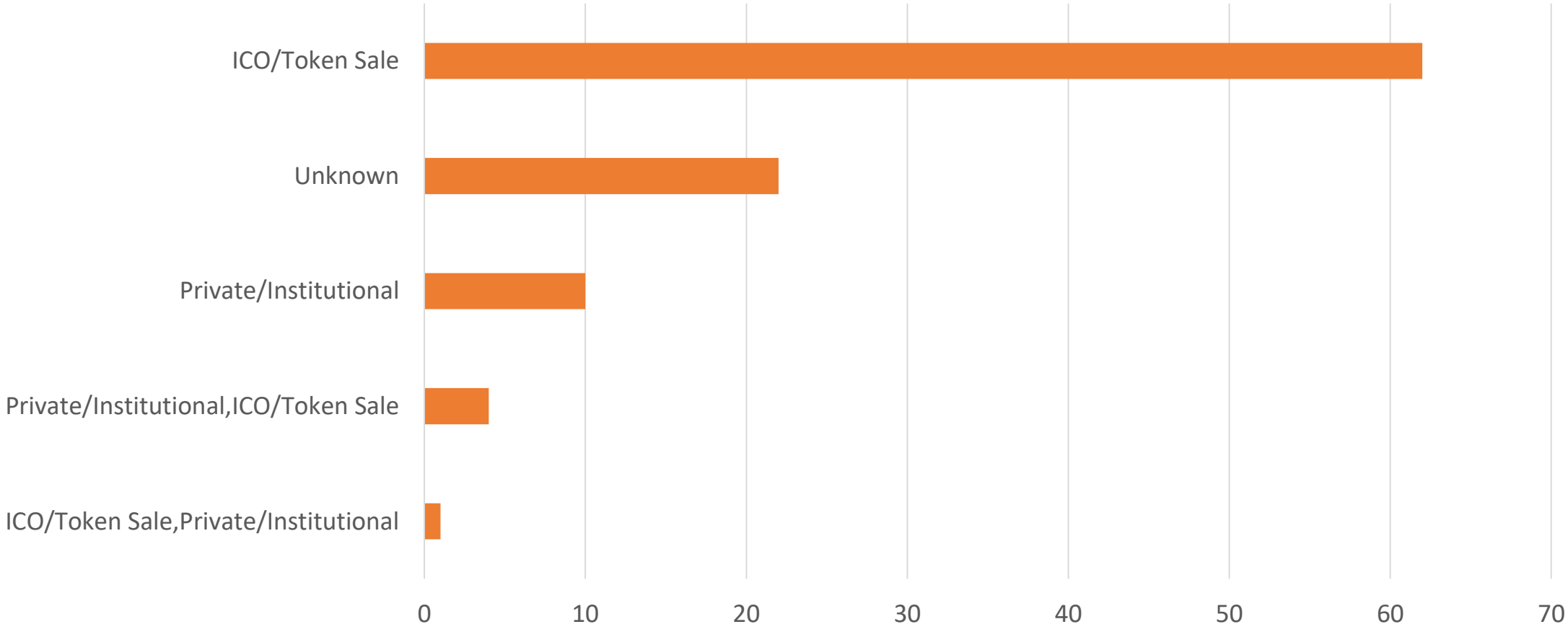


	Token Economy	BaaS	Development Platform	Blockchain Based Software Products	Network Fee Charge	Blockchain Professional Services	P2P Blockchain Business Model	Total
Available	23	9	4	6	0	2	0	44
Evaluation	5	1	0	2	0	0	0	8
Prototype	4	0	0	3	0	0	0	7
Concept	23	8	8	6	2	2	0	49
Pre-concept	9	0	0	0	0	0	1	10
Unknown	2	6	2	0	0	0	0	10
Scam	1	0	0	0	0	0	0	1

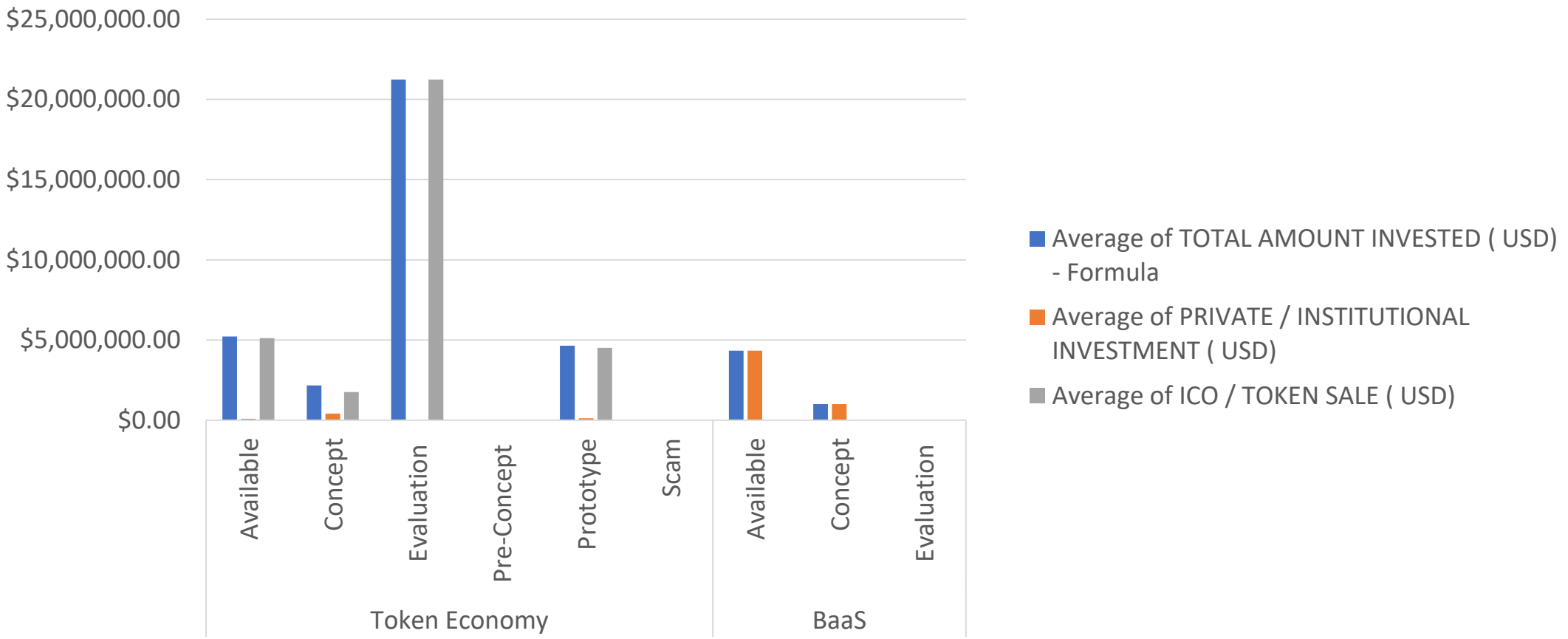
Platforms used



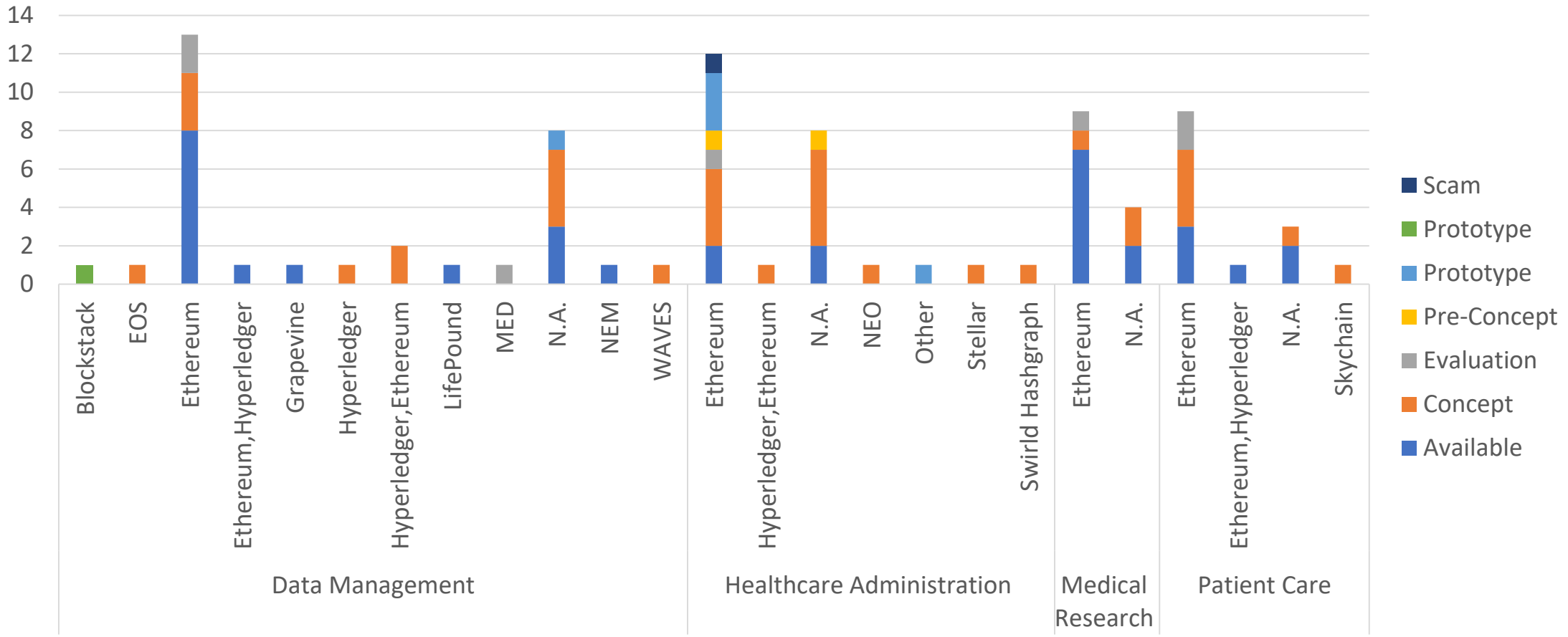
Funding method



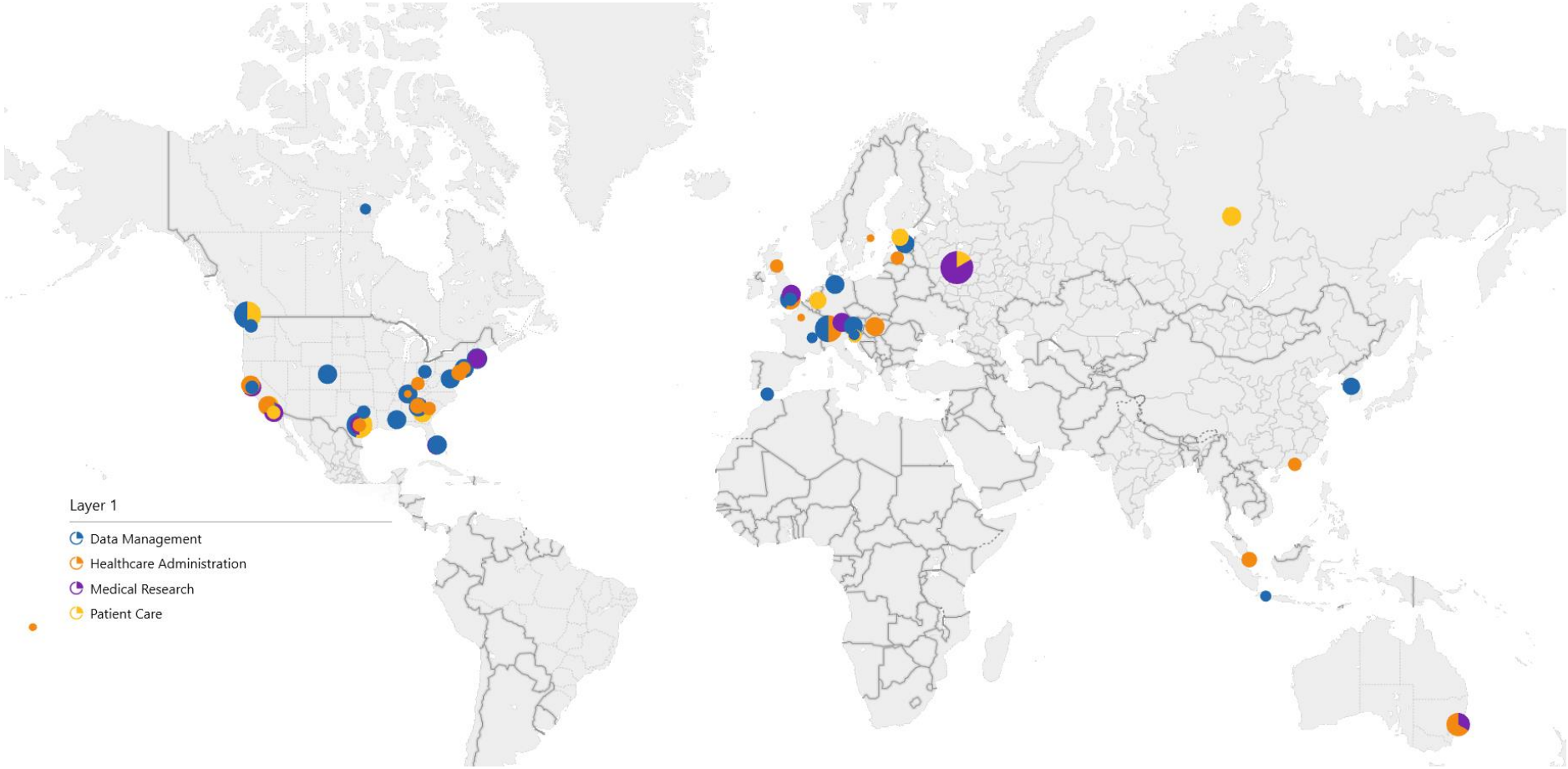
Average investment and maturity



Area of application, platforms and maturity

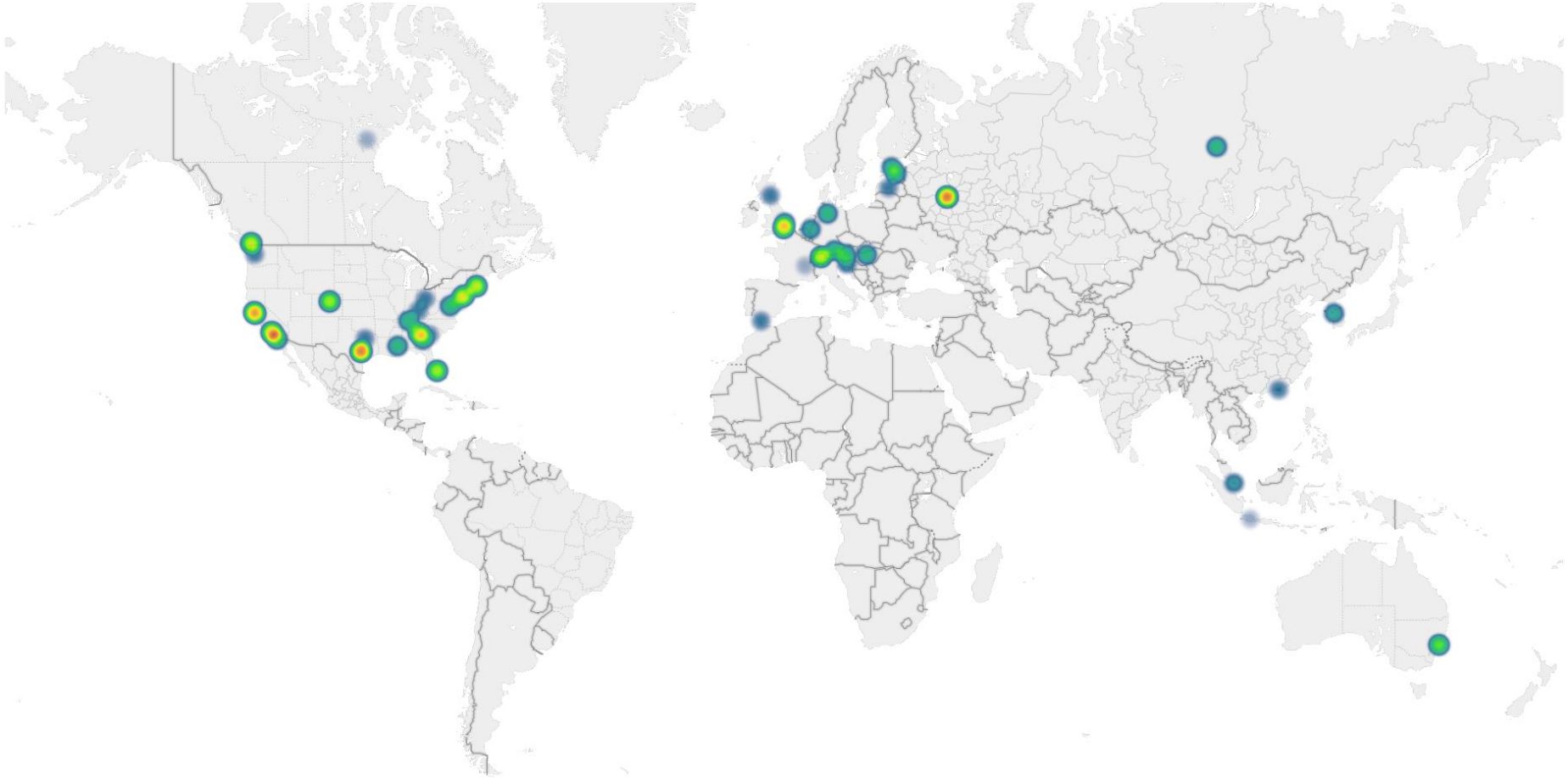


Geographic mapping of projects by application (mapping only available data)



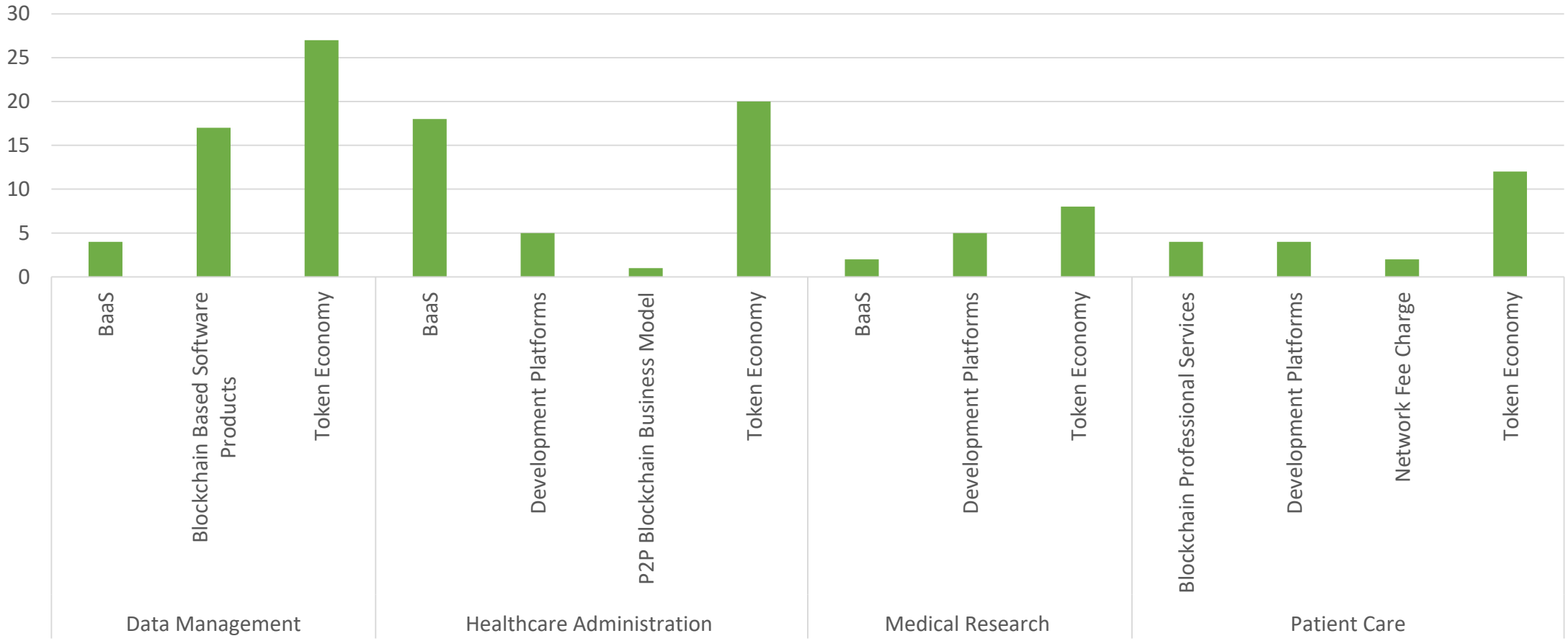
Geographic mapping of projects by business model (only available data)

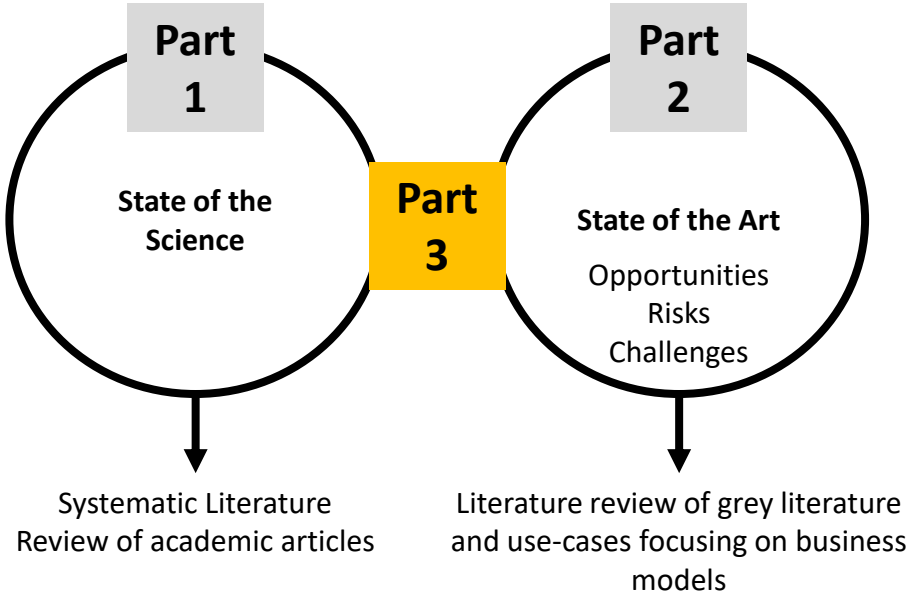
Geographic mapping of projects by maturity (only available data)



(heat corresponds to maturity level)

Business models and area of application





State of the Art vs State of the Science

Comparison

State of the Science

7 main problem variations, which healthcare blockchains are capable of solving:

- ***Data problems***
- *Security, Safety and Trust problems*
- *Computing and Sensing problems*
- ***Service Delivery problems***
- ***Verification problems***
- ***Financing problems***
- *Health-related fraud and corruption problems*

State of the Art

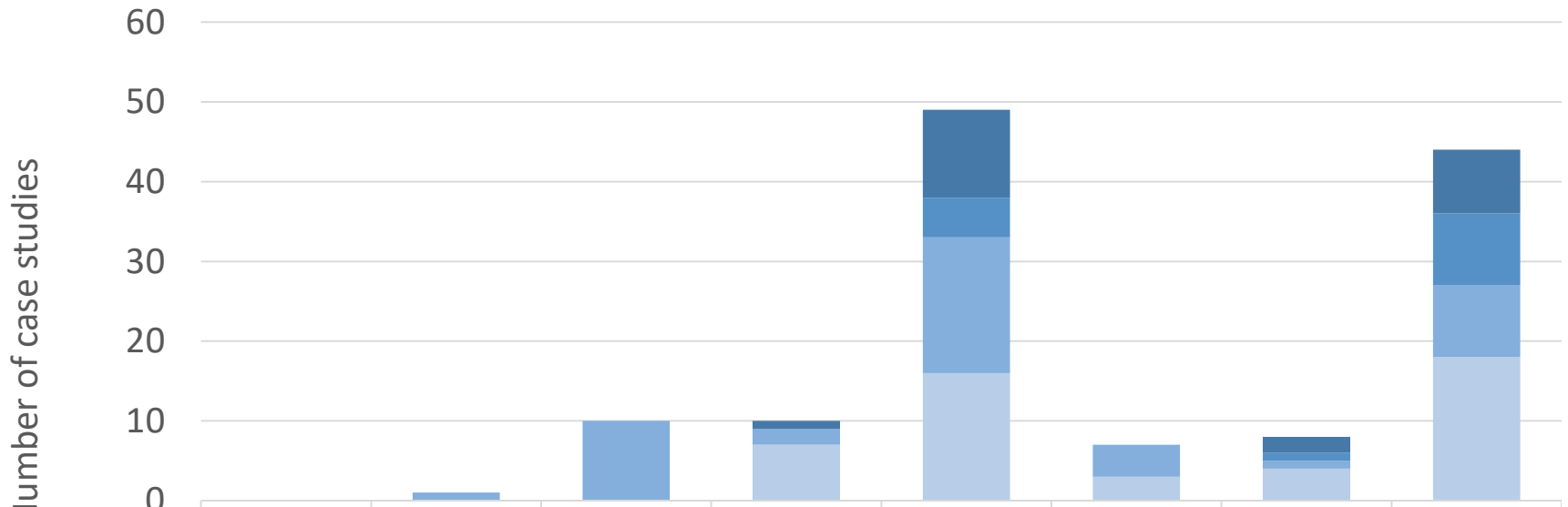
Only 4 of 7 variations are captured by the practice.

- ***Data Management*** applications provide an empirical mapping of ***Data*** **problems**
- ***Patient Care*** solutions capture ***Service Delivery*** **problems.**
- ***Medical Research*** implementations correspond primarily to ***Verification*** **problems**.
- **Healthcare Administration** solutions primarily map onto ***Financial*** **problems**.

Comparison

- Practical implementations do not leverage on the existing opportunities enough, the following categories do not receive sufficient attention of the practitioners :
  - *Security*
  - *Safety and Trust*;
  - *Computing and Sensing*;
  - *Health-Related Fraud and Corruption*.

State of the Science vs State of the Art



	Scam	Unknown	Pre-concept	Concept	Prototype	Evaluation	Available
Patient Care = Service Delivery	0	0	1	11	0	2	8
Medcal Research=Verification	0	0	0	5	0	1	9
Heathcare Administration=Financial	1	10	2	17	4	1	9
Data Management=Data	0	0	7	16	3	4	18

Conclusions

- Need to **match up a use case with a technical and non-technical solution** to the problem at hand.
- There must be a consideration of value when one considers the application
- Understanding trade-offs / for most cases blockchain is not necessary
- Innovators must have:
  - A deep understanding of the context. (It helps to have experience in healthcare)
  - An understanding of the technical options (beyond blockchain!)
  - Realisation that by solving the problem from a technical perspective it must lead to a new business model that is better than the one in place

Conclusion

- Blockchain offers a solution to a set of problems in healthcare
- Most of the opportunity lies in the administrative/financial/accounting/operations layer (not sexy)
- Due to limitations of blockchain, all other dimensions except administration are unlikely to benefit from blockchain applications: other technologies can be used to a better effect
- Blockchain applications can lead to systems rigidity that is bad for the users: good for administration/accounting, bad for clinical research or patient care
- Most blockchain solutions are not scalable and despite working at early stages they will fail later