Appendix to "Blockchain technology in operations & supply chain management: a content analysis"

Content

1. Detailed results of the CA

1.1 Results of the CA for the categories, subcategories and recording units

Preliminary remarks on the CA methodology:

- In the course of the auto-analysis, different spellings of recording units were considered and are indicated in the following comprehensive Table A1
- For some units of analysis, every word ending leads to the expected result. Therefore, we have included all of these word endings by using the word stem combined with an asterisk
- We ensured that the words are only counted in the relevant context through MAXQDA functionalities that allow counting words exclusively once they appear as whole words separately in the text
- The twelve categories of the developed framework are indicated in the first column with their subcategories in the second column. To explicitly include all industries at hand for the category 'industry focus', we used the NACE classification of the European Commission called 'EU Code A*38" (Eurostat 2008).
- The column "hits in the sample" indicates all hits for the specific recording unit(s) in the literature set, where several hits per document are also counted several times. The column "no. of articles" indicates the number of individual documents that contain the recording unit(s). The next column, "% articles", shows what percentage of the total item this represents. The last column, "hits per article", then provides information about the number of hits per article by dividing the total number of hits by the number of articles.

Table A1. Results of the CA for the categories, subcategories and recording units

Category	Subcategory	EU code A*38	Terms	Recording units	Hits in the sample	No. of articles	% of articles	Hits per article
Research focus	Operations management			operations management	109	40	12.6%	2.73
				manufacturing system*	38	20	6.3%	1.90
				operations strateg*	1	1	0.3%	1.00
	Supply chain management			supply chain management	1,058	216	67.9%	4.90
	Information systems			information system*	297	109	34.3%	2.72
Industry focus	Agriculture	A	Agriculture	agricult*, agri-cult*,	645	97	30.5%	6.65
				crop, seed*	259	35	11.0%	7.40
				animal*	104	33	10.4%	3.15
				agrifood*, agri-food*	428	52	16.4%	8.23
			Forestry	forest*	57	16	5.0%	3.56
				tree*	265	61	19.2%	4.34
			Fishing	fishing	52	15	4.7%	3.47
				aquacultur*	6	4	1.3%	1.50
	Mining	B	Mining	mining industr*	2	1	0.3%	2.00
				quarrying	2	2	0.6%	1.00
	Food	CA	Food	food*	2,883	201	63.2%	14.34
				meat	81	44	13.8%	1.84
				fruit*	82	38	11.9%	2.16
			Beverage	beverage*	46	19	6.0%	2.42
				wine	135	30	9.4%	4.50
				beer	2	2	0.6%	1.00
				drink*	16	10	3.1%	1.60
			Tobacco	tobacco	45	4	1.3%	11.25
	Textiles	CB	Textiles	textile*	96	15	4.7%	6.40
				apparel	121	19	6.0%	6.37
				leather	6	5	1.6%	1.20
				fast fashion	24	3	0.9%	8.00
	Wood	CC	Wood	wood*	81	21	6.6%	3.86
				paperwork*, paper-base*	123	42	13.2%	2.93
	Chemicals	CE		chemical	87	53	16.7%	1.64
	Pharmaceutical	CF		pharma*	620	78	24.5%	7.95
				drug*	945	51	16.0%	18.53

Category	Subcategory	EU code A*38	Terms	Recording units	Hits in the sample	No. of articles	% of articles	Hits per article
				medicine*	223	58	18.2%	3.84
	Metal	CH		metal, steel	51	16	5.0%	3.19
	Electronics	CI		electronics	185	30	9.4%	6.17
	Electricity	D		electric*	132	58	18.2%	2.28
				grid	96	33	10.4%	2.91
				energy	552	126	39.6%	4.38
	Water supply	E		Water	93	48	15.1%	1.94
				sewerage	2	2	0.6%	1.00
	Construction	F		construction	386	80	25.2%	4.83
	Wholesale	G		wholesale	473	74	23.3%	6.39
				retail	275	91	28.6%	3.02
	Transportation	H		transportation	1,578	174	54.7%	9.07
				railway	10	6	1.9%	1.67
				train	609	142	44.7%	4.29
				truck*	178	56	17.6%	3.18
				logistic industr*, logistics industr*	151	31	9.7%	4.87
	Financial	K		financial industr*, financial institut*	81	33	10.4%	2.45
				insurance	133	69	21.7%	1.93
				bank*	446	123	38.7%	3.63
				trade	1,304	188	59.1%	6.94
	Real estate	L		real estate	30	21	6.6%	1.43
				housing	146	60	18.9%	2.43
				land	58	38	11.9%	1.53
	Other	MA	Legal	legal	444	142	44.7%	3.13
				law*	281	99	31.1%	2.84
			Multimedia	media	240	49	15.4%	4.90
			Humanitarian	humanitarian	325	18	5.7%	18.06
	Public administration	O		public service	60	11	3.5%	5.45
				administration	98	55	17.3%	1.78
	Education	P		education	104	50	15.7%	2.08
				school	49	23	7.2%	2.13
	Human health services	QA		health care	37	19	6.0%	1.95
	Arts	R		arts	4	4	1.3%	1.00
				paint*	12	8	2.5%	1.50
	Automotive			car*	59	24	7.5%	2.46

Category	Subcategory	EU code A*38	Terms	Recording units	Hits in the sample	No. of articles	% of articles	Hits per article
				automotive	55	32	10.1%	1.72
				vehicle*	289	82	25.8%	3.52
				batter*	30	11	3.5%	2.73
	Aeronautics			aeronautic, aerospace	43	9	2.8%	4.78
				aircraft*, airplane*	84	19	6.0%	4.42
				drone*	46	9	2.8%	5.11
				space	386	92	28.9%	4.20
				satellite*	18	10	3.1%	1.80
	Defense			defense	20	15	4.7%	1.33
				military	17	11	3.5%	1.55
				firearm	0	0	0.0%	0.00
	Engineering			engineering	295	100	31.4%	2.95
	Maritime			ship*	265	67	21.1%	3.96
				vessel*	64	13	4.1%	4.92
	Petroleum			petrol*	4	4	1.3%	1.00
				oil	114	58	18.2%	1.97
	Postal			postal	12	5	1.6%	2.40
				parcel*	20	12	3.8%	1.67
	Tourism			tourism	46	13	4.1%	3.54
				travel	53	40	12.6%	1.33
Methods	Conceptual research			conceptual	370	128	40.3%	2.89
				framework	1.463	235	73.9%	6.23
				content analysis	9	7	2.2%	1.29
				bibliometric*	4	4	1.3%	1.00
	Survey research			survey*	393	99	31.1%	3.97
				questionnair*	114	38	11.9%	3.00
	Qualitative research			empirical	347	88	27.7%	3.94
				interview*	602	50	15.7%	12.04
				Delphi	136	13	4.1%	10.46
				DEMATEL	166	14	4.4%	11.86
				focus group*	34	6	1.9%	5.67
				panel*	162	20	6.3%	8.10
	Case study and action research			case stud*	488	99	31.1%	4.93
				action research	8	5	1.6%	1.60

Category	Subcategory	EU code A*38	Terms	Recording units	Hits in the sample	No. of articles	% of articles	Hits per article
	Archival research			secondary data	25	10	3.1%	2.50
				archival research	0	0	0.0%	0.00
	Simulation			simulation*	310	76	23.9%	4.08
	Optimization			optimization	201	73	23.0%	2.75
				heuristic*	4	4	1.3%	1.00
Theories	Transaction cost theory			transaction cost theory, transaction cost analysis, TCT, TCA	65	9	2.83%	7.22
	Resource-based view of the firm			resource based view, resource-based view, RBV	102	16	5.0%	6.38
	Market-based view			market based view, market-based view, MBV	10	4	1.3%	2.50
	Principal-agent theory			principal agent theory, principal-agent, PAT	45	8	2.5%	5.63
	Institutional theory			institutional theory	12	7	2.2%	1.71
	Network theory			network theory	19	10	3.1%	1.90
	Information theory			information theory	3	2	0.6%	1.50
	Innovation diffusion theory			innovation diffusion theory	10	9	2.8%	1.11
	Dynamic capability theory			dynamic capability theory	9	3	0.9%	3.00
	Technology adoption model			technology adoption model, TAM, TAM2	141	17	5.3%	8.29
	Technology-organization-environment framework			technology-organization-environment, TOE	87	11	3.5%	7.91
Interfaces	Internet of Things			Internet of things, IoT	2.161	183	57.5%	11.81
				smart device*	31	19	6.0%	1.63
	Artificial intelligence			artificial intellig*, AI	250	51	16.0%	4.90
				cognitive	59	14	4.4%	4.21
				neural	30	10	3.1%	3.00
	Big data analytics			big data, BDA	379	94	29.6%	4.03
				advanced analytic*	1	1	0.3%	1.00
				data mining	14	12	3.8%	1.17
				data science	15	5	1.6%	3.00
	Cloud computing/manufacturing			cloud comput*	101	59	18.6%	1.71
				cloud manufacturing	18	7	2.2%	2.57
				cloud system	8	3	0.9%	2.67
	Additive manufacturing			Additive manufacturing	51	14	4.4%	3.64

Category	Subcategory	EU code A*38	Terms	Recording units	Hits in the sample	No. of articles	% of articles	Hits per article
				3D print*	51	16	5.0%	3.19
	Cyber-physical systems			cyber physical*, cyber-physical*, CPS	72	21	6.6%	3.43
	Robotic process automation			robotic process automation, RPA	0	0	0.0%	0.00
	Industry 4.0			Industry 4.0	221	53	16.7%	4.17
				machine-to-machine, M2M	32	10	3.1%	3.20
	RFID			RFID, radio frequency, radio-frequency	1.270	162	50.9%	7.84
	Robots			robots	13	8	2.5%	1.63
				cobots, collaborative robots	0	0	0.0%	0.00
	Cybersecurity			cybersecurity, cyber security	67	25	7.9%	2.68
Business Areas	Strategic management			strategic management	4	4	1.3%	1.00
	Procurement, logistics and distribution			procurement	218	85	26.7%	2.56
				warehousing	135	54	17.0%	2.50
				inventory management	70	43	13.5%	1.63
				logistics	3.653	226	71.1%	16.16
				distribution	885	219	68.9%	4.04
				transportation	1.578	174	54.7%	9.07
	Supply chain risk management			supply chain risk*, SCRM	116	24	7.5%	4.83
	Operations			manufacturing	1.434	188	59.1%	7.63
				production	1.667	230	72.3%	7.25
	Finance and accounting			finance	475	132	41.5%	3.60
				accounting	180	64	20.1%	2.81
				supply chain finance	166	36	11.3%	4.61
	Marketing and sales			marketing, sales, aftersales	575	129	40.6%	4.46
Potential	Trust			trust*	3.250	281	88.4%	11.57
	Security			security, immutability	2.494	269	84.6%	9.27
	Transparency			transparency	1.886	267	84.0%	7.06
	Traceability			trace*, track and trace, tracking	4.744	280	88.1%	16.94
	Disintermediation			disintermediat*, intermediar*	645	146	45.9%	4.42
	Cost savings, increased efficiency			costs, efficien*	3.466	274	86.2%	12.65
	Collaboration			collaboration, collaborate	530	128	40.3%	4.14
	Information sharing			information sharing	428	110	34.6%	3.89
	Decentralization			decentralization, decentralized, DApp	1.380	225	70.8%	6.13

Category	Subcategory	EU code A*38	Terms	Recording units	Hits in the sample	No. of articles	% of articles	Hits per article
	Tokenization			tokenization	25	12	3.8%	2.08
	Autonomy			autonomy	21	15	4.7%	1.40
	Smart contracts			smart contract*	3.322	256	80.5%	12.98
Barriers	Awareness			aware*	291	101	31.8%	2.88
	Network setup			network setup, network cost, setup cost	22	7	2.2%	3.14
	Know-How			know-how, expertise, skill	215	47	14.8%	4.57
	Data disclosure			data disclosure, reluctance	16	11	3.5%	1.45
	Missing management support			top management support	44	12	3.8%	3.67
	Lack of trust			lack of trust	81	48	15.1%	1.69
	Unclear governance			governance	412	91	28.6%	4.53
	Missing standards			missing standard, no standard, standardization, standardisation	203	83	26.1%	2.45
	Legal uncertainties			legal issue*, legal uncertain*, legal compliance*, legal concern*	23	8	2.5%	2.88
	Regulatory uncertainties			regulatory*	401	106	33.3%	3.78
Adoption	Proof of concept			proof of concept, POC	94	29	9.1%	3.24
	Use case			use case*	532	107	33.6%	4.97
	Productive application			productive use, productive application	9	2	0.6%	4.50
Consensus	Proof-of-Work			Proof-of-Work, POW	191	54	17.0%	3.54
	Proof-of-Stake			Proof-of-Stake, POS	100	39	12.3%	2.56
	Proof-of-Authority			Proof-of-Authority, POA	68	12	3.8%	5.67
	Byzantine Fault Tolerance			Byzantine Fault Tolerance, BFT	97	44	13.8%	2.20
	Proof-of-Elapsed-Time			Proof of Elaps*, POET	55	13	4.1%	4.23
Platform	Ethereum			Ether*	1.003	159	50.0%	6.31
	Bitcoin			Bitcoin*	791	221	69.5%	3.58
	Hyperledger			Hyperledger	580	104	32.7%	5.58
	Multichain			Multichain	10	9	2.8%	1.11
	R3 Corda			Corda	12	10	3.1%	1.20
	Public blockchain			public blockchain	260	99	31.1%	2.63
	Private blockchain			private blockchain	245	83	26.1%	2.95
	Permissioned			permissioned	383	105	33.0%	3.65
	Permissionless			permissionless	103	49	15.4%	2.10
	Consortium			consort*	476	94	29.6%	5.06
Other	Green			green	487	71	22.3%	6.86

Category	Subcategory	EU code A*38	Terms	Recording units	Hits in the sample	No. of articles	% of articles	Hits per article
	Sustainability			sustainabil*	809	109	34.3%	7.42
	Environment			environmental	582	119	37.4%	4.89
	Cryptocurrencies			cryptocurrenc*	489	135	42.5%	3.62

1.2 Visualization of different categories and hits for the recording units in these categories
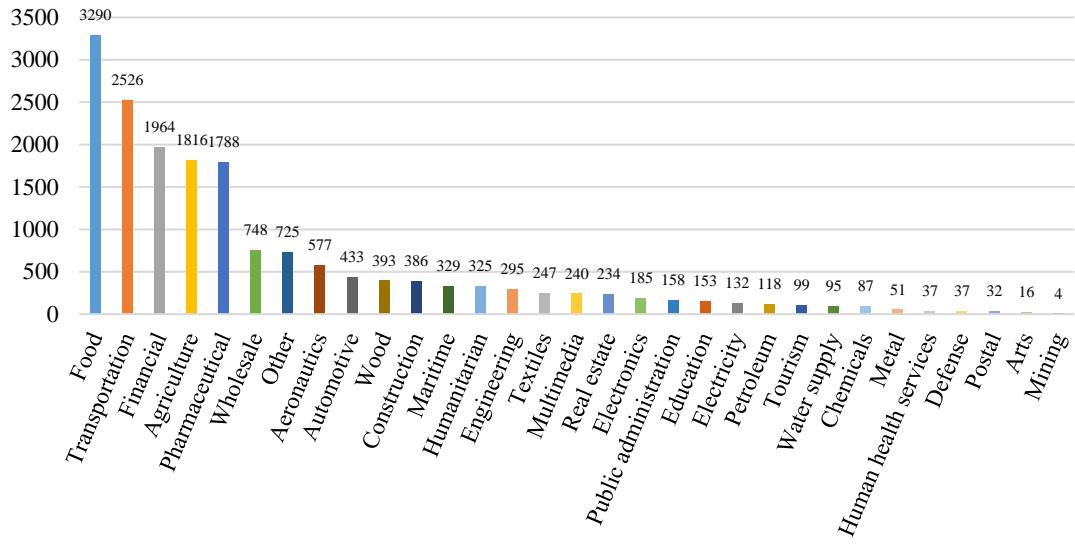
Figure A1. Hits for the category 'industry focus'
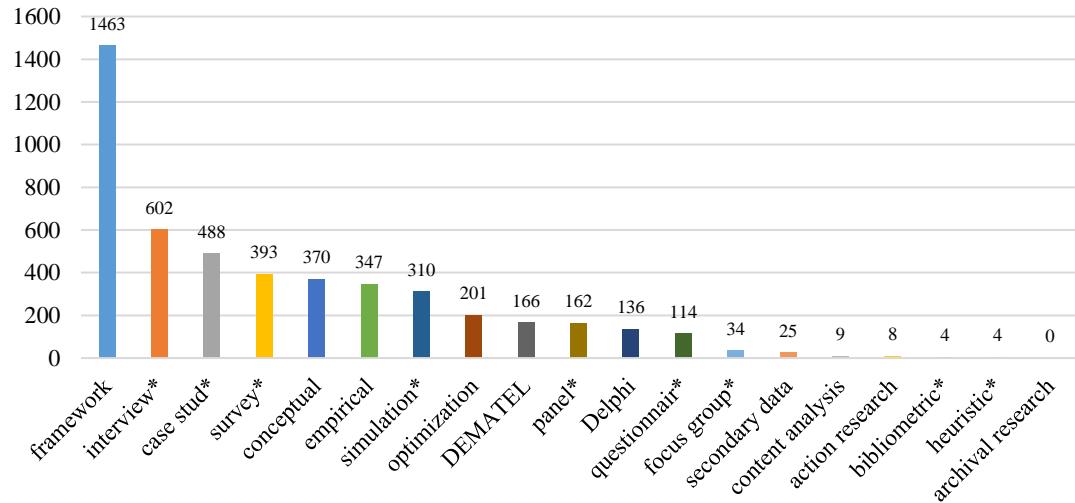
Figure A2. Recording unit hits in the category 'methods'

Table A2. Top 10 recording unit hits per article

#	Recording unit(s)	Hits per article	No. of articles	Hits	Category
1	drug	18.53	51	945	Industry focus
2	humanitarian	18.06	18	325	Industry focus
3	tracking and tracing	16.95	280	4,746	Potential
4	logistics	16.23	226	3,667	Business areas
5	food	14.35	201	2,885	Industry focus
6	smart contracts	12.98	256	3,322	Potential
7	cost savings, increased efficiency	12.65	274	3,466	Potential
8	interview	12.04	50	602	Methods
9	DEMATEL	11.86	14	166	Methods
10	Internet of things, IoT	11.81	183	2,161	Interfaces
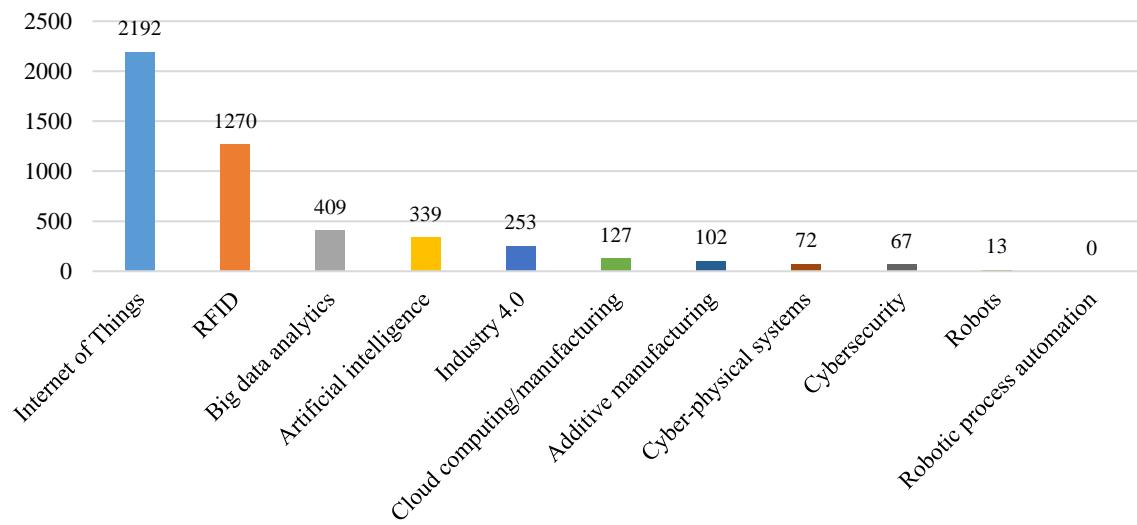
Figure A3. Number of hits in the category 'interfaces'
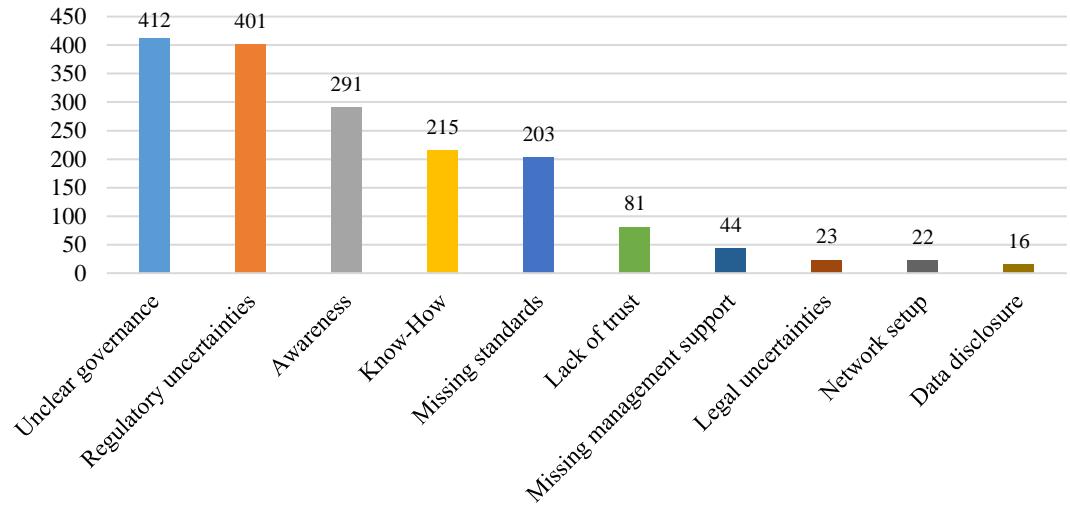
Figure A4. Number of hits in the category 'barriers'
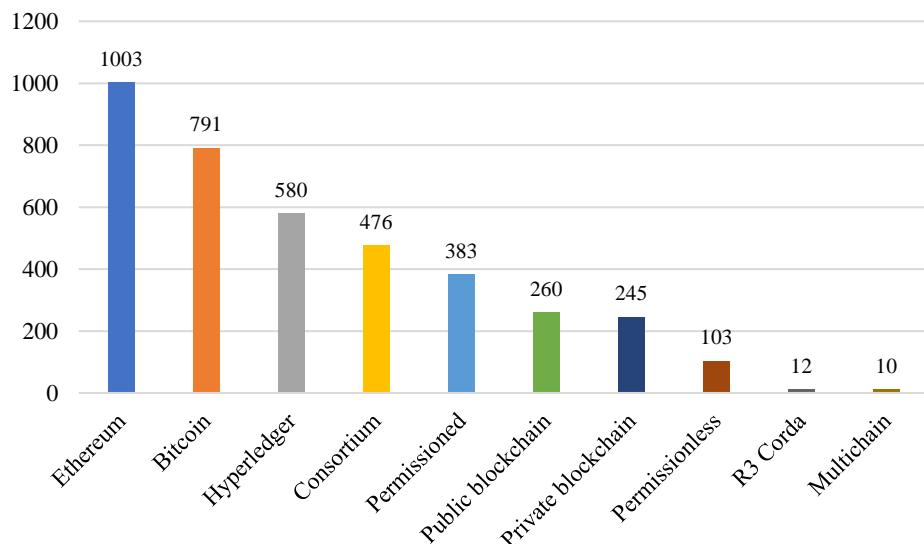
Figure A5. Number of hits in the category 'platform'
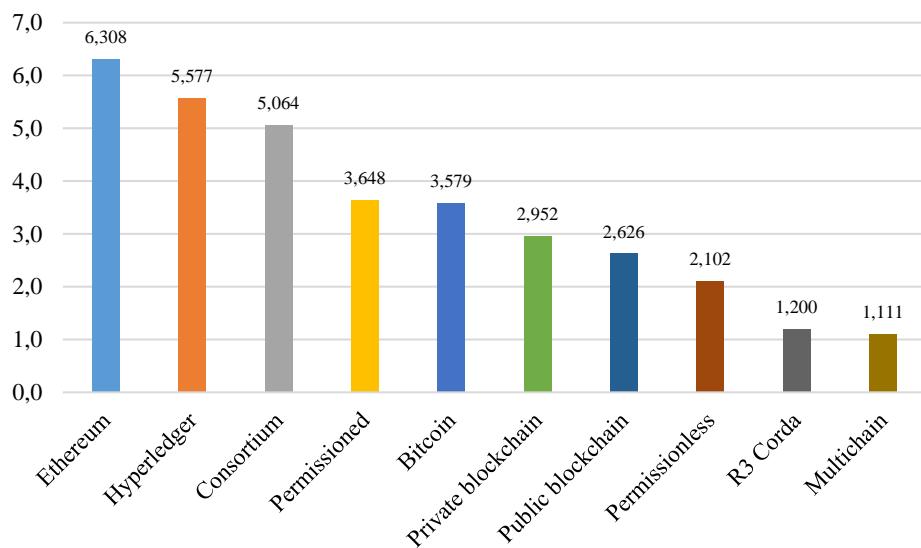
Figure A6. Hits per article for the subcategories in 'platform'

1.3 Keyword analysis

We also used the import feature of the MAXQDA software to analyze the .ris-file generated from all 318 documents that includes the keywords of each article. After filtering out single descriptors like "4.0", the word cloud in Fig. A7 was generated. The thickness of the font represents the frequency of the keywords. Consistent with the recording units, a focus on SCM and IoT can be identified. Frequently mentioned methods include design science, game theory, structural equation, and literature review. Industries in the research focus include food, agricultural or pharmaceutical supply chains. Potentials or application areas of the technology were indicated by information sharing, traceability systems, supply chain visibility, supply chain finance, inventory control, and decision making.

Figure A7. Word cloud of keywords used in the literature set

2. Existing literature reviews on blockchain technology in OM & SCM (tertiary analysis)

Several literature reviews have been published on blockchain technology in OM & SCM, each focusing on specific aspects. Table A3 summarizes the relevant information, including author names, publication year and journal, date of acceptance and publication, search dates, search strings, restrictions, and databases used.

Wamba et al. (2020) combine a literature review on bitcoin, blockchain, and fintech with a case-study approach and use a framework to classify the identified material. As the literature set is heterogeneous due to the three independent search terms, the authors only find five articles with SC reference and two with OM reference (search included articles until Dec 2017). More than 40% of the identified 141 articles deal with financial services. For the supply chain context, the authors conclude that blockchain reduces fraud and improves proof of origin tracking through

an immutable shared transaction, increases transparency in the chain, and may reduce transaction costs by disintermediation.

Wang et al. (2019) proposed another review with a narrower focus on SCM, where the authors aimed to identify drivers to blockchain deployment, valuable topics for blockchain use, barriers to technology diffusion, and a future research agenda. Piloting cases from industry were used as a supplement to the 29 selected academic articles (search until Jan 2018), which were mostly predictive and prescriptive. The main drivers of blockchain deployment are trust, SC transparency, as well as public and product safety. Areas with potential include product traceability, SC visibility, disintermediation, data security, and smart contracts, while challenges persist in the organizational, technical, and operational domains.

Queiroz et al. (2019) assessed current blockchain applications in SCM and the major disruptions in SCM due to blockchain adoption. The identified 27 articles (until Feb 2018) were mainly conceptual, framework proposals, and case studies. The main contexts for application were the electric power industry and the pharmaceutical supply chain. Disruptions were identified as disintermediation, automation through smart contracts, increased network transparency, and new business models. The authors conclude with future research opportunities related to empirical studies, governance models, and blockchain integration with smart production and IoT in the OM area.

Gurtu and Johny (2019) identified 25 articles with the keywords "supply chain" or "logistics" in their search up until Dec 2018. The authors discovered an increasing trend of articles with an SCM focus and constituted increasing trust as the technology's greatest potential.

Pournader et al. (2020) highlighted four clusters they identified in their literature set of 48 articles (until Oct 2018) on blockchain technology in the supply chain, logistics, and transport: technology, trust, trade, and traceability/transparency. The authors outlined the recent research efforts, the relevance, and implications for each cluster.

Frizzo-Barker et al. (2020) focused on business-related applications and themes of blockchain technology. Nearly three-quarters of articles in their literature set of 155 articles (until Dec 2018) were conceptual, while empirical research remained scarce. Concerning the distribution of topics, a similar picture emerges as in Wamba et al. (2020): financial topics are most strongly represented, while only nine papers relate to SCM or OM. However, the authors highlighted the significance of the domain, as evidenced by various industry use cases and initiatives.

Recently, Kummer et al. (2020) aimed at identifying the organizational theories applied in blockchain-SCM research, where transaction cost theory, principal-agency theory, network theory, resource-based view, information theory, and institutional theory were found in decreasing order of significance. The authors call for more interdisciplinary research to strengthen the theoretical foundation of research on blockchain technology.

Other articles with viewpoints and implications for blockchain technology are available but only referenced here for further reading due to space restrictions (refer to Treiblmaier 2018; Ivanov et al. 2019; Olsen and Tomlin 2020; Babich and Hilary 2020; Müßigmann et al. 2020; Bodkhe et al. 2020).

Table A3. Summary of existing literature reviews on blockchain technology in SCM & OM

Author	Journal and publication year	Accepted	Published online	Search until	Quantity of relevant articles	Search Strings	Search limitations	Databases
Wamba et al.	Production Planning and Control, 2020	03.08.2018	04.12.2019	Dez 17	141 of 314	Blockchain OR Bitcoin OR Fintech	All Content	ABI/INFORM Complete, Academic Search Complete, Emerald Journals, JSTOR and ScienceDirect
Wang et al.	Supply Chain Management, 2019	04.10.2018	14.01.2019	Jan 18	29 of 227	blockchain or "digital ledger" or "distributed ledger" or "shared ledger" consists of "logistics", "supply chain", "demand chain" and "value chain"	All Content	ABI Inform Global, Emerald, IEEE Explore, Jstor, Science Direct, Scopus, Springer, Taylor and Francis and Web of Science
Queiroz et al.	Supply Chain Management, 2019	06.12.2018	22.08.2019	Feb 18	27 of 92	blockchain AND (supply AND chain) OR logistics OR manufacturing OR transportation OR purchasing OR (smart AND contracts) OR (suppliers) OR (green AND supply AND chain) OR (sustainability) OR (environment) OR (production AND systems) OR (industry 4.0) OR (iot OR internet AND of AND things) OR (cps OR cyber AND physical-systems) OR (bda OR big AND data)	Title, abstract and keywords	Scopus, ScienceDirect (Elsevier); Emeraldinsight (Emerald); Wiley Online Library (Wiley); Taylor & Francis Online (Taylor & Francis); Sagepub (Sage Journals); IEEE Xplore Digital Library (IEEE); and Springer Link (Springer)
Gurtu & Johny	International Journal of Physical Distribution and Logistics Management, 2019	10.07.2019	29.11.2019	Dec 18	30 of 299	"blockchain"	Title, abstract and keywords	EBSCO Premium
Pournader et al.	International Journal of Production Research, 2020	16.07.2019	11.08.2019	Oct 18	48 of 132	blockchain OR distributed ledger OR smart contract AND supply chain OR logistics OR transport	Title, abstract and keywords	Scopus
Frizzo-Baker et al.	International Journal of Information Management, 2020	22.10.2019	11.11.2019	Dec 18	155 of 529	"blockchain"	Title, abstract and keywords	Business Source Complete, SpringerLink, and Web of Science,
Kummer et al.	Future Internet, 2020	21.03.2020	23.03.2020	Jan 20	22 of 228	"blockchain" AND "logistics" OR "SCM" OR ("supply chain") OR "transport"	Abstract	EBSCO Business Source Complete, (ISI) Web of Knowledge (Social Sciences Citation Index (SSCI)-Database)

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Bodkhe U, Tanwar S, Parekh K, Khanpara P (2020) Blockchain for Industry 4.0 : A Comprehensive Review. IEEE Access 8:. doi: 10.1109/ACCESS.2020.2988579

Frizzo-Barker J, Chow-White PA, Adams PR, et al (2020) Blockchain as a disruptive technology for business: A systematic review. Int J Inf Manage 51:0–1. doi: 10.1016/j.ijinfomgt.2019.10.014

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3. Full reference list of the final literature sample and PRISMA chart

This section contains the full reference list for the final literature sample used in the content analysis process. The list of all 421 assessed articles is available on request from the corresponding author. Figure A8 below further details the literature search process following the PRISMA flow chart style.
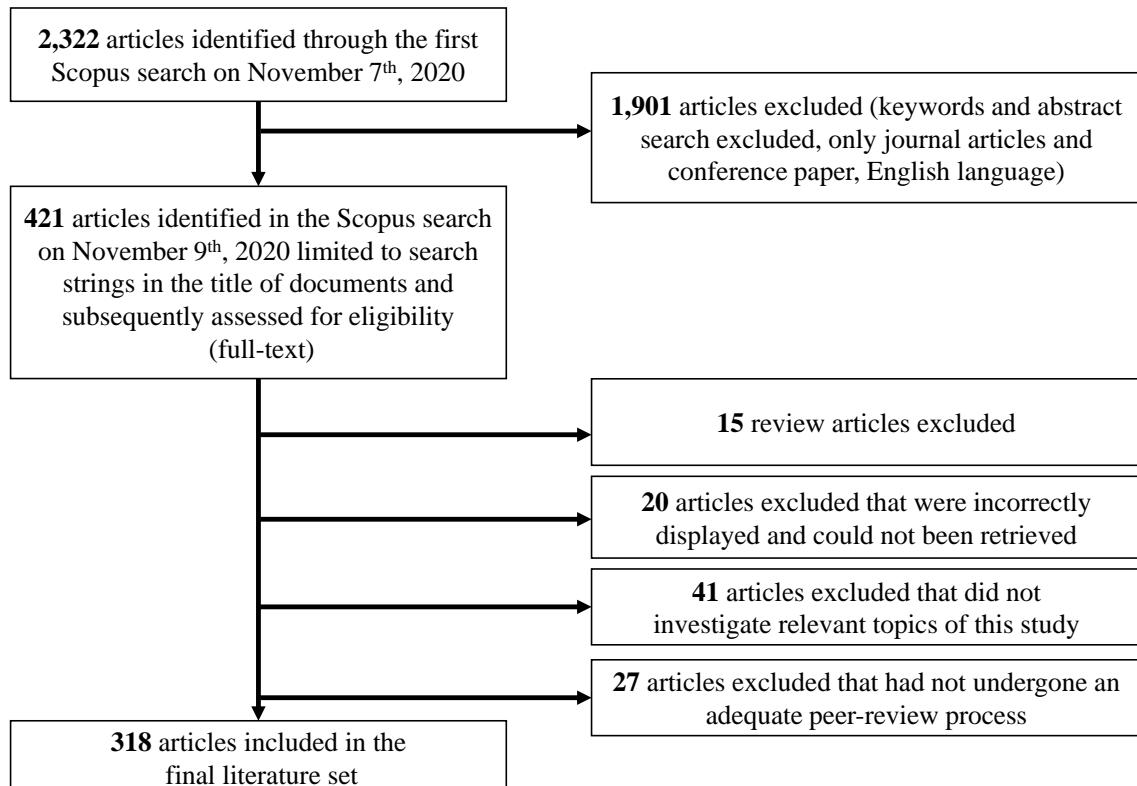

Figure A8. Literature search process

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