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A Knowledge Graph Perspective on Supply Chain Resilience

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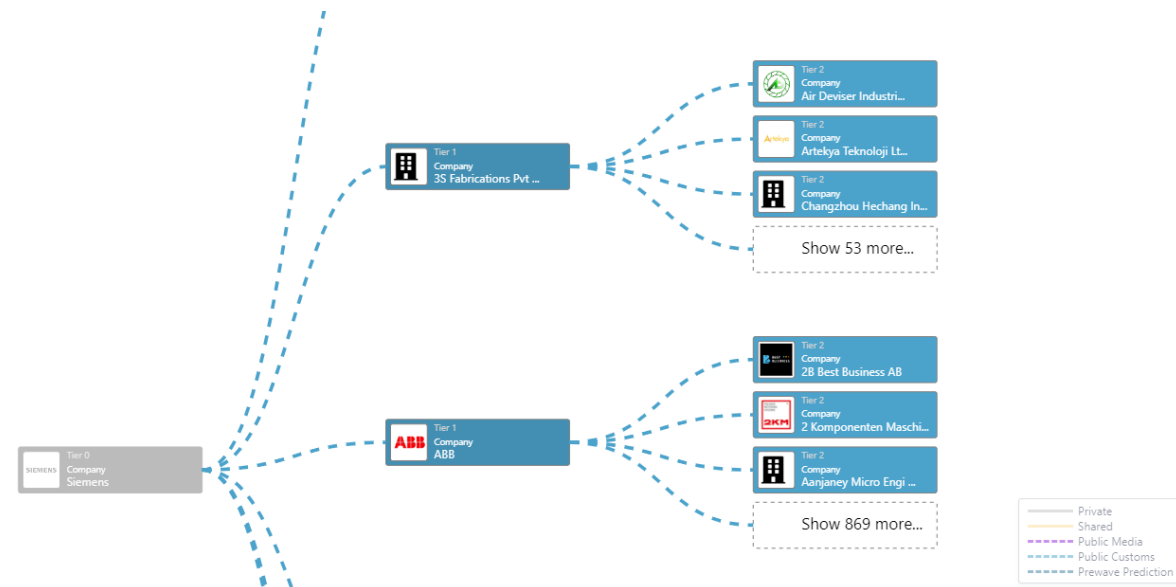
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Supply Chain Challenges

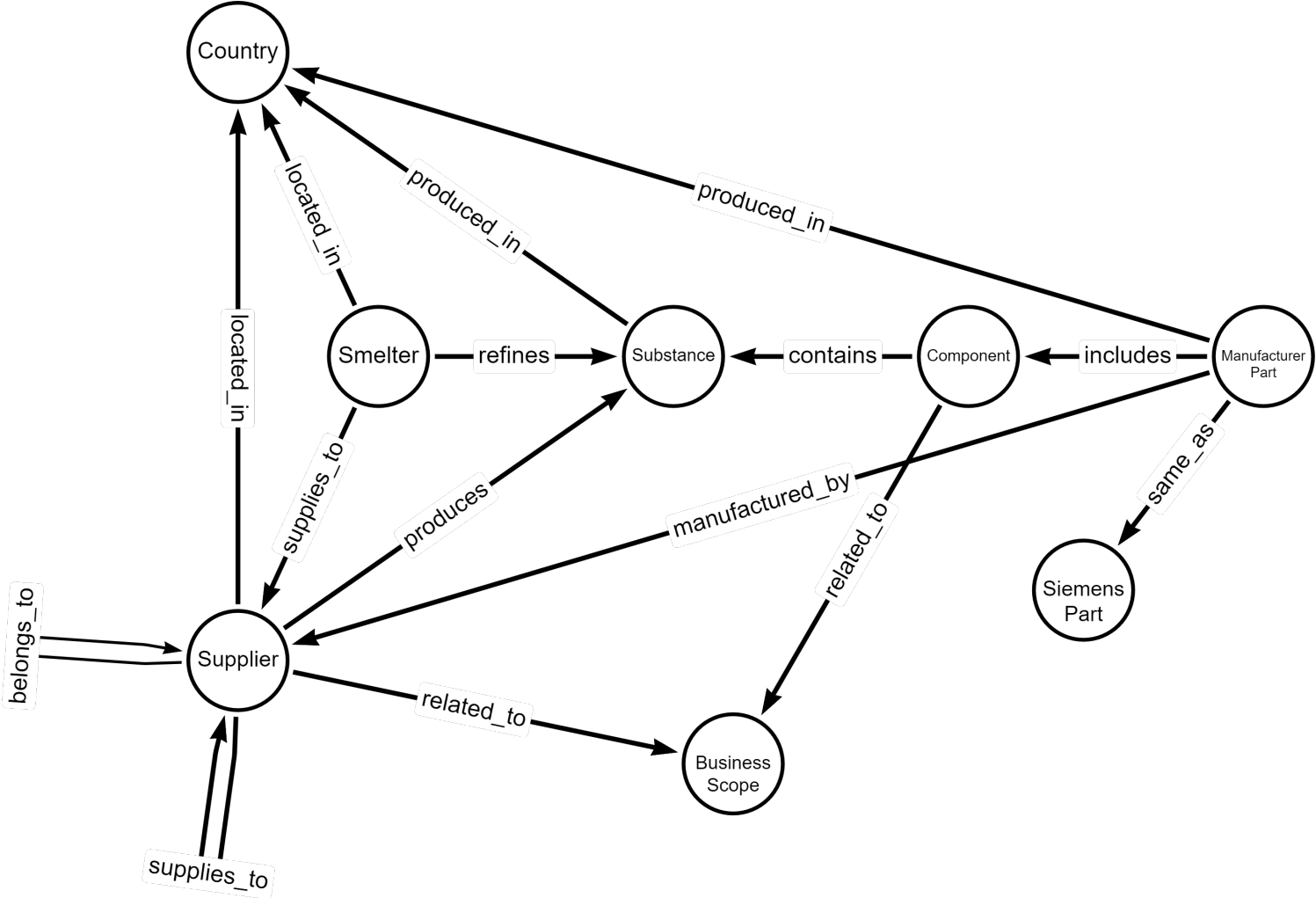
- ❖ Supply chain intransparency
- ❖ Data disconnectedness
- ❖ Data incompleteness
- ❖ Identification of criticalities



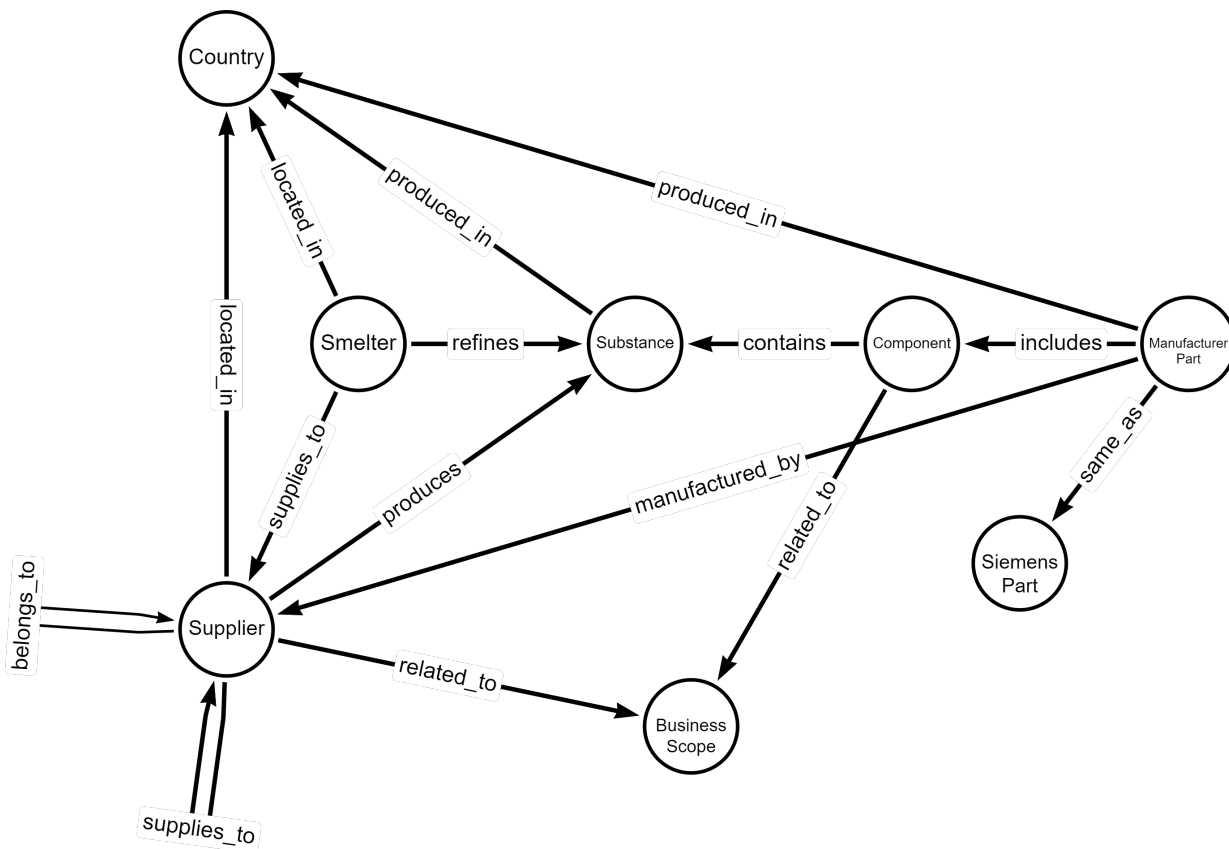
- Model existing knowledge via a knowledge graph
- Perform link prediction to complete missing information
- Use graph analytics to identify critical suppliers



Knowledge Graph Schema



Knowledge Graph Statistics



Entity type	Nodes	Relation type	Edges
Supplier	61,234	supplies_to	138,197
Manufacturer Part	1,650	related_to	59,894
Siemens Part	1,295	belongs_to	56,663
Smelter	340	located_in	30,107
Substance	321	includes	10,088
Component	233	produces	7,831
Country	172	produced_in	4,381
Business Scope	32	same_as	1,847
		manufactured_by	1,564
		contains	764
		refines	340
Total	65,277	Total	311,676

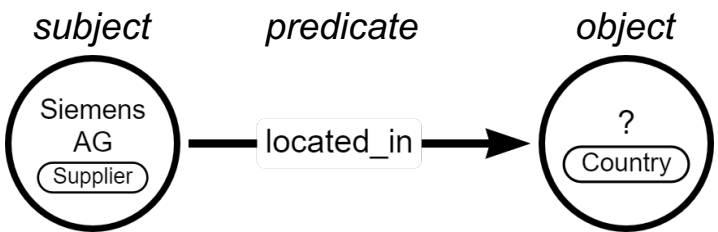
Siemens suppliers:

- ❖ Tier-1: 16,910
- ❖ Tier-2: 43,759
- ❖ Tier-3: 49,775

Knowledge Graph Completion: Link Prediction

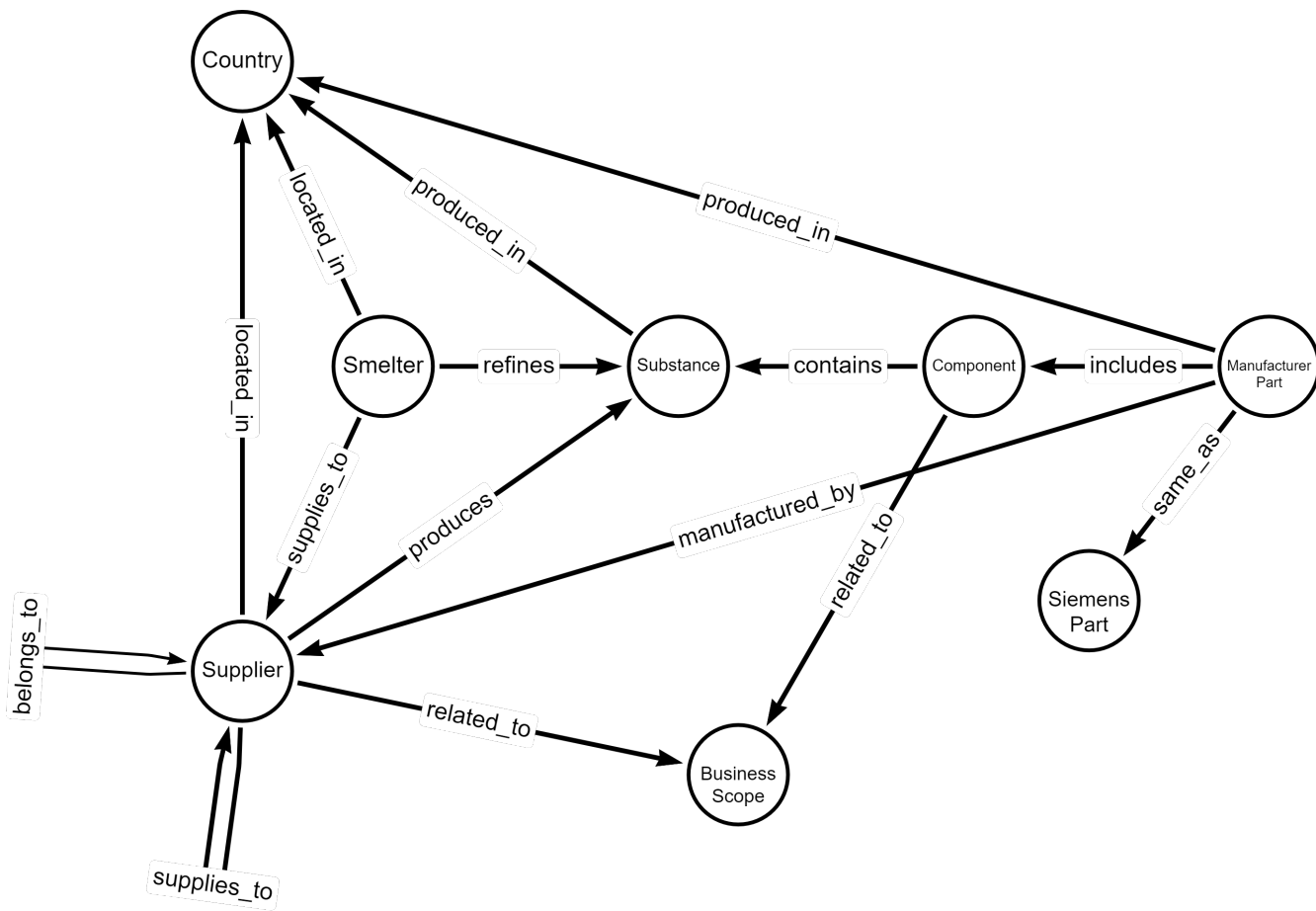
Object prediction for all relation types for a query

(subject, predicate, ?)



The diagram shows a query structure with three main components: a **subject** node labeled "Siemens AG" with a sub-label "Supplier", a **predicate** labeled "located_in", and an **object** node labeled "?" with a sub-label "Country". An arrow points from the subject to the object through the predicate.

Output: Ranked list of object candidates



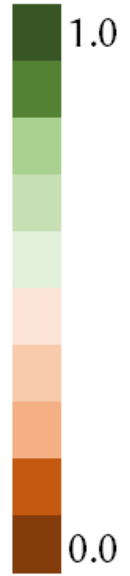
Link Prediction Results

- ❖ Apply link prediction methods based on
 - ❖ Tensor factorization: RESCAL, ComplEx, TuckER
 - ❖ Translation: TransE, RotatE
 - ❖ Neural networks: ConvE, RGCN, CompGCN

Method	MRR	Hits@1	Hits@3	Hits@10
RESCAL	0.1476	0.0684	0.1809	0.2772
ComplEx	0.2535	0.1793	0.2850	0.3949
TuckER	0.1738	0.0749	0.1878	0.4033
TransE	0.1595	0.0873	0.1733	0.3164
RotatE	0.4377	0.3686	0.4733	0.5627
ConvE	0.2289	0.1549	0.2438	0.3875
RGCN	0.2911	0.1784	0.3379	0.5195
CompGCN	0.2223	0.1271	0.2486	0.4229

Link Prediction Results

MRR	RESICAL	Complex	TuckER	TransE	RotatE	ConvE	RGCN	CompGCN
supplies_to	0.1422	0.2661	0.0539	0.0740	0.3499	0.1574	0.2116	0.1718
related_to	0.2900	0.2756	0.4317	0.3539	0.7256	0.4876	0.5025	0.3291
belongs_to	0.0039	0.3411	0.3428	0.6671	0.6675	0.0261	0.0548	0.4000
located_in	0.0003	0.0653	0.1500	0.0909	0.1526	0.1726	0.2241	0.1973
includes	0.0004	0.5259	0.4176	0.5084	0.8682	0.0734	0.4607	0.4390
produces	0.0006	0.2923	0.0341	0.0984	0.3975	0.0113	0.1845	0.2122
produced_in	0.0003	0.1939	0.2907	0.1131	0.3539	0.0813	0.2043	0.1668
same_as	0.0002	0.0022	0.0011	0.0003	0.0490	0.0001	0.0049	0.0020
manufactured_by	0.0005	0.5646	0.3831	0.1420	0.9564	0.0707	0.3648	0.1791
contains	0.0005	0.0212	0.0180	0.0024	0.2106	0.0015	0.1143	0.1362
refines	0.0014	0.4593	0.0152	0.0337	0.1501	0.0166	0.4567	0.0402



Identification of Criticalities

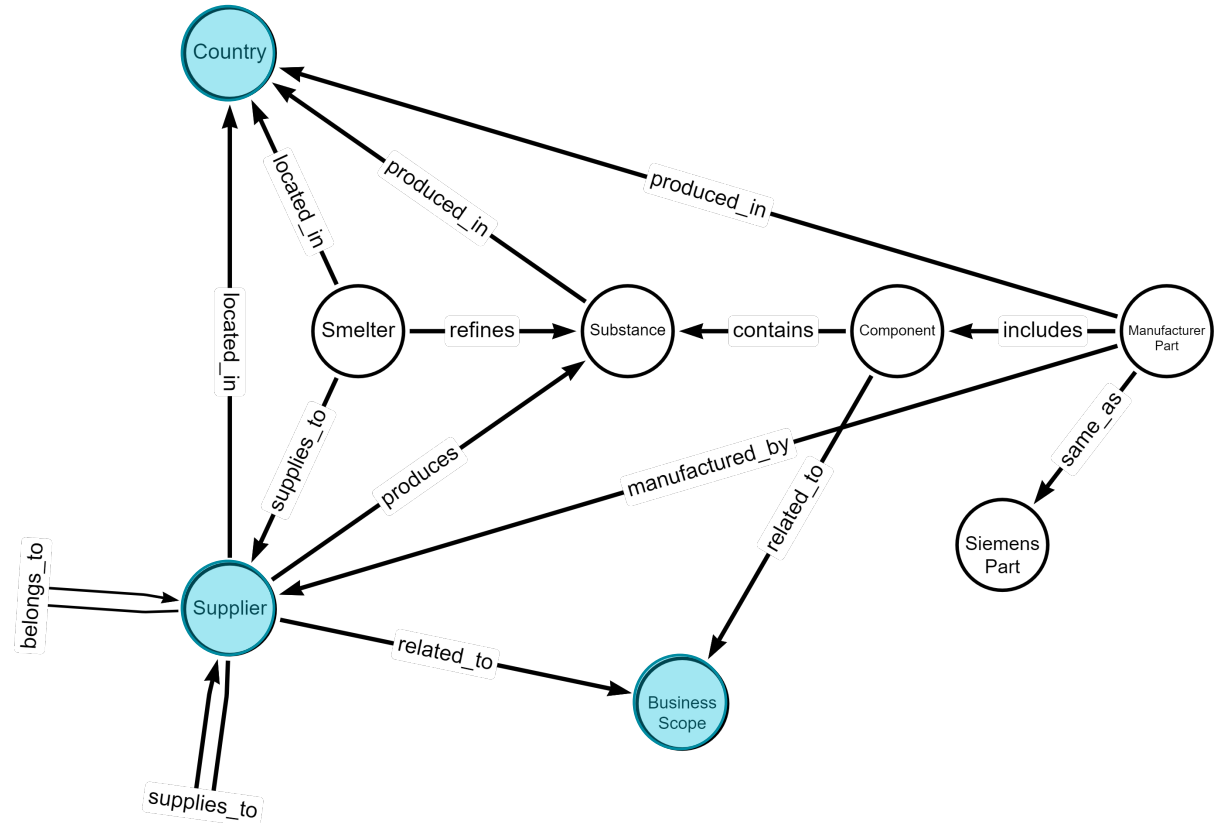
Who? Suppliers, Smelters, ...

Where? Countries, Regions, ...

What? Business Scopes, Components, ...

Examples of criticalities:

- ❖ Many suppliers are located in the same region
- ❖ Many suppliers have a high risk score
- ❖ Multiple tier-1 suppliers buy from the same subsupplier
- ❖ Only one supplier is related to a specific business scope



Graph Analytics: Identification of Critical Suppliers

Analysis on the supply network:

- ❖ **Degree centrality:** number of incoming edges (suppliers) and outgoing edges (customers)
- ❖ **Betweenness centrality:** based on the number of shortest paths that a node lies on
- ❖ **Closeness centrality:** average length of the shortest paths between a node and all other nodes
- ❖ **Triangle count:** number of adjacent triangles of a node
- ❖ **Aggregated score:** sum of normalized metrics

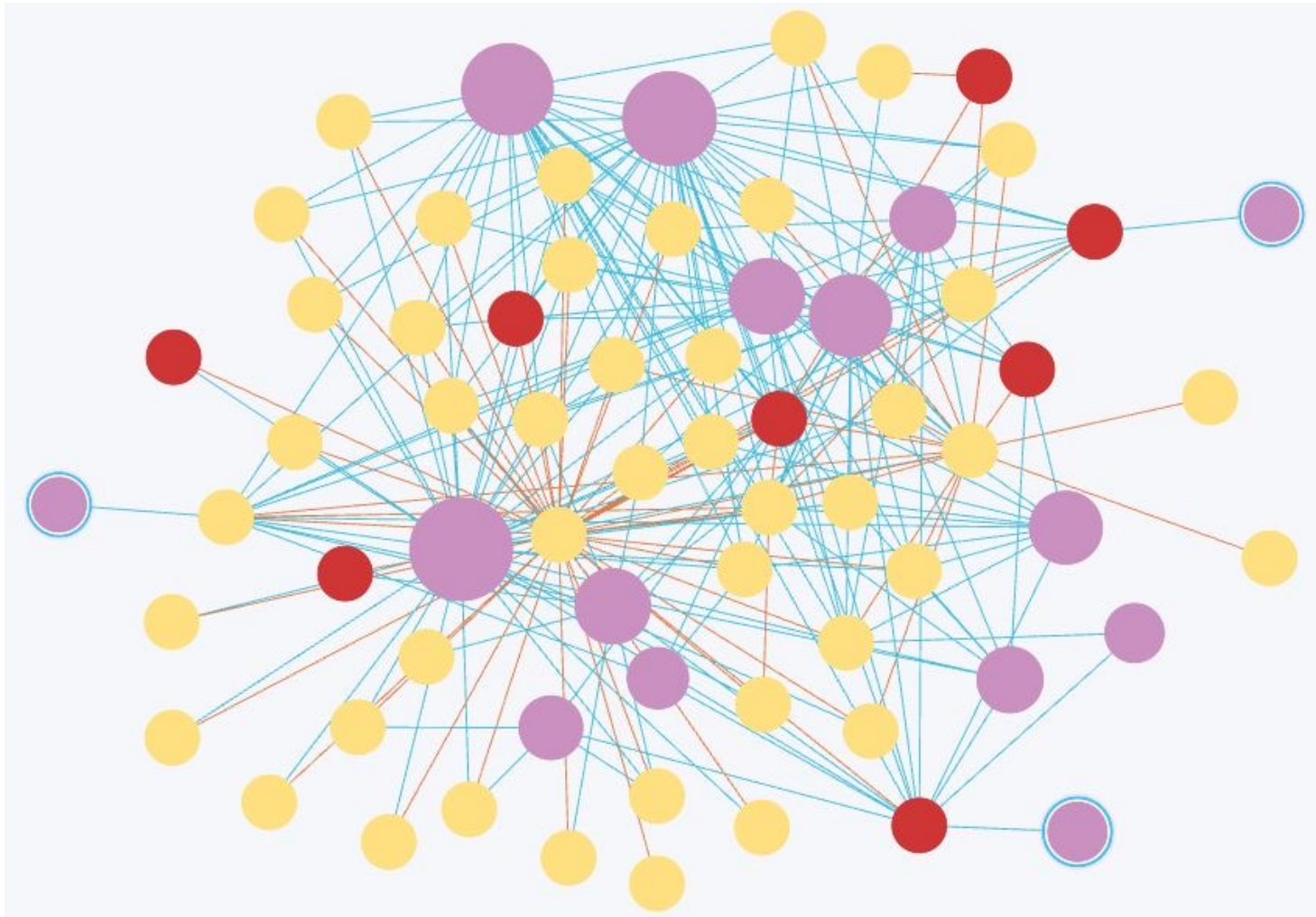
Graph Analytics: Identification of Critical Suppliers

Analysis on the supply network:

- ❖ Siemens score of 37.25
- ❖ 3 suppliers with a score above 15
- ❖ 988 supplier with a score above 10

Correlation	in-degree	out-degree	betweenness	closeness	triangle count
in-degree	1.0000				
out-degree	0.1969	1.0000			
betweenness	0.8816	0.3928	1.0000		
closeness	0.0686	0.2792	0.0859	1.0000	
triangle count	0.9809	0.2048	0.8774	0.0542	1.0000

Visualization of Critical Suppliers and Business Scopes



- Supplier
- Critical supplier
- Business scope
- *supplies_to*
- *related_to*

Summary and Outlook

- ❖ Connected supply-chain related information to a knowledge graph to increase transparency
- ❖ Applied link prediction methods for knowledge graph completion
- ❖ Identified critical suppliers using graph analytics based on centrality metrics

- Structured evaluation of results by domain experts
- Integration of node/edge properties
- Analysis based on the complete knowledge graph
- Increase explainability of results