

# Identification and Analysis of Inter- and Intraorganizational Interdependencies in Municipal Administrations

**Niklas Frings**

University of Wuppertal  
frings@uni-wuppertal.de

**Alexandra Schmitt**

University of Wuppertal  
a.schmitt@uni-wuppertal.de

**Sylvia Bach**

University of Wuppertal  
sbach@uni-wuppertal.de

**Frank Fiedrich**

University of Wuppertal  
fiedrich@uni-wuppertal.de

## ABSTRACT

Municipal administrations play a central role in crisis management in the German federal state, yet existing approaches to critical infrastructure (CI) interdependency analysis are not tailored to their organizational structures and decision-making processes. This paper presents the conceptual design of a scalable method for identifying and analysing inter- and intraorganizational dependencies within municipal administrations. Building on principles of Graph Data Science, the method combines a structured data model with a tailored data-collection approach that captures task-level dependencies, resource requirements, external actors and geographical relations. The feasibility of the approach is demonstrated through a pre-test conducted in two German municipalities, using both simple directed and bipartite graph representations to explore patterns of interconnectedness and task-level heterogeneity. The results highlight the value of fine-grained dependency modelling as a basis for subsequent analytical steps. The method is intended to support future network-based assessments and simulation-based analyses aimed at strengthening municipal resilience and crisis preparedness.

## Keywords

Interdependency Analysis; Municipal Crisis Management; Critical Infrastructure Interdependencies

## INTRODUCTION

Municipal administrations in Germany are the primary interface between the state, the economy and the public. Their internal coordination and external networks are essential to fulfilling municipal duties, and in crises or catastrophes these relationships become decisive since municipalities are both impacted and act as the first line of governmental response (cf. Bauer et al., 2020; Bundesamt für Bevölkerungsschutz und Katastrophenhilfe; Franzke, 2020). The importance of strong internal and external cooperation for effective local-level crisis management is evidenced by Schütte et al. (2022) who investigated the municipal crisis management in the context of the refugee crisis in 2015/2016 in Germany. Furthermore it is one essential part of DIN SPEC 91390:2019 *Integrated Risk Management in Civil Protection* (cf. Deutsches Institut für Normung, 2019).

It is not only the COVID-19 pandemic between 2020 and 2023 that has shown that local governments must not only act as crisis managers for society during crises, but also suffer the consequences of these crises themselves in many scenarios (cf. Schulte et al., 2024). Attacks on Berlin's power grid in the recent past also highlight this dual role of the administration, as they demonstrate that normal operations of municipal facilities are not possible in areas affected by power outages (cf. Deutschlandfunk.de, 2026). Finally, however, there are also known cases in which local governments have been directly targeted by attackers, resulting in the paralysis of key operations due to cyberattacks (cf. Mallwitz, 2026; Tagesschau, 2023; Westdeutscher Rundfunk, 2024). In summary, these examples alone make it clear that local governments play a unique role in crisis management, but that this also appears to leave them exceptionally vulnerable to disruptive events.

Although many modelling and simulation techniques targeting critical infrastructure (CI) interdependency analysis have been published since Rinaldi et al. (2001), none are specifically tailored to the interdependency

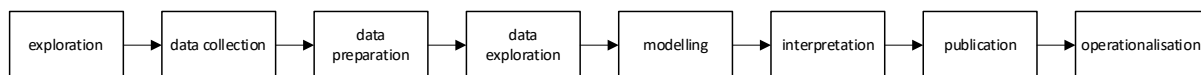
patterns and decision contexts of municipal administrations. Systematic reviews by Ouyang (2014) and Sun et al. (2022) indicate that most existing work focuses on the sector level—often conceptualised as Systems-of-Systems (SoS) analysis—which, however, is too coarse-grained for the requirements of municipal crisis management. Research on the infrastructure-level is limited, and none explicitly target municipal administrations. Hereby, the municipal administration domain poses specific difficulties for dependency mapping and modelling, owing to the large number and heterogeneity of its specialised functional areas, so that existing CI interdependency analysis methods are not directly transferable to the municipal context and require adaptation.

To address this methodological shortfall, this paper introduces the conceptual design of a hybrid method for interdependency assessment and analysis tailored to municipal administrations. The method is presently being applied in two German municipalities as part of the research project Krisenfit<sup>1</sup>. The method developed and presented should meet the following requirements:

1. Provision of a data model that maps inter- and intraorganizational, resource and geographical interdependencies of municipal administrations
2. A record system for capturing this data which can be implemented quickly and easily in local governments, taking into account limited financial and time resources
3. An evaluation and analysis method for identifying dependencies and potential consequences of system failures

This paper primarily addresses the research question of which metric is suitable for quantifying the complexity of tasks and dependencies between tasks in local governments, and how these can be measured in an objective and comparable manner.

This will subsequently help to better understand the complex internal and external interdependencies within local governments, conduct impact assessments of potential failures using simulations (e.g., based on Petri nets), and identify opportunities for resource-efficient resilience management (e.g., by creating redundancies). The developed method is based on the principles of the Graph Data Science workflow described by Schmidt (2023), as illustrated in *Figure 1*.



**Figure 1** Graph data science workflow (based on Schmidt, 2023, p. 172)

According to Schmidt (2023), each network-analytical task should be approached in eight steps: exploration, data collection, data preparation, data exploration, modelling, interpretation, publication and operationalisation. While all of these steps are essential for achieving robust results, this paper focuses specifically on the phases of data collection and modelling, as the evaluation and validation of the results available to date still has to be carried out within the ongoing project.

Specifically, this work aims to present a scalable data model and an associated data-collection method that together form the foundation for a graph-theory-based analysis of interdependencies in the CI context under consideration. In addition, several possible approaches for analysing the collected data are outlined, and the planned next steps in the research process are described.

## SCIENTIFIC CONTRIBUTION OF THIS PAPER

The scientific contribution of this paper can be roughly divided into three areas. As a first and primary objective, this paper presents a conceptual framework for a method that describes organizational, resource-based, and external dependencies at the task level within local governments and enables their analysis. Existing CI interdependency models predominantly operate at the sector or infrastructure-system level and therefore lack the granularity required to analyze processes and interdependencies in the area of municipal crisis management (cf. Ouyang, 2014; Rinaldi et al., 2001; Sun et al., 2022). The proposed model addresses this gap by enabling dependency mapping at a level of detail comparable to Business Impact Analysis like describes in ISO/TS 22317:2021 or the German BSI 200-4 standardization, but specifically designed for the requirements of municipal administrations.

Second, the paper presents a hybrid data-collection method that combines the BIA-based impact assessment with graph-theoretical modelling. Theoretical work about graph-theoretical approaches in data analysis like Newman (2016), Berge (1979) or Schmidt (2023) show that reliable conclusions based on network analyses can only be

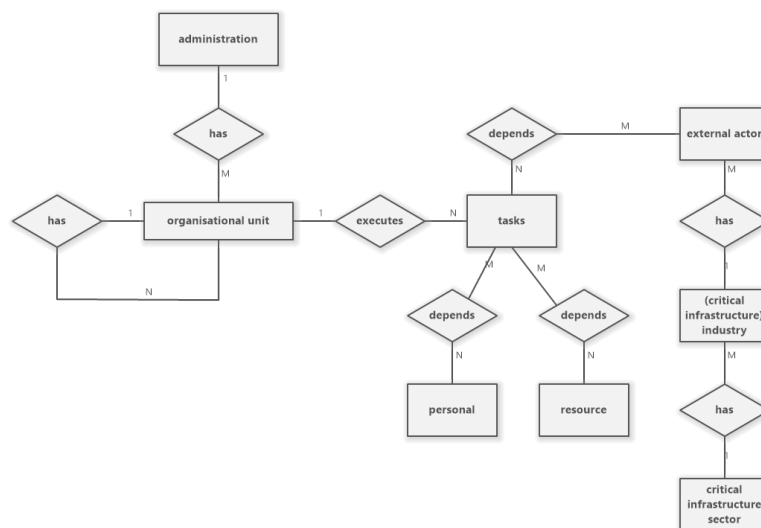
<sup>1</sup> The Krisenfit project is funded by the German Federal Ministry of Research, Technology and Space under the ‘Civil Security Research’ (sifo) funding scheme, with funding codes 13N17114 to 13N17118

drawn when data coverage is nearly 100%, and that the available data must be of a quantitative nature for use in weighted graphs. However, upon closer examination of the results of the reviews by Ouyang (2014) and Sun et al. (2022), no methods suitable for the quantitative assessment of criticalities, as planned for the KRISENFIT project and described above, could be identified.

Third, the paper demonstrates the analytical value of graph theory based analytic methods for identifying and analyzing interdependencies within and between organizational units in municipal administrations. This finding aligns with research on functional network structures and suggests that municipal administrations exhibit modular dependency patterns that cannot be captured through aggregated organizational-unit graphs alone.

## DATA MODEL

The data model needs to be capable of describing the organizational structure of the analysed municipal administration as well as all relevant interdependency entities and their relations between each other. With the developed method being applied in Germany, the foundation for the data model is the structure of German municipal administrations. In general, these consist of multiple departments with dedicated areas of responsibility, e.g. *general administration*, *financial administration* or *school and cultural administration*. Each department comprises several offices and staff units, which are responsible for carrying out the actual administrative tasks. Based on this structure and the beforementioned requirements, the data model shown schematically in **Figure 2** was developed.



**Figure 2** Schematic entity-relationship-diagram of the developed data model (notation according to Chen & S)<sup>2</sup>

The entity-relationship diagram (ERD) in **Figure 2** illustrates how the previously described structure of German municipal administrations is translated into the abstract, functional data model used to design the database that stores the data for analysis. At the top level, an administration consists of multiple organizational units, each of which performs a set of specific tasks. These tasks rely on two main categories of internal resources: personnel and material or technical resources. In addition, tasks may depend on external actors, such as service providers or partner organizations. Each external actor is assigned to one critical-infrastructure industry, which in turn belongs to broader critical-infrastructure sectors. This classification follows the European Union's approach to critical infrastructures as outlined in Regulation EU 2022/2557.

The data structure presented here deliberately captures not only the organizational structure of the administration under consideration but also the specific tasks performed by each organizational unit. Although the actual network analysis will be conducted at the level of organizational units, this task-level modelling is intended to support the completeness and quality of the data collected. A comparable approach is used, for example, in the context of Business Impact Analysis (BIA) as described in BSI Standard 200-4 (cp. Bundesamt für Sicherheit in der Informationstechnik, 2023) and ISO/TS 22317:2021.

<sup>2</sup> In accordance with the extended Chen notation, the figure shown labels “one-to-many” relationships with “1” and “N” and “many-to-many” relationships with ‘N’ and “M”.

## DATA COLLECTION

One of the main challenges in developing a method for interdependency analysis is obtaining the necessary information. Like Schmidt (2023, p. 12) describes, it is necessary to achieve almost 100 percent data coverage in order to perform a meaningful network analysis. Given that a local authority in Germany, may comprise up to 47 or more departments (cf. Bogumil & Jann, 2020, p. 207), each of which can be further subdivided into specialised units or teams, this represents an ambitious undertaking that requires a systematic and carefully designed approach. Conducting structured interviews or workshops requires a huge amount of time due to the large number of people involved, which is not easily manageable by the administrations.

Online surveys can serve as an alternative in this context, but they must be thoroughly tested to ensure that the required data can be collected with the necessary level of quality. When using online tools, it is particularly important to ensure that the rating scales employed—especially qualitative and semi-quantitative scales—are described in a way that guarantees comparability of all data collected across the organization under consideration. To ensure this, the method used to assess the criticality of individual tasks applies a combination of impact type, impact level, and time horizon—an approach also employed in the context of Business Impact Analysis (BIA). A comparable approach was proposed by Laugé et al. (2015) to investigate CI interdependencies between CI sectors defined by the EU-Directive 2008/114/EC but on a more qualitative level.

**Table 1** presents the impact types used in this study, along with the guiding questions that were introduced to enhance the usability and data comparability of the data assessment tool. The first three impact types *endangerment of human life and physical integrity*, *endangerment of public safety and public order*, and *severe disruption of societal life*, were selected based on Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (2023), while the fourth impact type, *endangerment of animal life*, was added after an initial test and corresponding feedback.

**Table 1 Impact types queries and guiding questions used in the online assessment (based on Bundesamt für Bevölkerungsschutz und Katastrophenhilfe, 2023, modified by the author)**

Impact type	Guiding question
Endangerment of human life and physical integrity	Assuming that the specified task fails or the indicated service cannot be provided: Does this lead to an (immediate) endangerment of human life and physical integrity?
Endangerment of public safety and public order	Assuming that the specified task fails or the indicated service cannot be provided: Does this result in an (immediate) endangerment of public safety and public order?
Severe disruption of societal life	Assuming that the specified task fails or the indicated service cannot be provided: Does this lead to an (immediate) severe disruption of societal life?
Endangerment of animal life	Assuming that the specified task fails or the indicated service cannot be provided: Does this lead to an (immediate) endangerment of animal life?

Like mentioned in ISO/TC 22317:2021, “impacts almost always increase over time” (British Standards Institution, 2022). To address this, the severity of potential failures of the respective task is assessed across different time frames, analogous to the BIA approaches according to BSI 200-4 or ISO/TC 22317:2021. Since the time horizons depend strongly on the specific context of the organization under investigation, they must be determined individually for each organization. For the analysis presented here, the time frames were defined based on prior experience in working with local authorities as follows: *immediately (0 to 1 hours)*, *1 to 8 hours*, *8 hours to 1 day*, *1 day to 1 week*, *1 week to 1 month*, *1 month to 3 months*, *3 months to 1 year*. For each combination of time frame and impact type, an assessment of the consequences of a potential task failure should be carried out. The impact levels shown in **Table 2** are used for this purpose.

**Table 2 Impact levels used in the online assessment (based on ISO/TC 22317:2021)**

Impact level	Description
0 – no impact	No impact
1 – minor impact	Only minor, barely noticeable effects on the protection objective or hazard under consideration are expected
2 – medium impact	The impacts on the protection objective or hazard under consideration are expected to be perceptible
3 – high impact	The impacts on the protection objective or hazard under consideration are expected to be intolerable
4 – very high impact	The impacts on the protection objective or hazard under consideration are expected to be existentially threatening

The identification and evaluation of resources and external actors is then carried out in a simplified form. For each task, the necessary resources and the external actors with whom cooperation or exchange is required are recorded. Subsequently, for each specified dependency, the type (physical, informational, geographical, legal, or personal), the direction (incoming, outgoing, bidirectional), and the time limits for normal and emergency operation are determined. The latter two are selected from the aforementioned time horizons. They indicate the period following a dependency failure during which the task can still be performed under normal conditions, as well as the maximum duration it remains feasible under emergency conditions.

Finally, the relevant geographical locations are recorded via GIS data to enable subsequent analyses of geographical dependencies.

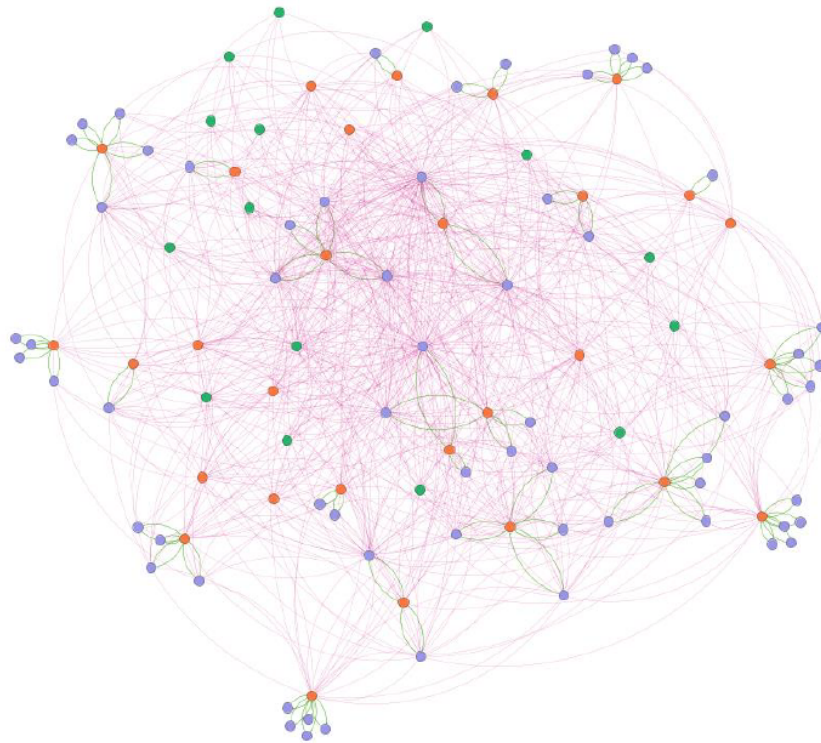
For an initial pretest, data was collected using the online survey tool LimeSurvey (cf. LimeSurvey GmbH, 2024). The data collection currently being carried out in two local authorities as part of the ongoing research project is being implemented using a data-collection and analysis tool developed specifically for this purpose. The system described above proved suitable in the pretest and, in terms of the expected workload, just about manageable for day-to-day municipal operations. It was therefore adopted in the project without major adjustments.

## DATA ANALYSIS

In the first step of the data analysis, an exploratory visual network analysis is conducted using the open-source software Gephi (cf. Bastian et al., 2009). Gephi enables interactive exploratory analysis, allowing users to examine individual elements of the graph by adjusting the visualization according to various parameters. For example, the criticality of processes can be visualized by automatically coloring nodes based on the collected failure impacts. Likewise, the criticality of resource interdependencies can be represented by adjusting the attractive forces used in the graphs layout algorithm by modifying edge weights according to the limits of normal and emergency operation. The node and edge lists required for this, including any parameters for weighting nodes and edges, are derived from the data structure presented in the preceding section. Gephi's internal implementation of the ForceAtlas2 algorithm (cf. Jacomy et al., 2014) is used for the layout of the graphs nodes. The methodological foundations required for this do not differ substantially from the procedures described in the foundational literature and are therefore not discussed in greater detail here (cf. e.g. Berge, 1979; Jansen, 2003; Newman, 2016; Schmidt, 2023).

The data collected in the pretest was visualized using two different graph representations. First, all task-level data was aggregated to the level of organizational units, enabling the construction of a directed simple graph in which the nodes represented only the organizational units as well as the external actors and resources of the local government under consideration. This summary of the data was obtained by assigning the highest reported criticality (cf. **Table 2**) from all processes identified within an organizational unit to that unit for each of the impact scenarios listed in **Table 1**. Similarly, resource and process dependencies were also aggregated by taking the maximum value. This provided an initial overview of which departments exhibit particularly high or particularly low degrees of interconnectedness and where clustering effects occur. The latter could also be identified using Gephi's built-in tools, including the specification of quantitative parameters. The resulting modularity classes offered insights into groups of organizational units with particularly strong interdependencies. A higher-resolution representation of the data can be achieved using a directed bipartite graph in which not only the organizational units, resources and external actors are represented as nodes, but also the tasks themselves. Given the wide range of visualization and analytical options offered by Gephi, it is not feasible to describe each interactive exploration in detail or to present all resulting views here. **Figure 3** therefore illustrates one representative example: a bipartite

graph that includes all organizational units of the local government examined in the pretest.



**Figure 3** Graphical representation of the bipartite graph showing the organizational units (orange = participated, green = not participated) and the processes (purple), as well as the dependencies between them (green = ownership, pink = dependency)

*Figure 3* provides an illustrative example of the bipartite representation of the data from the pretest. In this graph, organizational units and processes are modelled as distinct node sets, enabling a clear separation between actors and the tasks they perform. The color-coding of nodes and edges supports the interpretation of participation status and dependency types, allowing patterns of ownership and functional reliance to be identified at a glance. This representation also reveals structural characteristics such as central hubs, isolated processes, and asymmetries in dependency flows, thereby offering a more granular view of interdependencies than the aggregated non-bipartite graph.

As expected, the evaluation of the pretest data showed that not all tasks assigned to a given organizational unit necessarily exhibit all of its interdependencies. Instead, it became apparent that, particularly in highly interconnected organizational units, typically only one or two tasks require a high degree of networking, while the remaining tasks display comparatively few dependencies.

Even though these findings cannot be considered representative, they indicate that a detailed analysis of process- or task-level dependencies remain valuable in the further course of the work, particularly when it comes to allocating resources aimed at strengthening resilience and crisis preparedness.

A more in-depth analysis of the collected data could, for example, be conducted in accordance with the proposal by Stergiopoulos et al. (2015). In their paper, they present an algorithm that uses graph-theoretical centrality measures to identify opportunities for risk reduction in complex dependency networks. Other network analysis approaches can also be evaluated for their applicability and validity in the future. However, this is not addressed further in this work-in-progress paper, as the dataset collected in the pretest is far from sufficient for a meaningful validation of potential methods. Therefore, this paper remains focused on the actual data collection methodology, its potentials and the scales developed.

## PROSPECTS

Future research will examine whether—and to what extent—classical network analysis parameters, such as degree or Katz centrality, can be used to describe the criticality of individual organizational units within local government structures. In addition, the resulting data model will serve as the basis for conducting various simulations. These simulations will explore different scenarios, taking geographical dependencies into account, and will evaluate their effects on the overall system of the local government under study. The results will then be used to enhance the resilience and crisis preparedness of the respective administration.

## REFERENCES

- Bastian, M., Heymann, S., & Jacomy, M. (2009). *Gephi: An Open Source Software for Exploring and Manipulating Networks*. <http://www.aaai.org/ocs/index.php/ICWSM/09/paper/view/154>
- Bauer, M. W., Pöhler, J., Ruf, V., & Schomaker, R. M. (März 2020). *Wie krisenfest ist die deutsche Kommunalverwaltung? Erkenntnisse aus einer deutschlandweiten Befragung von Kreis-, Gemeinde- und Stadtverwaltungen*. German University of Administrative Sciences Speyer. [https://www.witi-innovation.de/wp-content/uploads/2020/10/Bauer-MW-P%C3%B6hler-Ruf-Schomaker-2020-Krisenfestigkeit-deutscher-Verwaltungen\\_WP-15.pdf](https://www.witi-innovation.de/wp-content/uploads/2020/10/Bauer-MW-P%C3%B6hler-Ruf-Schomaker-2020-Krisenfestigkeit-deutscher-Verwaltungen_WP-15.pdf)
- Berge, C. (1979). *Graphs and hypergraphs* (2., rev. ed., reprinted.). *North-Holland mathematical library: Vol. 6*. North-Holland Publ. Co.
- Bogumil, J., & Jann, W. (2020). *Verwaltung und Verwaltungswissenschaft in Deutschland: Eine Einführung* (3., vollständig überarbeitete Auflage). *Lehrbuch*. Springer VS. <https://doi.org/10.1007/978-3-658-28408-4>
- British Standards Institution (2022, February 1). *Tracked Changes. Security and resilience. Business continuity management systems. Guidelines for business impact analysis* (PD ISO/TS 22317:2021). British Standards Institution.
- Bundesamt für Bevölkerungsschutz und Katastrophenhilfe. Identifizierung im Kontext Kritischer Infrastrukturen. [https://www.bbk.bund.de/SharedDocs/Downloads/DE/Mediathek/Publikationen/KRITIS/baukasten-kritis-identifizierung-2.pdf?\\_\\_blob=publicationFile&v=8](https://www.bbk.bund.de/SharedDocs/Downloads/DE/Mediathek/Publikationen/KRITIS/baukasten-kritis-identifizierung-2.pdf?__blob=publicationFile&v=8)
- Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (2023). *Schutz Kritischer Infrastrukturen – Identifizierung in sieben Schritten*. [https://www.bbk.bund.de/SharedDocs/Downloads/DE/Mediathek/Publikationen/PiB/PiB-20-schutz-infrastrukturen-identifizierung.pdf?\\_\\_blob=publicationFile&v=12](https://www.bbk.bund.de/SharedDocs/Downloads/DE/Mediathek/Publikationen/PiB/PiB-20-schutz-infrastrukturen-identifizierung.pdf?__blob=publicationFile&v=12)
- Bundesamt für Sicherheit in der Informationstechnik (2023). *BSI-Standard 200-4 BCM*. [https://www.bsi.bund.de/SharedDocs/Downloads/DE/BSI/Grundschutz/BSI\\_Standards/standard\\_200\\_4.pdf?\\_\\_blob=publicationFile&v=8](https://www.bsi.bund.de/SharedDocs/Downloads/DE/BSI/Grundschutz/BSI_Standards/standard_200_4.pdf?__blob=publicationFile&v=8)
- Chen, & S, P. P. *The entity-relationship model : toward a unified view of data*. <https://dspace.mit.edu/bitstream/handle/1721.1/47432/entityrelationshx00chen.pdf>
- Deutsches Institut für Normung (Dezember 2019). *Integriertes Risikomanagement für den Schutz der Bevölkerung* (DIN SPEC DIN SPEC 91390:2019-12). Beuth.
- Deutschlandfunk.de. (2026, February 23). *Zehntausende Haushalte betroffen - Wegner nennt Anschlag auf Stromversorgung in Berlin Terrorismus*. Deutschlandfunk.de. <https://www.deutschlandfunk.de/wegner-nennt-anschlag-auf-stromversorgung-in-berlin-terrorismus-100.html>
- Directive (EU) 2022/2557 of the European Parliament and of the Council of 14 December 2022 on the resilience of critical entities and repealing Council Directive 2008/114/EC, Official Journal of the European Union 164 (2022). <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32022L2557>
- Council Directive 2008/114/EC of 8 December 2008 on the identification and designation of European critical infrastructures and the assessment of the need to improve their protection, Official Journal of the European Union 75-82 (2008 & rev. 2008). <https://eur-lex.europa.eu/legal-content/DE/TXT/PDF/?uri=CELEX:32008L0114>
- Franzke, J. (2020). Deutschlands Krisenmanagement in der CORONA-Pandemie. Herausforderungen eines föderalen politisch-administrativen Systems. *Rocznik Integracji Europejskiej*(14), 325–342. <https://doi.org/10.14746/rie.2020.14.21>
- Jacomy, M., Venturini, T., Heymann, S., & Bastian, M. (2014). Forceatlas2, a continuous graph layout algorithm for handy network visualization designed for the Gephi software. *PLoS One*, 9(6), e98679. <https://doi.org/10.1371/journal.pone.0098679>

- Jansen, D. (2003). *Einführung in die Netzwerkanalyse: Grundlagen, Methoden, Forschungsbeispiele* (2., erw. Aufl.). *UTB Sozialwissenschaft: Vol. 2241*. Leske + Budrich. [http://bvbr.bib-bvb.de:8991/F?func=service&doc\\_library=BVB01&doc\\_number=010342150&line\\_number=0002&func\\_code=DB\\_RECORDS&service\\_type=MEDIA](http://bvbr.bib-bvb.de:8991/F?func=service&doc_library=BVB01&doc_number=010342150&line_number=0002&func_code=DB_RECORDS&service_type=MEDIA)
- Laugé, A., Hernantes, J., & Sarriegi, J. M. (2015). Critical infrastructure dependencies: A holistic, dynamic and quantitative approach. *International Journal of Critical Infrastructure Protection*, 8, 16–23. <https://doi.org/10.1016/j.ijcip.2014.12.004>
- LimeSurvey GmbH. (2024, August 7). *LimeSurvey: Free Online Survey Tool*. <https://www.limesurvey.org/de>
- Mallwitz, G. (2026, January 26). *Daten aus Gemeindeverwaltung im Darknet*. <https://kommunal.de/cyberangriff-darknet-datenleck-untereisesheim>
- Newman, M. E. J. (2016). *Networks: An introduction* (Reprinted.). Oxford University Press.
- Ouyang, M. (2014). Review on modeling and simulation of interdependent critical infrastructure systems. *Reliability Engineering & System Safety*, 121, 43–60. <https://doi.org/10.1016/j.ress.2013.06.040>
- Rinaldi, S. M., Peerboom, J. P., & Kelly, T. K. (2001). Identifying, understanding, and analyzing critical infrastructure interdependencies. *IEEE Control Systems*, 21(6), 11–25. <https://doi.org/10.1109/37.969131>
- Schmidt, C. (2023). *Graphentheorie und Netzwerkanalyse: Eine kompakte Einführung mit Beispielen, Übungen und Lösungsvorschlägen. Lehrbuch*. Springer Vieweg. <https://link.springer.com/978-3-662-67378-2>
- Schulte, Y., Schönefeld, M., Schütte, P., Schmitt, A., & Fiedrich, F. (2024). *Kommunalverwaltungen im Krisenmodus: Fallstudienbericht*. Bergische Universität Wuppertal. [https://kovik.uni-wuppertal.de/fileadmin/site/kovik/daten/Fallstudie\\_Kommunalverwaltungen-im-Krisenmodus.pdf](https://kovik.uni-wuppertal.de/fileadmin/site/kovik/daten/Fallstudie_Kommunalverwaltungen-im-Krisenmodus.pdf)
- Schütte, P., Schulte, Y., Schönefeld, M., & Fiedrich, F. (Eds.). (2022). *Sicherheit – interdisziplinäre Perspektiven. Krisenmanagement am Beispiel der Flüchtlingslage 2015/2016: Akteure, Zusammenarbeit und der Umgang mit Wissen*. Springer VS. <http://www.springer.com/>
- Stergiopoulos, G., Kotzanikolaou, P., Theocharidou, M., & Gritzalis, D. (2015). Risk mitigation strategies for critical infrastructures based on graph centrality analysis. *International Journal of Critical Infrastructure Protection*, 10, 34–44. <https://doi.org/10.1016/j.ijcip.2015.05.003>
- Sun, W., Bocchini, P., & Davison, B. D. (2022). Overview of Interdependency Models of Critical Infrastructure for Resilience Assessment. *Natural Hazards Review*, 23(1), Article 04021058. [https://doi.org/10.1061/\(ASCE\)NH.1527-6996.0000535](https://doi.org/10.1061/(ASCE)NH.1527-6996.0000535)
- Tagesschau. (2023, April 19). *Cyberangriffe: Ein Weckruf für die Kommunen*. <https://www.tagesschau.de/inland/gesellschaft/cyberangriffe-verwaltung-101.html>
- Westdeutscher Rundfunk. (2024, October 30). *Heute vor einem Jahr: Hackerangriff auf Südwestfalen IT*. <https://www1.wdr.de/nachrichten/westfalen-lippe/ein-jahr-nach-cyberangriff-suedwestfalen-it-100.html>