

Supplementary Materials

Manuscript title: *A Multi-Hazard Digital Twin Framework for Climate Adaptation Planning of Interdependent Critical Urban Infrastructure*

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This supplementary material documents the complete traceable evidence corpus used in the revised manuscript: 22 DOI-verified journal articles. It improves transparency without claiming to reconstruct unavailable database searches, screening decisions, deduplication records, or the previously reported 97-study corpus.

Supplementary Table S1. Bibliography and Evidence Matrix (22 DOI-verified journal articles).

Ref.	Authors	Year	Article title	Journal	Volume / issue / pages or article no.	DOI	Primary evidence stream	Secondary / cross-theme contribution	Study / review type	Geographic or analytical context	Infrastructure sector or system	Digital-twin function	Hazard / climate-risk focus	Interdependency / cascading-risk treatment	Main contribution used in manuscript	Implication for proposed framework	Manuscript section(s)
1	Camilo Mora et al. (23 authors in DOI record)	2018	Broad threat to humanity from cumulative climate hazards intensified by greenhouse gas emissions	Nature Climate Change	vol. 8, no. 12, pp. 1062-1071	10.1038/s41558-018-0315-6	Multi-hazard climate-risk modelling	Infrastructure impacts and cross-sector consequences	Global empirical multi-hazard assessment	Global analytical assessment	Multiple societal systems, including infrastructure	Not applicable	Cumulative and concurrent climate hazards; direct climate-change relevance	Cross-sector impact pathways; no explicit infrastructure dependency model	Shows that multiple climate hazards can accumulate across systems; limitation: not a digital-twin or dependency-network study	Represent concurrent/cumulative hazards and cross-sector consequences	1; 3.2; Table 1
2	Jakob Zscheischler et al. (11 authors in DOI record)	2018	Future climate risk from compound events	Nature Climate Change	vol. 8, no. 6, pp. 469-477	10.1038/s41558-018-0156-3	Multi-hazard climate-risk modelling	Compound-event logic	Review/perspective	Climate-risk concepts	Not infrastructure-specific	Not applicable	Compound events and interacting drivers; direct climate-change relevance	No explicit infrastructure dependency model	Frames future climate risk from compound events; limitation: no infrastructure-network implementation	Use compound-scenario logic rather than isolated hazards	1; 3.2; Table 1
3	Colin Raymond et al. (14 authors in DOI record)	2020	Understanding and managing connected extreme events	Nature Climate Change	vol. 10, no. 7, pp. 611-621	10.1038/s41558-020-0790-4	Multi-hazard climate-risk modelling	Decision and governance connections	Interdisciplinary review/perspective	Connected extremes across time, space, and sectors	Cross-sector societal systems	Not applicable	Connected extreme events; direct climate-change relevance	Societal and governance connections; no explicit dependency-network model	Explains connected events and their decision context; limitation: not infrastructure-specific	Represent connected-event pathways and planning context	1; 3.2; Table 1
4	Giovanni Forzieri et al. (8 authors in DOI record)	2018	Escalating impacts of climate extremes on critical infrastructures in Europe	Global Environmental Change	vol. 48, pp. 97-107	10.1016/j.gloenvcha.2017.11.007	Multi-hazard climate-risk modelling	Infrastructure exposure and cross-sector impacts	Quantitative impact projection	Pan-European	Transport, energy, water, industrial, and social infrastructure	Not applicable	Multiple climate extremes under future climate; direct relevance	Cross-sector impact comparison; no explicit dependency network	Links climate extremes to critical-infrastructure impacts; limitation: does not model cascading dependencies	Connect future hazard exposure to multiple infrastructure sectors	1; 3.2; 3.3; Table 1
5	S. M. Rinaldi, J. P. Peerenboom, and T. K. Kelly	2001	Identifying, understanding, and analyzing critical infrastructure interdependencies	IEEE Control Systems	vol. 21, no. 6, pp. 11-25	10.1109/37.969131	Infrastructure interdependency and cascading risk	Cascading-risk foundations	Conceptual taxonomy	Critical-infrastructure systems	Multiple critical-infrastructure sectors	Not applicable	Generic disruption context; indirect climate relevance	Physical, cyber, geographic, and logical dependency types	Provides the foundational interdependency taxonomy; limitation: not climate- or twin-specific	Encode explicit dependency classes in the network layer	1; 3.3; 4.4; Table 1
6	Min Ouyang	2014	Review on modeling and simulation of interdependent critical infrastructure systems	Reliability Engineering & System Safety	vol. 121, pp. 43-60	10.1016/j.ress.2013.06.040	Infrastructure interdependency and cascading risk	Resilience and recovery	Review of modeling and simulation	Interdependent infrastructure systems	Multiple critical-infrastructure sectors	Not applicable	Generic disruption context; indirect climate relevance	Explicit dependency modelling, propagation, recovery, and resilience	Reviews infrastructure interdependency models; limitation: not a digital-twin adaptation application	Support network propagation and recovery-oriented analysis	1; 3.3; Table 1

Ref.	Authors	Year	Article title	Journal	Volume / issue / pages or article no.	DOI	Primary evidence stream	Secondary / cross-theme contribution	Study / review type	Geographic or analytical context	Infrastructure sector or system	Digital-twin function	Hazard / climate-risk focus	Interdependency / cascading-risk treatment	Main contribution used in manuscript	Implication for proposed framework	Manuscript section(s)
7	Sara Meerow; Joshua P. Newell; Melissa Stults	2016	Defining urban resilience: A review	Landscape and Urban Planning	vol. 147, pp. 38-49	10.1016/j.landurbplan.2015.11.011	Multi-hazard climate-risk modelling	Urban resilience and service continuity	Conceptual review	Urban resilience definitions	Urban systems broadly	Not applicable	Climate adaptation and disturbance broadly; direct conceptual relevance	System perspective; no explicit cascading-failure model	Clarifies resilience and adaptive capacity; limitation: no digital-twin workflow	Frame outputs around resilience and service continuity	1; 3.2; Table 1
8	Calin Boje; Annie Guerrero; Sylvain Kubicki; Yacine Rezgui	2020	Towards a semantic Construction Digital Twin: Directions for future research	Automation in Construction	vol. 114, Art. 103179	10.1016/j.autcon.2020.103179	Urban-infrastructure digital twins	City data integration	Review/conceptual study	Construction and built environment	Buildings and built assets	Semantic construction twin, asset/sensor integration, and life-cycle information	Not hazard-specific; no direct climate analysis	Asset level; no cross-sector cascade model	Identifies semantic integration and life-cycle requirements; limitation: asset-focused	Use semantic interoperability in the integration core	1; 3.1; 5.1; Table 1
9	Ehab Shahat; Chang T. Hyun; Chunho Yeom	2021	City Digital Twin Potentials: A Review and Research Agenda	Sustainability	vol. 13, no. 6, Art. 3386	10.3390/su13063386	Urban-infrastructure digital twins	Urban governance and research agenda	Literature review	City digital twins	City systems	City representation, data integration, and physical-virtual linkage	Generic urban context; no explicit climate-hazard analysis	Limited explicit cascading-risk treatment	Synthesizes city-twin opportunities and challenges; limitation: weak cascade/adaptation treatment	Extend integration and governance to city scale	1; 3.1; 5.1; Table 1
10	Eva Brucherseifer; Hanno Winter; Andrea Mentges; Max Mühlhäuser; Martin Hellmann	2021	Digital Twin conceptual framework for improving critical infrastructure resilience	at - Automatisierungstechnik	vol. 69, no. 12, pp. 1062-1080	10.1515/auto-2021-0104	Urban-infrastructure digital twins	Interdependency and resilience	Requirements analysis/conceptual framework	Critical-infrastructure resilience	Networked critical infrastructure	Digital twin across resilience and crisis-management cycles	Generic multi-threat context; climate not explicit	Networked infrastructure acknowledged; cascade detail limited	Connects twin functions to anticipation, response, recovery, and learning	Add resilience feedback and disruption-management functions	1; 3.3; 5.1; Table 1
11	Juan Manuel Davila Delgado; Lukumon Oyedele	2021	Digital Twins for the built environment: learning from conceptual and process models in manufacturing	Advanced Engineering Informatics	vol. 49, Art. 101332	10.1016/j.aei.2021.101332	Urban-infrastructure digital twins	Built-environment process modelling	Comparative review/conceptual study	Built environment and manufacturing-process analogues	Built assets	Asset synchronization, simulation, and life-cycle processes	Not hazard-specific	Limited cross-sector treatment	Structures conceptual and process-model requirements; limitation: no multi-hazard adaptation application	Use an ordered integration and process workflow	1; 3.1; 5.1; Table 1
12	Tianhu Deng; Keren Zhang; Zuo-Jun (Max) Shen	2021	A systematic review of a digital twin city: A new pattern of urban governance toward smart cities	Journal of Management Science and Engineering	vol. 6, no. 2, pp. 125-134	10.1016/j.imse.2021.03.003	Urban-infrastructure digital twins	Urban governance and data exchange	Systematic literature review	Digital-twin cities and smart-city governance	City systems	Urban governance, geospatial representation, and physical-virtual integration	Generic; no explicit multi-hazard focus	Limited cascading-risk treatment	Maps digital-twin-city governance and research patterns	Support urban governance and structured data exchange	1; 3.1; 5.1; Table 1
13	Deren Li; Wenbo Yu; Zhenfeng Shao	2021	Smart city based on digital twins	Computational Urban Science	vol. 1, no. 1, Art. 4	10.1007/s43762-021-00005-y	Urban-infrastructure digital twins	Smart-city functions	Conceptual overview	Smart-city applications	City systems	City-scale applications and physical-virtual exchange	Generic; no explicit climate-risk focus	Limited explicit interdependency treatment	Links digital twins to smart-city functions; limitation: no cascade/adaptation workflow	Represent city-scale twin functions	1; 3.1; 5.1; Table 1
14	Fabian Dembski; Uwe Wössner; Mike Letzgus; Michael Ruddat; Claudia Yamu	2020	Urban Digital Twins for Smart Cities and Citizens: The Case Study of Herrenberg, Germany	Sustainability	vol. 12, no. 6, Art. 2307	10.3390/su12062307	Urban-infrastructure digital twins	Participatory planning and local simulation	Case study/prototype	Herrenberg, Germany	Urban streets, mobility, and built environment	3D city model, street network, mobility/wind simulation, VGI, and VR	Local wind and mobility; not a multi-hazard climate-adaptation study	Street network represented; no cascading-failure analysis	Demonstrates visualization and participatory planning	Include visualization and stakeholder-facing functions	1; 3.1; 5.1; Table 1
15	Abigail Francisco; Neda Mohammadi; John E. Taylor	2020	Smart City Digital Twin–Enabled Energy Management: Toward Real-Time Urban Building Energy Benchmarking	Journal of Management in Engineering	vol. 36, no. 2, Art. 04019045	10.1061/(asce)jme.1943-5479.0000741	Urban-infrastructure digital twins	Sector-specific operations	Application/case study	Urban building-energy management	Buildings and energy	Real-time energy benchmarking digital twin	No multi-hazard analysis; indirect mitigation relevance	Single-sector; no interdependency model	Demonstrates an operational twin use case; limitation: narrow sector scope	Retain operational benchmarking while exposing sector-specific limits	1; 3.1; 5.1; Table 1
16	Valentina Gallina; Silvia Torresan; Andrea Critto; Anna Sperotto; Thomas Glade; Antonio Marcomini	2016	A review of multi-risk methodologies for natural hazards: Consequences and challenges for a climate change impact assessment	Journal of Environmental Management	vol. 168, pp. 123-132	10.1016/j.jenvman.2015.11.011	Multi-hazard climate-risk modelling	Climate-impact assessment	Review of multi-risk methodologies	Natural-hazard risk assessment	Not infrastructure-sector specific	Not applicable	Natural-hazard and climate multi-risk; direct climate-change relevance	Consequence-oriented; no infrastructure dependency model	Synthesizes multi-risk methods and challenges	Use multi-risk assessment concepts in the scenario layer	3.2; Table 1

Ref.	Authors	Year	Article title	Journal	Volume / issue / pages or article no.	DOI	Primary evidence stream	Secondary / cross-theme contribution	Study / review type	Geographic or analytical context	Infrastructure sector or system	Digital-twin function	Hazard / climate-risk focus	Interdependency / cascading-risk treatment	Main contribution used in manuscript	Implication for proposed framework	Manuscript section(s)
17	Joel C. Gill; Bruce D. Malamud	2014	Reviewing and visualizing the interactions of natural hazards	Reviews of Geophysics	vol. 52, no. 4, pp. 680-722	10.1002/2013rg000445	Multi-hazard climate-risk modelling	Hazard-interaction representation	Review and visualization study	Natural-hazard interactions	Not infrastructure-sector specific	Not applicable	Interactions among natural hazards; climate relevance varies by hazard	No explicit infrastructure treatment	Provides an interaction taxonomy and visualization	Represent interacting hazards explicitly	3.2; Table 1
18	Aloïs Tilloy; Bruce D. Malamud; Hugo Winter; Amélie Joly-Laugel	2019	A review of quantification methodologies for multi-hazard interrelationships	Earth-Science Reviews	vol. 196, Art. 102881	10.1016/j.earsci-rev.2019.102881	Multi-hazard climate-risk modelling	Interaction quantification and uncertainty	Review of quantification methods	Multi-hazard interrelationships	Not infrastructure-sector specific	Not applicable	Multi-hazard interrelationships; climate relevance varies by application	No explicit infrastructure treatment	Compares methods used to quantify interactions; limitation: not an infrastructure-twin study	Preserve interaction assumptions and uncertainty	3.2; Table 1
19	Jakob Zscheischler et al. (15 authors in DOI record)	2020	A typology of compound weather and climate events	Nature Reviews Earth & Environment	vol. 1, no. 7, pp. 333-347	10.1038/s43017-020-0060-z	Multi-hazard climate-risk modelling	Compound-scenario classification	Typology/review	Compound weather and climate events	Not infrastructure-sector specific	Not applicable	Preconditioned, multivariate, temporally compounding, and spatially compounding events	No explicit infrastructure treatment	Provides a compound-event typology	Classify compound scenarios systematically	3.2; Table 1
20	Wenjuan Sun; Paolo Bocchini; Brian D. Davison	2022	Overview of Interdependency Models of Critical Infrastructure for Resilience Assessment	Natural Hazards Review	vol. 23, no. 1, Art. 04021058	10.1061/(asce)nh.1527-6996.0000535	Infrastructure interdependency and cascading risk	Resilience assessment	Review of interdependency models	Critical-infrastructure resilience assessment	Multiple critical-infrastructure sectors	Not applicable	Generic hazards; indirect climate applicability	Explicit overview and comparison of interdependency models	Compares models used for resilience assessment	Support transparent model selection for interdependency analysis	3.3; Table 1
21	Leonardo Dueñas-Osorio; Srivishnu Mohan Vemuru	2009	Cascading failures in complex infrastructure systems	Structural Safety	vol. 31, no. 2, pp. 157-167	10.1016/j.strusafe.2008.06.007	Infrastructure interdependency and cascading risk	Service continuity and resilience	Infrastructure-network modelling study	Complex infrastructure systems	Interconnected infrastructure networks	Not applicable	Generic failure conditions; indirect climate applicability	Explicit cascading-failure model and propagation	Shows propagation and amplification across infrastructure	Represent cascading pathways in the network layer	3.3; Table 1
22	Gianluca Pescaroli; David Alexander	2016	Critical infrastructure, panarchies and the vulnerability paths of cascading disasters	Natural Hazards	vol. 82, no. 1, pp. 175-192	10.1007/s11069-016-2186-3	Infrastructure interdependency and cascading risk	Governance and social vulnerability	Conceptual analysis	Cascading disasters and critical infrastructure	Critical infrastructure and socio-institutional systems	Not applicable	Cascading disasters; climate relevance is contextual	Infrastructure, governance, and social-vulnerability pathways	Explains systemic vulnerability pathways	Include cross-domain cascades and indirect impacts	3.3; Table 1

Supplementary Table S2. Coding Definitions and Decision Rules.

Coding field	Operational definition	Permitted values or categories	Inclusion / assignment rule	Treatment of multiple applicable categories	Example application	Notes or limitations
Reference number	Stable identifier matching the manuscript reference list.	1-22	Assign the manuscript's existing number; do not re-number independently.	Not applicable.	Ref. 8	The number is an identifier, not a quality rank.
Primary evidence stream	The single stream most directly represented by the source's principal contribution to this manuscript.	Urban-infrastructure digital twins; Multi-hazard climate-risk modelling; Infrastructure interdependency and cascading risk	Assign one stream using the source title/record and the function for which it is cited.	Record other applicable streams under cross-theme contribution.	Ref. 8: Urban-infrastructure digital twins	A primary assignment simplifies mapping and does not imply exclusivity.
Cross-theme contribution	A secondary contribution to another stream or to a connecting concept.	Free-text controlled description; 'None identified' if absent.	Record only a contribution explicitly supported by the source's use in the manuscript.	Multiple concise contributions may be separated by semicolons.	Ref. 10: interdependency and resilience	Cross-theme coding is interpretive and not an effect estimate.
Study/review type	Broad design category evident from the publication record or title.	Review; systematic review; perspective; conceptual framework; taxonomy; typology; modelling study; quantitative assessment; case study/application.	Use the most specific defensible label; do not infer an undocumented method.	Use a compound label only when the publication explicitly spans types.	Ref. 14: case study/prototype	No formal methodological quality appraisal was performed.
Context or scale	Geographic, organizational, or analytical setting at which the source operates.	Global; regional; city; asset/building; infrastructure network; conceptual/analytical.	Use a named location only when explicit in the record or title.	Record geographic and analytical scale together when both are explicit.	Ref. 14: Herrenberg, Germany	Unreported context is marked 'not explicit.'
Infrastructure sector	Infrastructure system or urban service to which the source is applied.	Transport; water; energy; drainage; communications; buildings; multiple critical infrastructures; city systems; not sector-specific.	Assign only sectors supported by the record or manuscript use.	List multiple supported sectors; do not infer sector coverage.	Ref. 15: buildings and energy	Broad 'city systems' does not imply every municipal sector.
Digital-twin function	Capability attributed to a digital twin in the source.	Representation; physical-virtual linkage; integration; monitoring; simulation; life-cycle management; visualization; participation; benchmarking; resilience/crisis management; not applicable.	Code only when the source concerns digital twins.	Multiple explicit functions may be listed.	Ref. 8: semantic integration and life-cycle information	Absence of a function is coded 'not applicable,' not as a negative finding.
Hazard focus	Hazard or disruption process considered by the source.	Single hazard; compound/connected/multi-hazard; generic disruption; not hazard-specific.	Use the source's stated scope; avoid translating generic disruption into a climate hazard.	List interacting or compound categories when supported.	Ref. 19: compound weather and climate events	This field does not measure hazard severity.
Climate-change relevance	Degree to which climate change is explicit in the source's focus or is only an application context.	Direct; indirect/contextual; not explicit.	Assign 'direct' only when climate change/future climate is explicit in the title, record, or manuscript use.	One value only.	Ref. 4: direct	Indirect relevance is not evidence of a climate-impact result.
Multi-hazard treatment	How more than one hazard, driver, or event is represented.	Cumulative; compound; connected; interacting; sequential; comparative multi-risk; not explicit.	Assign only the treatment explicitly described or used in the manuscript.	Multiple applicable treatments may be listed.	Ref. 1: cumulative/concurrent	No numerical interaction model is inferred from a conceptual label.
Dependency type	Relationship through which one infrastructure system or asset depends on another.	Physical; cyber; geographic; logical; functional; generic interdependency; not explicit.	Use explicit dependency terminology; otherwise record 'not explicit.'	Multiple types may be listed.	Ref. 5: physical, cyber, geographic, logical	Contextual cross-sector discussion is not automatically an explicit dependency model.
Cascading-risk treatment	Extent to which disruption propagation or indirect consequences are represented.	Explicit model; conceptual pathway; contextual mention; not explicit.	Distinguish modelled propagation from conceptual or contextual treatment.	One principal level, with a short qualifier where useful.	Ref. 20: explicit cascading-failure model	No cascade magnitude or probability is inferred.
Service-continuity relevance	Connection to maintaining or restoring infrastructure services.	Direct; indirect; not explicit.	Assign direct only when resilience, recovery, service disruption, or continuity is central.	One value only.	Ref. 6: direct through recovery and resilience	This is a conceptual relevance code, not a measured outcome.
Synthesis contribution	The specific role the source plays in the manuscript's evidence narrative.	Concise source-grounded statement.	Describe only the contribution used in Sections 1, 3, 4, or 5.	One or more closely related contributions may be combined.	Ref. 17: hazard-interaction taxonomy	Not a summary of all findings in the source.
Research limitation identified	Boundary or gap visible when the source is considered against the manuscript's integrated planning aim.	Concise source-specific limitation; 'not assessed' if unsupported.	State a limitation only relative to the synthesis and without criticizing unassessed quality.	Multiple related limitations may be combined.	Ref. 15: single-sector and no multi-hazard analysis	No risk-of-bias or quality score is implied.

Coding field	Operational definition	Permitted values or categories	Inclusion / assignment rule	Treatment of multiple applicable categories	Example application	Notes or limitations
Framework implication	Design requirement or architectural function in-formed by the source.	Integration; scenario representation; interdepend-ency network; dynamic risk; prioritization; feed-back; visualization/governance.	Link the source's synthesis role to one defensible framework requirement.	Multiple linked implications may be recorded.	Ref. 5: encode dependency classes	Implications are conceptual, not validated design effects.
Manuscript use	Location where the source is cited or represented in the revised manuscript.	Section number(s) and/or Table 1.	Record all verified uses in the current clean manu-script.	Multiple locations are separated by semicolons.	Ref. 8: Sections 1, 3.1, 5.1; Table 1	Page/line positions may change during typesetting.

Methodological note. The dictionary implements the hybrid deductive-inductive approach described in Section 2.2. No duplicate independent coding, inter-reviewer reliability statistic, formal quality appraisal, or external validation is claimed.

Supplementary Table S3. Source-Record Audit.

Ref.	First author and year	DOI reported in manuscript	DOI verification status	DOI-resolved article title	DOI-resolved journal	Resolved year	Consistency with manuscript reference	Cited in manuscript	Manuscript section(s)	Verification or correction note
1	Mora (2018)	10.1038/s41558-018-0315-6	Verified via Crossref on 22 July 2026	Broad threat to humanity from cumulative climate hazards intensified by greenhouse gas emissions	Nature Climate Change	2018	Consistent	Yes	1; 3.2; Table 1	No correction required.
2	Zscheischler (2018)	10.1038/s41558-018-0156-3	Verified via Crossref on 22 July 2026	Future climate risk from compound events	Nature Climate Change	2018	Consistent	Yes	1; 3.2; Table 1	No correction required.
3	Raymond (2020)	10.1038/s41558-020-0790-4	Verified via Crossref on 22 July 2026	Understanding and managing connected extreme events	Nature Climate Change	2020	Consistent	Yes	1; 3.2; Table 1	No correction required.
4	Forzieri (2018)	10.1016/j.gloenvcha.2017.11.007	Verified via Crossref on 22 July 2026	Escalating impacts of climate extremes on critical infrastructures in Europe	Global Environmental Change	2018	Consistent	Yes	1; 3.2; 3.3; Table 1	No correction required.
5	Rinaldi (2001)	10.1109/37.969131	Verified via Crossref on 22 July 2026	Identifying, understanding, and analyzing critical infrastructure interdependencies	IEEE Control Systems	2001	Consistent with documented metadata variant	Yes	1; 3.3; 4.4; Table 1	Crossref omits the author list and gives the container as 'IEEE Control Systems'; manuscript authors and fuller journal title retained. DOI, title, year, volume, issue, and pages are consistent.
6	Ouyang (2014)	10.1016/j.ress.2013.06.040	Verified via Crossref on 22 July 2026	Review on modeling and simulation of interdependent critical infrastructure systems	Reliability Engineering & System Safety	2014	Consistent	Yes	1; 3.3; Table 1	No correction required.
7	Meerow (2016)	10.1016/j.landurbplan.2015.11.011	Verified via Crossref on 22 July 2026	Defining urban resilience: A review	Landscape and Urban Planning	2016	Consistent	Yes	1; 3.2; Table 1	No correction required.
8	Boje (2020)	10.1016/j.autcon.2020.103179	Verified via Crossref on 22 July 2026	Towards a semantic Construction Digital Twin: Directions for future research	Automation in Construction	2020	Consistent	Yes	1; 3.1; 5.1; Table 1	No correction required.
9	Shahat (2021)	10.3390/su13063386	Verified via Crossref on 22 July 2026	City Digital Twin Potentials: A Review and Research Agenda	Sustainability	2021	Consistent	Yes	1; 3.1; 5.1; Table 1	No correction required.
10	Brucherseifer (2021)	10.1515/auto-2021-0104	Verified via Crossref on 22 July 2026	Digital Twin conceptual framework for improving critical infrastructure resilience	at - Automatisierungstechnik	2021	Consistent	Yes	1; 3.3; 5.1; Table 1	No correction required.
11	Davila Delgado (2021)	10.1016/j.aei.2021.101332	Verified via Crossref on 22 July 2026	Digital Twins for the built environment: learning from conceptual and process models in manufacturing	Advanced Engineering Informatics	2021	Consistent	Yes	1; 3.1; 5.1; Table 1	No correction required.
12	Deng (2021)	10.1016/j.jmse.2021.03.003	Verified via Crossref on 22 July 2026	A systematic review of a digital twin city: A new pattern of urban governance toward smart cities	Journal of Management Science and Engineering	2021	Consistent	Yes	1; 3.1; 5.1; Table 1	No correction required.
13	Li (2021)	10.1007/s43762-021-00005-y	Verified via Crossref on 22 July 2026	Smart city based on digital twins	Computational Urban Science	2021	Consistent; documented metadata presentation variants	Yes	1; 3.1; 5.1; Table 1	Crossref deposits the Chinese name parts in reversed given/family fields and reports issue 1; the conventional manuscript author order, volume 1, and article 4 are retained. No correction required.
14	Dembski (2020)	10.3390/su12062307	Verified via Crossref on 22 July 2026	Urban Digital Twins for Smart Cities and Citizens: The Case Study of Herrenberg, Germany	Sustainability	2020	Consistent	Yes	1; 3.1; 5.1; Table 1	No correction required.
15	Francisco (2020)	10.1061/(asce)jme.1943-5479.0000741	Verified via Crossref on 22 July 2026	Smart City Digital Twin–Enabled Energy Management: Toward Real-Time Urban Building Energy Benchmarking	Journal of Management in Engineering	2020	Consistent	Yes	1; 3.1; 5.1; Table 1	No correction required.
16	Gallina (2016)	10.1016/j.jenvman.2015.11.011	Verified via Crossref on 22 July 2026	A review of multi-risk methodologies for natural hazards: Consequences and challenges for a climate change impact assessment	Journal of Environmental Management	2016	Consistent	Yes	3.2; Table 1	No correction required.
17	Gill (2014)	10.1002/2013rg000445	Verified via Crossref on 22 July 2026	Reviewing and visualizing the interactions of natural hazards	Reviews of Geophysics	2014	Consistent	Yes	3.2; Table 1	No correction required.

Ref.	First author and year	DOI reported in manuscript	DOI verification sta- tus	DOI-resolved article title	DOI-resolved journal	Resolved year	Consistency with manuscript reference	Cited in manuscript	Manuscript sec- tion(s)	Verification or correction note
18	Tilloy (2019)	10.1016/j.earsci- rev.2019.102881	Verified via Crossref on 22 July 2026	A review of quantification methodologies for multi-hazard inter- relationships	Earth-Science Reviews	2019	Consistent	Yes	3.2; Table 1	No correction required.
19	Zscheischler (2020)	10.1038/s43017-020-0060-z	Verified via Crossref on 22 July 2026	A typology of compound weather and climate events	Nature Reviews Earth & Environment	2020	Consistent	Yes	3.2; Table 1	No correction required.
20	Sun (2022)	10.1061/(asce)nh.1527- 6996.0000535	Verified via Crossref on 22 July 2026	Overview of Interdependency Models of Critical Infrastructure for Resilience Assessment	Natural Hazards Review	2022	Consistent	Yes	3.3; Table 1	No correction required.
21	Dueñas-Osorio (2009)	10.1016/j.strusafe.2008.06.00 7	Verified via Crossref on 22 July 2026	Cascading failures in complex infrastructure systems	Structural Safety	2009	Consistent	Yes	3.3; Table 1	No correction required.
22	Pescaroli (2016)	10.1007/s11069-016-2186-3	Verified via Crossref on 22 July 2026	Critical infrastructure, panarchies and the vulnerability paths of cascading disasters	Natural Hazards	2016	Consistent	Yes	3.3; Table 1	No correction required.

Availability of Original Review Records

The following original materials were unavailable for verification:

- database exports
- original database search strings
- search histories
- reference-library files
- deduplication records
- title-and-abstract screening sheets
- full-text decision logs
- exclusion-reason logs
- reviewer-role records
- the original coding matrix
- the documentary basis for the previously reported 97-study corpus

Consequently, the revised paper does not claim a reproducible systematic search. The earlier numerical PRISMA-type flow has been withdrawn, and no retrospective screening or deduplication arithmetic has been reconstructed. The auditable evidence base is limited to the 22 DOI-verified journal articles cited in the manuscript. This supplement is intended to improve transparency, not to retrospectively recreate unavailable review records.