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Mapping Synergies and Trade-offs Among Climate Resilience Indicators: A Systematic Review Based Cross-Impact Framework for Buildings

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With the increasing frequency of climate change-induced stressors, enhancing building resilience is vital to safeguard long-term structural integrity, occupant safety and comfort. Research and insurance institutions consistently warn that delayed or inadequate climate adaptation efforts could amplify economic losses by up to fifteen times, underscoring the need for decisive action. Since buildings are typically constructed or renovated only once or twice in a lifetime, embedding resilience into long-term decisions is critical. However, current practices remain largely mitigation-centric, with limited attention to resilience, particularly in the context of multiple, compounding climate hazards. To address this gap, this study conducts a systematic literature review to identify and classify resilience indicators across five climate risk domains: thermal, energy, flood, fire, and wind. These indicators are synthesized into a Cross-Impact Matrix (CIM), which captures the nature of pairwise relationships, synergistic, conflicting (trade-offs), or independent. This structured mapping enables the identification of indicators that offer co-benefits across multiple hazards, where trade-offs occur, and how strategies can be bundled to maximize resilience. To further explore these interrelations, qualitative network analysis is applied in CIM. Indicators are modeled as nodes and their interactions as edges, enabling assessment of indicator centrality, influence, and interdependencies. This approach identifies key leverage points, indicators that have the most influence on the resilience system and thus should be prioritized in planning. By combining CIM with network analysis, this study offers a structured approach that can inform more integrated, multi-hazard-aware decision-making in building design and renovation. Such analysis serves as a foundational step towards developing an integrated multi-hazard assessment framework that could assess the overall climate resiliency of the building in the future. The framework supports climate-smart, evidence-based renovation and building design decisions.