A Digital Platform to Streamline Early Phase Resilience Research for the Architecture Design Team

Abstract

Resilience to extreme weather and natural disasters is vital in healthcare architecture—protecting lives, budgets, and operations for clients, users, and designers alike, from the societal scale down to the individual site. Despite the availability of many resources, the integration of resilience in current design practice remains limited. In response, this research explores how the project team can more effectively utilize available resources to thoughtfully and strategically be best informed in the resilience design research process.

Based on a review of current literature, resources, and a detailed survey and in-depth workshops, this study proposes an essential workflow that addresses the limitations of several existing frameworks. The tasks within the essential workflow are designed precisely for use cases at the early design phase. Then, based on the essential workflow, a web-based platform is developed, providing architectural design teams with a more accessible and friendly approach to streamline the resilience design research workflow: identifying the specific concern, assessing risk and vulnerability, and navigating resilience-related resources.

This study delivers the first lightweight, task-oriented workflow that unifies dispersed resilience data, tools, and precedents within a single, designer-friendly platform. By mapping resources directly to early-phase tasks, the platform gives project teams—and the wider resilience community—an accessible hub for rapid, structured inquiry. Methodologically, the work introduces a Retrieval-Augmented Generation (RAG) approach tailored to AEC design tasks, demonstrating how bespoke, in-house AI applications can streamline niche workflows and open a new direction for building-design technology.

Table of Contents

Acknowledgements

This executive summary builds on the collective insight of many contributors across academia and practice, with special gratitude to ZGF.

Dr. Flavia Grey, my firm advisor at ZGF, provided unwavering mentorship whose clarity and pragmatism shaped every milestone. I also thank Professor Karen Chen, my ARC faculty advisor, for her steady academic guidance and for bridging the fellowship's research goals with this project's objectives.

Equally, I am grateful to Sarah Crochet, Marty Brennen, Tim Myers, Jonah Hawk, Dane Stokes, and Chuou Zhang, Chunya Wu, Anitda Praseutsinh, and to many more colleagues whose generosity and enthusiasm enriched this work. Special thanks to the ZGF partner Todd Stine who championed the ARC Fellowship and secured the resources that made this research possible.

I acknowledge my thesis committee at the University of Washington: Dr. Narjes Abbasabadi, who safeguarded the academic direction, and Professor Heather Burpee, whose incisive domain guidance aligned this work with the standards of the Master of Science in Design Technology program.

Finally, I thank the ARC Fellowship leadership—Renée Cheng, Teri Randall, and Carrie Sturts Dossick—for launching and stewarding the program and for the opportunities to present and refine this work.

Your collective commitment to innovation and open collaboration is the cornerstone of this project!

Use of AI: Portions of the platform's proof-of-concept code were drafted and refined through iterative prompts with GitHub Copilot (VS Code extension, May 2025) and ChatGPT (GPT-4o, O1, O3, Jan–May 2025). Every AI-assisted snippet was manually reviewed, refactored, and tested locally to verify functionality, security, and license compatibility. I retain full responsibility for the accuracy and integrity of all content.

I also acknowledge the global open-source community and developer forums whose libraries, best practices, and troubleshooting guidance made rapid experimentation possible.

Any errors or omissions that remain are entirely my own.

Chapter 1. Research Background

The United States has witnessed a growing frequency of “billion-dollar” disasters, accompanied by escalating financial losses and fatalities (NOAA National Centers for Environmental Information (NCEI), 2025). Meanwhile, resilience in the built environment has attracted increasing attention from both industry and academia as a critical factor in enabling buildings to withstand hazards, particularly those related to climate change and natural disasters.

Resilience is essential for both society and the stakeholders who use or live in proximity to buildings, and it should be an integral part of architectural design. Architects, as key agents in the built environment, are responsible for incorporating resilience into their design strategies. However, project teams often face substantial challenges during the design process when attempting to implement resilient design principles.

This research addresses the following key questions:

- What are the current resources and challenges encountered by project teams in implementing resilient design across different design phases?
- What approaches are currently used in resilience design research?
- How can a systematic tool be developed to support project teams through the most essential steps of the resilience research workflow?

In response to these questions, the aim of this study is to develop a digital platform that offers project teams a more accessible and user-friendly means of streamlining the resilience research process. Specifically, the platform will:

- Provide a guided, easy-to-adopt workflow with embedded access to essential data;
- Facilitate efficient navigation of resources, including precedent, strategies, tools, support, etc.;
- Deliver a guide for new projects, new projects, integrating a precedent library, resource navigation modules, and existing tools into an interactive, unified platform.

Chapter 2. Related Work and Scoping

The current literature discussion on resilience largely concentrates on conceptualizing resilience frameworks, developing metrics for assessment, or enhancing specific components within the broader resilience process. However, from the practitioner’s perspective, a recurring question emerges: *How can this research be applied to everyday project workflows?*

On the other side, a wealth of resources now exists to support resilience planning in architecture design. Reputable organizations such as the American Institute of Architects (AIA) and the Federal Emergency Management Agency (FEMA) offer open-access toolkits, data repositories, and analytical frameworks to facilitate resilience-focused research and design. These tools can serve as foundational starting points for design teams embarking on resilience initiatives.

However, despite the abundance of resources, design professionals continue to highlight difficulties in effectively navigating and integrating them. The current research process often lacks a clear structure, resulting in significant time lost toggling between fragmented resources and isolated tasks.

Several practice examples are studied to understand how resources are utilized in different tasks as well-supported and resource-rich projects. However, they raise a critical question: *What does resilience research look like in less ideal or less resource-intensive settings?* To develop a broader understanding of the current resilience landscape in architectural practice, it was essential to hear from a wide range of design professionals with diverse project experiences and organizational contexts.

To obtain a panoramic view of how resilience research is currently practiced, an online questionnaire was distributed across six architecture and design firms: ZGF Architects, DLR Group, 7 Directions Architects/Planners, Mithun, Schemata Workshop, and Glumac. The objective of the survey was threefold: (1) to assess participants' resilience-related knowledge, experience, and exposure to typical hazards; (2) to identify barriers encountered at different design phases; and (3) to gather insights into what types of tools, resources, or guidance would help bridge existing practice gaps. The survey is then followed by a series of in-depth workshops within ZGF, to get further granularity —specifically, to identify *which tasks within which design phases* require the most immediate attention and *what types of support* design teams actually need.

Together, the survey's breadth and the workshop's depth map a clear route forward: resilience strategies must be integrated early—at the point of scope definition and risk framing—through content that is layered, easily navigable, and communicative:

- **What – Key Barriers:** Early-phase communication gaps with owners, fragmented or inaccessible resources, and unstructured hazard assessment practices remain the primary hurdles. These barriers hinder both the justification and implementation of resilience measures.
- **Where – Critical Phases.** The decisive moment is the *Define Scope* stage, where alignment on time, cost, and performance goals sets the trajectory for the project. Systematic *Risk Assessment* is the next linchpin, ensuring that all relevant hazards—and not just the obvious ones—inform design. Finally, *Develop Strategy* benefits from a structured, tiered knowledge base to translate analysis into actionable design moves. Noticeably, the key steps are highly aligned with what we find out in the practice examples.
- **How – Support Pathways.** Both datasets converge on four intervention themes:
    - Rapid, compelling risk-communication tools for owner engagement.
    - A centralized, context-tagged resource hub that unifies data, case studies, and guidance.
    - Funding or ROI modules that pair cost–benefit logic with real-world success stories.
    - A minimal workflow with baseline resources that elevate internal capacity and embed resilience thinking as early as the RFP or pre-design stage.

Chapter 3. Workflow

The results from survey and workshop unveil where (which steps and tasks) and how (what the workflow should offer) the design team would love to improve. A simplified yet focused version of the previous comprehensive workflow is tailored for these feedbacks. This version concentrates on the tasks most critical to early-phase project development, especially for teams with limited time, experience, or access to specialized resources. The essential workflow emphasizes three key steps:

- identifying hazard: what hazard would happen on this site;
- assessing risk: how the hazard(s) would impact each system of the building project, and at what level or risk;
- navigating resource: browse a selected range of resources, most importantly, case study and strategy collection, so that can later be used for strategy development;

These steps are also the "resource-oriented" steps, enabling broad applicability without requiring deep project-specific customization. As mentioned in Chapter 2, one common limitation of existing toolkits analyzed is that they attempt to be very comprehensive and general on not only the range of resources but also the range of tasks. While well-intentioned, this ambition often results in tools that are overwhelming or difficult to adopt—especially for smaller teams in early-phase design. In contrast, the essential workflow is purpose-built for rapid, deep, and focused research, enabling users to access specific tasks and resources with minimal friction.

		Parameters	source	Example
Core Factors in the workflow	**Site Context & Hazard**	**Location**	User specify	Seattle, WA
		Historic Hazard (type, frequency)	FEMA API	
		Other Context : Typology, Project constraint, scale, etc.	User specify	Hospital; Height limit, Historic district, etc. 200,000 sf building
	Precedent & Strategy Library	**Case study**	Workflow Embedded + User upload	
		Strategy	Workflow Embedded + User upload	
Supportive Factor	**Building System List**		Workflow Embedded	
"Other resource"	**Any types of resource**		Workflow Embedded + User upload	

Table 3.1 Parameters for workflow

The primary obstacle encountered during data collection was the scarcity of publicly available, high-quality case studies and strategy records that are narrowly focused on healthcare resilience. Most open-access information is fragmentary, buried in unstructured reports or conference slide decks, and therefore ill-suited to direct query or comparison. Facing this barrier, this research would leverage readily available resilience datasets that, while not exclusive to healthcare, share a schema compatible with the Option Database (*All Options Embed*, n.d.), and thus provide a foundation for search and retrieval.

Although these public datasets lack the depth and clinical specificity of a bespoke collection, they serve as effective placeholders for validating the platform's search and recommendation engine. All demo datasets were drawn from authoritative sources cited in Section 2.2.1—FEMA, NOAA, and other government portals—and are both freely accessible and carry no material licensing barriers to commercial use by licensing restrictions. With the data gap acknowledged and a surrogate corpus in hand, the project can advance to the next phase: constructing and refining the tool itself.

Category	Dataset / File	Size	Key Fields (if table file)	Original URL	License / Availability	Question
Case-Study Library	fema-case-study.csv	1,255 records	Title, Hazard, Location, Description, URL	https://www.fema.gov/emergency-managers/practitioners/case-study-library	Public domain / CC0	Q3, Q5
Hazard Guidance	fema-publication.csv	441 records	Title & PubNo, Year, Description, Hazard, URL	https://www.fema.gov/emergency-managers/risk-management/building-science/publications	Public domain / CC0	Q6
Strategy Library	All Options Embed.csv	1,061 records	Option, Hazard, Asset, Action, Description, URL	https://toolkit.climate.gov/option	Public domain / CC0	Q4, Q5
Other Resource (Funding)	Building Code Funding Opportunities.pdf	4 pages	Funding source, eligibility, application notes	https://www.fema.gov/emergency-managers/risk-management/building-science/building-code-funding-opportunities	FEMA open PDF	Q6
Other Resource (Healthcare Speciality)	CR4HC_1_All_Multiple Hazards.pdf (one chapter of the original 373-page pdf)	38 pages	Healthcare-specific steps, tools, resource links	https://toolkit.climate.gov/topic/health-care	NOAA open PDF	Q6
Hazard	FEMA Disaster Declarations API	68,193 records	Hazard, State, County, BeginDate, EndDate	https://www.fema.gov/openfema-data-page/disaster-declarations-summaries-v2	Public domain / CC0	Q1–Q4, Q6
Systems Checklist	City of Vancouver Building Resilience Planning Worksheet	–	System name, function, resilience target, redundancy level	https://vancouver.ca/files/cov/resilient-buildings-planning-worksheet.xlsx	Municipal open data	Q2

Table 3.2 Data used as demo for building the platform

Chapter 4. From Workflow to Platform

What this platform is and is not

This research positions the proposed platform as an **open, expandable toolkit** for supporting **early-phase resilience exploration** in architectural design. Its primary aim is to demonstrate that, even using **imperfect but schema-compatible public datasets**, design teams can rapidly transition from hazard identification to precedent exploration and initial strategy formation. As such, the core focus of this research lies in the **design of the workflow**, **processing of structured data**, and **creation of a usable, intuitive interface**—one that demonstrates how disparate information streams can be normalized, queried, and meaningfully compared within a unified platform.

This platform is **not intended to function as a comprehensive or expert-curated knowledge base**. Nor does it seek to replace detailed resilience modeling, code compliance workflows, or the professional judgment of licensed experts. The current data layer serves as a **proxy**, enabling proof-of-concept validation; richer, practice-specific content will only emerge if and when the design community or design firms contribute high-quality **case studies, strategies, and metrics**.

Because the platform remains open and collaborative, users play a pivotal role. They are responsible for validating the accuracy, relevance, and intellectual-property status of any material they upload. In short, the tool supplies the structure and search intelligence, but the community must supply and curate the knowledge that gives the structure lasting value.

Essential functionality and component

Based on the essential workflow and the typical user questions identified at each step, this section outlines the core **functional components** necessary for translating the workflow into a usable, browser-based platform. Each component represents a high-level encapsulation of multiple lower-level functions, spanning both **frontend** and **backend** operations. Here is a list of 6 core components:

1. Hazard Finder: Retrieves and visualizes hazard records from FEMA based on user-specified location. Users would select hazards most relevant to their site for further analysis.
2. Risk Assessor: Guides users through evaluating the impact of selected hazards on relevant building systems and subsystems, including assessing future likelihood and prioritizing high-risk scenarios.
3. File Curator: Enables users to upload structured files (e.g., tables, PDFs), parse and save content, and interact with it via a chatbot-style interface.
4. Context Composer: Helps users define project-specific parameters such as location, building typology, scale, regional setting, and other contextual fields in a structured format.
5. Query & Answer: Supports semantic search within uploaded documents. Accepts natural language questions, retrieves relevant text segments, and optionally summarizes the findings.
6. Knowledge Explorer: Visualize retrieved results from “ Query & Answer” by mapping semantically connected results—especially from structured files—based on shared context. This feature helps users discover related strategies or precedents.

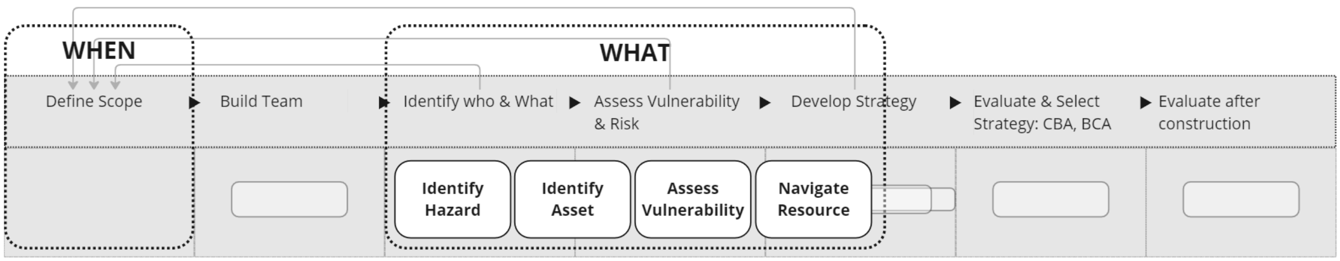

Figure 4.1 Essential Workflow and Components (high-level)

To structure the essential workflow, each input factor was evaluated against two key criteria: Frequency—how many of the core questions the factor can answer—and Usage Pattern—the typical way a design team interacts with that factor (Search, Consult, Exhaust, or Compliance). By mapping each factor to the question set and tallying its hits, an initial priority ranking is obtained.

Factor	Q1	Q2	Q3	Q4	Q5	Q6	Total Freq	Dominant Pattern	Additional Comment
Site Context & Hazard	●	●	●	●	–	●	5	Search	Critical starting point for all assessments
Precedent & Strategy Library	–	–	●	●	●	–	3	Search	Mentioned in the survey and workshop
Consultant / Gov Agency	–	–	–	–	–	●	1	Consult	Existing tools like “Procore Network”
Certification & Funding	–	–	–	–	–	●	1	Consult + Compliance + Funding	Not task-specific in early phases
Building & Local Code	●	●	–	–	–	–	2	Compliance	Existing tools like “UpCodes”
Essential Asset List	–	●	–	–	–	–	1	Exhaust (list all)	Too project-specific, not “reusable” for more projects

Table 4.1 : Selecting Factors for Questions

Component and Step	Input from User	Other Input data	What this Component would do	Key Technology
Step 1: Hazard Finder	location	FEMA API	Fetch all hazard records from FEMA with the user’s input location, render and display to the user, and record hazards selected by the user	FEMA api, Recharts, Express.js
Step 2: Risk Assessor	building system-subsystem,	User-selected hazards (from previous step)	Guide the user through the process of assessing the impact of the hazard on the related building system-subsystem, assessing the likelihood of the hazard happening in the future, and selecting prioritized risks to consider in later steps	React, MaterialUI

<table>
<tr><td>Step 3 +

File Management:

File Curator</td><td colspan="2">File (table file or pdf)</td><td>Handle file uploading and parsing, provide a chatbot-like window for the user to quickly talk with a file</td><td rowspan="4">Backend:

Multer, OpenAI, LangChain, etc.

Frontend:

React, MaterialUI, React-force-graph-3d, etc.</td></tr>
<tr><td>Step 3:

Context Composer</td><td>Project context (text)</td><td>–</td><td>Define project context in a more structured way, including location, typology, scale, geography region, and other customized fields.</td></tr>
<tr><td>Step 3:

Query & Answer</td><td>Question in natural language</td><td>Retrieved Chunks from previous Query (if asked to perform summarization)</td><td>Perform semantic search with the user’s message within a specific range of files, render and display retrieved results; also support summarization of retrieved results</td></tr>
<tr><td>Step 3:

Knowledge Explorer</td><td>–</td><td>Retrieved Chunks from previous Query</td><td>Visualize the retrieved result from “ Query & Answer” by connecting results with the same context, only support the result from the table file</td></tr>
</table>

Table 4.2 : Data and Knowledge in a Typical Architecture Design Process

Chapter 5. Result and Discussion

Building on the platform’s core objective—lowering the barrier to early-phase resilience work—its contributions can be viewed through four lenses: the day-to-day needs of design teams, the collective interests of the resilience community, the strategic goals of design firms, and the broader potential of lightweight in-house software.

- For the design team, the platform offers a user-friendly, centralized tool for early stage resilience planning, especially helpful for those with limited experience or resources;
- For the resilience-design community, the platform ast as an open-access repository that encourage knowledge sharing, lowers the barriers for small offices and junior designers;
- For design firms, the platform has the potential to transform archived knowledge into searchable assets, enhancing project delivery;
- For innovation in practice: this project showcases a digital transformation with light-weight AI application.

However, his research has several limitations, which can be grouped into three categories: data, technical implementation, and use case scope.

- Data limitation: step 1 only contains historical hazard data with in US, ;and step 3 relies on loosely-fit public resilience data (not specifically for healthcare building design);
- Technology limitation: Only tabular and PDF formats are supported; images in PDF will be ignored;

- Functionality limitation: Step 2 still requires much manual judgement, which is far from true automation, and might introduce bias from the individual; Step 3 does not support ranking or filtering the search result.

Following the development of the platform prototype, feedback was solicited from several ZGF design professionals as representative early-phase users. Although the sample size was limited, a number of clear feedback clusters emerged. Additional feedback was also gathered during the public thesis presentation session. Responses largely centered around four themes: interface and user experience (UX), integration of additional data sources, bridging workflow and data, and the platform's broader utility for the architectural design community.

- Interface design: User would prefer the technical details being hidden first while remain accessible;
- Data: Granular hazard metrics from insurance or engineering companies would be helpful;
- Manual Scoring: Step 2 still requires manual input for all the assessment. Future enhancements may include in-house semi-automated calculators.
- Target Audience, The platform is valuable for small offices lacking a dedicated resilience team, and could also be applied by planning and landscape professionals.

Beyond the limitations and feedback addressed above, the platform offers longer-term implications for knowledge infrastructure in architectural practice. As more firms build in-house resilience teams and design technology units, this platform could be deployed as the backbone of a firm-specific knowledge base. With appropriate data privacy measures, firms could integrate proprietary high-quality case studies, internal strategies, and performance metrics into the existing schema, enabling the creation of a private yet navigable knowledge layer. More broadly, this work illustrates the possibility of combining modular web infrastructure, open-source AI models, and distributed data stewardship to drive accessible innovation—both within individual firms and across the design profession.

Reference

All Options Embed. (n.d.). Airtable. Retrieved June 9, 2025, from https://airtable.com/apppEQekkkpbTtdBe/shr4XOlRsOoaMyGmh/tblO7BbuRztHLgfVS

NOAA National Centers for Environmental Information (NCEI). (2025, January 10). *U.S. Billion-Dollar Weather and Climate Disasters: State Summary—United States*. https://www.ncei.noaa.gov/access/billions/state-summary/US