

Resilient Homes Online Design Aide: Connecting Research and Practice for Socially Resilient Communities

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Resilience in architectural research, discourse, and practice tends to focus on physical aspects of the built environment. Much of the discussion within this technological domain of resilience resolves around singular, unique, and high-value facilities: ignoring the vast fabric of buildings where most people live. However, studies in socioecological resilience suggests that resilience in the built environment must address people and systems, not merely property. Transitioning to this focus will both require and result in broadening architecture's interest and influence beyond the normal physical boundaries of the built environment. To effectively engage this broader scope, new tools must enable new modes of public outreach, information sharing, data analysis, decision support, and ultimately create new knowledge. This paper describes the motivation, development, and preliminary findings of one such tool, the Resilient Home Online Design Aide (RHOnDA). This results suggest a cycle of participatory architectural research to advance socioecological resilience.

INTRODUCTION

Studies in socioecological resilience suggest that resilience in the built environment is fundamentally about people and systems, rather than property.¹ While architects contribute important work by building resilience of individual buildings as shelter against specific hazards, and adapting them to new conditions, improving urban resilience must also address the existing urban fabric of repetitive, residential buildings that architects have historically neither designed nor studied. Carpenter et al.² formulated resilience assessment as relating object(s) and hazard(s), succinctly asking “resilience of what to what?” but uncertainty about both the object (individual structures comprising the urban fabric) and the hazard (the broad array of short- and long-term hazards) complicates such assessment of resilience in the built environment. Thus, evaluations of and interventions in social resilience require a fundamental shift in architecture research and practice; from performing highly-specific, detailed analysis of an exceptional object for an expert audience (elements of our prior research and teaching) to identifying a broadly applicable set of generic probabilistic trends and communicating them to the widest possible audience (the subject of this article).

Embracing this approach demands new definitions of the architectural project that combine rigorous research with social engagement, including new methods for analysis and modeling, as well as new methods and tools

of communication. RHOnDA—the Resilient Home Online Design Aide—is an example of this type of work. To better understand and improve the resilience of existing residential buildings, we adopted a sampling and modeling approach of randomly-selected buildings within broad types to represent the entire urban fabric of a city, simulated their performance and trained a machine-learning algorithm to tailor generic information to any specific home of that type based on user inputs. The results of this modeling and analysis are presented in an interface that gives access to a national database of risks and socio-ecological factors of resilience, making publically available data accessible and customized to a user's location, household, and building type; and providing clearly explained and illustrated recommendations and opportunities for action. This new method of outreach and communication leverages and expands public agency in the resilience of the built environment.

Engaging with the existing urban fabric expands the conventional physical and social boundaries of Architecture: improving social resilience for individuals and communities while broadening design to areas of the built environment not ordinarily considered. More than a publicity program, public engagement and empowerment are inherent features of these new disciplinary tools. Because feedback from users generates new knowledge and directions for researchers and practitioners it effectively connects research, education and practice to build social-resilience.

NOT JUST A BUILDING: BUILDING FABRIC

Academic and practice-based research into the resilience of the built environment follows the contours of the academic and professional discourse, considering only the unique and high-value assets as “Architecture”. Conversations about resilience within architecture tend to focus on singular buildings designed for specific hazards. This is important work, as it tests ideas and develops methods for assessment, and possible design solutions. However, it depends on a client with both the desire and ability to investigate and incorporate these designs, and is inherently specific, detailed and unique. This work is in line with the general focus of the academic and professional discourse: the few rigorous estimates available are decades old, but suggest between 2% and 5% of buildings worldwide are designed by architects, with higher totals in some countries like the UK.³ More recent data for the housing sector aligns with those figures: the design of housing constitutes only 4% of the billings from the top ranking

architecture and engineering firms in the United States⁴; and architects only design about 2% of the houses in the United States.⁵ As a result, the insurance industry dominates research about resilience for the residential building stock, and understandably focuses on hazards to property as measured by greatest economic cost. Similarly, climate adaptation planning often emphasizes risk assessment at urban scales to guide new construction, with little agency over existing structures. Taken together, there is scant attention to the existing residential fabric, even though it represents a vast proportion of buildings and provides dwellings for most Americans. We believe the repetitive nature of this urban fabric could be modeled, to generate regionally specific but broadly applicable knowledge and inform programs for mitigation and adaptation with widespread benefits.

LOW-DENSITY URBANISM

Fabric buildings are not a uniquely urban phenomenon: most new development in the United States occurs on the fringes of cities: in suburbs and exurbs, a landscape dubbed—and dismissed—as urban sprawl. Drawing on a range of sources, Ellen Dunham-Jones estimates that approximately three-quarters of new US construction occurred in what she describes as a “a vast landscape almost entirely uninformed by the critical agendas or ideas of the discipline.”⁶ While increased global urbanization means that 55% of people worldwide live in cities⁷, more than half of the US population lives in suburbs. A 2017 analysis based on 2016 census data suggests that the overall trend from the end of the 20th century still continues, noting that “the fastest growth was in the lower-density suburbs of large metros, with midsize and smaller metros growing more slowly and non-metro counties lagging.”⁸ Even the narrative of urban revival seems to be primarily a product of wealthy, well-educated moving to particular neighborhoods, than a general trend⁹. While these demographic shifts within neighborhoods also warrant study, the college-educated millennial seems likely to be the exceptional homeowner able to hire (or to be!) a professional who can evaluate resilience as part of renovating the home.

Urban is to us, the urban agglomeration, not just the dense core or inner ring suburbs; it is urban problems extrapolated across areas of low density. When it comes to addressing issues of resilience, the need for tools may be greater in non-urban areas without sufficient density to support the planning and programmatic resources of a large city. Certainly, suburban and even rural areas have a greater percentage of homeownership than cities. Distributed ownership is a challenging characteristic for resilience in the built environment, as it requires action by thousands of more-or-less well informed independent actors, each with their own motivations and agendas. In this milieu the contemporary model of architectural practice as a service for elite clients has little to offer. Whether the cause or effect of their disconnect from architectural discourse, suburban

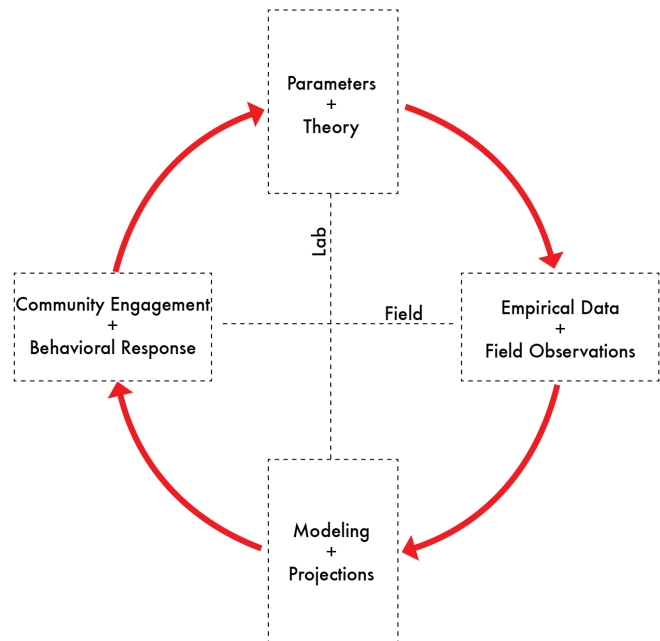


Figure 1: Conceptual diagram of feedback loop between academic research and community engagement, building social resilience in architectural research and practices (by authors).

homes are perceived as standardized, formulaic, market-driven¹⁰, yet this very consistency simplifies assessment and renders findings more generalizable to a larger population. Furthermore, for architects to affect social resilience requires engaging with the very same economic and cultural systems that generate this environment, to influence them through research, advocacy and collaboration.

THE ROLE OF THE ARCHITECT IN SOCIAL RESILIENCE

Our point is not that architects have limited scope in the design of buildings, but rather, that the role of architects is not merely to design buildings. In this case, developing new tools expands the discipline to engage the social, economic and political systems operating in the existing built environment that are not currently part of the discourse. In the design for resilience, architects are sometimes cast as “information managers” or “creative individuals” interpreting the brief of a project and allowing the free flow of information between stakeholders¹¹. In this role, architects can advance social resilience by creating a feedback loop of information from research to practice to users, back to researchers and other actors of the built environment: informing reorganization and adaptation. (See Figure 1)

The work here lies not in discovering new techniques in the design (or even re-design) of particular buildings, but rather in the realm of public education, communication and policy. Boshier described the research challenge of



Figure 2: Building typologies defined and modeled for RHOnda based on City of Boston database and sampling, include: single-family home, triple-decker, duplex, row house, and low-rise multi-family building (by authors). This methodology exclude building types of 5 stories or more.

resilience as one of implementation, technology transfer and diffusion— not of generating new knowledge per se— using existing frameworks, that are sufficiently flexible and reconfigurable to enable users to appropriate them for their own requirements and contexts.¹² To that end, we developed a methodology that can be applied in almost any region of the country to bring high-quality research to a wide audience that could not normally access sophisticated analysis, expertise and judgement to make good on these findings. It translates building-specific research into generalized probabilistic trends, and then tailors and communicates those findings to the situation of specific users. This tailoring to make the information useful and accessible to individual people depends on gathering information. Consistent with the non-expert audience and goal of wide adoption, the interface gathers just enough information; asking users very basic questions to input into the model and anonymizing it for user privacy. In addition to driving the user tailoring, this information represents a valuable body of data about individual households for future research.

SAMPLING AND ZIP CODE DATA

One benefit of a repetitive built environment is that it becomes reasonable to use statistical approaches to evaluate general trends. Sampling from a relatively repetitive environment avoids the need for finely-resolved information about each property, with a commensurate, but acceptable, reduction of fidelity in the results. To that end we clustered the assessor data into groupings or types, for example single family, or row houses as illustrated in figure 2. These five to six types (depending on city) were held to be sufficiently similar that findings from one could be generalized across the type with only minor adjustments (for example scaling by floor area). We then drew samples of each type from the assessor's data and developed a detailed data model of each of the sample buildings, including systems information, year of construction, size, envelope characteristics and so on. We analyzed the performance of each sample building using these data and looked at the findings across the sample as representative of the whole type in that city. This process has been repeated in three cities with different building stock, climate, and risks. In some cases where precise values were unknown, a range of data consistent with the findings

in the type were used. This process allows for some degree of uncertainty. The samples then yield generalizable multi-variable algorithms, so any other house of the type (even one we did not model) may be approximated.

While sampling provides information about the vulnerabilities of each property type, evaluating and responding to risk also requires understanding the hazard. While there is a great deal of data publicly available from both government, Industry and NGO sources—including FEMA, NOAA, DOE, SurgingSeas, Insurance Institute for Business and Home Safety—we observed that available hazard data is both highly dispersed across those multiple sources and generally directed at an expert audience. We addressed these challenges by classifying hazards into twelve types (e.g. high winds, power failure, high-heat, storm surge). We then identified the best data sources available for each and converted all the data to a spatial constant spatial resolution of zip code. While this is an imperfect geographic measure, the resulting zip code-based national database addresses multi-hazard resilience, and, critically, can translate those hazards into localized risks.

NOT JUST MULTIPLE BUILDINGS: SYSTEMS

Determining hazard by combining information about the home and the risks it faces, while useful and certainly temptingly architectural, are only a small part of the challenge of resilience. Working to conceptualize and measure resilience, a team of researchers at the Multidisciplinary Center for Earthquake Engineering Research (MCEER) developed a model that organizes the factors affecting resilience into four mutually-exclusive and collectively-exhaustive domains, dubbed the Technical, Social, Organizational, and Economic domains.¹³ The technical domain includes the physical infrastructure of the built environment. The organizational focuses on the structure for procedures and policy that govern both the technical environment (such as building codes) and human relations (such as emergency management plans). In contrast, social relates to the attributes of the human population such as age, health, and affluence. Affluence is one manifestation of the broader economic domain, which relates to both economic resources and instruments like insurance, as well to the economic drivers of resilience, such as natural resource availability, innovation,

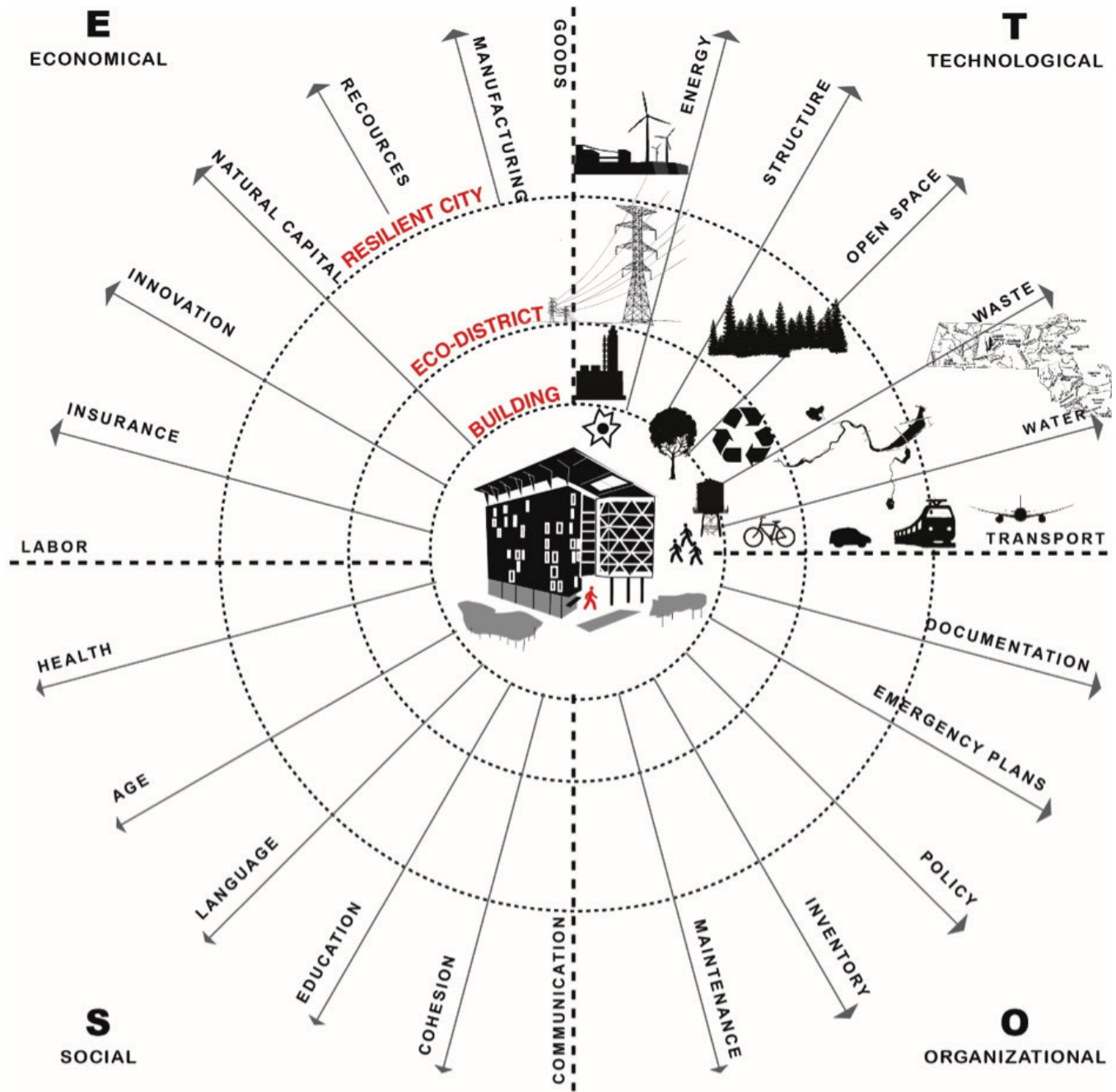


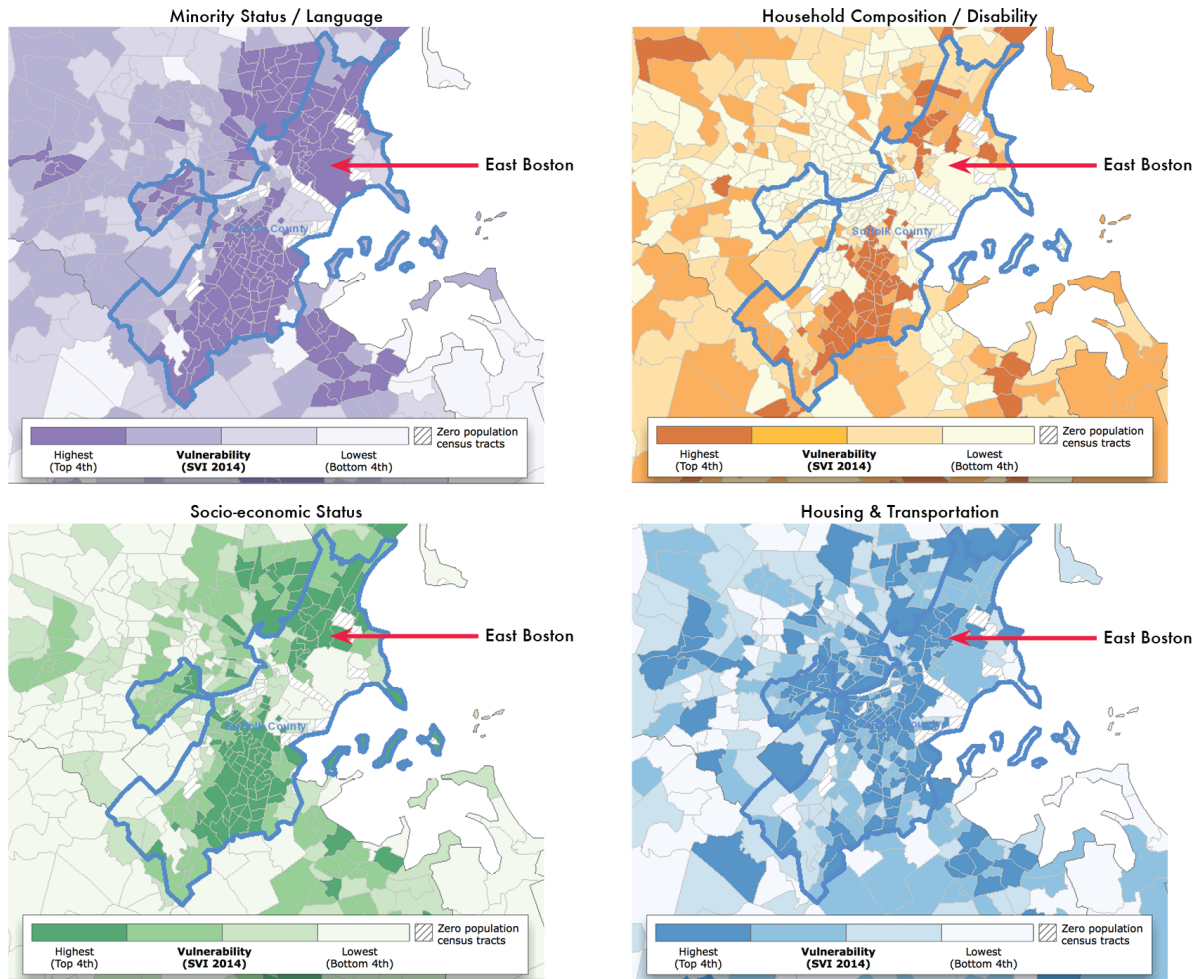
Figure 3: Domains of resilience (image by authors, first published in: Michelle Laboy and David Fannon, “Resilience Theory and Praxis: A Critical Framework for Architecture,” *Enquiry: A Journal for Architectural Research* 13, no. 2 (December 11, 2016), <https://doi.org/10.17831/enq:arcc.v13i2.405>).

and manufacturing infrastructure. The diagram in Figure 3 illustrates these domains across multiple scales, from people to buildings to districts to cities and regions.

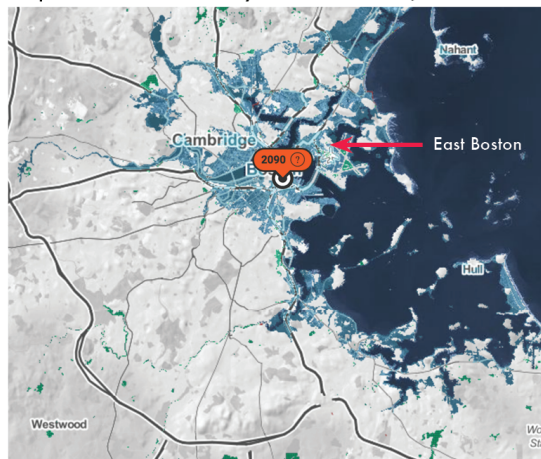
In the TOSE model, system resilience is not necessarily controlled by the lowest common denominator: increased resilience in one domain may offset fragility in others. However, fragility in any domain places additional demands

on the others, possibly causing constructive interference and cascading failure. The model is sometimes criticized for focusing on human systems, and not adequately incorporating natural phenomena and ecosystems and their reciprocal influence on the resilience of the human environment. Such an anthropocentric view of resilience is particularly acute in the built environment. Architecture—like engineering—tends to focus almost exclusively on the technical domain, and ideas

Boston, MA (Suffolk County)



Maps of Social Vulnerability Index Indicators (Source: www.svi.cdc.gov)



Maps of Coastal Flooding: 10% accrued probability over 7ft by 2090, Unchecked Pollution Scenario (Source: [Surging Seas, Climate Central](http://SurgingSeas.ClimateCentral.com))

Figure 4: Comparison of Social Vulnerability Indicators and Coastal Flood Risk in the City of Boston (Suffolk County, MA).

of property protection. However, because architects design social environments and systems, and because resilience is about interdependent systems, we can and must engage with the other three domains. The limitations of focusing on one domain are not merely theoretical or idealistic: social and physical vulnerabilities often overlap. Figure 4 shows maps of social vulnerability index (from the CDC) and coastal flooding from sea level rise (from *Surging Seas*), showing that the most socially vulnerable populations are disproportionately affected. The flooding in New Orleans after hurricane Katrina offers one example from a tragically-large body of research showing the convergence of vulnerability hazard¹⁴ and the ethical dimension of spatial design.

The increased frequency and severity of hazards requires approaches for people to shelter in place, and thrive in this new, risky, normal. In response, we need to map and communicate risks across all domains and multiple natural hazards. The temptation is to treat each hazard in isolation as a technical problem, while treating them in conjunction, using the lens of the household, connects the physical home and the people dwelling in it. To that end, in addition to natural hazards, we added socio-ecological factors of resilience, including community factors, for example accessibility and social vulnerability (income, disability, demographics

METRICS: HOW TO ENGAGE SYSTEMS OUTSIDE TECHNICAL

The complexity of socio-ecological resilience in the built environment is well documented.¹⁵ The challenge lies in defining and measuring performance and in considering trade-offs. Too often, resilience is described as a new buzzword replacing sustainability, or assumed to be in opposition with it; that “stronger” necessarily implies more environmental harm. While resilience sometimes demands excess capacity, and sustainability sometimes seeks optimization, both offer architecture transformative new dimensions to assess our work, including social and ecological aspects. A 2017 paper addresses the concordance, reviewing seven frameworks for evaluating resilience and identifying 88 unique resilience strategies in five broad thematic groupings. Of the strategies, 35 were positively correlated with sustainability, and only 14 were negative. The remaining 39 were conditional on the particular circumstances¹⁶. Such findings motivate the present work, which hopes to clarify the contingent strategies as positive or negative for specific homes.

One key feature of enabling social resilience is education, about the hazards and about steps to mitigate them, the so-called resilience strategies used as recommendations in the RHONDA tool. Over one hundred recommendations were drawn from an extensive literature review of research papers, insurance industry guidelines, new building codes and standards, and government programs. These were combined using expert judgement into simple descriptions

and illustrations accessible to a non-expert audience, tagged by climate zone, risk, and construction type; and cross-linked with others that either reinforce or contradict them. For example, recommendations for continuous insulation cross-reference with fire hazards if the products used are flammable. The response to the questions about the home, occupants, their expectations and preparedness determine if each recommendation applies. Extensive reference sources and citations offer additional information and assistance, so users can dive more deeply.

The design question is how to make this mass of possible recommendations accessible, and not overwhelming. We developed multiple ways to enter and filter the recommendations from a dashboard that summarizes resilience indicators at the household and community level; designed to interactively visualize complex data, like flooding probabilities over the years specific to the home. Results can be searched and sorted by hazards, physical or time scale, or other user priorities. These recommendations are also graded by level, for example, flood risk may be a high priority for a new home in a low-lying area, but the recent construction might render energy upgrades for passive survivability unnecessary.

NOT JUST SYSTEMS: PEOPLE (FUTURE DIRECTIONS FOR THIS WORK)

While serving the needs and desires of clients who hire them, architects’ primary professional duty is to protect the Health, Safety, and Welfare of the public¹⁷. The profession continues to expand the understanding of that obligation beyond mere compliance with the building code to encompasses environmental sustainability (e.g. 2030 challenge); health (e.g. WELL standard); and increasingly in preparing for and recovery from natural hazards. As detailed previously, nascent efforts have yielded several standards for resilience, but these remain primarily technical in orientation, and expert in application¹⁸, without addressing the essential complexities of socio-ecological resilience. As ever, incorporating social forces into architecture demands forms of social engagement beyond the conventional architect-client relationship, and tools beyond the public meeting¹⁹. Understanding the architectural problem of resilience in this way militates for a new participatory model; the true measure of effectiveness comes through users, both individuals in their own homes and especially groups and communities. Unlike normal dissemination of findings, or a public information program after the fact, public engagement is an inherent feature of working in the domain of social resilience in which the public both learns about and shapes the built environment. Developing this tool became a mechanism to engage with diverse groups and communities to address what might be called the triple bottom line of resilience²⁰.

COMMUNITY GROUPS (PEOPLE)

Neighborhood of Affordable Housing, Inc. (NOAH) like many community development organizations, focuses on issues of housing, environmental justice and community planning²¹. NOAH is focused primarily in East Boston, an economically challenged and majority minority area of the city located between the Harbor and Massachusetts Bay, and built on historic marsh fill, that faces significant risk for coastal flooding and sea level rise (see Figure 4). Because of the intersection of risk and social vulnerability, we engaged with the staff to develop early conceptual directions that would respond to the specific community and developed a plan for specially-trained youth workers to go door to door and help residents navigate the tool and interpret the results. In addition to the pragmatic benefits of multi-lingual, technically-savvy young people extending the reach of these tools, the very act of the survey builds social and community bonds. With some training these young people become resources in their community, while themselves developing research and leadership skills. As researchers, we are collaborating with NOAH in pursuing sources of funding to do this work as part of the evaluation of the impact of the tool. As a future stage, we can even imagine the tool becoming a platform for social connections and two-way communication. For example, if the evaluation identifies a home susceptible to heat is occupied by particularly vulnerable resident, a forecast for a heat event could prompt an alert, directly to that resident, as well as via phone or in person, perhaps even by same youth worker. This personalized outreach connects the resident to the community, and to community resources and services, such as transport to a neighborhood cooling center. While there are undeniable benefits to enabling stronger ties, this approach would require the tool to store results, rather than anonymize them, with the attendant privacy and security concerns. As part of our ongoing engagement we participated in their community design workshops for flooding protection at an infrastructural scale, to understand the motivations, concerns and interests of the community in design; and are planning a future workshop with community members particularly focused on flooding protection of homes using RHOnDA.

INSURANCE & FINANCE (BUSINESS)

As described above, the insurance industry constitutes an important—in some ways dominant—actor in the resilience of the urban fabric, which suggests that the discipline of architecture should understand and engage with these economic systems if we are serious about building resilience beyond the technical domain. For understandable reasons, insurance companies worry most about the risks that they insure, and which have the greatest likelihood of financial harm. The National Flood Insurance Program distorts the market by insuring high risk properties against catastrophic losses that private homeowners policies do not cover²². Thus private insurance is concerned less about coastal flooding than, say, leaky plumbing; as evident in

the work of the Insurance Institute for Business & Home Safety, an industry-funded research and communication organization²³. In meetings with leading insurance companies, it became clear that fire, although not a natural hazard, was of particular concern, especially in sustainability improvements. The financial incentive of reduced risk is real but difficult to assess without knowing a great deal more about the homes. Similarly, mortgage lenders have a real interest in ensuring that the valuable asset of a home survives the term of a loan. In fact, the Multihazard Mitigation Council of the National Institutes of Building Sciences proposed the “resilience mortgage” as one of the best strategies to increase resilience of the residential fabric²⁴, and called for new tools to enable these public-private incentive programs. Recommendations included software tools, and perhaps a new workforce position for a resilience evaluator—much like a home inspector or energy auditor—who would conduct a software-assisted walkthrough home-visit. In preliminary discussions with industry representatives, it was suggested that tools like RHOnDA could serve to mediate information exchange between homeowners and businesses about their property, clarifying coverage, evaluating risk and incentivizing mitigation either in advance of or conjunction with the on-site evaluation.

PLANNING AND POLICY (GOVERNMENT)

The third thrust of socio-ecological resilience lies in policy, which includes incentive programs and regulations that are part of climate mitigation and adaptation planning occurring at many levels of government. We engaged the Climate Preparedness Task Force of the Metropolitan Mayors Coalition of Greater Boston, a group convened and supported by the Metropolitan Area Planning Council which works to coordinate the climate mitigation and adaptation activities of fifteen member-municipalities in the Boston area, ranging from urban to suburban, as well as state and federal agencies²⁵. After a presentation to the task force, we began hosting workshops in specific communities to understand users, and ways the tool might be customized to best meet their needs and demographics. For example, Cambridge has high-resolution hazard data and many available programs, however, citizens find it difficult to find, interpret, and understand their eligibility. Instead of the general, and slightly generic recommendations, a customized web tools could deliver links to specific local programs, for tree planting, PV installation, HVAC upgrades and so on. This interface between people and policy promotes even greater organizational and social resilience within communities.

CONCLUSION

A resilient built environment depends not only on the technical domain, but the social, organizational, and economic one as well. Architecture, with fundamental responsibility to shape the interaction between humans and our built environment is uniquely able to promote socio-ecological resilience. This can be done not only through better fundamental research and design, but especially by developing new tools for the

discipline to explore and test the impact of new forms of participation with architecture's public. Building social resilience needs to be focused on people, which includes not just educating and empowering the public that will need to adapt their homes and neighborhoods in place, but also better preparing the discipline of Architecture itself to lead, reorganize and redesign buildings, cities and infrastructure in uncertain futures. Architecture research can expand the tools of architectural practice, and in turn, that engagement with community-based practices can enable a feedback loop of information to inform new directions for research and thus new guidelines for practice.

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