Resilience hubs: a Maui case study to inform strategies for upscaling to resilience hub networks across island, coastal, and remote communities

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Abstract. Resilience hubs are buildings that enhance community cohesion during normal operations, while also enhancing resilience during emergencies. Maui Island is part of the Hawaiian archipelago, approximately 2500 miles from the nearest major continent. Due to its remote location, Maui is ideal to pilot projects that enhance resilience in isolated communities. At the neighborhood-scale, there is a need for establishing sites that empower communities to strengthen their cohesion, resilience and self-sufficiency. This can be achieved by investing in facilities that offer critical community services during emergencies (e.g. backup power, telecommunications, medical supplies, shelter from weather, and food and water rations). Ideally, local communities have a sense of ownership of resilience hubs and frequently use them during both normal and emergency periods. This ensures that hubs are accepted and trusted. Use cases presented in this research offer a methodology for assessing the suitability of proposed resilience hub pilot sites. Resilience hubs must also be assessed for vulnerabilities to climate change impacts and natural disasters, such as flooding, tsunamis, hurricanes, wildfires, and sea level rise. Resilient power systems can be developed for resilience hubs to ensure services are powered whether the power grid is operational or down, as well as to provide additional benefits during normal periods. These methodologies can be used by communities pursuing the establishment of resilience hubs. The highlighted methodologies are particularly applicable to island communities, coastal areas and remote locations, which are disproportionately affected by climate change impacts and natural disasters. This research paper describes three sites on Maui assessed for their suitability as resilience hubs by using the aforementioned methodologies. This research provides a methodology for establishing local resilience hubs on Maui, and how to upscale for application in other communities facing similar conditions. Once established, resilience hubs become a critical part of community resilience planning, while providing year-round benefits and services to local residents and enhancing community cohesion and emergency response and recovery capabilities.

1. Introduction (Resilience Hubs Overview)
Maui Island is part of the Hawaiian archipelago, approximately 2500 miles from the nearest major continent. Due to its remote location, Maui is an ideal location to pilot projects, such as establishing resilience hubs, that have the potential to enhance community resilience. According to the Urban Sustainability Directors Network (USDN), resilience hubs are community-serving buildings with associated sites that are optimized to support local residents, coordinate communication capabilities,
serve as a focal point for critical resource distribution, and reduce greenhouse gas emissions (GHGs) and associated pollution while at the same time enhancing community resilience (USDN 2019b). Resilience hubs enhance community cohesion during normal operations, while also enhancing community resilience during periods of emergency response and recovery.

Community cohesion can be defined as an effort to intentionally incorporate and go beyond the concepts of race equality and social inclusion. As such, a cohesive community embraces a shared vision and sense of inclusiveness for all members of a community. It supports and values diversity of its residents’ backgrounds and circumstances, while enabling equal access to opportunities for people of all backgrounds. A cohesive community fosters the development of strong and positive relationships among its diverse residents (Local Government Association 2002).

Resilience hubs can foster community cohesion by providing safe, inclusive and trusted spaces for community members to work together on meaningful projects, build new relationships and strengthen existing ones, and actively engage in community decision-making (USDN 2019). Community resilience can be defined as the ability of a community to assess and prepare for various risks, minimize the impact of those risks, and readily recover from associated shocks and stressors through a combination of survival, adaptation, evolution, and the reestablishment of an improved new state of growth in post-recovery when faced with disruptive change. Such an approach necessitates proactive mitigation and planning by a cohesive community (Small Planet Networks 2016).

In assessing the success of a community’s recovery when faced with a disaster, one can use metrics such as assessing how quickly a community is able to have its residents return to work, reopen local schools and businesses, and restore critical services communities depend on to thrive economically and socially. As stated by USDN, although the term “resilience” is often used to describe a community’s emergency preparedness and response capabilities, when using the term “resilience” within the context of resilience hubs a more holistic and comprehensive definition of resilience is appropriate. Within the context of resilience hubs, resilience includes concepts of improved quality of life, systems reliability, and communities that thrive both economically and socially (USDN 2019b).

In order to assess the level of risk a community faces, one must assess the nature of the hazards it faces, how vulnerable a community is to the potentially damaging effects of those hazards, and its coping capacity relative to the effects of those hazards (Ribeiro and Bailey, 2017). This relationship can be expressed through the following formula: Risk = Hazards x Vulnerability ÷ Coping Capacity. The risk to community resilience is impacted by each factor in this equation. In this relationship, hazards represent threats faced by a community; vulnerability represents how exposed or susceptible a community is to the potential impacts of a hazard; and coping capacity represents the degree to which a community is able to respond to the potential impacts of a hazard (Ribeiro and Bailey, 2017).

Within the context of resilience hubs, a resilient power system can be defined as a system that continues to provide power for services deemed critical or essential by a community during a power outage, while at the same time providing economic and environmental benefits during normal periods when the electric grid is up and running. The year round economic and environmental benefits provided during normal periods can include: reducing power bills, generating revenue from providing grid services and carbon credits, and reducing the carbon footprint or greenhouse gas (GHG) emissions of a facility by replacing fossil fuels with renewables as a source of power generation (Clean Energy Group 2014).

This paper does not focus on the community engagement methodologies used to select resilience hub sites on Maui Island. Those topics are covered in a separate research paper. Rather, this paper focuses on proposed methodologies for resilience hub use case and pilot site selection, hazard vulnerability assessments, and resilient power feasibility studies applied to three sites selected as pilot resilience hubs for Maui County.

Although this research can help to inform the development and specification of design elements for new construction projects, this research is primarily intended to inform resilient retrofits and improvements to existing buildings and sites. This focus on existing structures and sites reflects the reality that, worldwide, communities have a much greater existing building stock to tap into in
developing resilience hub networks than they have new buildings being constructed. Furthermore, selecting resilience hubs as new construction projects not only requires significantly more upfront capital investment, but also does not lend itself to using existing trusted community sites that can be designated as local resilience hubs and accepted by community members. Selecting new construction sites as resilience hubs runs the risk of detracting from the trust and community cohesion that can be enhanced by using existing trusted community sites. It should be acknowledged however, that new construction does offer the opportunity to optimize buildings for resiliency from initial design stage, as well as to consider community services being integrated into programming of new construction projects that could also enhance community cohesion. Therefore, although this research is intended to primarily inform resilience hub retrofits to existing structures, opportunities to apply these concepts to new construction projects should not be ignored.

Figure 1: Services that Could be Provided by Resilience Hub in Normal and Emergency Modes

2. **Methodology and Research Approach**

The development of resilience hubs in communities can originate from and be driven by various community actors or stakeholders. These actors can include local non-profit organizations, local or state government agencies, universities, or community groups and associations. No matter which type of organizations initially spearhead a local resilience hub initiative, it is critical to the success of the initiative that a broad and representative group of community stakeholders be invited to actively participate in planning and implementation efforts. Doing so will increase local support and buy-in of the initiative and the likelihood of success of desired outcomes. In the case of Maui County, although various community stakeholders have been involved in community resilience efforts for many years (and in the case of the indigenous host culture, for several centuries), the concept of resilience hubs was first brought to the attention of the County of Maui by way of its participation and membership in USDN. USDN is a non-profit organization whose mission it is to connect local government practitioners to accelerate urban sustainability in U.S and Canadian communities. USDN has engaged with numerous communities across the USA and Canada to support them in developing resilience hubs and has developed a suite of resources, tools and methodologies to help support these efforts. The following describes methodologies used to establish use cases, conduct hazard vulnerability assessments, and structure resilient power feasibility studies for resilience hub pilot projects.

The Maui County resilience hub project and implementation methodology contribute directly to several United Nations Sustainable Development Goals (SDGs). Specifically, this research contributes to SDG 7: Affordable and Clean Energy, SDG 11: Sustainable Cities & Communities, and SDG 13: Climate Action. A key component of resilience hubs is to integrate resilient power systems into
community serving structures. This includes first identifying opportunities to optimize structures targeted to serve as resilience hubs for energy efficiency in order to minimize energy demand loads, and to then deploy renewable energy generation and energy storage systems, such as photovoltaics and battery systems. As such, this approach contributes to SDG target 7.2 by “increasing substantially the share of renewable energy in the global energy mix” and to SDG target 7.3 in helping to “double the global rate of improvement in energy efficiency”. Resilience hubs also contribute to SDG 11: Sustainable Cities and Communities in several ways, including contributing to target 11.3 by promoting and engaging local communities in “inclusive and participatory planning and management of the built environment”. The resilience hub methodology specifically recommends having local community members directly contribute to the identification of appropriate sites to locate resilience hubs, as well as to help inform the services resilience hubs should provide to their neighborhoods. Yet another SDG addressed by this resilience hub methodology is SDG 13: Climate Action. One of the primary goals of developing resilience hub networks within local communities is to “strengthen resilience and adaptive capacity to climate-related hazards and natural disasters”. This, along with strengthening of community cohesion, are some of the core tenets of the resilience hub methodology.

2.1. Use Case and Pilot Project Selection Methodology

In terms of identifying use cases to serve as a basis for resilience hub pilot project sites, it is important to select a suite of use cases that is representative of the diversity of the targeted region or municipality. This diversity should take into account factors such as whether use cases represent centrally located or remote communities, economically disadvantaged or affluent communities, urban or rural communities, and the level of vulnerability to hazards with a high likelihood of occurring various communities may have. Once the desired use cases have been identified, these can then be used to help inform the selection of appropriate sites to serve as initial pilot projects intended to become a part of a larger regional resilience hub network. When selecting specific existing facilities to serve as resilience hub pilot project sites it is important to consider the following factors: degree of trust and acceptance of the site by local community members, ease of access to the structure, ease of access to building plans (including electrical plans) and building utility data, the availability of funding to implement resilience improvements to the facility and associated site, and the level of funding needed to bring the site to a minimally accepted level of resilience (i.e. the minimally accepted level of resilience should be established ahead of time by the project team and informed by community input). Other considerations can include assessing the current programmatic offerings at a given site and the ability to enhance these offerings to further community cohesion, including programming that can enhance the community’s emergency preparedness, response and recovery capabilities.

2.2. Hazard Vulnerability Assessment Methodology

In selecting a potential site for developing a resilience hub, it is critical to assess the potential vulnerabilities and level of exposure to various hazards that a prospective site may be exposed to given its geographic and topographic location. Conditions and hazards to assess for vulnerability and risk exposure may include: inland flooding, coastal flooding, sea level rise and coastal erosion, hurricane/tropical storm (i.e. high winds), tornados, extreme temperatures (e.g. heat waves or cold fronts), earthquakes, landslides, tsunamis, drought, wildfires, and lava flows. The selected hazards to prioritize for vulnerability assessments should be those that have the highest likelihood of occurring in a given area and could have the most significant negative impacts on a given community. Additionally, project teams should consider focusing on hazards for which they have good available data to use in their vulnerability assessments and have the best ability to mitigate against given available budget, technologies and other mitigation measures.
2.3. **Resilient Power Feasibility Study Methodology**

In order to conduct a thorough feasibility study to assess how to design and optimize a resilient power system for a pilot resilience hub facility, both basic and more complex building data inputs need to be collected and modeled for financial and system performance optimization. Required building data to collect includes a description of any existing on-site power generation and energy storage, building utility bills (including current and projected electric power demand (kW) and consumption (kWh) and any other type of power demand and consumption such as liquid fuels or natural gas), roof type and age (to assess suitability for photovoltaic or other appropriate on-site generation technology), identification of power loads deemed as critical loads for business continuity, as-built building plans (including electrical plans), any planned building improvements, and any studies or audits previously conducted for the building. This data, along with details of desired services and programming currently and planning to be offered at the site can be used to model financial projections and sizing and makeup of an on-site resilient power system. Results of this analysis for the three resilience hub pilot project sites are not yet available at the time of writing of this paper. A more in-depth description of this methodology and results for the three resilience hub pilot sites will be addressed in a future research paper.

3. **Results and Discussion**

3.1. **Use Case Selection Results**

As a result of consultation with community stakeholders, technical experts and local government representatives, it was determined that the following use cases should be selected for Maui’s resilience hubs pilot project initiative: an urban use case located in a population hub, a rural use case located in a remote community of Maui, and a use case located in an area adjacent to a resident population hub that is also located near an area that serves the large visitor population responsible for an important sector of Maui’s tourism economy. In alignment with these recognized use cases, the selected sites (shown below in Figure 2) were the Velma McWayne Santos Community Center located in urban core of Wailuku, the Hana Community Center located in the remote rural community of Hana, and the Lahaina Civic Center located in Lahaina near a relatively large resident population hub and in between the tourist destination of historic Lahaina Town and the resort destination of Kaanapali.

Figure 2: Resilience Hub Pilot Sites Selected by the County of Maui

![Figure 2: Resilience Hub Pilot Sites Selected by the County of Maui](Source: Map data ©2020 Google)
3.2. Hazard Vulnerability Assessment Results

For the purposes of this research, the assessed hazard risks include inland flood risk, coastal flood risk, sea level rise and coastal erosion risk, tsunami risk and wildfire risk. These were chosen based on the availability of data, likelihood of occurrence and severity of potential impact.

3.2.1. Wildfire Risk

In terms of vulnerability and exposure to wildfires, analysis and mapping tools that provide resilience hub planners with historical wildfire incidents as well as areas with vegetation that pose high risk for wildfires are useful resources to assess whether a proposed resilience hub site may be in a high risk area for wildfires. Given the significant negative impact that wildfires can have on local communities, having one or more resilience hubs situated close to but not within the high wildfire risk area would be strategic so as to be able to serve these communities in times of need. Wildfire risk can be assessed by using the following formula: Ignitions + Fuel (Hazardous Vegetation) = High Wildfire Risk (HWMO, 2019). As can be seen below in Figure 3, Lahaina is an area of high concern and high historic frequency of wildfires. As such, Lahaina Civic Center is in the highest risk area of the three selected resilience hub pilot sites.

Figure 3: Areas of Wildfire Concern by Community Members and Maui Fire History 2002-2012

Source: HWMO 2019

3.2.2. Inland Flooding and Sea Level Rise Risk

In terms of assessing inland flood risk, Federal Emergency Management Agency (FEMA) flood map layers were used to identify high inland flood risk areas. This analysis also includes high wave flooding, coastal erosion and passive flooding associated with a projected 3.2ft of Sea Level Rise (SLR). As can be seen below in Figure 4, although the Lahaina Civic Center is not in danger of direct impacts from inland and coastal flooding, nearby access roads are highly vulnerable to these risks and could cut off access to the site by the community in times of need. Although the Hana and Wailuku sites do not exhibit high risk to inland flooding and sea level rise risk under current conditions, the Wailuku site is near a levee zone of the Wailuku River. Should the levees fail, the Wailuku site could be prone to inland flooding if the Wailuku River flooded over its river banks. Flood proofing measures are therefore recommended as appropriate mitigation measures for the Wailuku site. It should also be noted that 3.2ft of SLR is a relatively conservative estimate of forecasted SLR. Other SLR viewers such as the NOAA SLR viewer allows for analysis of up to 10ft of SLR. Resilience hubs project teams must decide what risk tolerance they have when conducting hazard vulnerability analyses. The authors suggest project teams use 6ft of SLR as a more proactive approach to SLR associated threats. Climate change experts, such as Dr. Chip Fletcher of the University of Hawaii, have stated that there is a 10% chance that 6ft of SLR could occur by 2100.
3.2.3. **Tsunami Risk** All three resilience hub pilot project sites are located outside of the tsunami evacuation zones. However, Lahaina Civic Center (see Figure 5) in particular is at risk of indirect impacts from a tsunami as most of the coastal access roads to the site would be inundated and likely severely damaged from a tsunami making access to the site very difficult for local community members. An extension of the Lahaina Bypass located inland and at higher elevation is planned and would reduce the vulnerability of this site to tsunami impacts.

4. **Conclusions and Recommendations**
There are several evolving promising practices and methodologies being used by communities and promoted by public, private and non-profit organizations assisting such communities to establish resilience hubs, including scaling up to establish networks of community resilience hubs. These methodologies provide guidance for how to engage with local communities in pursuing these efforts. This includes having local community members actively participate in initially defining what services a resilience hub should offer their respective communities, informing the selection of resilience hub siting, and having local community members actually operate and actively use resilience hub sites on a year-round basis, whether during normal conditions or in times of emergency response or recovery.
This research is intended to help inform and serve as a model for efforts by other island, remote and coastal communities interested in pursuing their own resilience hubs initiatives. As more case studies emerge and promising methodologies are developed to support and inform resilience hub initiatives worldwide, it is likely that resilience hub projects and solutions that are adapted to their specific local contexts and locally optimized will scale-up globally and further contribute to global sustainability goals such as the United Nations SDGs. As stated by USDN, “Resilience Hubs, defined and led in partnership with members of the community, should meet the unique needs of residents and organizations in that neighborhood. This means that no two Resilience Hubs are likely to be identical” (USDN 2019).

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