Mapping a community resilience management system: building operational knowledge

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***Abstract*— System standards have been implemented in many contexts over the last few decades. Using closely aligned standards such as the emerging ISO 37120 typology for sustainable and resilient communities, and by drawing from various recognized capability models and indices, this paper develops a structure for operationalization of a community resilience management system, and then maps the system against the key attributes of a resilient community. This effort is a first step toward the management of long term resilience in our communities.**

Keywords*— *Community resilience, resilience management systems, operational resilience, metrics.

I. Introduction

As a construct, community resilience is both broad and deep; thus the literature contains a multitude of published models, methods and composite indices to demonstrate resilience capacity for a particular city, region or nation [1-14]. Moreover, some efforts seek to operationalize resilience either overtly, such as Rockefeller Foundation's 100 Resilient Cities [15], or in related capacities such as the emergency management accreditation program (EMAP) [16], ISO 37120 [17], and the Argonne model [18]. FEMA's own recovery continuum focuses on implementing the recovery process [19]. These efforts all provide a foundation to measure the resilience of a community; some, realizing that resiliency assessment needs to be an ongoing effort, aimed at operationalizing that measurement.

Recent work focused on communication infrastructure showed that communication is not only a key critical infrastructure in itself, but is also a component of recovery systems, including establishment and measurement of community resilience [20]. This duality for infrastructure, which represents not only its operation but also its impact, is not unique to communication, and is likely reflected by other critical systems and capacities in our communities. To efficiently use knowledge about our key capacities, a system needs to be instituted to manage our efforts to impact community resilience over time.

Consensus standards focused on operations, such as those from ISO [17], have led to the implementation of management systems that govern the operation of many facets of society, including quality, corporate environmental performance, and risk. These systems are effective in bringing clarity and structure to a process that engages diverse stakeholders contributing to a complex system. As community resilience results from a highly complex and diverse system of systems [18], a management system-based approach can organize and implement contributing processes so that they can function efficiently.

This paper applies the concepts and strategies from management system implementation to community resilience management, shows their relationship to the indicators and metrics used to measure performance capability, and then demonstrates how such approaches provide a framework to guide efforts from mitigation to response, leading to the management of long-term resilience.

II. Background

Our previous work delved into key elements that create community resilience, from assessment of critical infrastructure and key resources [21] to the measurement of locality specific resilience [1]. These efforts focused on understanding key attributes, challenges and vulnerabilities, and then measured relative capacities or the maturity of resilience. The next stage is to move toward the design and implementation of a system to manage the resiliency process strategically over time Community resilience is difficult to manage because of the broad range and scope of the impacts that could occur. For clarity, we begin by defining the following key concepts:

- *Metrics*: To determine what measurements are most effective, it is crucial to identify the aspects of the community that will have the most potential to have an impact, and then design indicators or measures that demonstrate the magnitude of that impact. Metrics are defined as a combination of indicators or measures that reveal the relative trajectory of the outputs over time; in other words, our focus is on establishing that actions are creating useful results [1]. These metrics can be classified as short-term, medium-term, and long-term. Short-term metrics are usually based on existing technology and are clearly achievable. Medium-term metrics focus on process maturation, while long-term metrics may not have specified targets, but help to drive continuous improvement [1, 2]. This classification of metrics is particularly critical for creating a resilience management system that can reflect and respond to local requirements.

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- *Capacity and capability*: In the current context, capacity is the ability to act as desired to impact or mitigate a particular hazard risk (a causal relationship), while capability is the measure of that capacity over time. Both are required attributes in any operational system [1, 2].

A. Management systems overview

Standardization has helped to increase the implementation and usage of management systems that govern the operation of modern society. A typical management system enables an organization to improve their performance level in different areas through continuous improvement, addressing factors such as quality, corporate environmental performance, and risk. These systems also provide a standardized process for how organizations collect, measure, report and review information, permitting them to meet stated goals and objectives [22].

The increasing drive for organizational performance is complementary to driving value. Management systems can thus be effective at bringing clarity and organization to a process that engages diverse stakeholders contributing to a complex system.

B. Extending management systems to community resilience

The definition of resilience often refers to the "ability to prepare and plan for, absorb, recover from or more successfully adapt to actual or potential adverse events."[1] In ideal resiliency, the community is able to recover from a hazardous situation or disaster simply by adjusting its own developed system, and people living in the community are similarly able to adapt to the changing conditions. Therefore, if a community seeks resilience, it needs to "understand and measure the entire system in order to fully implement resilience," because "you cannot manage what you cannot measure" [1]. This task is accomplished by establishing a framework to measure resilience by categorizing complex hazard and resilience elements and then selecting a set of indicators to measure resilience for the particular community [14]. Next, a community should formalize its management of resilience to support the development of a better decision-making process with built-in improvement mechanisms, which builds confidence for residents, businesses, and community leaders. In short, a healthy, safe and sustained community is no longer a state but instead more of a series of dynamic maintenance actions to allow self-healing, or continuous improvement.

Given that community resilience results from a highly complex and diverse system of systems, a management systems approach helps to organize and implement contributing processes that can function efficiently. Current resilience models are often based upon community data and previous research, and lack the capacity to evolve and improve. Most regional models have no connections with each other; further, many models are built for specific purposes and have unique modalities, making results difficult to compare or benchmark. For example, Peacock's Coastal Resilience Index (CRI) is based on community questionnaires that convert each category of resilience into three levels: low, medium and high [11]. The Social Vulnerability Index (SoVI) only shows social factors such as gender and age to evaluate an area, and the result is separated geographically from the study site [8]. On the other hand, Argonne National Laboratory's model is very broadly applicable, but could be a complicated approach for localities that are just beginning to implement resilience tools [18]. All systems show similar indicators and possible synergies [2, 14]. Our approach not only allows a community to develop its system to suit its unique needs and environment, but also promotes community benchmarking.

III. Methodology

Although creating community resilience will require a broad range of active stakeholders, the proposed methodology reflects the view of the emergency manager [19], as many localities continue to place the responsibility for resilience within emergency management; the methodology may need to be extended in the future to capture the fact that some localities have begun to appoint chief resilience officers, thus requiring additional viewpoints. Next, even though planning departments tend to have a large presence within resilience management, they usually take on a supporting role instead of a major decision-making one. In recent years, emergency management in the US has begin to increasingly focus on mitigating risk than merely responding to hazards.

A. Mapping the dynamic system

As the application of the management system is intended to facilitate easier management, the functional system needs to be mapped by collating and evaluating various models and tools to determine the most effective methods for demonstrating local resilience. Many systems-driven related approaches to community resilience exist, including BS 8904 (Guidance for community sustainable development) [23], ISO 22301 (Business continuity) [24] and ISO 37120 (Sustainable development of communities) [18]. Community resilience planning guide for buildings and infrastructure systems [25] and the CERT resilience management model [26] are specialized applications. These management systems all have a similar base structure comprising leadership, policy, planning, support/resources, operational goals, and performance evaluation, as shown in Fig. 1. As our focus was on usability, not necessarily optimization, we also identified indicators and metrics that illustrated relationships. Moreover, as these indicators and metrics need to be accessible to an emergency manager, we preferred to support implementation, not necessarily perfection. We then collated the best small set of metrics or indicators for the various domains or subsystems. From this point, each relationship can be mapped at a finer level of detail as demanded by the system manager. Although simplified choices may occasionally result in an incomplete map, our experience has been that it is more useful to begin and build forward rather than not begin at all.

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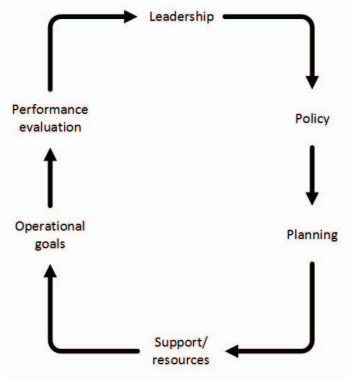

Fig 1: Base management system structure

We then mapped each indicator and metric cross-functionally to identify both the contributing processes and actors within the system.

Next, we mapped relationships not only between capacities (for example, context and critical operations and key resources) but also by the relative position within the management system: is a particular capacity a crucial leading system attribute, or does it follow others? Fig. 2 depicts the managerial relationships that create a functional system, and explicitly calls out the context (environment and organizational culture) that is the impetus for any management system. This map also shows the planning, implementation, and checking and corrective action phases that are typical for any management system application.

B. Implementation of a community resilience management system

Before installing any management system, certain steps must be followed:

1) Determine the leadership policy. This step focuses on obtaining feedback from internal and external stakeholders, and deciding the overall stance of the organization, for example, will the community aim to be the most resilient, or will it simply to protect its systems? Some management system processes are driven by normed voluntary initiatives, such as Rockefeller Foundation's 100 Resilient Cities [15], which go beyond regulatory expectations.

2) Assess and leverage local culture and environment. In many applications, this step is not given the attention it deserves. However, as no effort exists in a vacuum, system implementors need to consider organizational structure and systems of accountability, as well as the external context/environment occupied by the community. The implemented system, goals and actions also must reflect the context the community finds itself in, not the context it wishes to occupy. Over time, the system can be modified to reflect growth and maturity.

3) Set program goals. At this point, program goals are set that consider the internal (system) culture, the external environment, and the overall leadership policy. Since these goals may be far reaching, management may decide to break the overall goals into shorter term targets that lead the

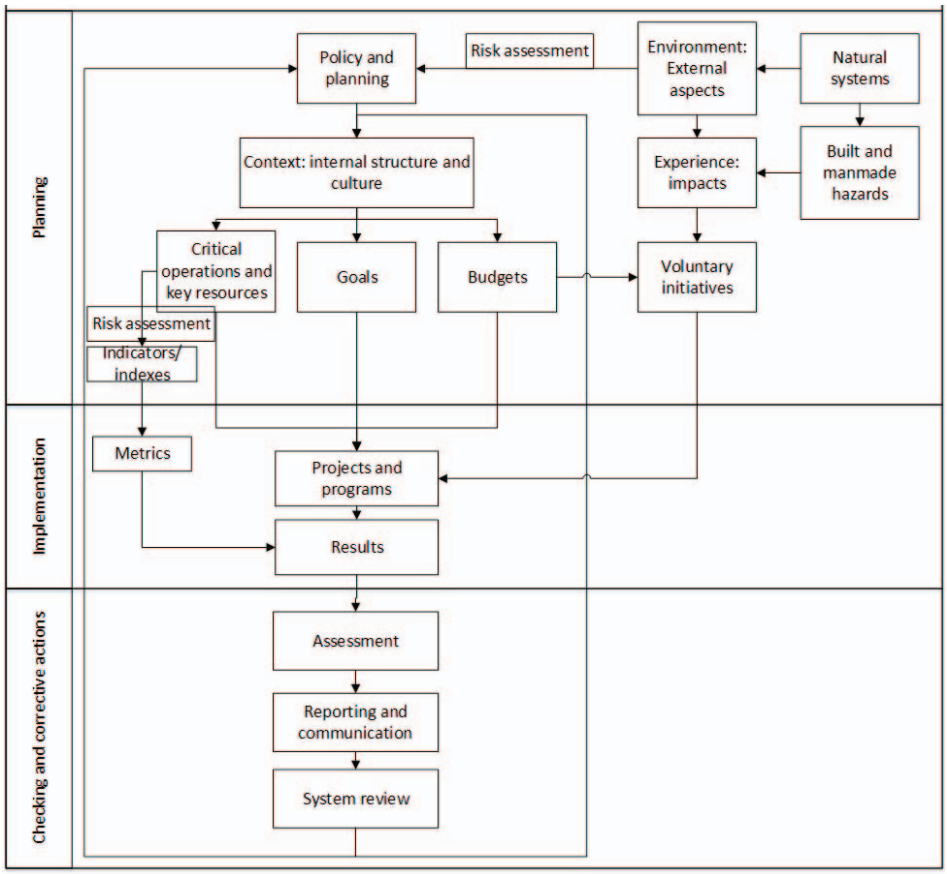

Fig. 2: Management system mapping

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process toward long term improvement. This step is where the use of measurement of maturity in indicators, and their companion metrics, becomes so powerful.

4) Collect process results. Sometimes, simply obtaining the results in a systematic fashion is enough to spur continuous improvement, because actors know that they are accountable. Once a target is reached, the leadership can decide when and how to move forward to the next maturation point.

5) Assessment. In this step, a regular and visible assessment process, containing clear targets and timelines for completion, should be established.

6) Reporting and communication. Sharing assessment results with the relevant stakeholders, especially those stakeholders that are integrated into the management system, is critical to buy-in and ultimate success of the system.

7) System review. A regular review of the system itself is necessary to support the implementation of corrective actions and revised targets and goals.

C. Relationship between community resilience measurement and overarching management system

A community resilience management system is implemented to support the creation of sustainable, long term community resilience. While we note that there are many composite indices, in our example we are focusing on those that are most accessible to an emergency manager. The indicators we use in this paper for community resilience have been extracted from multiple resiliency frameworks and models such as Argonne Laboratory's RASS (now termed ARISE) model [18], the UN's Disaster Resilience Scorecard [27], and the Community Assessment and Resilience Tool (CART) [28]. Although communities will differ in regards to their specific requirements for resilience, this indicator set (shown in Fig. 3) should effectively demonstrate operational resilience.

Once appropriate indicators are selected, a community can then determine the appropriate metrics of performance and intermediate targets that will be used to support the implementation of the management system. Indicators and metrics must reflect and adapt to specific needs, geographic locations, and types of hazards present in each of the communities. For example, the city of New Orleans would focus heavily on metrics related to flooding in metropolis areas whereas Anchorage would focus more on metrics related to earthquakes. This differential focus is not simply a pick or choose situation, but rather a prioritization based on requirements and needs. Three general categories of indicators were shown earlier in Fig. 1; human, natural, and physical. These indicator sets reflect the general structure of the models presented in the introduction.

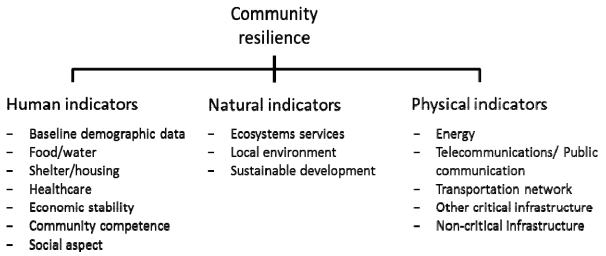

Fig. 3: Community resilience indicators

Although the indicators appear to be separate, they are not exclusive of each other. Baseline demographic information should be collected during the planning phase and used as a starting point for most metrics throughout the system, as most of these reflect percentages of the total population. Included also is data on vulnerable members of the community such as the elderly, disabled, and other groups who may be more susceptible to the impacts of disasters. As an application example, we focus on flooding, which poses a common risk for many communities, and therefore is an effective means to show applicability of the metrics and management system approach. First, we assess the potential (scope or aspect and impact) for a flood, and then measure our vulnerability and resilience to those potential impacts. Many of the indicator and measurement systems we noted in the introduction do a fine job of assessing the impact of these contributing factors, such as flood hazard, to overall resilience. We then devise our strategy through selected indicators and then metrics of performance. In a coherent management system application, this step goes beyond a simple mitigation project but integrates the effort into the system. As shown in Figs. 4, 5 and 6, we applied metrics to the indicators presented in this effort to reflect such a flooding scenario. This step enables us to show and track point-in-time resilience metrics, continuous improvement, and the maturity of the applicable metrics.

Human indicators are those that are focused on basic human needs, economic stability, and structures that foster social cohesion such as community relationships and planning, social support, public-private partnerships, and sense of community [18, 27, 28]. The National Consortium for the Study of Terrorism and Responses to Terrorism (START) has developed a toolkit that effectively assesses the social aspects of community resilience. This toolkit, called the Communities Advancing Resilience Toolkit (CART), has been chosen to assess engagement, communication, community problem solving, and social cohesion [28]. Demographic data should be collected during the planning phase to gather baseline figures to be used throughout the various metrics. The specific metrics related to our human indicators can be seen in Fig. 4. Disease, injury, and other negative health effects are a common occurrence during a flooding disaster. Flood waters and standing water after the disaster can cause infectious disease, diarrheal diseases, and wound infection [29]. Food and water sources can also be impacted through contamination, furthering the spread of disease and decreasing food and water supply. Emergency medical services (EMS) and healthcare provide assistance to individuals suffering from injury and illness both pre and post incident. Of special mention here is the subset of social competence indicators. Inherently, as a system, community resilience is only as strong as its weakest link. Human

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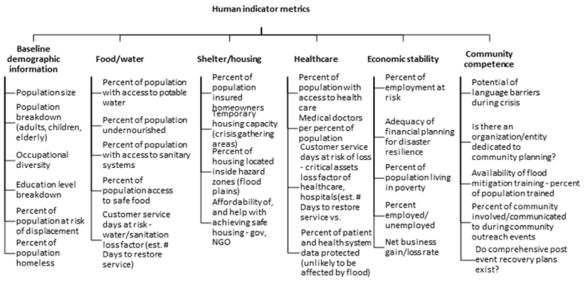

Fig 4: Selected human indicator metrics

capability and capacity or social competence can be the most difficult aspect to assess.

Natural indicators relate different environmental aspects to community resilience such as ecosystem services, local environment, and sustainable development. Natural indicators for resilience include four different categories related to the environmental aspects of a community: Ecosystem Services, Local Environment, and Sustainable Development [30]. The specific metrics related to our natural indicators can be seen in Fig. 5.

Physical indicators represent the operational components of a community's critical infrastructure (CI) and non-critical infrastructure. CI is identified by the Department of Homeland Security as 16 different sectors: chemical, commercial, communications, critical manufacturing, dams, defense industrial base, emergency services, energy, financial services, food and agriculture, government facilities, healthcare and public health, information technology, nuclear entities, transportation, and water and wastewater systems. Physical indicators for resilience include six different categories related to the critical operational components and functions of a community: energy, telecommunications and public communication, transportation network, other critical infrastructure, and non-critical infrastructure [31]. The specific metrics related to our physical indicators (critical infrastructure) can be seen in Fig. 6.

IV. Discussion

Mapping a management system allows users and stakeholders to visualize the extent of interrelationships in the application and operation of the system, not simply view them as a linear set of assessment opportunities. As with other management system maps, Fig.2 shows a simplified skeleton over which deeper and broader metrics can be employed as the entire system and its stakeholders become more experienced and mature, and build capacity and become more capable. Each relationship represents a capacity to be assessed and improved. In addition, specific resilience performance metrics can be modified as the system itself matures and becomes more capable. The indicator sets are the supporting measures of the results from the management system and its operational context.

With this established foundation of a high level overview of all applicable indicators, we can apply metrics to indicate the relative trajectory of the indicators. Set guidelines and criteria are available during metrics selection. To be effective, the data required for measurement must be readily accessible, or at least obtainable. Metrics used must be appropriate for communities of different sizes, ranging from small towns to large metropolitan areas, thus ensuring the system operation across all types of communities.

Once the system is mapped, and indicators and metrics selected, roles, responsibilities and resources may be assigned to each functional area, ultimately creating a pattern of communication and accountability. This approach supports long term strategic process improvements, and also ensures actions do not occur in a vacuum, thus are coherent with one another. In other words, a known driver and goal for each system step supports the overall system functionality.

V. Conclusion

By viewing resilience as an evolving system, this paper supports the organization of strategies needed to operationalize them within a community. Proactive management is the next step in realizing sustainable long-term resilience. The existing foundational efforts provide the basis needed to create an operational community resilience management system. Management system maps are useful visualizations of functions, actions, and their relationships for both emergency managers and the larger group of

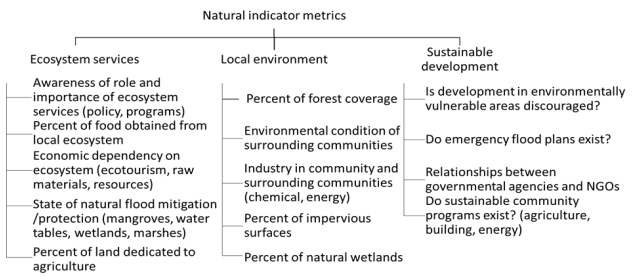

Fig. 5: Natural indicator metrics

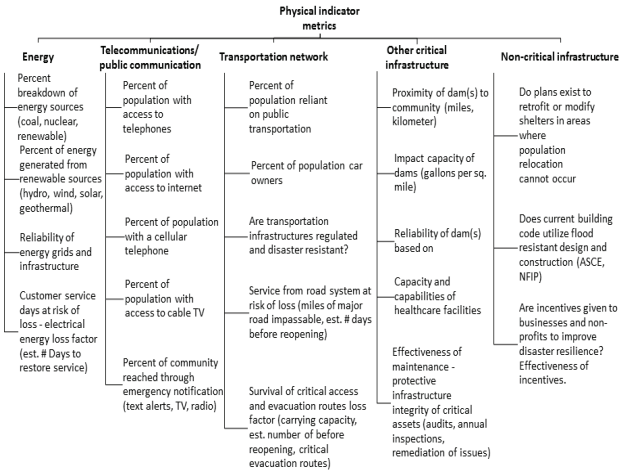

Fig 6: Selected physical metrics

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stakeholders that must contribute to this process, by illustrating their contributions within the overall effort. This paper attempts to advance the actual implementation of resilience initiatives as a community system, and support the overall growth of resilience.

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