PLANNING RESILIENT COMMUNITIES

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Abstract

Our world is changing. Extreme events are becoming less predictable with greater consequences. Infrastructure hardening alone is proving both inadequate and unaffordable. Resilience is not about preventing change – change is inevitable – rather, it is about managing change and adapting, responding, and recovering from disruptive events. How we manage change will be defined by how we manage the risk context, using urban planning to reduce the consequence of shocks and stimulate the collective ability to respond and recover. By focusing on people and the community operations that support their lives as the essential purpose of resilience, we can focus our actions more effectively. Infrastructure is built to support a purpose. That purpose does not disappear during a shock. Therefore, we should plan and design infrastructure and services to support the continued delivery of that purpose. The net result is an holistic view of community function and how it can manage both stresses and shocks to protect livelihoods, continued prosperity and quality of life. In effect we propose a framework for planning resilient communities that can support society in an increasingly unpredictable world.

Keywords

Urban Planning, Resilience, Protection, Municipalities, All-Hazards

A Shifting Risk Context

The hazards and risks we face today are different – and in most cases more extreme – than a generation ago. In fact, what constitutes a hazard is also evolving. For example, twenty years ago a cyber attack would not have been thought of as a threat to communities. Today it is one of the greatest threats to the Systems Control and Data Acquisition (SCADA) systems that manage municipal infrastructure. A successful SCADA attack today could be catastrophic. Our policies and practices have yet to adapt to this and many other realities of modern community life. Extreme weather events have become more frequent and more severe in recent years. The Canadian Disaster Database[1], maintained by Public Safety Canada, shows clear upward trends for flooding, wildfire and wind. When these trends are compared to the preceding 100 years, there is a clear disparity between what has been used to base our infrastructure designs on and what we are today experiencing. It can be no surprise that much of the protection incorporated into our infrastructure designs is proving inadequate, sometimes with catastrophic results. Our codes of practice were not written for this.

Technical advancement has greatly benefitted communications and the conduct of trade and business. Each advancement has also introduced a new range of hazards that we have yet to fully comprehend. However, the pace of technological change is so great that many of the vulnerabilities and incremental hazards are buried deep in the systems architecture and remain unidentified, or simply unrecognised. For example, the use of the 'Cloud' for data storage and access has greatly improved business transformation and opportunity[2], but substantially increased vulnerability to power outage, as well as a host of privacy and cyber security risks.[3] These secondary and tertiary vulnerabilities are increasing in direct proportion to the sophistication of the systems we rely upon, making a clear understanding of what precisely we rely upon and to what extent all the more important.

The consequence of loss is similarly escalating. Over the last generation, we have seen a steady concentration of value in infrastructure ‘nodes’ and clusters, such that the consequences of that node being lost are ever greater. This concentration of value can be due to increased operational activity and dependency, such as the increased number of financial transactions passing through a stock exchange or a SCADA system for a regional transportation network. The insurance industry records a far sharper increase in the financial consequence of catastrophic events, in large part because of this increased concentration of value.[4] When we combine all these trends, the Risk Context for any operation or community is highly complex with little relevant guidance to refer back to. It is in effect a highly complex amalgam of ad hoc sub systems without a map.

To illustrate, the power station at East 14th Street and Avenue C, New York, NY, was storm surge protected to 12.50 ft; greater than the historic worst case of 10.02 ft recorded during Hurricane Donna in 1960. Superstorm Sandy delivered a 13.88ft storm surge[5] that flooded the station with a consequent catastrophic loss of power to Lower Manhattan Island. The damage caused by the storm is estimated at $30Bn, yet the subsequent losses are still being counted and exceed $50Bn at the last estimate[6]. The true losses caused by these events far exceed the direct infrastructure and asset loss, they are the loss to operations and functions that the infrastructure was designed to enable. We must look beyond the headline $10Bn losses when the New York Stock Exchange was disrupted for two days. It is the interdiction of community operations directly affects livelihoods and the very viability of communities.

Modern societies are enormously complex networks of highly connected, and highly valuable systems. The consequences of a shock or stress to one part of the system is felt throughout the network and often far beyond the spatial boundaries of the affected area. Often these consequences are amplified as the impact is propagated from one system to another. If we are to make our communities resilient to the stresses and shocks we anticipate, we must understand this risk context. We need to map the connections between critical infrastructure systems and model the impact of the stresses and shocks to understand the cascade of consequences to all of the systems in the network. In effect, we must create a blueprint of community functions and the infrastructure that supports them. Recognizing that we cannot protect everything, this identifies what we must protect to preserve the capacity for self-recovery and resilience.

Are We Managing the Risk?

Traditionally, human settlements were acutely responsive to natural and man-made hazards – recognizing that catastrophic events will happen from time to time, but the settlement must endure. Floods, fires, famines, wars, all required resilience strategies. For example, traditional settlements would clear the scrub around the outside of the settlement to starve wildfires of fuel so that they could not enter the settlement. Typically, this would be achieved through use of farmland as the buffer. Today, the National Building Code 2010 makes no provision for building proximity to forest for wildfire protection, despite mounting evidence that it is necessary[7]. Alberta has issued guidance of 30m – 50m set back between institutional buildings and forest,[8] recommending many of the same considerations that earlier generations considered normal practice. Suburban sprawl and municipal budget constraints have in many communities resulted in no scrub clearance and an associated increase in direct wildfire threat to the communities themselves, particularly with the risk of spot fires resulting from a wildfire in moderate to high winds[9]. Recent fire events in Australia and California point out the folly of this approach. This does not mean that the street tree canopy is lost and the quality of living space sacrificed, but rather that in understanding the hazard, the density of fuel available to the wildfire threatening the settlement was managed. Similarly, conventional wisdom dictated that we should not build on flood plains and when it was necessary, for mills etc, specific design precautions and recovery strategies could be taken to ensure that the impact of a flood was limited.

Recent experience would suggest that we no longer recognise our relationship with the natural environment. Cost savings measures have resulted in reduced urban watercourse maintenance[10] with the result that during extreme rainfall periods the culverts become clogged, potentially leading to major road blow-outs. The Finch Culvert in Toronto is one such example, requiring 15 months for all services to be fully reinstated after the last flood. [11] The increasing development on flood plains is another prime example, despite regular warnings from the insurance industry[12] and the natural environment that it is unwise[13]. This increased development of flood plains changes the water flow during a flood, resulting in worse flooding conditions and an increased canalisation into downtown cores. Calgary, AB, is a case in point, where despite the experience of serious flooding in 2005, flood plain development of the Bow and Oxbow Rivers continued apace contributing significantly to the extent and impact of the 2013 floods[14]. There appears to be a reluctance to address the questions that such events raise[15]. Our day-to-day relationship with the natural environment is much the same as the contextual influence of demographics and technological change, manifested as stresses to our community and business operations. When

these stresses are not actively managed they draw in progressively more operational resources, thereby increasing the overall logistic burden and constraining the capacity for response to a shock or catastrophic event. We are not managing the risk and have not learned from our parents.

In parallel to this steady dis-association with the natural world and increased urbanisation, we have shifted our focus from the protection of livelihood to the protection of life. In protecting livelihood, we were concerned with our community's survival, its continued economic growth and development and the enhancement of civil society. This forced a longer perspective of time, meaning that continuity and recovery were every bit as important as mitigating the immediate effects of a disruptive event itself. In shifting the focus to the preservation of life as opposed to livelihood, we refined our codes accordingly. The fire provisions of the National Building Code[16] are concerned with safe evacuation of occupants rather than structural stability, operational continuity during the response or any residual occupancy value of the structure following the fire. It is interesting to note that 18% of firefighter deaths are caused by structural collapse[17] and that 44% of businesses fail to reopen after a fire[18]. These statistics are consequent to the prevailing infrastructure/asset performance focus on the immediacy of the event (evacuating to save lives) rather than the continuity of operations and what follows after the disruptive event. This suggests that we are not managing the risk because we don't understand it; a situation exacerbated by the shift in strategic decision making from time-based vision to commitment-based decisions[19]. To understand the risks, we must understand our [operating] purpose in context.

Shifting the focus

Understanding purpose

To be truly resilient, a community, a city, a business, must begin by understanding its purpose. Only then will it be able to comprehend what is critical to that purpose and be able to prioritize strategies for mitigating the impacts to it. While some communities will be able to identify one particular purpose centered on its industrial function, others, especially larger ones, will have many - sometimes in conflict with each other. Each purpose must be defined so that the operations that support it can be identified, mapped and prioritized in terms of their critical contribution to resilience of the whole.

In analysing an operation, there will be certain defining essential functions that must continue through and following a disaster to enable operational continuity and self-recovery. Each function is in turn analysed to determine what services and infrastructure it depends upon. These are in turn analysed for what they depend upon and gradually we grow a dependency chart or *Causal Chain*. Using a directed graph, the dependency relationships between the operations, functions and supporting infrastructures are defined by consequence of failure (mission critical, political and financial). This means that when we shock any part of the Causal Chain with a hazard effect, we can cascade the consequential effects in terms of direct cost of loss/compromise, operating performance and market position / brand / influence. The ability of any one node to withstand the effects of shock and not cascade them up or down the chain will be determined in part by the contextual stresses that the operation experiences.

If we now apply this construct to a community or to a City's civic functions, we see how our management of normal civic stresses can influence our ability to self-recover in a catastrophe. However, if left unmanaged these same stresses can superimpose and cause catastrophic effects in themselves. Detroit is a useful case study of unmanaged stresses accumulating to be every bit as devastating as a major shock. Balancing this management of stresses and planning for degrees of failure allows communities to become resilient.

Constructing community resilience

In applying this approach, we necessarily need to make the process collaborative, encouraging a contribution of informed solutions and 'work-around' that allow us to limit the effects of a failure and mitigate cascading failure through the causal chain. A community's ability to respond and recover from a shock is an intensely human one. The best designed infrastructure in the most resilient strategic framework will not deliver resilience to shocks and stresses unless the human component is actively engaged. The community must 'own' its fate. Communities[20] that self-recovered and thrived following a catastrophe display common characteristics, absent in those that failed. This does not reflect any level of development, wealth or education. All resilient communities have an identity and a focus[21], infrastructure in balance with its needs, they exist within a strategic relationship with neighbouring communities and the city/region, and had confidence in their leadership[22] during an emergency. These characteristics are consistent with the approach outlined above, specifically the local nature of community resilience. The measures employed to manage the trending stresses in one neighbourhood will be completely inappropriate in another neighbourhood in the same city. We, therefore, need a framework that allows us to apply this approach; to capture the operation requirements and risk context with the influencing community dynamics. This allows us to stimulate community resilience and identify which infrastructure and services require protection, in priority.

Shifting Practice

Having identified that change is inevitable, that we cannot protect everything and that a focus on infrastructure rather than the continuity of operations is not producing resilience, we propose four key shifts in resilience practice.

Focus on people and operations, not just infrastructure

Shifting the focus to operational continuity does not mean that we reject the protection of infrastructure and other physical assets; quite the reverse. By understanding operational continuity needs as they apply to community resilience, we can focus infrastructure protection efforts on those projects that will produce the greatest resilience effects. We use protection to address the routine stresses that are expected through normal routine operation. This promotes operating efficiency. The level of protection required is determined by the tolerance for interruption of the essential function in question. Specifically, the protection investment to remove power spikes and short power interruptions might be entirely appropriate for a business, whereas the investment in complete standby power generation facilities might not, since in an emergency all generator fuel is requisitioned by the City for hospitals. This small fact has caught many unawares. In determining our level of protection, we must anticipate some degree of

failure in a catastrophe. To operate through this failure, we need to understand completely both our own operation and what it depends upon, and the risk context in which it all exists.

Examine both shocks (the extraordinary) and stresses (the ordinary), not just shocks

Greater media attention is focused around the big catastrophic shocks; events, such as floods, explosions and ice storms. It is also easier, in the public eye, to establish a causal relationship between the event and its impact. Nevertheless, it is not only the shocks that disrupt an operation or a community, it is also the slower-brewing stresses such as economic downturns, shifts in demographics, congestion, and so on. Both can constitute a hazard and source of change to which a community must adapt and respond in order to sustain a larger vision of itself.

Redefine the concept of failure (around people and operations, not just infrastructure)

If we are to be true to the purpose, we must approach resilience by (re)defining what constitutes 'failure' for any given operation, community, city, or region. Failure will be defined very differently by a hospital than by a regular office building. The tolerance for downtime or recovery time for different operations will vary and so too the necessary strategies to mitigate hazards. Determining what constitutes failure requires a critical reflection of purpose. What truly matters to us, and what does our purpose depend upon?

Go beyond prevention, into adaptation, response and recovery

Typically resilience initiatives have focused on preventing change with bigger and stronger infrastructure. However, prevention is only half of the equation. Resilience is also about how we adapt to change, recover from and manage the impacts of change. By planning for the aftermath of a hazard, we are better able to adapt, react, respond, and recover. Resilience Plans provide people and decision-makers with the proper tools to manage change. Infrastructure should be designed to support efficient operations and facilitate incident reaction, response and recovery. The strategic development plans and infrastructure design briefs must include the multi-phase functional requirements for resilience if they are to support sustainable development[23].

A Framework for Community Resilience Planning

Implementing the shift in both the focus and practice of community resilience planning suggested so far requires a replicable process. The following *framework* provides a broad-stroke method for undertaking this re-focused Community Resilience Planning (CRP) approach. Inevitably each community and business situation requires a nuanced and tailored approach.

Step 1: Scope Definition

The first step is to define the boundaries, scale, magnitude, and context of the community to be studied. Resilience Planning (RP) is a methodology that can focus on succinct operations (an institution, a facility, an emergency services operation) and/or broader scaled communities (a town, neighbourhood, city, or region). In all instances, Resilience Planning requires a full

understanding of the operation/community and its dependencies, as well as the background context in which it exists. This includes the geospatial context of the subject.

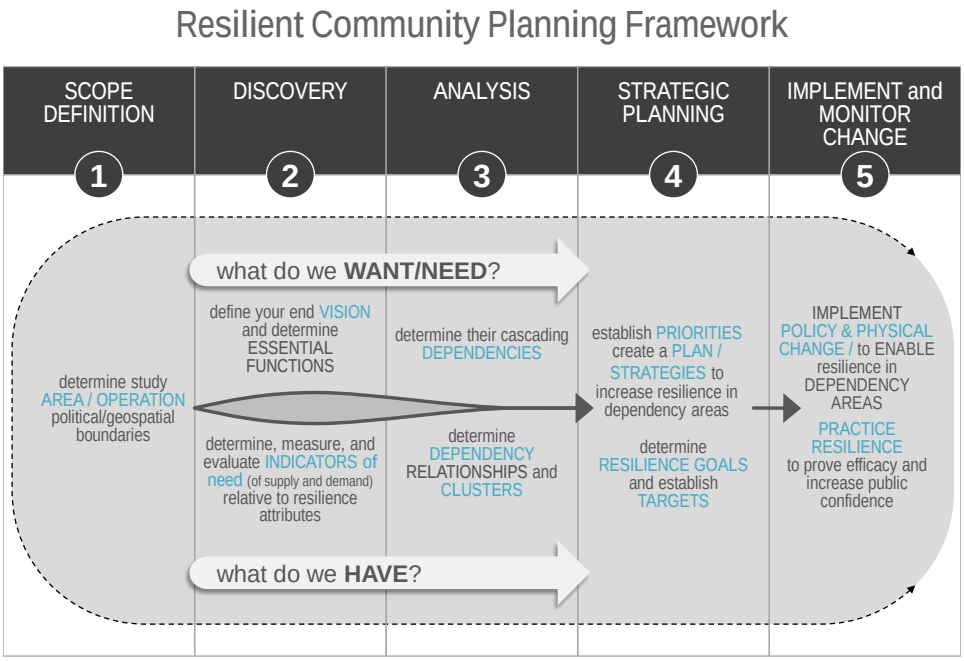

Figure 1. The Resilient Community Planning Framework

<u>Step 2: Discovery</u>

This step in the process is twofold, and asks of the operation/community: what do we envision? and what do we have, today? It is the process of discovering the operations and functions and all the systems that support them. Establishing a vision for the operation/community is about determining the end goal, and elucidating the essential functions that support that Vision. For example, a community may have a goal of overcoming the booms and busts of the economy, and retaining its fleeting youth. A hospital may have a vision of continued operations through the most dramatic conditions. We need to understand the goal, in order to plan how we get there.

The second element in establishing a baseline is understanding the existing conditions. This is a mapping exercise that looks at a series of factors and indicators in order to establish the health or vulnerability of the operation/community, relative to broader resilience goals. Using a population density map as the base layer, we will employ a broad variety of indicators that will include:

1. People – the people for whom resilience is developed and upon whom it depends. The indicators will employ geo-referenced metrics of personal safety and health, access to shelter and sustenance, access to cash and freedom of movement.

2. Infrastructure and Ecosystems – the physical and socio-economic systems that sustain an operation/community. These encompass utilities infrastructure, distribution of goods and retail, access to areas of social gathering and coincidence (the public realm) and the natural ecosystems.

3. Organizational Capacity. The ability of people to manage and adapt infrastructure and ecosystems systems toward resilience goals. These will centre of the strategic vision and plan for the municipality or business and include both formal and informal systems of governance, social support structures and economic dependencies.

Step 3: Analysis

Once we have determined our end-state and situation, we need to understand how and where the vision and the existing conditions are at risk (Risk Context) and what the factors are upon which they depend (Dependency Mapping). The objective is to determine all the pathways of exposure to risk in the current state and analyse options to address those identified risks in order to deliver a more resilient operation/community. In order to understand the Risk Context, we need to evaluate the potential source of hazards, be they shocks or stresses.

From the Vision, we derive a chain of dependencies that are critical to realizing the vision. An operation comprises essential enabling functions, each of which will rely upon infrastructure systems, which in turn rely upon other systems and so on. As a minimum, we must be able to recognise the 3rd order of dependency, though there is no specific limit. In mapping these operational dependencies, it must be very clear how the infrastructure systems inter-relate with the personnel and organisational dependencies. For example, the vision for an economically resilient downtown depends upon entrepreneurial start-ups, which depend upon attracting and retaining talent, which in turn depends upon a certain urban life-style.

The vision for continued operations at a hospital depends on power and water supplies, both of which depend on a power grid and when that fails a back-up power generator, which depends on a fuel supply and integrity of the fuel supply system. While the hospital controls its own generator for internal power, it does not control back-up power generation for the water supply upon which it has a critical upstream dependence. Therefore increasing auxiliary power generation for the hospital does not increase its resilience unless the critical dependence on an external water supply is also mitigated. In both cases, understanding the vision helps us map out the critical dependencies, identify third order vulnerabilities (and beyond) and mitigate them. From the Mapping of Existing Conditions, we derive a clustering of highly dependent areas. In a community, it may be an area where people are particularly vulnerable given low income levels, non-availability of fresh food, and lack of transportation options. Within an operation, it may be that a multitude of processes are critically dependent on a single power supply outside of its control. Clusters of multiple sole-dependencies are particularly vulnerable and demand attention.

In both instances it is critical to understand the operation/community's Contextual Relationship. There are multiple operations within the Risk Context and so the operation that is the subject of the resilience analysis and planning should be considered a subset of that Context. It is therefore necessary to understand how the components of an operation and their respective dependencies link to and are influenced by the background context. For example, the engineer for the hospital back up power system mentioned earlier lives in a dormitory town 20km away from the hospital. During a flood, public transport is unavailable and the back-up power system fails. His colleague, the engineer at the water purification and pumping station becomes stranded taking

himself and his neighbour to work. The water plant doesn't have backup power but the ministry is sending a generator over and the engineer is required to hook it up. There are other stationary engineers within the municipality that in fact live closer to the hospital and the water plant but they cannot be accessed easily, even in an emergency. As a result all the emergency preparedness in the hospital is rendered moot and emergency hospital care compromised. This example is typical of anecdotal evidence from many emergency events and reinforces that resilience is as much about organisational and human factors as it is infrastructure protection. This does not mean that key personnel must reside where they work, but rather that for personnel who support critical operations or dependencies, the operation manager can access key capabilities in his immediate locale and allocate them to reduce vulnerability to disruptive events such as an ice storm or a flood. In this case, the hospital engineer might be assigned a more local emergency role or a workers bus schedule provided (as by the French national railway).

Once we understand the influences of the context on the essential functions and dependencies, we are able to recognise both the destabilising and stabilising properties of the whole. By being able to recognise what works and therefore how to reinforce / capitalise on that, we can add direct and significant value to the user. Furthermore, if we are to identify the stimuli for community resilience to any measure of detail, we must understand how the community is affected by and influences the operation and its components. Similarly, when looking at shocks and creeping stresses to the operation, we will need to recognise both the community tolerance for stress and the investment balance between hazard prevention and systems recovery.

Step 4: Strategic Planning

Every operation/community will have different Resilience Goals and priorities. These will depend on its Vision and on its operational requirements. Hospitals, for example, are usually a high priority in emergency situations and will require operational continuity throughout an extreme weather crisis. An office building, depending on its function, may tolerate a certain amount of down-time and the business or agency it houses can be mostly preoccupied with ensuring the wellbeing of its people and the protection of property. The converse would be true in a cyber attack where the office building housed the cyber defence team and their information technology infrastructure. In either scenario Resilience Goals and priorities will be established for the different milestones following a hazard (see Figure 2):

1. Routine: a base-line state of operational performance. Part of a routine operation should be implementing strategies to prepare for, and adapt to, future changes.

2. Reaction: the immediate period following a hazard, when systems 'react' automatically. These are the default, pre-established procedures that sustain life and minimum of operational capacity.

3. Response: the period following a hazard when people are able to orchestrate a 'response', ideally by following a Plan, but inevitably needing to make decisions and adapt to circumstances. These are the actions that enable the restoration of pre-determined business continuity.

4. Recovery: the longer, pre-defined and concerted effort, geared towards restoring the intended level of operational performance.

5. Routine (New Normal): a new base-line state of routine operational performance. Part of this new routine operation should be implementing strategies to prepare for the next changes.

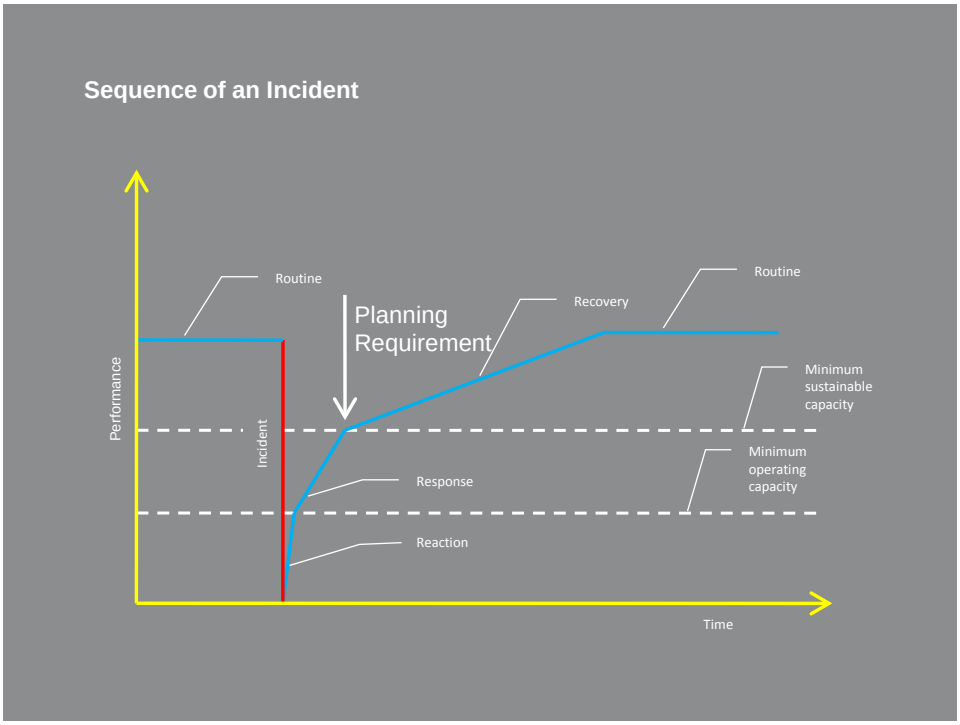

Figure 2. Incident timeline showing the different stages of the incident.

As a general approach, consideration should be given to Dependency Management, Clustering and Demand Management.

Attributes of Resilience (Dependency Management)

Redundancy	Having viable alternatives for each critical system or resource.
Diversity	Having a range and mix of choices.
Flexibility	Having agility to change in purpose or dependencies.
Adaptability	Having agility to change to a new set of conditions.

Components of Resilience (Clustering)

Islanding	The ability for an area/operation to be self-sufficient and endure isolation.
Interconnectedness	The inter-dependencies between areas/operations.
Logistic Burden	The critical path and expense (capital/human/time) of supporting a dependency

Demand (Demand Management).

Managing and forecasting the demand for resources of an area/operation.

From these it is possible to establish priorities and strategies for the subsequent creation of a Plan to deliver on the Resilience Goals. Strategically, a Plan will focus on the areas of high-dependency and on the critical functions of an operation/community, in balance with managing the demand and resources required. A Plan will outline:

Purpose	The vision, principles, goals, and objectives for Resilience.
Environment	documenting a baseline along key indicators, and describing strengths and weaknesses (risk context, dependencies, and clusters) of both the operation/community and of the background context within which it exists.
Priorities	Focusing in from a comprehensive approach to determine the areas of both greatest concern and of greatest potential.
Strategies	Both pro-active and re-active strategies for managing dependencies and delivering on.
Resilience Goals	These should include: strategies; actions; triggers, targets; responsibilities; and resources.
Monitoring	Mechanisms to actively track progress and re-direct, as required.

Step 5: Implement and monitor the plan

Implementing the Plan is an ongoing exercise. Some of the strategies will be enacted prior to any occurrence, as part of adapting for change. Some of the strategies will unfold during the reaction, response, and recovery stages.

Conclusion

The accelerating pace of change in our world today makes any prediction of extreme event severity or frequency virtually impossible over the 25 - 100 year life of the infrastructure we build. Rather than resisting these changes through ever greater infrastructure hardening, we must manage it. In accepting that there will be failure, the focus switches to the continuity of essential functions through a catastrophe and into the recovery in order for communities and businesses to survive and prosper. This also means that we must address the contextual stresses that influence our ability to respond to and rapidly recover from a shock. The proposed Resilient Communities Framework relates the community operation and its dependencies to the community context to not only provide an holistic understanding of the risk context, but offer an indication of how managing the routine stresses can influence resilience of the whole. It affords a construct by which we can measure the value of infrastructure investment in terms of resilience and community survival.

Municipalities across the world are struggling with infrastructure investment to sustain economic development over the next generation amid the forecast migration of populations into cities. As we slowly emerge from the effects of the worst recession in history, we must make every investment count. While finding efficiencies in the procurement program will help, a clear strategic plan based upon a common vision of how a municipality/organisation sees itself in the future will ensure that each investment contributes to the common benefit. It is time to consider whether we will enable the sustainable development of the next generation or leave them beneath the Sword of Damocles.

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