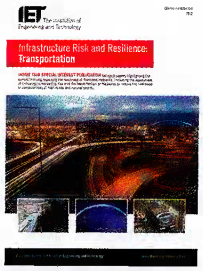

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Surviving catastrophic events: stimulating community resilience

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Abstract: Resilience is a characteristic of an operation and distinct from Protection, which pertains to assets. It is achieved through demand and dependency management to limit consequence of a catastrophic event, and so provide an assurance of operational continuity. When one analyses an operation's dependencies in context, it is possible to avoid the boundary conditions that arise between different system networks when they are analysed spatially, as assets. This necessitates a cyber, human and temporal as well as spatial definition of infrastructure. The recent City of Toronto Infrastructure Resilience Study successfully mapped the dependencies of the City operation, demonstrating a scalable application of resilience planning to a large scale complex operation. However, it also raised new questions that directly affect the City's ability to function during and recovery quickly from a catastrophic event. Demand clusters represent some degree of dependency, which can become critical during an emergency and impede even paralyse the City's ability to recover. The communities where these critical dependencies arise would seem to exhibit an imbalance in focus, ownership and infrastructure. Furthermore, an initial investigation of communities that survived catastrophic events clearly demonstrates a coincidence of these traits within a strategic framework and a consenting leadership dynamic between the communities and their higher authorities. This paper proposes a theory on community resilience that is based upon established resilience planning practice and the observed coincident traits in resilient communities, offering a way of potentially stimulating community resilience in the future.

1 Introduction

When Hurricane Sandy, reclassified as a super-storm, struck the coasts of New York and New Jersey states, it caused an estimated US$24Bn of direct damage and some US$62Bn[1] in subsequent business losses. This was sufficient to reduce the regional gross domestic product (GDP) by around one quarter of a percent[2]. Unsurprisingly, questions are being asked whether the subsequent loss in business was avoidable and much, if not most, of it would have been. This question of whether business could have survived such a catastrophic event is a question of resilience. More specifically, resilience relates to an operation and its component infrastructure, personnel and organisations, all within an operating context and environment. If one can understand the dependencies associated with a given operation, it is possible to not only determine how to make it resilient, but also how to stimulate recovery of an operation. The infrastructure applications and the efficiency benefits are significant. This paper looks at the current state of resilience practice and thinking and offers some thoughts on achieving community resilience.

[1]Official figures have not yet been released and these values are based upon news reports and published insurance losses. However, it is the general difference between direct and business losses that is significant.

[2]Taken as a percentage of GDP, however, the longer term effect is likely to result in a boost to GDP through the increase in construction. See also Bloomberg Businessweek 30 October 2012 'After Sandy's pain, there will be gain' by Matthew Philips.

2 The resilience concept

Resilience relates to the operation. It is about the ability of that operation to continue irrespective of what happens to

the components that enable the operation. These components are infrastructure, personnel and the organisation/s, not only during normal routine, but during the catastrophic event and immediately following. If an operation is resilient it will be able to adapt and absorb a catastrophic event within pre-specified performance and time tolerances and quickly recover to full[3] operating performance. The operation co-exists with other operations that describe its operating context. The operating context includes all those operations and functions that affect and are affected by the operation in question. All this exists within the operating environment, which will exist whether the operation exists or not. Fig. 1 illustrates this relationship. Those familiar with ISO31000:2009 Risk Management will recognise that the combined operating environment and operating context are the same as the Risk Context. This is not just a coincidence, because resilience is an application of risk management. As with risk management, understanding the risk is the key to making intelligent decisions about managing the risk of operational failure in a disaster.

Each of the components has a purpose, defined by the operation. Installed equipment and plant are part of the infrastructure, whereas portable equipments are simply tools drawn from the surrounding environment to be used by the personnel and the organisation. Understanding this operation, its components and its context and environment is the key to successful resilience planning. Simply put, one must understand the operation and its dependencies in order to determine how a given event will affect the operation, from which one determines vulnerabilities and mitigation strategies. The US Coast Guard in Florida once did a critical assessment of their infrastructure and operating resilience. The planners reasoned that in an emergency it was always possible to get more airframes, more fuel, change landing sites etc., but they needed a critical assurance that the aircrews would fly. There are many examples around the World where emergency personnel have failed to report for duty because their first priority was to take care of their families. Through understanding this dynamic and acting upon it, the performance of the US Coast Guard helicopter crews following Hurricane Katrina is extraordinary and far exceeded any reasonable expectation upon them. In fact, the US Coast Guard is widely considered to have been the only effective Federal agency during the disaster and their resilience approach is an interesting contrast to the standard Protection approach promoted by the Department of Homeland Security [7]. That human dependency critically defined the assurance of operational survival during and immediately following a catastrophic event, particularly pertinent for an organisation with a domestic responsibility to operate during disasters. So how does one go about understanding the operation?

[3]Practically interpreted as normally acceptable performance.

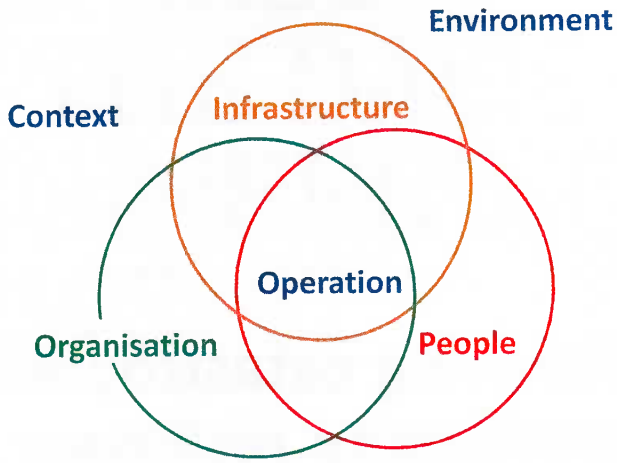

Figure 1 *An illustration of the operation, its components, environment and context*

Operations are generally made up of processes, simple and complex, single and multiple. Each process depends upon specific resources, either consumable or functional, within certain tolerances. For example, a particular aluminium smelter may consume 400 tonnes of bauxite per day under normal conditions. However, if the supply of bauxite falls below 100 tonnes per day, the value of production may no longer exceed the cost of electrical power and the operation becomes unsustainable. Similarly, the operation may not be able to sustain such a reduced supply for more than 10 days, before the operation again becomes unsustainable. One would therefore say that this particular dependency, the bauxite supply, has an operating threshold of 100 tonnes/day over 10 days. Each of the operating dependencies is analysed in this manner. Each of these dependencies is in turn analysed for what it depends upon and so on. Generally, one only analyses to the third degree of dependency, as there is typically a dispersion or concentration of consequence at around the third degree. Looked at in reverse, this dependency tree can be stressed by a particular event. The event will have an effect upon a specific resource which will have consequences for the dependent actions. In this way, one is able to understand how an event can affect the operation and quantify the consequences, as well as identify the possible mitigation measures. This approach is essentially relationship based rather than the traditional 'tombstone' approach to protection planning, which looks at nodes and their criticality. The immediate advantage to a relationship mapping approach to operating dependencies is that it avoids the 'boundary conditions'.

Simplistically, consider a commuter corridor from Etobicoke to downtown Toronto. The spatial networks will show a tram system, buses and a subway. It would appear that there is a diversity of transport means for commuters to use. From an operational perspective, these are tools that enable commuter transport and in looking at the dependencies for each, we discover that directly or

indirectly each depends upon a single electrical substation in Etobicoke. The substation feds the subway and the tram lines, as well as powering the liquid petroleum gas (LPG) compressors that refuel the buses. The indirect association and interdependency between networks and even associated systems is too often missed with a purely spatial analysis, but is brought into stark relief using operational dependencies. This is particularly relevant when one looks at the human and cyber links between the systems, such as the drivers for each of these transportation systems need to get to work somehow. Is the dependency a closed loop relationship?

Infrastructure networks are designed according to the purpose and function of that infrastructure and developed for optimum operating efficiency. Consequently, the infrastructure network for electrical power will be different to that for telecommunications or water supply. When overlaid against each other, it is almost impossible to connect the dependencies between each of the networks unless there is a direct spatial node coincidence. However, when each system is defined by its contribution to the operation where and how, the links/dependencies between the networks are defined first and the network is then built around these links. It is also important to remember that infrastructure is not just spatial, but has temporal, cyber and human dimensions too. For example, a road is built between two communities. Over time, other communities are developed around the road and its use begins to change. Not only has it influenced the development of the communities by its presence, but as its use has also changed so too the dependencies upon it. In time a new dual carriageway is built to connect the two original communities, reflecting the increased traffic demands. This does not mean that the original road can now simply be removed. It has changed in function and use. There has been a temporal change, as well as a human one. As part of its home mission, a military installation is required to continue operations through a catastrophic event and enable local recovery. Over time, the housing on and around the base has been rationalised and the priority given to soldiers or council priorities. The contracted staff who maintain the base and are responsible for emergency power generation and water supply, are now resident in the next town or even the next county. When the area is flooded and the power supply is down, who will bring the emergency power supply on line? Not so hypothetical a situation as one might think. The cyber dimension is less tangible and requires a clear understanding of how essential operating data is accessed and stored. Many organisations are increasingly relying on the internet for control of remote plant through supervisory control and data acquisition (SCADA) systems or the 'cloud' for ubiquitous access to operating data. When a global/regional event such as an ice storm interrupts several cell towers at once, the inherent redundancy in access to the 'cloud' is lost. One's dependency on the data stored in the 'cloud' will determine operational survival.

3 Resilience Practice and Management

This 'understanding' process is still being developed and the recent City of Toronto Infrastructure Resilience Study was the first time that the dependencies of a large scale complex operation were successfully mapped showing the interdependencies between infrastructure and the operational functions and services. The driver for this study was to understand how extreme weather can affect the City's operation, though it remains equally applicable to other threats and hazards, whether natural, accidental or malicious. However, the study did raise some interesting questions, specifically around the concept of demand clusters.

Resilience is managed through a balance of demand and dependency. One can not be successful with one without addressing the other. Dependency is usually managed by adaptation, redundancy and diversity. None of these is really effective unless one can manage demand such that it is proportionate to how the dependency can be managed. For example, if one operates a major supermarket and is entirely dependent upon Grid supplied electrical power, it will be difficult to achieve any cost effective diversity of supply without also managing and prioritising the energy demands by function. The essential electrical demands may be security, refrigeration and emergency lighting. Thereafter, items such as area heating/cooling and general lighting will come a close second. By using light tubes, improved insulation and compartmentalisation, essential electricity demands can be brought to within practical scales of alternative and diverse energy supplies and the capacity of Uninterruptable Power Supply units. Demand is being managed as part of a dependency management scheme. Consider Fig. 2. The normal electrical power usage (green line) for a supermarket is shown against the threshold for high user tariff. This compares with the power usage for essential operations only (blue line). If one then compares these same two power usage curves against

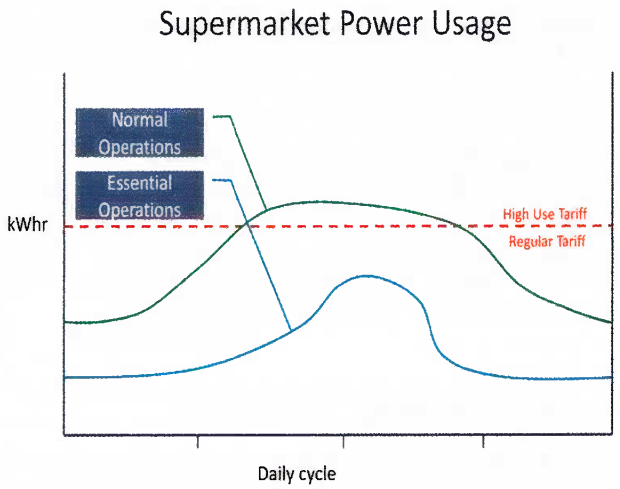

Figure 2 *Supermarket Power Usage*

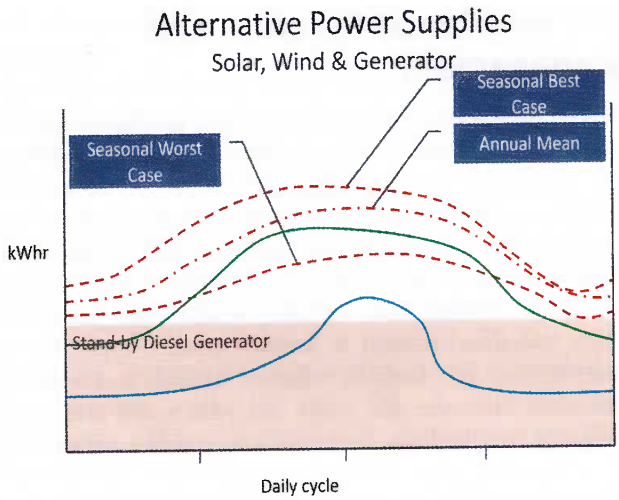

Figure 3 *Supermarket Power Usage against combined alternative power supplies*

the total available by other alternative means (diesel generator plus photovoltaic and wind turbine), it is clear that all the essential operations needs are met by these alternative sources and even, depending upon the season, the normal operating demand. Fig. 3. This means that if one can reduce the peak power demand to within the capacity of the combined alternative power sources, one has a makings of a resilient power supply. However, what happens when demand is concentrated and can affect dependency?

Generally speaking, demand is grouped in clusters around a particular focus, which could be a location or function or identity. Under normal operations each demand cluster will have a managed dependency of some sort. Within a city it would likely be on the city's corporation resources. However, during a catastrophic event the City needs to apply its available resources to manage the situation and enable rapid recovery. Often the routine dependencies of these demand clusters can be suspended for some time, because the tolerances are actually quite accommodating. However, in some cases the dependencies increase significantly during a catastrophic event and are further elevated by political imperative. These are dependency clusters. Occasionally, the dependencies on emergency resources are so significant that they can inhibit or even prevent effective City management of the incident and recovery. These are said to be critical dependency clusters. This begs the question 'How do we recognise critical dependency clusters and how do we manage them?' More to the point, how can a city prevent its neighbourhoods becoming critical dependency clusters? The same applies to counties, provinces or states and countries, though the priority interest is with cities.

4 Community resilience

Many cities are the product of planned and unplanned growth of communities that steadily incorporated smaller surrounding villages and towns. The net result is a patchwork of neighbourhoods, which have been individually developed as self-contained communities. Between these neighbourhoods are the poorly- and un-serviced areas so often used for community housing. These are known as interstitial communities and are quite often food deserts, which are areas without direct access to fresh food. Consider this research project question at the University of Toronto Centre for Resilience of Critical Infrastructure (CRCI) and the complexities become more apparent. 'How does an elderly infirm widow who lives alone on the 24th floor of a community housing block in an interstitial community feed and warm herself during a prolonged winter power outage?' During the Montreal Ice Storms, even essential power was not provided for over 7 days in some areas. She will need to descend 24 flights of stairs, walk 5–7 blocks to a grocery store and back and climb up the stairs because the lifts will not be working and the buses will not have been refilled with LPG because the compressors are run on electricity. Also, in many areas the water supply is through direct demand pumps and so potentially the same widow has no water either. The isolation of the vulnerable creates an increased dependency burden at precisely the time that it can least be afforded. Interestingly, many municipalities will respond to such a situation by using buses to set up temporary shelters, until something more suitable can be found. This will coincide with an already elevated public transport resource burden. Each expedient action moves the city corporation further into the risk funnel and eventually effective control of the incident is lost and with it the intrinsic capacity to manage its own recovery. The 'research question' is well-illustrated in New York tenements following Super-storm Sandy. How does one make a community resilient, so that the dependency burden does not increase unmanageably during a crisis? This is as far as current understanding and practice bring us, yet historical studies may provide the vital framework that allows us to project our current understanding that next bound; to stimulate the development of resilient communities.

There have been some very interesting publications in the last few years on communities destroyed by natural events and others who survived [1–3, 9, 4, 6, 7]. One of the things that come out strongly from these studies is that so much comes down to the attitude of the community. An initial review of the examples would appear to suggest that this attitude arises out of a coincidence of community focus and collective ownership with an infrastructure that supports them. That is not to say an infrastructure that provides perfect protection or one that is undeveloped, but one that is in balance with what the community does and how it sees its survival. This appears to echo the work of Jared Diamond [6] and Jane Jacobs [4], though they were not looking specifically at resilience. However, if one develops this idea a little further it would suggest that the community focus that Jane Jacobs [4] talks about is that essential awareness by the community as a whole of its members and their situation. One can generate this subliminal awareness by having a focal point in the

community that everyone must interact with at some point and so will encounter neighbours and become aware of their situation. It could be as simple as a close proximity of church, pub, general store, grocer, diner, post office and bank. This awareness stimulates multiple individual local actions that are community centric and which combined produce an uncontrolled [collective] community response to an incident. This idea of multiple local actions resonates closely with the idea of emergence, explained so well by Steven Johnson [5]. However, this alone does not deliver the essential resilience attitude. The collective attitude that gives the community awareness a focus is closely related to the community's relationship with its neighbours and the higher authority. Where there is the expectation that the higher authority, say the City, must provide during an emergency, it suggests an aspect of learned helplessness. However, where the community expects to deal with the initial mitigation of consequence itself – checking on and assisting vulnerable people etc., it suggests a sense of ownership of both their actions and influence if not control over their fate. So often, this would appear to be determined at the Parish Council or Residents Association level. Assuming that infrastructure has a purpose, the development of infrastructure within and supporting that community will either impose dependencies or vulnerabilities on the community or be in balance with its demand and operational dependencies. This includes not only the type and capacity of the water, electrical and telecommunications supplies to the community, but how much diversity and redundancy there might be in and around the community and how the infrastructure is used, both in terms of demand and interpretation. For example, some communities will interpret the construction of levees as making house construction on the flood plain a viable activity and others will see it as a mitigation measure that makes the existing community safer and no more. In effect, we are observing the same component construct around resilient communities as the fundamental concept of resilience. The difference is, that through this initial study, we would appear to have identified some of the key stimuli to developing resilience in communities [Operation] – [Infrastructure] delivering demand and dependency balanced infrastructure in and to the community, [Personnel] a focus and identity to foster community awareness, and [Organisation] ownership. What is especially interesting is that in all the cases of successfully resilient communities looked at; it was collective individual actions rather than directed and controlled actions that delivered the vital mitigation of consequences and effects, known simply as emergence. Quite how palatable this concept might be to a municipal or regional authority is not clear, when so often leadership is associated with direct control.

This theory would appear to hold for localised, such as a terrorist bombing, and global events, such as an ice storm or area flooding. An initial review of both World Trade Centre bombings [1993, 2001] in New York, the Oklahoma Murrah Federal Building bombing [1995], multiple London bombings [ten times between 1990 and 2005], the various Madrid bombings [four times between 1993 and 2006] and various other European bombings, would indicate that this essential balance and coincidence of community focus, ownership and enabling infrastructure mark out those resilient communities. The one anomaly in this initial review appears to have been the behaviour of the population in London following the 7 July 2005 bombing. Experienced in terrorist bombing campaigns by any international city standards, in this case the population of London resumed normal operations, as far as permitted, the following day with London Transport operating a normal service to all intents and purposes. This really stood out. London's responses to other terrorist events were investigated further and there appears to be a different relationship between the governing authorities and the governed. Londoners expect the authorities to get on with it, or put more succinctly they expect leadership. The leadership dimension was looked at for the other cities and it also appears to have influenced resilience. However, effective leadership alone did not correspond to rapid recovery, but instead would appear to set the conditions. In effect, it would appear to be the dominant influence in the Operating Context. There was an interesting study on the political leadership in the US following the 11 September 2001 terrorist attacks [8] and is worth reading.

This idea has also been applied to flooding, drought, wildfire and earthquakes. Indeed, the last of these would appear to provide the starkest comparison. Considering the devastating earthquakes in New Zealand [7 times in Christchurch during 2011], Haiti [Port-au-Prince/Leogane 12 January 2010] and Chile [Concepcion 27 February 2010], it is apparent that the differences in infrastructure were not significant, though the differences in death tolls and recovery were. For example, Chile experienced an 8.8 magnitude event that destroyed 500,000 buildings with a loss of 795 lives, yet Haiti experienced a 7 magnitude earthquake that destroyed 280,000 buildings with the loss of 220,000 lives, most of whom were subsequent to the event[4]. See also Time 'Chile and Haiti: A Take of Two Earthquakes' Tim Padgett 1 March 2010.. The relationship between communities and the authority only really changed in New Zealand, where there appears to be a loss of faith in geological science and the engineering professions rather than an issue over leadership. However, the most significant differences were in community ownership, which corresponded directly to their performance through the immediate aftermath and recovery. It suggests that the pre-existing community and leadership dynamics in Haiti were the single greatest cause of the high death toll and poor recovery.

5 Conclusion

This paper has outlined the concepts underpinning current practice and how this is being progressed through research

[4]Christian Science Monitor 'Chile earthquake much stronger than Haiti's but far less damage. Why?' Witte & Llana 27 February 2010.

into demand and dependency clusters and infrastructure and dependency recognition. The issue of community resilience, whether in isolation or within cities would appear under initial investigation to be an extension of the same underlying resilience concept. The theory that emerges out of this is that one can influence the development of community resilience through community focus and ownership and balanced enabling infrastructure within a reliable leadership context. More detailed research is needed to substantiate the theory, though there are several examples around the world where city planners are seeking to influence the self-reliance of neighbourhoods and communities using one or more of the measures described here. This is perhaps the best laboratory for this investigation. The applications of this theory extend beyond town and city planning, to provincial reconstruction and nation building following war and national policy development for domestic security development.

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