
Daniel H. Nall

Building Resilience For the MEP Engineer

BY DANIEL H. NALL, P.E., BEMP, HBDP, FAIA, FELLOW/LIFE MEMBER ASHRAE

Although the term "resilience" has become a hot button in the high performance building community, it seems to have different meanings in different contexts. This column will try to identify these differences and discuss the issues the concept raises for MEP engineers.

A common definition of resilience is the capacity to adapt to changing conditions and to maintain or regain functionality and vitality in the face of stress or disturbance. It's the ability to endure the disturbance, and, then, to bounce back after the disturbance with little interruption of service. In the architectural and sustainability communities, the differences in the interpretation of resilience tend to be generated by the definition of the changing conditions and of stress or disturbance.

For some, long-term trends such as dwindling fossil fuel resources or the increased temperatures and water shortages associated with global climate change are the kind of stresses that must be addressed. For others, more acute situations, such as terrorist attacks or extreme weather events, are the disturbances that must be overcome. Fundamentally, these two situations are very different, in that the former assumes continuing almost business-as-usual occupancy of the facility while the latter assumes a substantially modified temporary occupancy, followed by prompt resumption of business-as-usual when the disturbance has ended. The latter type of resilience is more difficult to address in that the nature of the temporary use may vary and even in the simplest of cases is difficult to define.

Designing for a gradually changing climate is significantly different from designing for a sudden catastrophic event. Interior conditions and occupancy functions can be assumed to be defined operating procedure. Outdoor design conditions may vary from currently published conditions based upon the specified future horizon and a selected projection for temperature rise. While scenarios for global climate change are available, based upon different assumptions about the global level of carbon emissions from National Oceanic and Atmospheric Administration (NOAA) and Intergovernmental Panel on Climate Change (IPCC), translation of these scenarios into modification of design temperatures for specific sites is very difficult.[1]

Even so, results of the analysis of regional projections for climate change can be applied to existing design conditions for a specific site, and the resulting uncertainty can be factored into design calculations.[2] Life-cycle cost studies can be performed using energy modeling results calculated with weather data altered to reflect future conditions and projected future energy costs.[3] Feasibility studies for other sustainable measures, such as rainwater harvesting and renewable energy generation, can also be performed using altered weather data.

Design of building systems to accommodate extraordinary events, on the other hand, includes not only making assumptions about the impact of the event on the building, but also the desired functionality of the building during and after the event and the impact of the event on the surrounding community and its infrastructure.

Building resilience is inseparable from community resilience. To the extent that community infrastructure can survive disasters or other extraordinary events, the demands of building resilience systems are reduced. As an example, a community served by flood-proofed natural gas pumping stations with backup generation, along with seismic design of distribution systems, would greatly improve the effectiveness of a building's backup

Daniel H. Nall, P.E., FAIA, is vice president at Syska Hennessy Group, New York.

electrical generation systems and reduce the building's need for on-site fuel storage.

Had the New Orleans community flood control pumps not failed, the flooding damage caused by Hurricane Katrina would have been greatly reduced. Flood-proofing strategies for electric distribution, including protection of substations, switchgear and cable terminations, also decrease the need for backup building generation.

The relationship between resilience and life-safety requirements is obvious. A primary requirement of both is that the building and its systems retain integrity sufficiently to protect the life and health of the occupants during the event itself. Issues such as blast and seismic resistance, avoidance of progressive collapse and materials failures of various kinds fall within the primary purview of the structural engineer and architect. Once the danger of immediate death or injury to occupants has passed, life-safety requirements relate to evacuation of the building, while resilience capabilities enable continued operation in some form and rapid return to normalcy after the crisis resolution.

Clearly, for a building to be resilient, it must withstand rigors imposed by the initial emergency. For some natural events, such as windstorms and earthquakes, and for some human events, such as terrorist attack, structural design enables the building to maintain integrity through the event. Once the building itself has survived an event, resiliency is achieved by maintenance of its critical internal infrastructure.

The Role of MEP Engineers

MEP engineers have been providing resilient systems for many years, to healthcare, military, financial services and data processing facilities, among others. These systems can be characterized as having redundant or "hardened" supply chains for critical services to the facility. Typical examples of resilient strategies include redundant services for water or power, and on-site storage of critical resources, such as water or electricity (in the form of electrical storage in UPS systems or fuel storage for on-site generation). These measures are intended to ensure that critical functionality will be maintained throughout a challenge to the site supply chain infrastructure. The process for designing these systems is pretty sophisticated. Next, I'll outline the steps.

1. **Goal setting.** What is the nature of the continuity to be maintained in the facility through the disruption?

PHOTO BY JOCELYN AUGUSTINO, NOV. 2, 2012

PHOTO 1 New York City residents use a police department vehicle to recharge electronic devices after Tropical Storm Sandy hit the city.

2. **Threat analysis.** What kinds of defensible threats might be encountered at the site?
3. **Vulnerability analysis.** How might the identified threats impact the critical supply chain infrastructure for the site?
4. **Gap-analysis.** For existing buildings, identify gaps in existing systems that prevent meeting continuity goals in the face of identified threats.
5. **Counteractive measure identification and assessment.** Identification and evaluation of measures to overcome identified vulnerabilities.
6. **Cost-effectiveness evaluation.** Evaluation of the cost of proposed alternate measures compared with cost and probability of loss of service.
7. **Implementation.** Selection and implementation of measures.
8. **Emergency response plan.** Creation of a detailed emergency response plan to ensure that resilient measures are deployed appropriately during an emergency.

Tropical Storm Sandy

After Tropical Storm Sandy, the City of New York realized that resilience considerations should be applied to more than just recognized "critical facilities" and convened a volunteer group of professionals, the New York City Building Resiliency Task Force, under the management of the Urban Green Council, to outline steps to fortify New York's buildings and strengthen building standards. One of the primary findings of the task force was that the goals for different building types were very different.

The resilience goals for commercial buildings are the least rigorous. The Task Force described the minimum goal for commercial buildings as follows. "The level of preparation for commercial buildings, both large and small, is fundamentally a business decision for their owners. Task Force recommendations are intended to minimize interruptions to building functionality while allowing the market to dictate the need to implement resiliency measures. Still, the city has an overall interest in maintaining a viable economy by reducing large-scale business disruption."[4]

Several events in New York City have, however, illustrated the need for an expanded goal for commercial buildings: providing temporary shelter for commercial building occupants who may be stranded due to disruption of transportation systems. Events such as the 2003 blackout and Tropical Storm Sandy resulted in numerous workers spending one or more nights in office buildings that were without power. Provisions of areas for temporary shelter in commercial buildings, provided with minimal electrical service, passive conditioning, sanitary and potable water service and access may be a requirement for commercial buildings in locations that may suffer disruption of transportation systems during emergencies.

The Task Force decided that the goals for residential buildings are more rigorous, recognizing that the building must remain habitable, perhaps with reduced amenity, throughout an emergency and should be able promptly to return to full functionality after the emergency is resolved. "Multifamily residences, dorms, hotels, and adult care facilities must provide for essential needs such as safety, drinking water, habitable temperatures, and functioning stairs and elevators."[5]

Critical buildings have the most rigorous requirements for resilience in an emergency. "A critical facility is required to withstand the effects of a disaster and remain in operation, whether to safeguard the activity conducted within it, or the lives and well-being of its occupants, other disaster victims or emergency-services personnel. Critical facilities include, for example, hospitals, police and fire stations, data centers, evacuation shelters, and buildings or portions of buildings that provide essential support to them."[6] For critical buildings, no loss in functionality is acceptable through the duration of a crisis.

Improving Resilience

One of the lessons learned from Tropical Storm Sandy was that flooding is a significant obstacle to resilience, both from the standpoint of immediate loss of function and prompt return to service. Recent experience has indicated that current flood zone maps are out of date, given recent climate changes. The revised New York City flood zone maps, shown in *Figure 1,* incorporate projections for sea level rise in the next century, assuming the rapid ice melt scenario developed by the Urban Climate Change Research Network.[7]

Some measures engineers can help implement to maintain function, reduce damage and facilitate recovery in the face of a flooding event are listed here.

- Raise critical building systems above flood level.
- Protect critical areas with dry flood-proofing, including both permanent and temporary flood barriers to ensure spillover elevation into the building is greater than identified flood level.
- Rely on wet flood proofing (sump pumps) only when reliable stand-by power is available.
- Identify and secure non-obvious water inlet pathways, such as sewer or roof drains, power and data entry conduits, passive room vents, fuel oil tank fill and vent locations.
- Use mold- and salt water-resistant materials in areas that may become wet during a flood to reduce post-disaster recovery time and cost.

Loss of electric power is another challenge to meeting goals for functional continuity within a building. Strategies for dealing with this type of emergency in residential, critical facilities and commercial facilities requiring continuity are listed here.

- Provide on-site stand-by power generation. Assess relative probability of natural gas supply failure compared with loss of truck access for fuel oil replenishment to determine fuel choice. (Some Authorities Having Jurisdiction may require on-site fuel storage for life-safety back-up generation.)
- Implement and encourage load management to minimize required stand-by power capacity.
- Improve efficiency of systems used during utility failures to extend useful life of backup supply of fuel or water.
- Enable islanding capability for on-site renewable electric generation assets during utility outages with grid disconnection to protect the grid and workers from back-fed site-generated power.

Maintaining habitability of residential buildings is a particular challenge. Following are some more detailed strategies to achieve that end.

- Put basement sump pumps and domestic water booster pumps on emergency power.

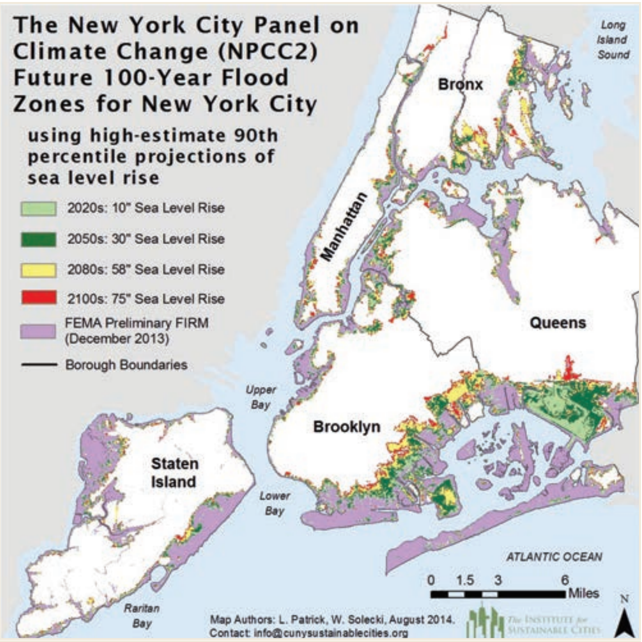

FIGURE 1 Flood zones in New York City for several sea level rise scenarios.

- Put one elevator on emergency power to facilitate access for mobility impaired occupants.
- Provide one or more standard 120 V outlets with emergency power in each apartment to recharge communication, lighting and medical devices.
- Provide domestic water storage as part of the domestic water pressure maintenance system, either in the form of roof tanks or intermediate break tanks.
- Incorporate passive conditioning techniques such as operable windows and direct gain passive solar strategies into the building design to mitigate temperature extremes during loss of active conditioning systems.
- Use harvested rainwater for nonpotable end uses to mitigate potable water consumption during water service loss or curtailment.

Resilience vs. Sustainability

While many of the resilient strategies might be considered sustainable, the goals of these efforts are quite different. Sustainability measures reduce the environmental impact of the building construction and operation, while improving the health and comfort of the occupants during normal use. Resilience measures enable the building to meet desired functionality goals during defined extraordinary conditions that usually include disruptions to the building's normal infrastructure supply chain. Electric power, natural gas, potable water, sewer, surface access for goods delivery and waste removal are all community

functions subject to curtailment by the same events that limit the building functionality. Optimized resilience for the building is achieved through addressing the resilience systems in both the building and the community infrastructure. From the standpoint of resilience, environmental impact is a lesser consideration than maintenance of the required functionality. The survival of a resilient building after a catastrophe, however, achieves a sustainable result through preserving the materials and construction of the building and avoiding the waste incurred by its demolition.

Summary and Conclusions

Building resilience is the ability of a building to maintain required functionality during and after extraordinary events. Arguably, the frequency of such events has increased over recent years, due to climate change, increased political unrest and sea level rise. The measures required to achieve increased resilience are primarily integrated measures, requiring the coordinated efforts of most of the building design disciplines, including architectural, structural, mechanical, electrical, plumbing, and civil. Each of these disciplines must understand the bigger picture and the goals to be achieved, to the benefit of both building owner and occupants. As more buildings incorporate the principles of resilience, safety and value will be increased for all stakeholders.

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