INFRASTRUCTURE RESILIENCY MODEL

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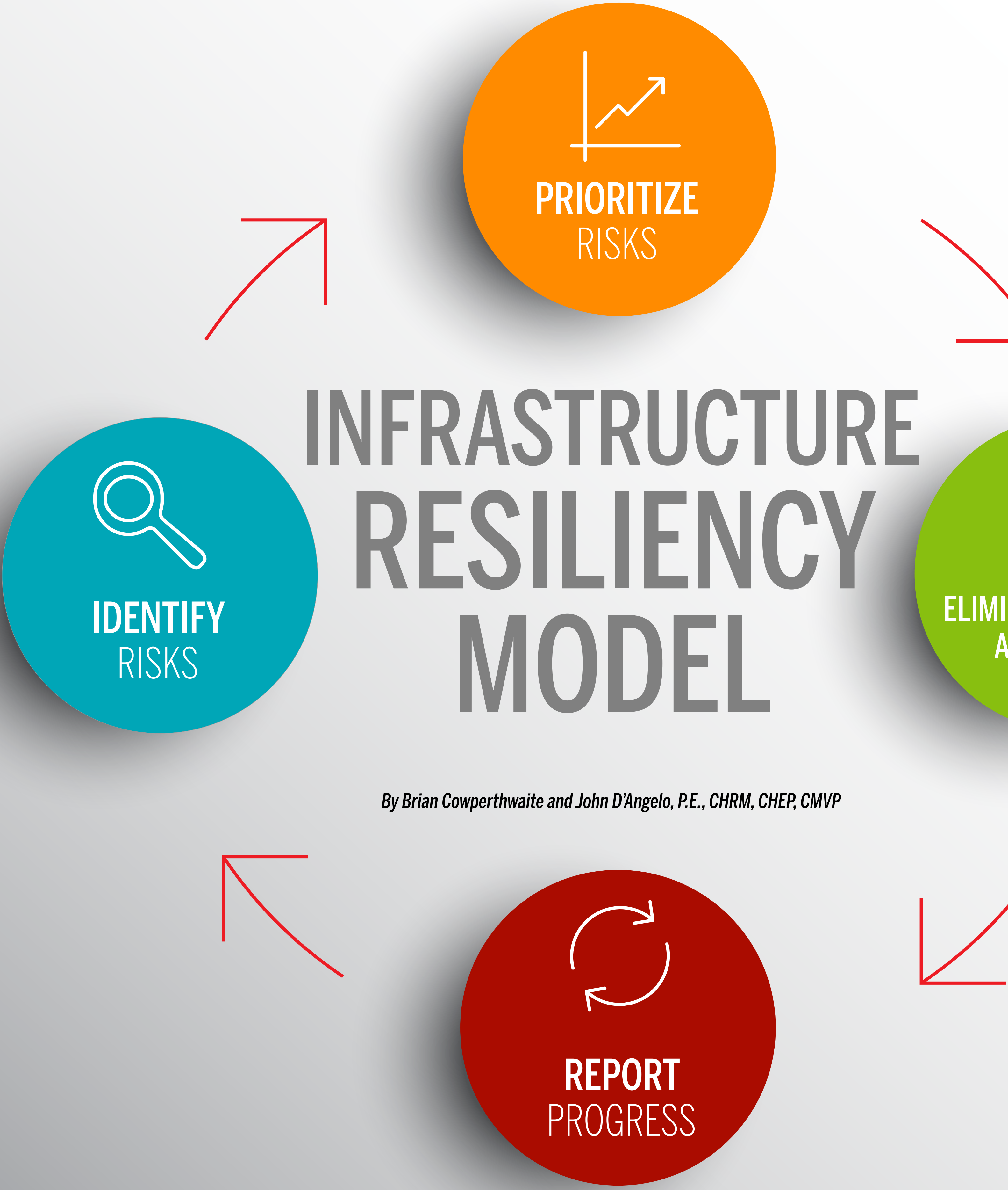

NATE, MITIGATE,
ND REDUCE
RISK

Deferred maintenance, facility condition index (FCI), and critical backlog are not inherently bad benchmarks; they just miss an opportunity to programmatically address risk mitigation as the primary function of facilities maintenance and operations, and fail to engage other critical stakeholders in the program development process. Each creates a mathematical model expressed either directly or indirectly in terms of cost to establish a current state. They each can express their future state in terms of positive, negative, or neutral trends based on future investment levels. However, they each fail to engage institutional leadership within a framework and a business language that can be clearly understood or directly (without need of translation) tied to institutional goals and imperatives.

For most asset portfolios, the magnitude of dollars contained within the benchmarks are so large that investment is either seen as potential competition to institutional initiatives or as eroding the credibility of the facilities organization. A $1 billion deferred-maintenance benchmark would not be welcomed by even the wealthiest institutions, and a $1 billion investment to eliminate it would not really eliminate organizational risk as the primary driver of why the benchmark is measured.

Focusing the benchmark on risk mitigation allows the team to express readiness in terms that are important to the organization and in the language that institutional leadership can understand without translation. It also allows the team to create a programmatic response that aligns processes, priorities, and deliverables toward that common goal. Using the Infrastructure Resiliency Model (IRM) allows the facilities team to specifically apply the data already developed for its deferred-maintenance or FCI benchmark within a framework that addresses probability and severity of risk while allowing for real-world drivers, constraints, and restraints. IRM also integrates operating account maintenance with recapitalization projects within the same framework.

The foundational driver of resiliency is found in appropriately matching the strategies of redundancy, reliability, and recoverability to the organizational risk. Each is based on the assumption that all systems will fail and will usually do so at the worst possible time.

RESILIENCY = REDUNDANCY + RELIABILITY + RECOVERABILITY

Redundancy is the most expensive strategy and should only be applied where system failure causes unacceptable consequences. Life-safety systems are generally protected from disruption due to a power failure with a statutory requirement for a backup emergency generator. Data centers and high-acuity research may have redundant temperature and humidity control systems, and patient care areas have backup plans in place for medical gases.

Both the initial cost and the maintenance of redundant systems are costly, and they are generally employed when the cost of failure to the services they provide far exceeds this investment. In other words, most organizations employ at least an informal risk model in their redundancy business case.

Reliability can be achieved through a variety of strategies. The simplest is by increasing preventive or predictive maintenance on critical systems or equipment and by ensuring that system components are purchased based on durability and functionality factors and not on price alone. Reliability can also be improved with easy-to-use computerized maintenance management systems, which contain accurate and up-to-date information. Drawings, spare parts lists, manuals, and options for rapid service both reduce and improve maintenance cycle times. Low or no-cost improvements to reliability can also be created with policy changes, such as response prioritization or support agreements, such as a standby contract for bulk bottled water delivery.

Recoverability is a measure of the speed and cost required to restore normal conditions after a system failure. Common examples of recoverability strategies may include a HAZMAT spill cleanup kit located near storage areas or electrical pigtails prewired into a main disconnect to accept a portable generator. Recoverability can also be expedited with a focus on prioritized risk identification. Identification of life-safety and critical systems can enable a preplanned response as well as the critical spares available to limit severity.

Redundancy, reliability, and recoverability will not prevent failures, but they can mitigate or eliminate the risk to safety and disruption of business continuity. The following fictional example helps illustrate how an organization can implement an IRM.

INFRASTRUCTURE RESILIENCY MODEL

1. Identify Risks

Each institution will have different risks and risk priorities dependent upon their mission, their culture, their infrastructure portfolio, and their geographic location. In general, the primary risks that institutions will focus on are those that impact safety, operational continuity, and brand. These risks can be further categorized into environmental drivers, technological drivers, and human drivers. Whichever categories an institution chooses should have the goal of engaging key stakeholders from across the organization in risks and impacts. An example list developed from these stakeholder conversations may resemble the table below.

2. Prioritize Risks

The impact of each risk depends upon the probability of occurrence, the severity of the occurrence, and the ability to recover from the occurrence. Creating an algorithm with weighting factors appropriate to the organizational mission and culture provides a manageable framework for stakeholder agreement on prioritization. Once developed, this framework provides a baseline mathematical model that can measure changes to organizational risk over time or due to changes to probability, severity, or recoverability from real-world events.

Additionally, the framework becomes integral to evaluating and prioritizing institutional projects and processes and to communicating those recommendations to resource decision-makers. Furthermore, there is no need to speculate what the most probable and likely risks facing an organization might be. Institutions have an overabundance of data and information at their fingertips within computerized maintenance management systems (CMMS), building automation systems, and condition assessments; the IRM provides a specific, repeatable algorithm through which this data can be applied.

Looking at the example in the table below, the highest organizational risks are from an internal flood (126.7 score), a cooling system failure (102 score), or a fire (93.8 score). The drivers for each risk are different, and therefore the mitigation strategy for each needs to be different. This organization rated the probability of an internal flood at 50 percent due to a behavioral challenge with vandalism intentionally blocking toilet and shower drains, and due to mechanical rooms located above finished space; these are real issues identifiable via their CMMS. They rated the probability of a cooling system failure at 60 percent due to an end-of-life chiller that is undersized for the load it supports. This stakeholder group rated fire risk high

Risk Examples and Types

Risks		
Environmental	**Technological**	**Human**
Extreme Heat	Electrical Disruption	Labor Strike
Extreme Cold	Natural Gas Disruption	Hacker/IT Attack
Blizzard	Potable Water Disruption	Active Shooter
Icing	Sewer Failure	Civil Unrest
Hail	Fire Alarm Failure	Mass Casualty
Tornado	Heating System Failure	Transportation Disruption
Strong Winds	Cooling System Failure	Supply Disruption
Hurricane	IT Failure	Accessibility Disruption
Lightning	Telephone Failure	Epidemic
Flood	Internal Flood	HAZMAT Exposure
Fire	BAS/SCADA Failure	OSHA Compliance
Earthquake	Roof/Facade Failure	VIP Visit

due to the high-severity scores for impacts to safety, operations (business continuity), and physical damage, even though the probability of a fire is not high.

As the table below shows, the internal flood causes more damage than the cooling system failure, and both the internal flood and cooling system failure equally impact safety and operations. The cost and time to recover from internal floods has been higher than the cost and time to recover from cooling system failures for this organization. Based on the knowledge gained from the stakeholder conversations and leveraging work order data and the high risk ranking, the team decides to pursue mitigation strategies to reduce this risk.

3. Eliminate, Mitigate, and Reduce Risk

Understanding the drivers and relative scale of each risk allows the organization to prioritize its efforts and resources

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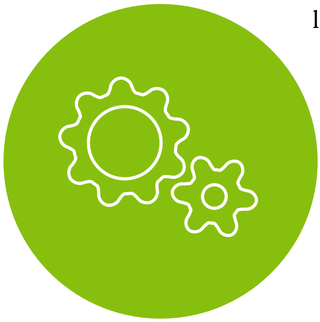
Risk Weightings and Ratings

		Probability (0-10)			Severity (0-10)				Recoverability (0-5)			Risk
	Risk	**External**	**Internal**	**Overall**	**Safety**	**Operations**	**Damage**	**Overall**	**Time**	**Cost**	**Overall**	**(P*S*R)**
Environmental Risks	Electrical Disruption	2	2	**2.0**	3	9	1	**4.3**	2	2	**2.0**	**17.3**
	Natural Gas Disruption	1	2	**1.5**	2	7	0	**3.0**	2	2	**2.0**	**9.0**
	Potable Water Disruption	3	4	**3.5**	6	9	4	**6.3**	3	2	**2.5**	**55.4**
	Sewer Failure	1	2	**1.5**	1	3	3	**2.3**	1	2	**1.5**	**5.3**
	Fire Alarm Failure	N/A	3	**3.0**	8	4	1	**4.3**	4	3	**3.5**	**45.5**
	Heating System Failure	N/A	4	**4.0**	6	5	5	**5.3**	2	2	**2.0**	**42.7**
	Cooling System Failure	N/A	6	**6.0**	6	7	4	**5.7**	3	3	**3.0**	**102.0**
	IT Failure	2	2	**2.0**	3	7	0	**3.3**	1	2	**1.5**	**10.0**
	Telephone Failure	2	2	**2.0**	3	5	0	**2.7**	1	1	**1.0**	**5.3**
	Internal Flood	N/A	5	**5.0**	5	7	7	**6.3**	3	5	**4.0**	**126.7**
	BAS/SCADA Failure	N/A	3	**3.0**	3	5	3	**3.7**	1	1	**1.0**	**11.0**
	Roof/Facade Failure	N/A	4	**4.0**	6	4	6	**5.3**	2	3	**2.5**	**53.3**
Technological Risks	Extreme Heat	2	2	**2.0**	6	2	1	**3.0**	1	0	**0.5**	**3.0**
	Extreme Cold	2	2	**2.0**	6	3	2	**3.7**	1	1	**1.0**	**7.3**
	Blizzard	3	3	**3.0**	4	5	3	**4.0**	2	1	**1.5**	**18.0**
	Icing	2	2	**2.0**	5	3	2	**3.3**	1	1	**1.0**	**6.7**
	Hail	1	1	**1.0**	3	0	3	**2.0**	1	2	**1.5**	**3.0**
	Tornado	1	1	**1.0**	6	6	8	**6.7**	5	3	**4.0**	**26.7**
	Strong Winds	3	3	**3.0**	5	3	8	**5.3**	3	3	**3.0**	**48.0**
	Hurricane	0	0	**0.0**	8	8	10	**8.7**	4	4	**4.0**	**0.0**
	Lightning	2	2	**2.0**	7	1	1	**3.0**	1	3	**2.0**	**12.0**
	Flood	0	0	**0.0**	4	4	4	**4.0**	4	4	**4.0**	**0.0**
	Fire	1	4	**2.5**	8	8	9	**8.3**	4	5	**4.5**	**93.8**
	Earthquake	0	0	**0.0**	4	2	7	**4.3**	3	4	**3.5**	**0.0**
Human Risks	Labor Strike	4	1	**2.5**	0	7	0	**2.3**	2	0	**1.0**	**5.8**
	Hacker/IT Attack	2	1	**1.5**	2	7	2	**3.7**	1	1	**1.0**	**5.5**
	Active Shooter	1	1	**1.0**	10	5	0	**5.0**	1	0	**0.5**	**2.5**
	Civil Unrest	2	1	**1.5**	4	4	2	**3.3**	1	0	**0.5**	**2.5**
	Mass Casualty	2	1	**1.5**	1	4	1	**2.0**	1	0	**0.5**	**1.5**
	Transportation Disruption	2	1	**1.5**	1	8	0	**3.0**	1	0	**0.5**	**2.3**
	Supply Disruption	2	1	**1.5**	1	6	0	**2.3**	1	2	**1.5**	**5.3**
	Accessibility Disruption	0	4	**2.0**	2	2	0	**1.3**	1	1	**1.0**	**2.7**
	Epidemic	1	1	**1.0**	2	4	0	**2.0**	1	0	**0.5**	**1.0**
	HAZMAT Exposure	N/A	1	**1.0**	5	1	2	**2.7**	1	1	**1.0**	**2.7**
	OSHA Compliance	N/A	2	**2.0**	4	1	1	**2.0**	1	1	**1.0**	**4.0**
	VIP Visit	1	1	**1.0**	0	5	0	**1.7**	1	0	**0.5**	**0.8**
												738.4

toward eliminating and mitigating root causes in order to reduce overall risk to the portfolio. Absent this knowledge and prioritization, the organization may spend significant effort and resources repeatedly treating symptoms.

In order to deal with the internal flood example shown above, the organization evaluated ways to reduce both *probability* and *severity* (see table below). Understanding their drivers, they found that the majority of the cost and time (*severity*) related to recovery was from floods in the mechanical rooms located above finished spaces. Although they were not able to relocate equipment from these rooms, the team discovered that cleaning unnecessary storage out of the mechanical rooms, sealing the floors, and creating a monthly preventive maintenance task to check for leaking equipment and clogged floor drains cut the time and cost to recover in half for this entire category of risk. An added level to reduce severity may introduce a mixture of water sensors that allow the staff to respond more rapidly and limit the impact.



Additionally, the removal of storage in the mechanical room also reduced the *probability* of an internal fire by a full point. The stakeholders estimated the cost of these measures and combined it with the significant portfolio risk reduction as the business case to request funding.

The organization further found that the high *probability* of internal floods was primarily due to the behavioral issue. They evaluated several strategies to reduce the impacts, including increased day porter staffing in high-vandalism areas, switching to waterless urinals, and replacing paper towels with electric hand dryers, the item primarily used to vandalize the fixtures. As the cost for these initiatives was roughly equal to the mechanical room initiatives above, and the resultant risk reduction was much poorer in comparison, the organization chose to fund the former.

Regarding the cooling system failure, the organization looked at replacing the chiller with the same-size model or with a larger-capacity model. The larger chiller had a more expensive first cost and a more expensive annual operating cost, and lowered the probability of failure more than the direct replacement. The organization also calculated a reduced recovery time based on the larger chiller capacity, making its higher initial cost well worth the investment (see table below).

4. Transparently Report Progress

Unlike deferred maintenance, FCI, and critical backlog, the IRM described above connects investment and deferral decisions directly to the risks involved as opposed to age of plant or proxy financial benchmark. Also, unlike these other indices, IRM uses an “all-hazards” approach, meaning that it is not limited to buildings and systems, but evaluates all aspects of the physical environment. By evaluating all hazards, the stakeholder team evaluation of risk extends beyond facilities professionals, yielding a better understanding of the second- and third-order impacts, better response and recovery protocols, and more focus and agreement on investment priorities. One final difference is that IRM is not restricted to routine capital solutions. Prioritized

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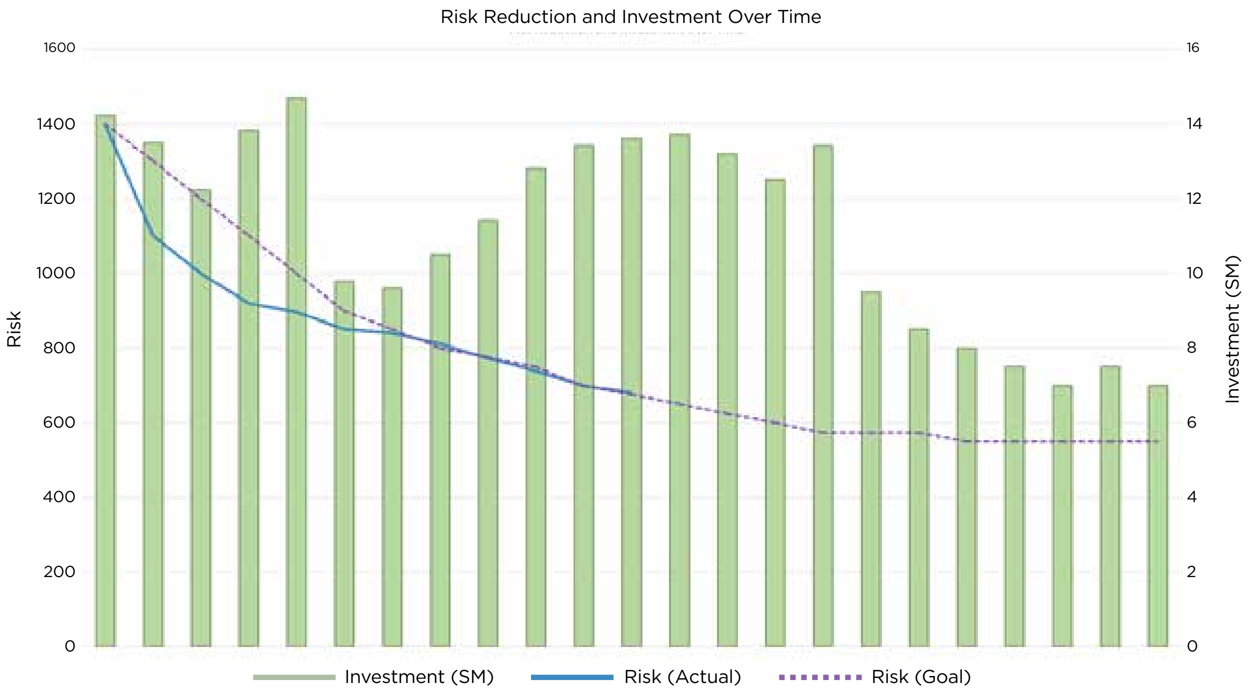
Reducing Risk Probability and Severity

	Probability (0-10)			Severity (0-10)				Recoverability (0-5)			Risk
Risk	**External**	**Internal**	**Overall**	**Safety**	**Operations**	**Damage**	**Overall**	**Time**	**Cost**	**Overall**	**(P*S*R)**
Internal Flood (as is)	N/A	5	**5.0**	5	7	7	**6.3**	3	5	**4.0**	**126.7**
Internal Flood (proposed)	N/A	5	**5.0**	4	5	4	**4.3**	1	3	**2.0**	**43.3**
Fire (as is)	1	4	**2.5**	8	8	9	**8.3**	4	5	**4.5**	**93.8**
Fire (proposed)	1	3	**2.0**	8	8	9	**8.3**	4	5	**4.5**	**75.0**

Calculating Risk Recovery and Costs

	Probability (0-10)			Severity (0-10)				Recoverability (0-5)			Risk
Risk	**External**	**Internal**	**Overall**	**Safety**	**Operations**	**Damage**	**Overall**	**Time**	**Cost**	**Overall**	**(P*S*R)**
Cooling System Failure (as is)	N/A	6	**6.0**	6	7	4	**5.7**	3	3	**3.0**	**102.0**
Cooling System Failure (replace chiller)	N/A	5	**5.0**	6	7	4	**5.7**	3	3	**3.0**	**85.0**
Cooling System Failure (larger chiller)	N/A	4	**4.0**	6	7	4	**5.7**	12	3	**2.5**	**56.7**

Risk Reduction and Investment over Time



risks can be abated or mitigated by any combination of capital replacement, operating maintenance, policy and procedure creation, or recovery plan development.

Because the IRM uses a numerical evaluation of *probability*, *severity*, and *recoverability*, it can easily be converted to a time-based key performance indicator that shows how investment or deferral decisions impact risk. Although impossible to reduce risk to "zero," this indicator allows the institution to establish a risk goal to achieve and maintain. Transparent reporting assists in this goal becoming an institutional imperative: to preserve the balance between investing in new opportunities and maintaining the existing portfolio.

Certain trends in the above fictional graph can be expected in most cases. Initial risk reduction per capital dollar invested will be high as noncapital (targeted maintenance, policy creation, and recoverability plan development) opportunities are available. Risk reduction opportunities will become more reliant on capital investment during a "catch-up" phase. As the investment decisions are driven by risk, this total tends to be much less expensive than similar investments in deferred maintenance or FCI "catch-up" phases. Finally, maintaining the institutional risk goal requires continued investment at a much lower, but consistent level.

5. Things Change

As discussed above, the stakeholder conversations inherent in the Infrastructure Resiliency Model have a secondary benefit when real-world events cause changes to probabilities. The decision framework provides an opportunity for the organization to respond to these changes within the redundancy, reliability, and recoverability realms. A simple example could be taking the car in for an oil change, deep service including tire evaluation, and the purchase of a road-hazard plan such as AAA before taking a long road trip with the family. This is warranted in the IRM framework, as the recoverability factors increase due to being far from home on the long trip, and the severity factors increase from having your spouse and children in the car.

A real-world example of the above methodology includes Superstorm Sandy. On October 29, 2012, Sandy made landfall just north of Atlantic City, New Jersey. Despite being compliant with some of the most stringent codes in the facilities management industry, several New York City (NYC) hospitals were forced to evacuate during the height of the storm. One in particular had to evacuate 45 critical-care patients and 20 babies down stairwells lit by cell phones, while another hospital attempted to carry diesel fuel by bucket brigade from its underground storage tanks to its rooftop generators. The challenge for NYC residents did not end with Sandy moving on, as one hospital took more than four months to recover and reopen, putting pressure on all other hospitals in the area to make up their bed count.

Other large, nearby hospitals with the exact same aging infrastructure challenges not only survived Sandy but were able to fully recover and work on providing increased capacity to make up for that lost by their area competitors. Although hurricanes did not receive a high priority during their annual review of risks, tracking Sandy allowed these organizations to update the probability and reevaluate risks and appropriate mitigations in real time.

Being comfortable with this process allowed one hospital to understand the secondary and tertiary risks that the hurricane posed, and the hospital anticipated that both commercial power could be lost and that Manhattan's bridges and tunnels could be closed. The growing probability of the storm increased these risks and resulted in mitigation plans that allowed the hospital to put in place a plan for resupply, including diesel fuel for their generators. In this case, they rented a diesel tanker and driver and sheltered them on the island.

Both anticipated events eventually occurred: A commercial power substation failed, resulting in a complete blackout to lower Manhattan; the tunnels flooded; and the bridges were closed. Had this hospital not prepositioned the diesel truck and driver, they would not have been able to provide the same level of service to patients, as their storage tanks would have run dry.

In the aftermath of Sandy, NYC reevaluated its codes and discovered that despite existing codes being well thought out, well written, and well enforced, they applied to discreet, tactical elements instead of holistic preparedness strategies. The city set up a task force to change this, and on June 11, 2013, they released a comprehensive plan entitled "A Stronger, More Resilient New York" (*https://www1.nyc.gov/site/sirr/report/report.page*). Hopefully, more cities will follow NYC's example and, in the interim, more institutions will adopt a risk-based approach to keeping our campuses safe and functional.

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