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Climate Change Risk Assessment for a University Campus[1]

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ABSTRACT

This article presents an approach to determining the impacts of climate change on a university campus by focusing on the Boston University Medical Campus. The methodology uses enterprise risk management paradigms that identify the climate-related risks and quantifies their impacts. The focus is on personnel impacts, along with business impacts separated into education and research activities. Results suggest that the highest risk ranking for the campus are associated with IT outages, staff/student access issues, and public and private transportation disruptions. The enterprise risk methodologies applied are robust and can be duplicated at other university campuses.

KEYWORDS: Enterprise risk management, Hazard vulnerability analysis, Climate change, Criticality assessment, Predictive modelling, Meta-analysis

INTRODUCTION

The City of Boston, Massachusetts is the home for 35 higher education institutions serving over 150,000 students. Boston is especially vulnerable to climate change impacts, and climate change is expected to compromise the ability of its universities to service their students. The City's Climate Vulnerability Assessment Report lists extreme heat, stormwater flooding, and coastal and riverine flooding as the major impacts of climate change in the Boston area (Climate

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Ready Boston, 2016, pp. 13-72). Some impacts are indirect. For example, a hurricane often leads to flooding, which can increase the potential for power outages and sewer damage. The City also consists of an aging public infrastructure that was built without consideration of climate related risks. Its public transit system, building codes, street organization, underground heating, ventilation, and air conditioning (HVAC) equipment, low-lying emergency stations, and old water mains operate without significant backup capabilities should a major disruption occurs.

This article applies an enterprise risk management (ERM) framework to illustrate how a university campus should be evaluated based on its unique business model, stakeholder configuration, location, and physical structure. Prior work suggests that universities face many challenges, including their broad scope of activities, personnel backgrounds, and the need to customize each analysis. The methodology suggested by the authors is illustrated by an analysis of how climate change will likely impact the ability of the Boston University Medical Campus (BUMC) to serve its stakeholders (students, researchers, faculty, staff, etc.). The anticipated climate change impacts will likely affect the BUMC by compromising staff availability, research activities, students' access to classes, resource availability, and/or personnel access to food. Extreme weather-related events may also damage facilities and increase power outages. These events will have a cascading impact amplified throughout the BUMC; for example, its access to many outsourced IT services will be disrupted when power failures impact important information technologies.

BACKGROUND

ERM is a profession that covers the identification, quantification, and mitigation of risks across an organization, including operational risk, strategic risk, and financial risk (Lam, 2014, P. 10). ERM professionals seek to create organizational resiliency in the presence of risks and vulnerabilities that can impact their organization's ability to operate effectively in the short or long term. However, barriers exist in many organizations, including over-confidence, development plans that do not account for risk, and the need to customize the analysis to account for specific features of each sub-organization (Sapountzaki, 2022, P. 12-13). A hazard vulnerability analysis (HVA) is a tool that assesses risks that concerns "naturally occurring events, technological events, human-related events, and events involving hazardous materials" (Fifolt, 2016).

Researchers have addressed resiliency on university campuses using a variety of methods. Hites et al (2013) used focus groups to determine the perception of safety on a university campus. Badajoz and Caelian (2020) used a survey to show that multiple campuses across a large university need to treat the campuses differently because of their unique risk profiles. Some studies consider a subset of a university's portfolio. For example, Young et al (2023) look at the resiliency of the portfolio of academic majors. De los Reyes et al (2022) considered the resiliency associated with teaching faculty.

Recently, the COVID-19 pandemic has created an intense interest in ERM at many colleges and universities in the US (e.g., Yamey and Walensky, 2020) and abroad (e.g., Wang et al, 2020). Challenges exist in these settings because universities often operate like small cities, with their own police forces, transportation systems, and other public infrastructures (Mitroff et al, 2006). As such, they face challenges not unlike other public sector organizations, including top leadership exposure to ERM, resource limitations, and many undocumented processes (Maleyeff, 2014).

The disruptions associated with the COVID-19 pandemic should convince university administrators that anticipating climate change impacts is important, and not only because climate change may make pandemics more common (Marani et al, 2021). Stein (2023) suggests that universities need to play a socially responsible leadership role by confronting climate change. The impact of climate change on universities has not been studied extensively, although many researchers have studied how curricula need to adapt (e.g., Fahey, 2012) or how the university can play a role in public education on climate change (e.g., Hess and Maki, 2019). Some researchers have focused on carbon emissions that universities generate caused by factors such as international student mobility (Shields, 2019) and the prevalence of faculty air travel (Baer, 2023).

Boston Climate Change Projections

The BUMC is located in the south end of Boston where flooding and extreme weather are expected to increase in intensity. Its elevation is equal to sea level, and flooding potential exists from both rivers and the ocean. The adverse effects of climate change, such as increased sea-level rise, flooding, storms, and extreme heat, amplify the occurrence of hazardous events. For example, during a severe storm in 2014, many of Boston's parking lots and public walkways experienced significant flooding. Events like these are expected to become more frequent in the future.

Douglas & Kirshen (2022) predicted more intense extreme weather events in Boston, including increases in maximum temperature (Figure 1), flood height (Figures 2 & 3), and sea-level rise (Figure 4). These predictions are based on the representative concentration pathways (RCP) index, where higher values represent more significant greenhouse gas and aerosol emissions (Meinshausen et al, 2011). Consequently, the potential for hazardous events to impact the city's infrastructure and daily life is likely to escalate, underscoring the importance of proactive planning and adaptation measures.

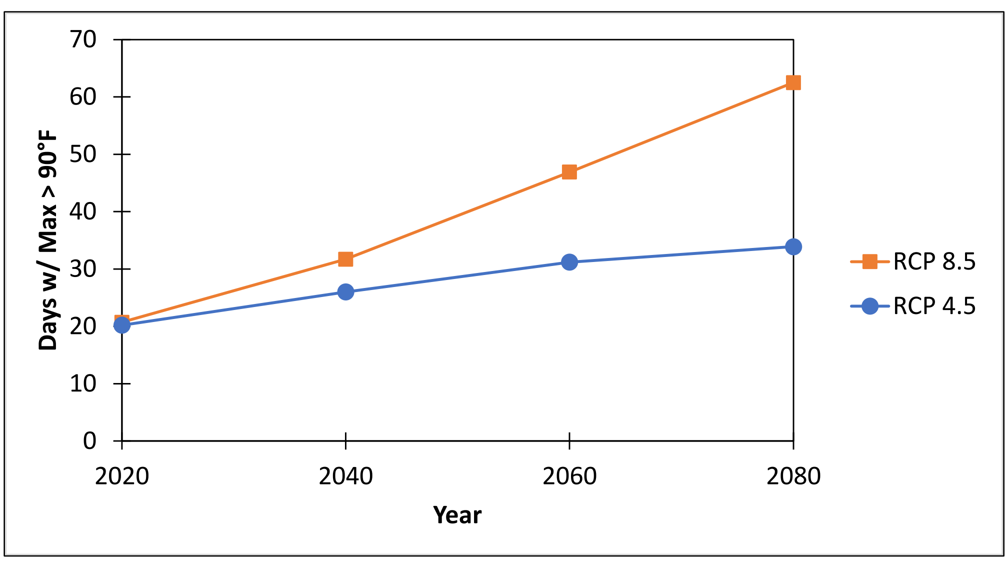

Figure 1: Projections for Number of Days w/Max Temp > 90 (°F) in Boston

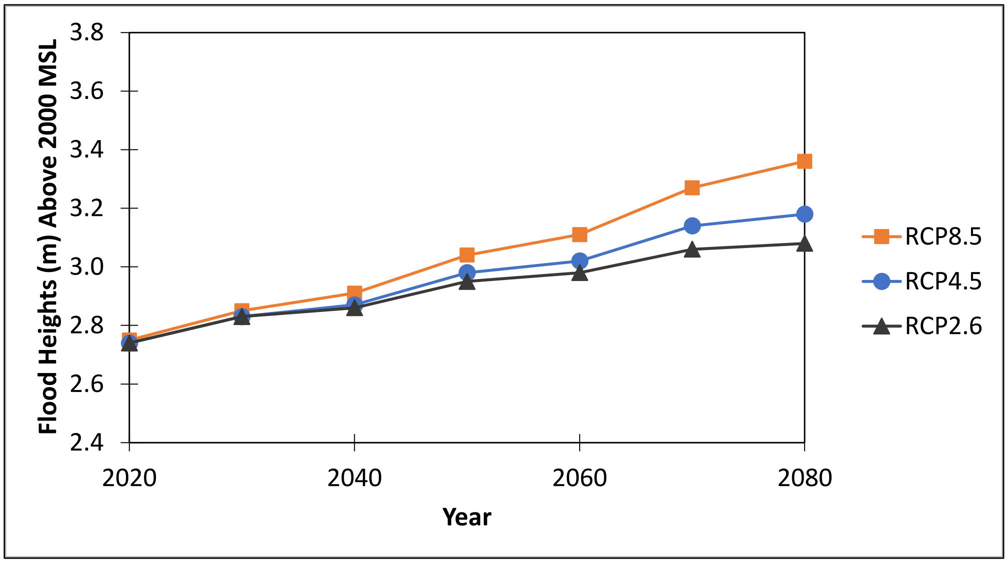

Figure 2: Projections of 10-year Winter Median Flood Heights in Boston

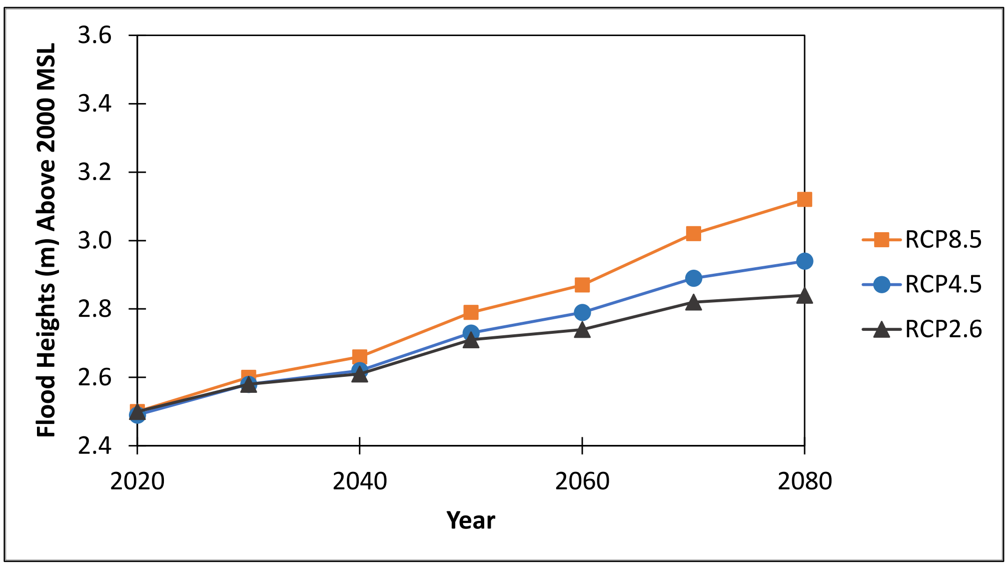

Figure 3: Projections of 10-year Summer Median Flood Heights in Boston

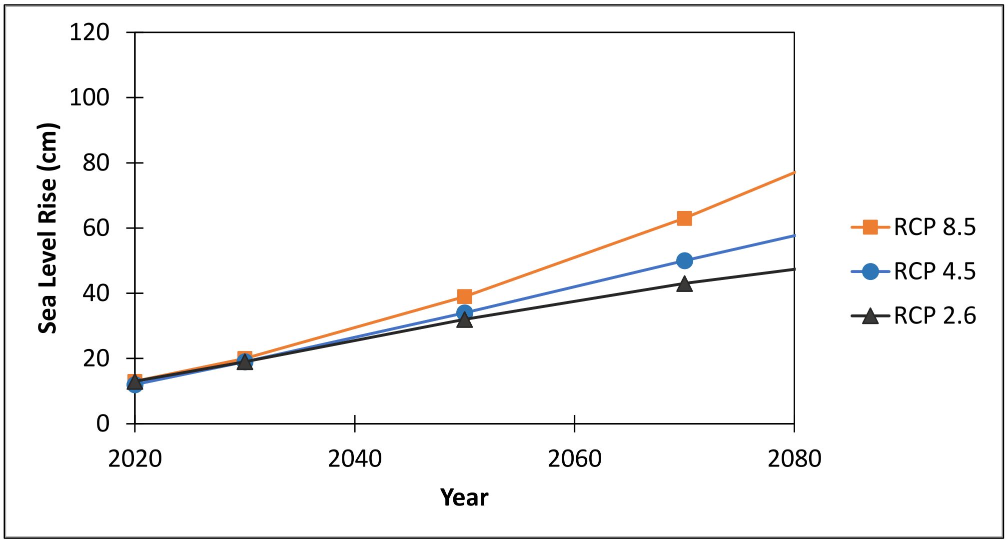

Figure 4: Projections of Median Relative Sea Level Rise for Boston Harbor

METHODOLOGY

The article's methodology consisted of an ERM assessment that incorporates meta-analysis and predictive modelling. First, the physical infrastructure of the BUMC was evaluated by touring the campus and interviewing management personnel. This evaluation resulted in a criticality analysis of the BUMC infrastructure in terms of the business activities that take place in each location. Results are documented using a scorecard as well as a display that maps the relationship among the BUMC buildings and the impacts of climate changes on the locations' ability to maintain business operations. Second, a HVA was completed based on the meta-analysis of published literature and an analysis of data relevant to climate change impacts in Boston. Input weather data were obtained from the National Oceanic and Atmospheric Administration (NOAA) that includes historical weather and extreme weather events by zip code in daily increments. Response data were also obtained from public sources.

RESULTS

The BUMC criticality analysis focused on its facilities and uncovered important risk-associated information regarding the business operations in each location (i.e., each building within which business activities take place). One important outcome of this assessment is that the BUMC facilities maintain a clear distinction between educational activities and research activities. In most cases, the research focused buildings did not include educational activities, and the classroom focused buildings did not include research activities. In only a few cases, notably where some laboratories are used for both research and as classrooms, did dual-use facilities exist.

Table 1 presents the results on the criticality analysis of each important building on the BUMC. The scale for criticality scoring was: Insignificant (Score 1), Low (Score 2), Moderate (Score 3), High (Score 4), and Essential (Score 5). Most of the criticality levels are at the extremes - insignificant or essential, which is consistent with the distinction between the education and research activities that take place within each facility.

Table 1: Criticality Analysis

Facility Name	**Address**	**Critical Level**	
		Education	**Research**
Center for Adv Biomedical Research	700 Albany St	1	5
Biosquare Building	670 Albany St	5	3
Evans Biomedical Research Ctr – X Bldg	650 Albany St	1	5
Evans Biomedical Research Ctr – E Bldg	75 East Newton St	3	5
Dermatology- J Building	609 Albany St	1	3
School of Dental- G Building	635 Albany St	5	1
School of Medicine - M Building	75 East Concord St	1	1
School of Medicine – L Building	72 East Concord St	5	4
School of Medicine – A Building	72 East Concord St	5	1
School of Medicine – R Building	72 East Concord St	3	4
Medical Research – K Building	71 East Concord St	1	5
School of Medicine – B Building	750 Harrison Ave	2	1
School of Public Health – T Building	715 Albany St	5	3
School of Public Health – Crosstown	801 Mass Ave	1	4
Parking Garage	610 Albany St	2	2

Figure 5 shows a mapping of the climate change effects expected in Boston (more frequent and extreme flooding, storms, extreme heat, and sea level rise), and how these effects will impact the BUMC facilities. The impacts are color coded by three categories: human impacts, physical impacts, and business impacts. These categories are further subdivided as shown in the display. Colors are used to match each facility with the impacts expected to affect that facility's activities. For example, climate change will disrupt activities of the Biosquare building by limiting students' and faculty/staff access, compromising building infrastructure, and restricting medical equipment operation and supply.

The HVA shows estimates of probabilities and impacts associated with climate change effects expected in Boston's south end. It includes probability predictions for each potential disruption and impact projections for each disruption should it occur. The estimated probabilities and impacts are scored using a 1-5 scale on a relative basis. HVA accuracy is dependent on consistency in scores among the risk factors rather than an absolute quantitatively derived basis for each score.

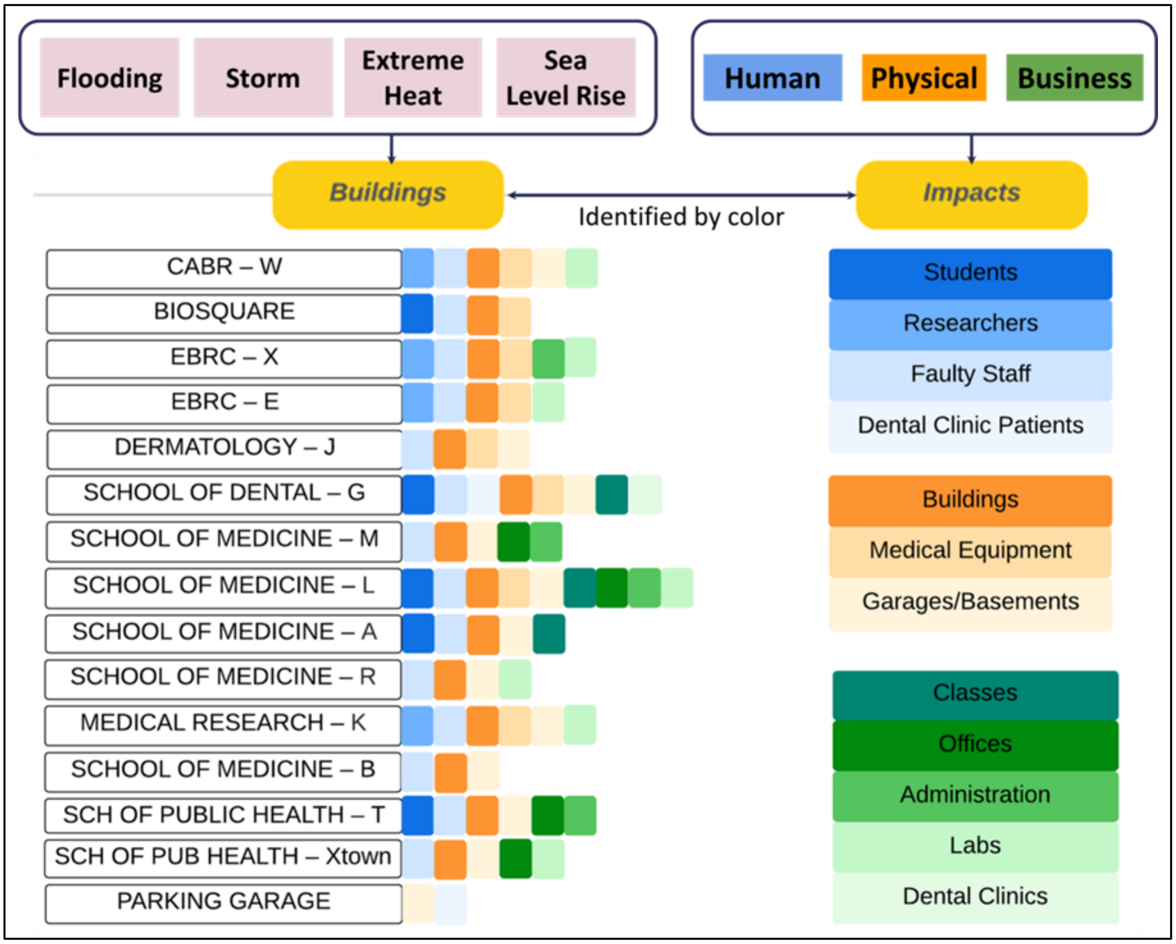

Figure 5: Display of Impacts

The scoring scale for probabilities is as follows: Insignificant (Score 1), Low (Score 2), Moderate (Score 3), High (Score 4), and Inevitable (Score 5). These scores are justified by an analysis that combines climate change projections (i.e., Figures 1-4) and estimates of specific impacts based on the meta-analysis and predictive data analysis. The impacts are separated by education and research activities, with scoring as follows: Insignificant (Score 1), Low (Score 2), Moderate (Score 3), High (Score 4), and Catastrophic (Score 5). Justification for these probability estimates and impact scores is based on the meta-analysis and data analysis (detailed in the text that follows the table). The score for risk ranking is determined by summing the impacts (education plus research) and multiplying this sum by the probability. Risk projections for the current time period, as well as 2040 and 2060, are shown in Table 2.

Justification for the scoring estimates is detailed in this section. For educational impacts, the authors considered the new remote learning enhancements at BU introduced during the COVID-19 pandemic, so that today most educational activities can be successfully conducted online. The online work option is less feasible for many research-related activities.

Table 2: HVA for the BUMC

EFFECT	YEAR	PROBABILITY	IMPACT		RISK RANKING
			EDUCATION	RESEARCH	
Power Outage	2023	1	2	3	5
	2040	2	2	3	10
	2060	3	2	3	15
IT Outage	2023	2	4	4	16
	2040	3	4	4	24
	2060	3	4	4	24
Water Failure	2023	1	1	3	4
	2040	2	1	3	8
	2060	2	1	3	8
Natural Gas Incident	2023	2	2	3	10
	2040	3	2	3	15
	2060	3	2	3	15
Extended Enterprise	2023	1	1	4	5
	2040	1	1	4	5
	2060	1	1	4	5
Last Mile Delivery	2023	2	1	4	10
	2040	3	1	4	15
	2060	3	1	4	15
Private Transit Access	2023	2	2	4	12
	2040	3	2	4	18
	2060	4	2	4	24
Public Transit Access	2023	3	3	4	21
	2040	4	3	4	28
	2060	4	3	4	28
Staff/Student Access	2023	2	2	4	12
	2040	3	2	4	18
	2060	4	2	4	24
Staff/Student Illness	2023	1	2	5	7
	2040	2	2	5	14
	2060	2	2	5	14
Air Quality	2023	1	2	3	5
	2040	2	2	3	10
	2060	2	2	3	10

Power Outage

Extreme weather can cause disruptions to power grids (Stone et al, 2023). For example, in 2012 Hurricane Sandy resulted in 15,000 outage locations and affected more than 500,000 customers in Connecticut (Caron et al, 2013). The analysis uses a quantitative approach based on response data derived from Boston's historical power outage information obtained from Eversource (the primary electricity provider in Boston) from 2017 to 2021, along with historical weather data from NOAA. It projects both the number of outages and the number of customer's affected, as shown in Equations 1 and 2 (were Y_O is the number of outages per day, Y_C is the number of customers affected per day in thousands, $X_H = 1$ when the day has high heat intensity, $X_F = 1$ when the day has severe flooding, $X_W = 1$ when the day has high wind intensity, $X_T = 1$ when the day has thunderstorms).

$$Y_O = 438 + 111X_H + 648X_F + 669X_W + 612X_T \quad [1]$$

$$Y_C = 1.6 + 4.2X_H + 2.9X_F + 3.7X_W + 3.5X_T \quad [2]$$

The HVA result is based on these results and several factors including the climate event impact to the power distribution availability, the scale of power outage, and the accessibility of alternative structures. Some research equipment, such as sterilized or hazardous equipment, requires a constant power supply and cannot be easily replicated in an online setting.

IT Outage

Although power outages can disrupt cell phones, television, home telephones and Internet services, IT infrastructures can be affected when power is not disrupted. During Hurricane Sandy, for example, 25 percent of region's FCC cell towers were not operating, Verizon's central offices had telecom equipment that was flooded, and other providers had service disruptions of varying degrees (Reuters, 2012). The impacts of IT outages can be substantial for both education and research because remote learning and work-from-home capabilities will be compromised. The HVA result is based on several factors, including the close association between power outages and IT network issues, and the varied IT infrastructure and services delivery systems including wireless, fiber, cable, satellites, and towers.

Water Failure

Floods can damage water treatment infrastructure, affecting the availability of safe and potable water for drinking (Wade et al, 2014). Ambient temperature is an important determinant of water quality because temperature compromises the ability of chlorine to kill bacteria (Hua et al, 1999). Andrade et al (2018) reported an association between floods and waterborne infections or enteric diseases via groundwater contamination. The HVA result is based on several factors, including the severity of the weather events and the effects of weather events on the city's road accessibility.

Natural Gas Incident

The aging distribution of natural gas within the City of Boston has already been shown to have substantial and widespread leaks throughout the system (Phillips, 2011). The vulnerability of the system will increase as sea levels rise, because much of the soil that supports and surrounds these pipes and joints has not been exposed to regular flooding. Soil stability will become a growing concern as flooding becomes more frequent and the structural support for the gas piping becomes less reliable. The HVA result is based on several factors, including the relationship between IT outages and power outages, the volume and magnitude of existing gas leaks throughout the Massachusetts distribution system, and the effects of future sea level rise and flooding on the city's gas infrastructure. However, natural gas is a primary heat source for only a small number of buildings on the BUMC.

Extended Enterprise

Like most enterprises, BU outsources a significant portion of its support activities and therefore can be susceptible to disruptions in their ability to provide good and services to their campuses. According to BU Environmental & Safety (2023), several prominent vendors are currently under contract with BU, providing a wide range of essential services and products, including Accutome (eye care equipment and instruments), Bayer Health (health care products and solutions), Henry Schein (surgical materials and medical equipment), and Sigma Aldrich (pharmaceutical supplies and chemicals). These and other BU suppliers are multinational corporations that maintain extensive global networks and implement contingency plans to ensure supply chain resilience in the face of potential disruptions. Although the likelihood is low, the HVA result indicates that research activities could be significantly impacted because laboratories depend on various equipment and supplies. This risk assessment is based on several factors, including the severity of the weather events and the effects of weather events on the city's road accessibility.

Last Mile Delivery

Last mile delivery (i.e., the local distribution of good to specific homes and businesses) has become an important aspect of many organizations' ability to service its customers (Joselow, 2020). These services will be disrupted when drivers' availability is compromised or when road access is limited (Gopal & de Miquel, 2017). The HVA result is based on several factors, including the severity of the weather events and the effects of weather events on the city's road accessibility, as well as the knowledge that last mile delivery is used for lab equipment (e.g., pipettes, scales, centrifuges, Bunsen burners, freezers, and hot plates).

Private Transit Access

A Fort Point Associates (2021) survey showed that about a third of the BUMC staff and students utilize private travel modes, including driving alone (23%), carpooling (3%), and biking (9%). Key driving routes to BUMC include I-93 (a primary Interstate Highway exclusive to the region), I-90 (the Massachusetts Turnpike), and the very popular Storrow and Memorial Drives. Flooding due to sea level rise can disrupt travel in Boston's artery and tunnel system, as well as sections of Storrow and Memorial Drives. The HVA result indicates that research activities are at risk because of several factors including the severity of the weather events and the effects of weather events on the City's road accessibility.

Public Transit Access

The Fort Point Associates (2021) survey also indicated that about half of the BUMC staff and students utilize public travel modes, including subway (21%), commuter rail (12%), and bus (15%), that are operated by the Massachusetts Department of Transportation (MassDOT) and the Massachusetts Bay Transportation Authority (MBTA). Climate change may present a considerable risk to the MBTA's rail rapid transit system (Martello, 2020) under the assumption that the Boston Harbor flood risk model's projections prove accurate in representing sea levels (Miller, 2019). The MBTA offers a comprehensive bus service to BUMC (MBTA, 2023), which serves as a crucial means of public transportation for students and staff traveling to the medical center. Many subway and bus routes are at risk of flooding (Martello, 2020). The HVA result is informed by the projected sea-level rise in 2040 and 2060, leading to a higher likelihood of disruptions to public transit access.

Staff/Student Access

This category covers the ability of staff and students to enter and make use of BUMC buildings and other facilities. The likelihood of this risk will increase from current levels and will impact research functions. The impact will be exacerbated due to the HVAC equipment found in the lower levels of the buildings. The HVA result is based on several factors, including the level of sea rise, the impact of flood to the campus building area, and the critical activity on each building.

Staff/Student Illness

Many researchers have studied the current and future impact of climate change on public health. These impacts can affect the BUMC by reducing the availability of workers and disrupting educational activities. Power outages can increase the incidence of food and water borne diseases (Deng et al, 2022). Rising temperatures will increase the prevalence of a heat-related illness (HRI), such as heat cramps, heat exhaustion, and heat strokes (Khan, 2019; Fuhrmann et al, 2016). High humidity also impacts the incidence of a HRI (Ortega et al, 2016). In Massachusetts, tick-borne diseases are also projected to increase (McDermott, 2022; MDPH, 2017). Romanello et al (2021) found that the Boston region can see increases in various Vibrio bacteria-related diseases such as gastroenteritis and sepsis. The HVA result considers the current low incidence of a HRI, tick-borne, and bacteria related disease in Boston so a sharp increase in their frequency will likely not significantly impact the campus. The activities of any research-focused staff or students who do contract one of these diseases will be disrupted substantially.

Air Quality

Although many adverse effects of poor air quality on the BUMC can exist, this analysis focuses on the asthma-related health impacts because the relationship of air quality to asthma has been well established (e.g., Reid et al, 2016). The HVA result is based on several factors including 8-hour ozone exceedance trends from 2012 until 2021 (MDEP, 2022), and asthma-related 911 calls trend (Reid et al, 2016). Although the chance of a large-scale asthma outbreak affecting many people simultaneously is low, disruptions to research activities may be significant because some research requires sterile conditions and others are sensitive to environmental factors, making it difficult to proceed during episodes of poor air quality.

CONCLUSIONS

This article details an ERM analysis for a university campus. It illustrates how the combination of a criticality assessment, impact mapping, and a HVA should be used to perform a comprehensive ERM analysis. The approach taken in this work makes it clear that a fundamental step in the ERM process is to separate a university's many functions into its core activities that may not always overlap within each critical facility. Although for the BUMC analysis, educational and research needed to be bifurcated, other universities or higher education institutions may be well served to consider the teaching impacts only.

Over the period covered in this work, the highest risks for the BUMC involve IT outages, staff/student access issues, and public and private transportation disruptions. The results of this project will assist BU management in further identifying and developing climate-ready resiliency strategies. Future work at BU should include the development of risk mitigation strategies while cooperating with Boston and Massachusetts agencies to coordinate mitigation policies.

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