Transformative Actions in the Boston Harbor: Lessons Learned from Past Projects Toward a Resilient and Sustainable Urban Future

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Abstract

Following a long history of transformative environmental policy and massive investment in infrastructure, Boston's harbor has transformed in the last 30 years from an industrial wasteland to an essential resource for urban development, economic growth, and public benefit. Today, amidst rapid urban expansion, an increase in population, and impending climate threats, Boston's waterfront is poised for a critical subsequent transformation. This paper examines comparable urban projects and gathers lessons to address resilience as the next major urban challenge for the Boston metropolitan area. The 2016 Climate Ready Boston initiative framed the City's particular vulnerabilities and has resulted in the Mayor's Harbor Vision for unifying objectives aimed at leveraging open spaces for resilience and equity. The implementation of such a vision will require a herculean effort and will undoubtedly transform the public realm for the better. This study conducted a retrospective review of the Boston Harbor Cleanup and the construction of the Central Artery Tunnel to extract methods and challenges for implementation and evaluate the long-term impact on the City. This paper focuses on two key aspects: (1) tools for implementation (2) project benefits. Tools for implementation include strategies for financing, regulatory challenges, opportunities for new governance and organizational structures, community engagement, and the role played by civic groups and philanthropy. The impacts explored include the value of environmental cleanup, public health, and social equity. This paper concludes by proposing a framework for the best practices to implement Climate Ready Boston and emphasizes the significance of public participation in the process. It summarizes how this endeavor can be seen as an opportunity to reenvision the waterfront and learn from past projects as the City's waterfront continues to transcend from industrial uses toward recreational, ecological, and sustainable purposes.

Keywords

Resilience • Boston harbor • Waterfront design • Climate change • Governance • Urban planning

1 Introduction

Urban adaptation to climate change involves complex systems, planning across time scales, and diverse urban environments. Urban adaptation to potential climate impacts will provide the ability to recover, sustain, grow, and to be resilient, after an extreme weather event. Designing with risk in mind includes the overhaul of the built environments and standard processes. The destructive hurricanes of the last decades and the subsequent adaptation programs showed that coastal infrastructure alone could not achieve long-term physical and social resilience. Such initiatives include opportunities for rethinking drainage and wastewater infrastructure, transport networks, open space and ecological systems, and their integration with and goals for neighboring communities. Engagement and citizen interest in public decision-making are the critical apparatus for designers and developers to achieve collective priorities and goals, encouraging equitable public engagement and successful projects.

Boston Harbor is vulnerable to coastal flooding and has experienced several occurrences of coastal flooding in the recent decade (Fig. 1 shows flooding from the King Tide

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Fig. 1 King tides in Downtown Boston, October 2020 (MyCoast, 2020)

Event in October 2019). This risk will increase in scale and frequency with climate change, rising sea level, and extreme storm events. Implementing an urban adaptation project to address these issues is an immense endeavor that will transform the public realm and connection to the waterfront, particularly for the 47 miles long Boston coastline. It will require a multilayered approach to provide redundancies at the risk reduction level and address local community needs such as equity and accessibility to public space. The urban resilience project as a whole is greater than the sum of its parts, and the level and quality of co-benefits are the primary evaluation criteria for many strategies. The urban adaptation project is not only a highly complex multilayered infrastructural effort, but it is also a long-term vision for the City and its residents; it is primarily an investment in the social and economic strength of the community. To take upon this challenge, the City of Boston has developed a series of conceptual plans and a comprehensive citywide vision—the Resilient Boston Harbor Vision (Fig. 2 from the City of Boston website) (City of Boston, 2018b). The Resilient Boston Harbor Vision is framed under the Climate Ready Boston 2016 (CRB) initiative to develop flood protection solutions that integrate resilience infrastructure with open space, by way of design and community outreach.

CRB is a framework for multiple interdisciplinary efforts to be developed and addressed over the next decades in terms of design, construction, policy, governance, and regulation. The CRB initiative emphasizes equity, access, and aims to provide a roadmap to address social resilience and environmental justice. Environmental justice is crucial to climate projects as cascading threats are compounded for traditionally underserved populations. Integrating the goals of these communities will contribute to an equitable resilience solution. The CRB initiative comprises: the initial scientific analysis of site-specific climate risks and vulnerabilities, districts plans with near and long-term solutions, the Boston Harbor Vision, policy, and design guidelines for city

Fig. 2 Resilient Boston harbor vision (City of Boston, 2018b)

Fig. 3 Climate ready Boston districts (City of Boston, 2016a, b)

infrastructure and private property, alongside other studies that will be necessary for the formation of the comprehensive, resilient and sustainable future of the City (Figs. 3 and 4 from the 2016 Climate Ready Boston report) (City of Boston, 2016a, b).

At the core of this paper are the district plans created as part of the CRB initiative in 2017–2020. They outline design and planning concepts with the potential timeline and steps to realize these strategies (i.e., implementation roadmap). Per each district, an implementation roadmap outlines the next steps for three decades into the future and identifies challenges from financing, engineering complexities, coordination, governance, and necessary regulatory changes. Additional studies from local research institutions suggest innovative solutions resolve these challenges. However, despite the extensive preparation and the urgency of the impending risk, the City has not taken clear actions toward implementation. Significant policy and regulatory issues still need to be addressed; the main challenges related to governance and funding are hindering due to local political will.

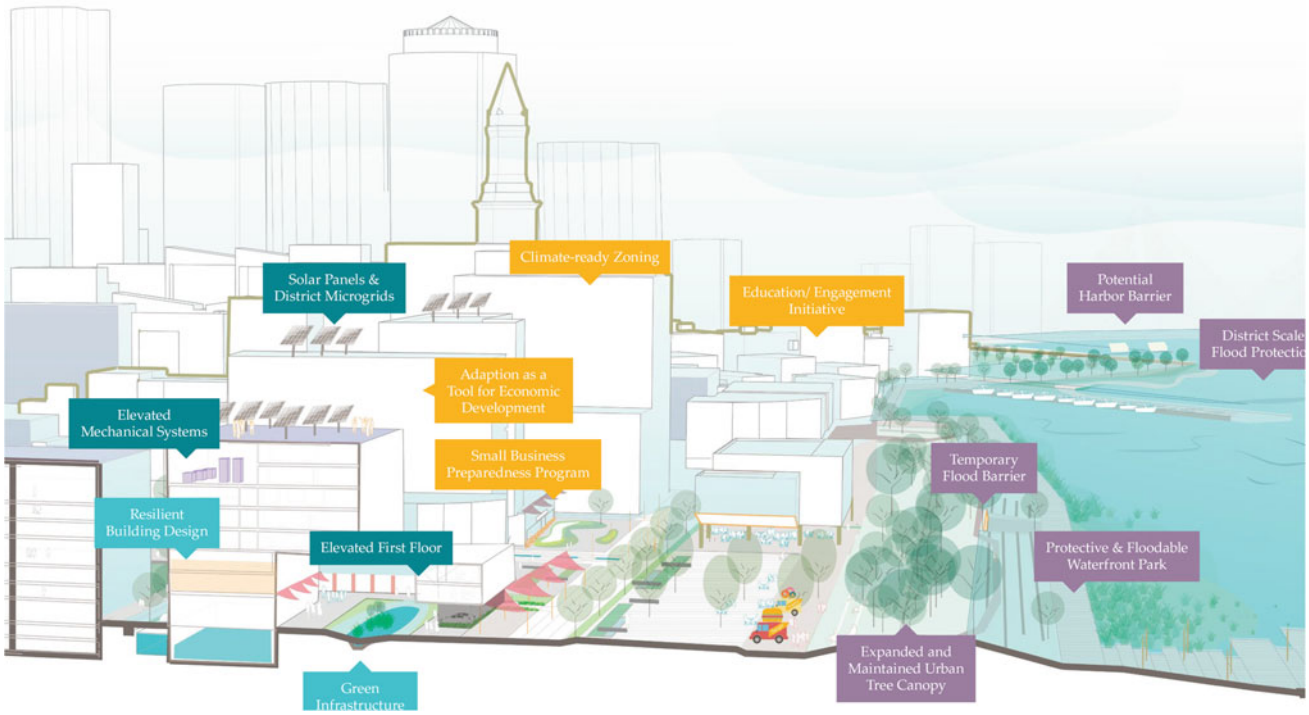

Fig. 4 Climate ready Boston strategies (City of Boston, 2016a, b)

In order to drive the process forward, this paper seeks to ask crucial questions about what needs to happen. How will urban adaptation projects on a 47-mile-long coastline come to life in these modern times? An effort of this scale is not new to the City of Boston; in the last three decades, the City has completed two massive public work projects: the Boston Harbor Project and The Central Artery/Tunnel (CA/T). This prompts the question of, what can we learn from how these projects unraveled? Are there any lessons from the tools they used to implement the projects? Or, what drove the state and the City to take action?

This paper will review the plans and documents developed for the CRB and the vision presented by the Mayor of Boston (Walsh, 2018). It will start with the scientific study undertaken by the Boston Research Advisory Group (BRAG) (The Boston Research Advisory Group, 2016) pertaining to climate projections in relation to the geographical context and the flood maps developed for the City as part of work done by The Boston Harbor Associations (Douglas et al., 2013). A deep analysis of the proposed district strategies available will identify implementation challenges per each neighborhood: East Boston (City of Boston, 2017), South Boston (City of Boston, 2018a), Downtown, and North End (City of Boston, 2020). These changes will be explored with focus on social resilience and the important connection between equity and public investment (Martin, 2014). To better understand the potential strategies to drive implementation, the paper will review two reports on Governance and financing strategies from the University of Massachusetts Boston (UMass Boston) (Kruel, 2018; Levy, 2018). To explore comparable aspects to the CRB from the Boston Harbor Project and the CA/T, the methodology will be to review three aspects of each case study (1) What role did civic activism play? (2) Which new institutions were established for this purpose? How was the project funded and executed? (3) What are the benefits of the project? This will be accomplished through an examination of research by Save the Harbor/ Save the Bay and the economic valuation of the cleanup project (Jin et al., 2018). Finally, the paper will conclude with a discussion of the operational lessons that can be taken from the two case studies, by the CRB. Additionally, how civic action pushed the City and state to implement the case studies and how public opinion and action help to improve the outcome. The critical role of communities and stakeholders in climate adaptation and large-scale development projects is twofold. Essentially, they are the client, as the design process will deliver a project that will serve their needs and safety, and they are the driving force behind it, building political commitment and long-term capacity. Therefore, the public must play a significant role in the design, and community priorities must be incorporated in the CRB concepts.

2 Background and Historical Context

2.1 The Resilient Boston Harbor Vision

At the Greater Boston Chamber of Commerce speech in October 2018, Boston's Mayor Martin J. Walsh presented his vision for an ambitious resilience plan. This vision was based on preliminary work for the Climate Ready Boston framework in 2016, and other initiatives along the 47-mile-long coastline (City of Boston, 2016a, b). The objective approaches resilience from both physical and social angles. The plan aims to protect the City of Boston from the rising sea level and future storm surges, while creating a more equitable and accessible waterfront. As the Mayor defines it, "this is the opportunity a resilient Harbor presents—to protect Boston, connect Boston, and enhance Boston, now and for future generations." (Walsh, 2018). This ambitious plan builds on the City's history of large and transformative urban projects. It provides a political legacy to address the impending risks of climate change and coastal flooding. The need to involve the local Chamber of Commerce emphasized the need for broad public support and potential financial commitments from the participants. Political buy-in (or civic support), financing, and an innovative governance structure are all at the foundation of what this effort will require.

The presented vision will address the 40 sea-level rise and coastal flooding projected to occur by the end of the century. The estimated cost of such a project is in the range of several billions of dollars spanning over 10–15 years of design and construction. Public projects at this scale are rare in Cities in contemporary times—and need a great political will to support implementation. $1 billion is the estimated cost for just one of the neighborhoods, South Boston, which is only a fraction of the whole system (Chesto & Logan, 2018). According to a financial study performed by the Sustainable Solutions Lab in the University of Massachusetts (UMass) Boston, the total cost of mid-century adaptation strategies for the vulnerable districts can reach $2.4 billion (Levy, 2018). This estimated cost is a tremendous effort even for a relatively wealthy city like Boston. Therefore, the adaptation narrative has to be of a collective vision, an aspirational idea with multiple benefits extending beyond the protective barrier services.

2.2 Boston Harbor and Waterfront Transformation

Like many coastal cities, Boston is facing significant risk from future high-intensity storms and the rising sea level. As is typical of most cities, Boston's activities, density, and life

Fig. 5 Boston shoreline composite (Map Works Inc., 1999)

evolved along the coastline. Boston's urban form and history, beginning as a merchant port city, are deeply rooted in its connection to the harbor; life in the seventeenth and eighteenth centuries always followed the rhythm of the port (Glaeser, 2003) (Fig. 5). Marine industries occupied the waterfront along the harbor; with the technological changes in the nineteenth century, they experienced decline while inland manufacturing increased. Rapid growth and urban expansion in the nineteenth century led to one of the largest public works efforts faced by the city, in the construction and land reclamation of Back Bay. Urbanization outpaced the city's ability to update and invest in its sewer and water systems and was exacerbated by the urban decline of the mid-twentieth century, thus leading to Boston Harbor earning the questionable title from local media "Harbor of Shame" in the early 1980s. "The Harbor was the most degraded in the United States, with twelve billion gallons of raw or partially treated sewage…" Charles Monroe Haar writes in his book outlining the public and private partnership that led the harbor clean-up (Haar, 2005). The City's Cleanup process was initiated by the requirements of the Clean Water Act of 1972, necessitating an update to infrastructure, institutions, and governance mechanisms. In actuality, this process took several decades to materialize.

Thirty years after the initiation of the process, Boston's waterfront is once again the urban and economic anchor for the city. As analyzed by Save The Harbor/Save The Bay in the Boston Harbor Indicators Report (i.e., an advocacy group founded in 1986 to maintain the public pressure and involvement in the public investment towards a clean harbor): "Today, Boston Harbor—the natural foundation on which Boston's economy was first built—is once again at the center of the City's future" (Save The Harbor/Save The Bay, 2004). The report identifies development and growth along the waterfront as driven by the public investment of $21 billion over three decades—including The Boston Harbor Project, The Central Artery/Tunnel Project (CA/T also known as the "Big Dig"), and The Rose Kennedy Greenway. The investment was focused on regional infrastructure with local impact on the improvement of the urban realm and public spaces. New development along the coast over the last 15 years introduced more than a dozen million square feet and thousands of residential units (Save The Harbor/Save The Bay, 2004). The changes simultaneously brought about new industries, such as tourism, which leveraged the improved access to public parks and the historic waterfront, restored landmarks, and mix-use development with commercial attractions.

A large section of the development incepted by these transformative improvements included the Seaport district in South Boston (Fig. 6) (Allen, 2015). The neighborhood transformed a 1000-acre concrete wasteland over the last two decades into a burgeoning skyscraper realm. The Seaport neighborhood was constructed on low-lying reclaimed land historically known as the South Boston flats (and the Commonwealth flats); the development and plan for the area was initiated in concert with the construction of the Central Artery Tunnel (Seasholes, 2018). The South Boston Waterfront Municipal Harbor Plan outlined access to the waterfront, parcellation of blocks, and open spaces (Boston Redevelopment Authority, 1999). Construction of the commercial and residential building and the development of the public realm started incrementally after Mayor Menino presented in 2010, "the Boston Waterfront Innovation District" plan (Hoban, 2018). Hurricane Sandy devastated East Coast cities in 2012, including New York City, yet Boston was fortunate as it reached the city six hours after the high tide. At the time, the Seaport properties were in the early

Fig. 6 Boston Seaport district (Allen, 2015)

stages of design, thus requiring property owners to make efforts to increase resilience measurements for their buildings. Moreover, the existing projection and resilience standards outlined in the City's zoning and design guidelines were connected to the historic FEMA Flood insurance rate maps (Flood Hazard District, Article 25). Simultaneously, the City started mapping and developing science-based long-term climate projections for sea-level rise (SLR) and storm surge, which showed a greater risk to the area and an increase in the frequency of tidal flooding.

2.3 The Climate Ready Boston Analysis and Initiative

The Boston Harbor Association (TBHA) developed a series of maps that examine the extent of the area at risk of coastal flooding (Douglas et al., 2013) taking into account SLR and future climate change projections. The study was launched as a response to the severe IPCC reports from 2007 and an increase in nuisance flooding across the city, as the FEMA maps proved to be insufficient, limited only to historic data of past floods. This initial study identified that 6% of the City could be underwater in the event of a 100-year coastal storm surge at high tide at the time of the report, and 30% of the City would be affected in a mid-century storm event. While the City already initiated climate studies and expressed interest in exploring some adaptation planning in 2009, the findings of this study recommended comprehensive preparedness planning with clear co-benefits to reduce vulnerabilities in the near and long term. This planning initiative would be grounded with an in-depth vulnerability assessment and updated science and models (Douglas et al., 2013). Climate Ready Boston was the initiative established to accomplish these recommendations from the science, adaptation, and preparedness strategies, while providing implementable solutions. Similar to the other city-wide efforts carried out in the twentieth century, this was a collaboration between philanthropy, the state, local business, and the City.

The Climate Ready Boston climate change and SLR projections were prepared by the Boston Research Advisory Group (The Boston Research Advisory Group, 2016). The group's objective was to build a consensus around science-based climate projections for sea-level rise, intense storms, and heat. They cited over 100 sources and developed localized standards for projections. Acknowledging that in order to prepare for the future, the city needed to look forward and depart from solely historic data, the report established a framework for updating the standards and science as we learn more about the pace of the changing climate. The report

summarized three SLR scenarios based on the IPCC Representative Concentration Pathway and ocean dynamics. According to the BRAG model, by 2100, the extent and scale of the current 1% probability storm surge (100-year storm) will become an annual occurrence with rising sea levels. Furthermore, the 100-year storm in 2100 "under both scenarios the heights for a 1% probability flood are ~1.5–2.5 m higher than today, the latter value representing a near doubling of their current value" (The Boston Research Advisory Group, 2016). With some level of uncertainty towards the end of the century, the report nonetheless anticipates more intense and frequent storms towards the middle of the century.

The vulnerable landmass area identified in the TBHA report is mostly reclaimed land and tidal mudflats filled by residents over generations since the arrival of the British. Reclaimed land accounts for almost a third of the area of the city and therefore, the projected losses are extreme. A study of flood losses in coastal cities estimated that without proper planning and design for adaptation to sea-level rise, subsidence, and intense storms, the projected annual loss for Boston in 2050 will be $741 million (Hallegatte et al., 2013). The Climate Ready Boston presented the climate projections as developed by the BRAG; the report summarized risks from extreme heat, precipitation, and sea-level rise, analyzing the specific risk per the city's neighborhoods, and presented an implementation roadmap with necessary planning, policy, and solutions that will be needed to prepare and address the risks. For coastal flooding, the report focused on three scenarios: "9 SLR with 100-year storm surge (1% annual chance flood) for the year 2030—with the neighborhoods East Boston, Charlestown, South Boston, Dorchester, and Downtown at the highest risk, 21″ SLR with 100-year storm surge (1% annual chance flood) for the year 2050, and 36″ SLR with 100-year storm surge (1% annual chance flood) for the year 2070 "exposing over 15% of the population to flooding" (City of Boston, 2016a, b). Beyond potential damage to property, the reports attribute asset loss to critical infrastructure and regional transportation systems, adding business disruption to the accumulated cost of inaction (Fig. 7 created by author for this paper).

The CRB initiative outlined strategies built around community needs, local knowledge, and climate risks. The result was a district-specific approach driven by an overarching vision with both resilient infrastructure and equitable

Fig. 7 CRB districts with 1% probability storm floodplain in 2070 (image created by authors)

public open space. District-focused plans will guide implementation as a tool to mitigate the scale of the project. The timeline prepared to oversee the implementation process will address immediate risks and their solutions; future solutions will need to accommodate multiple benefits.

2.4 Physical and Social Resilience

The CRB initiative included several parallel processes. The first was a district-scale vulnerability assessment and vision planning effort for each of the five coastal neighborhoods including: East Boston, South Boston, Charlestown, Dorchester, and Downtown. The second was a development of guidelines and zoning overlay for buildings in the floodplain to ensure new development and retrofits are constructed above the design flood elevation (i.e., the projected flood with a freeboard for subsidence). The third was establishing standards for public works projects, to leverage ongoing and planned capital projects to improve their resilience. Finally, the Mayor Harbor Vision in 2018 combined all projects and proposals into one unified narrative. A resilient waterfront will require a physical transformation of the coastline; in many of the studied areas, the edges will need to be raised between 8′ and 6′ to withstand the rising seas, tidal changes, and storm surges. Potentially, this is an opportunity to rethink the extensive waterfront as a public asset, to provide open space and improve accessibility and diversity of uses suitable to the current and future population of the city. The relationship between the city and the harbor was defined in every generation by the economy and the people of Boston; in this evolution, the waterfront is the driver of growth and protection.

The particular facet of maximizing public benefit and providing value beyond the utility of flood protection is an essential component of resilience planning. CRB mapped socially vulnerable populations in areas prone to risk and identified a disproportionate susceptibility to direct and cascading impacts of climate risks. Dr. Atyia Martin, The Chief Resilience Officer for the City of Boston, defines social vulnerability as "compounding factors of long-term discrimination and exclusion from planning and emergency management practices" (Martin, 2014). The populations identified as more vulnerable are usually at higher risk of isolation, making it more difficult to engage and participate in the planning process. Therefore, approaches for mitigation should connect residents to resources, social capital, and increasing physical spaces and official frameworks to engage and connect with City officials and community members. Through this approach, rebuilding the coastline will need to address inequalities, deteriorating urban infrastructure, and the preservation of affordable housing, while fostering local wealth-building opportunities. The public project as a whole is greater than the sum of its parts and the level and quality of co-benefits are the main evaluation criterion for many strategies.

3 Main Challenges in Implementing Resilience

3.1 District Scale Climate Solutions

This section focuses on the review of the proposed district plans and the challenges identified by this study for implementation. The implementation roadmaps of these plans look 15–25 years into the future, to accomplish the full vision.

East Boston, one of the most diverse communities in the city with approximately 55% of the population identifying as Hispanic/Latino, established the first CRB district plan in 2017. East Boston consisted of five islands connected by reclaimed land and was therefore significantly susceptible to coastal flooding. Historically, it was a working neighborhood with a water-dependent industrial waterfront, but the neighborhood started changing with the success of the harbor cleanup project. New developments started rising along the coastline; in fact, one of the most recent developments, the Clippership Wharf (opened in 2019), was mentioned as an opportunity in 2004 Save the Harbor/Save the Bay report. These new properties comply with the limited guidelines provided by the City at the time and therefore have ground floors constructed above the projected flood elevation, offering building protection for coastal flooding. The intention to resolve the imbalance of protected new developments vs. vulnerable low-income housing and the need to provide public access and equitable resilience was at the base of the Coastal Resilience Solutions for East Boston and Charlestown report (CRSEB) (City of Boston, 2017) (Fig. 8).

The East Boston vulnerability analysis identified near-term flood pathways that are projected to extend inland during an event of a 100-year storm with the SLR of 9″. Several flood pathways breach the coastline at Jeffries Point and converge at the low point in the Greenway, with an additional pathway located by Central Square. Both areas have experienced coastal flooding during winter storms in the last decade. These breach points between the raised new waterfront developments were visible during the two Nor'easter storms in January and March of 2018; the January storm reached the City's highest recorded tide of 15′ above sea level (Caperton Morton, 2019).

It is estimated that, beyond 2030 (when sea level rises more than 9″), the ocean will overtop the extent of the coastline. The plan proposed a layered strategy with near-term solutions aimed to address the urgent threats at the Greenway flood pathway. A deployable barrier system was proposed and installed at the entry point to the Greenway.

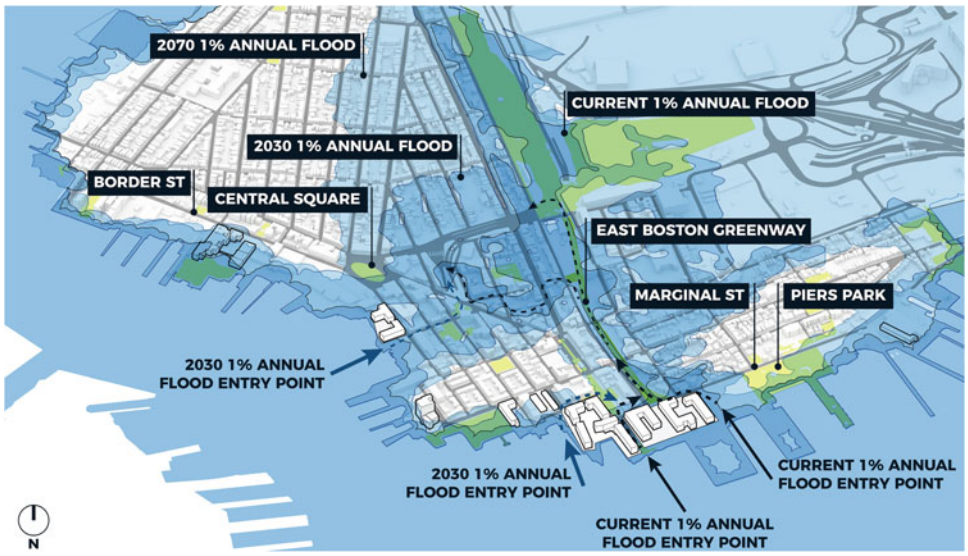

Fig. 8 East Boston flood pathways (City of Boston, 2017)

The long-term strategy focused on a system of continuously elevated parks with 11 acres of open space along the coastline, which currently consists of new developments, deteriorated piers, and underutilized industrial lots. The report estimates the cost of this project as between $121 and $200 million. An additional cost that is not represented in the construction is future maintenance and the operation of the integrated flood barrier and park. To maintain the infrastructure as operational throughout its lifecycle, the City will need to designate and train personnel. The implementation roadmap (City of Boston, 2017) outlines the necessary steps for the realization of this project. In the next 30 years, the project will face a series of challenges based on the site conditions, namely, related to ownership structure, policy, and regulations; these challenges are consistent across the five neighborhoods and district plans. At the same time, it is important to consider the current population of the East Boston neighborhood and the challenges that they are experiencing through gentrification and displacement. The strategies and solutions proposed can exacerbate these issues if not addressed with the involvement of the community.

The CRSEB plan provides a preliminary framework for an integrated system of recreational spaces, nature-based solutions (wetlands), and coastal barriers. However, it lacks concrete guidelines to address the fundamental complexities and challenges. One issue that was overlooked by the plan is infrastructure and utilities. For example, stormwater infrastructure is not addressed in this study and is critical for the success of a flood barrier. The existing combined sewer overflow outfalls are at the same elevation as MHHW (i.e., Mean High High Water level—highest predicted elevation of an astronomical tide) (Fig. 9) (City of Boston, 2017).

In the East Boston context, implementation challenges can be broken down into several areas:

- Majority of the coastal lots are privately owned. To ensure continued implementation of an integrated barrier, there is a need for coordination on timing, design, and operations after construction. A regulatory mechanism will need to ensure owners to preserve space for a barrier (Fig. 10) (City of Boston, 2017).
- Policy and regulations will need to be studied to find the balance between the water-dependent industrial uses and the integrated park/flood barrier. Designated Port Area (DPA) is a state policy, with which public access and raised shorelines might be in conflict. DPAs are areas regulated by the Coastal Zone Management office at the state. They were created to protect water-dependent industries such as marine industries, shipping, fishing, etc.
- This waterfront section has the potential for new development, making it important to work with the local community to find the best mix between the land uses they prioritize, and the land uses the property owners would like to develop. Community buy-in will be necessary to drive a large-scale public project forward.
- Cost and financing—to secure federal funding for the construction of the barrier, the City will need to show public interest in the land. The City will need to acquire easements to receive federal funding for infrastructure on privately owned lots. Innovative financing mechanisms based on value capturing from new development and public–private partnerships collection could provide additional financing sources.

The Seaport in South Boston is susceptible to tidal flooding that can occur monthly. Due to the topography of the neighborhood, the current 100-year storm floodplain covers most of the area by over-topping the coastline. The

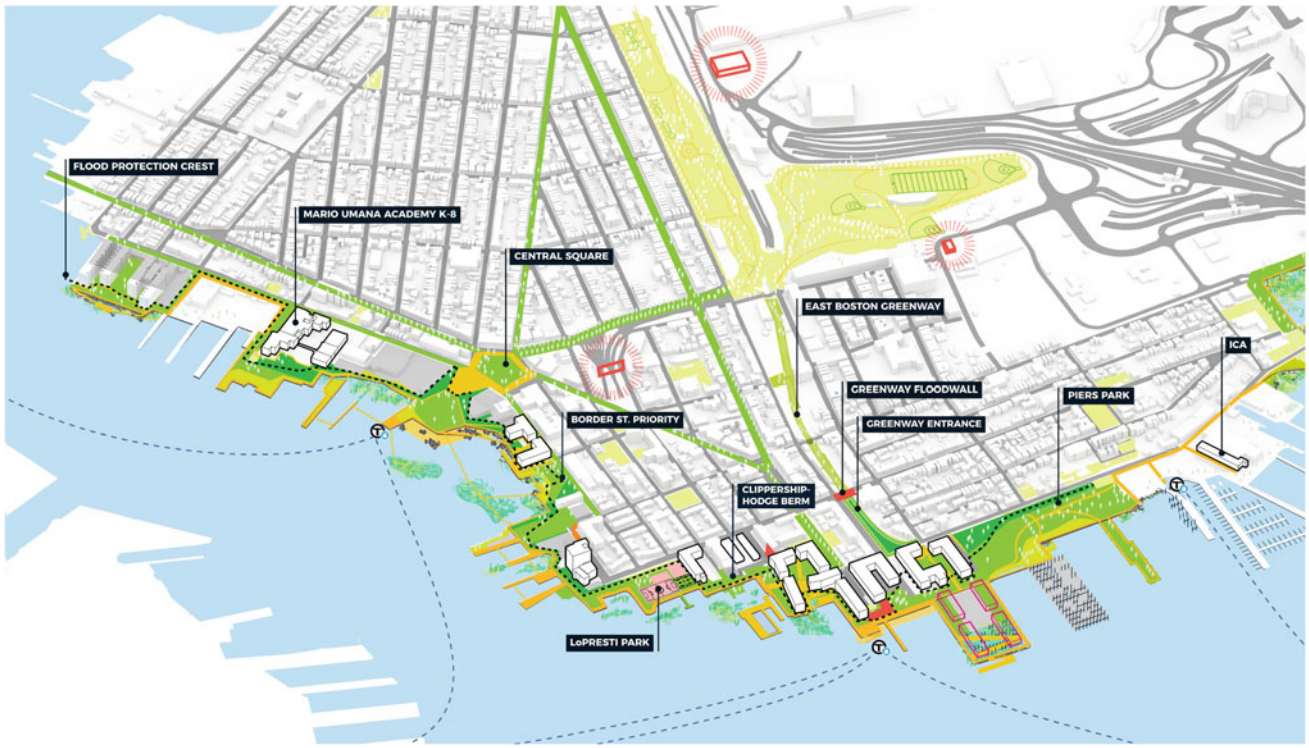

Fig. 9 East Boston long term vision (City of Boston, 2017)

Fig. 10 East Boston coastal zoning (City of Boston, 2017)

Fig. 11 South Boston resilient solutions (City of Boston, 2018a)

Coastal Resilience Solutions for South Boston (CRSSB) project estimates that over 5000 buildings will be exposed to coastal flooding during a 100-year storm toward the end of the century with 36″ SLR and an expected loss of $8 billion (City of Boston, 2018a). The plan explores multiple solutions for sections of the coastline; the primary strategy is to aspire for a waterfront alignment to protect the whole area. The cost of the plan is estimated at $521 M to $1.0B with annual operational costs of $7.8 to $15.2 M. CRSSB points out three main challenges to implementation: governance (private–public ownership), state and federal regulations for in-water land expansion, and funding mechanisms (City of Boston, 2018a) (Fig. 11).

The CRB district plan envisioning the coastal protection approach for the Downtown and North End encounters a different environment from East Boston and the Seaport (City of Boston, 2020). The Downtown is the historic core of the City; the coastline was reclaimed over the years, and the piers and wharves stand on centuries-old foundations. The subgrade in Downtown contains multiple utility and transit systems. The estimated cost of the waterfront option, according to the study, can be up to $300 M. Similarly, the challenges of the previous district plan funding and regulations are a significant issue that the City will need to resolve upon implementation. Governance, ownership, and jurisdiction play a critical role in the success of the waterfront solution; the potential strategy can provide a framework for property owners to come together and develop a design with the guidance of the City. The challenge in this case will be to balance interests and facilitate agreements and incentives. The second question regards implementation in a dense and active area such as Downtown and the need to minimize disruption during construction.

Overall, the challenges can be summarized into four main categories: civic activism and social equity, governance, regulatory practices, and funding. Each of these district plans has a detailed implementation roadmap and recommendations for the next steps; however, to start implementation, the City needs to resolve the complex challenges described above. The broad-scale overhaul of the City's built environment requires a reflection on past projects and an inquiry into the lessons learned from these processes.

3.2 Implementation Challenges

The implementation of large-scale public infrastructure requires robust public interest to support the effort, cost, and potential disturbance to the daily order during implementation. The vision plan provides an opportunity to evaluate the cascading impacts, explore systematic relationships, and outline the objective of benefits and transformations to the urban realm. Gradually aggregating and detailing projects from the larger scale brings attention to the missing links in

the urban planning system to create the long-term collective and knowledge required for adaptation.

The CRB work presented several implementation challenges that will require further study and the development of strategies to resolve. The main issues this study unravels are questions regarding the organizational authority and the governance framework to span the challenges of public, private, state, and city. This organized effort can support the other difficulties of alignment policy, regulations, and developing financing mechanisms. The Sustainable Solutions Lab at the University of Massachusetts, Boston conducted the following two studies to address these issues: Governance for a Changing Climate: Adapting Boston's Built Environment for Increased Flooding (Kruel, 2018) and Financing Climate Resilience: Mobilizing Resources and Incentives to Protect Boston from Climate Risks (Levy, 2018).

In general terms, the Governance for a Changing Climate: Adapting Boston's Built Environment for Increased Flooding report recommends forming new institutions to foster collaboration between the state, city, and municipalities in the metro area. The study connects resilience with "the region's equitable economic growth" by phasing the creation of partnerships and institutions to collect data for monitoring and analyzing these incremental changes (Kruel, 2018). Governance consists of both the establishments and the regulations created to support these institutions. To adapt existing institutions to climate change; institutions will be required to create a framework to integrate flexibility while maintaining reliability. Multiple existing zoning laws and policies can be tied to science and data to allow future adaptability without needing new regulations. Additional recommendations focus on equitable planning; for ongoing public support and trust, there is a need to expand climate-related projects and policies to include multiple benefits and social equity for the community. Finally, the report recommends expanding the authority of institutions such as the Massachusetts Water Resources Authority and the Metropolitan Area Planning Council, to include the resilience vision.

The Financing Climate Resilience: Mobilizing Resources and Incentives to Protect Boston from Climate Risks (Levy, 2018) report looks at the cost-benefit of adaptation projects like a basic tool for incentives. It suggests developing better metrics for risk and more accurate ways of pricing potential impacts for both property owners and insurers. The financing will have to come from multiple sources to spread the burden from the state, federal, city, and residents and per each entity, there are multiple traditional tools and mechanisms that can be utilized, including value capture, carbon tax, resilience dividend, sewer bills, and special zones. Any proposed mechanisms will need to be equitable in regard to risk exposure, ability to pay, carbon footprint, a transparent and engaged decision-making process, and injecting money back into the public realm and benefit.

The literature from CRB to the UMass Boston reports, highlights traditional and innovative tools to address the implementation challenges. Whether the strategy is incremental or proposes substantial structural changes, the timeline estimated for coastal adaptation is projected to span more than two decades. Bostonians raised concern that while the concepts and plans are a step in the right direction, there is not enough action forward (Caperton Morton, 2019; Conservation Law Foundation, 2020; Wilkinson, 2018). The concepts are not enforced by zoning and regulations and remain as a recommendation and guideline. While action stagnates, the waterfront continues to develop, leading to future risks and vulnerabilities. Three main questions lie at the center of advancing urban climate adaptation: (1) What is the scale of public and political interest needed to drive action and how can civic leadership support action? (2) What were the challenges for implementation? (3) What are the benefits of transformational change in the urban realm? The case studies (discussed in the proceeding section) aim to address these questions by identifying successful strategies for implementation, to address the common challenges of large-scale transformational infrastructural projects.

4 Case Studies

4.1 Methodology

This paper's methodology is focused on a robust analysis of comparable case studies to offer approaches to resolve the challenges identified in the implementation of a large-scale, urban adaptation project. This study draws from multiple resources and papers to provide a detailed comparison of qualitative and external qualitative data. The two projects presented here as case studies are: The Boston Harbor Cleanup and the CA/T, both implemented between 1985 and 2004. These projects were selected due to the size of operation; both are expansive public infrastructure projects. Similar to the CRB initiative, these projects required coordination between state and city operations, needed unique pressure to start implementation, and had a long-term transformative impact on the City, its economy, and the built environment. The Boston Harbor Cleanup overhauled a deteriorated infrastructure system across the City, required the construction of one of its king wastewater facilities, established a new state agency, and created a new public park on Spectacle Island. The Central Artery project transformed and revived the urban environment of downtown. Challenges and failures in the CA/T process of implementation have created financial challenges for the City and State and harmed the public trust (Figs. 12 and 13) (National Governors Association, 2019).

Fig. 12 Downtown and the Central Artery 1982

The previous portion of the paper highlighted the implementation complexities of the city-wide resilience project. Climate Ready Boston will have to materialize incrementally and be planned and managed in a multidimensional manner. The design and construction of such a project will need to occur at the small scale of several abutting lots, their owners, and the City. Planning and permitting will have to be coordinated with the district plan and other stakeholders (City and State agencies, utilities, etc.). Constant disruption to the urban environment will continue for years, and the public will need to be reminded of the original vision and the positive outcome. Dividing the district plans into smaller projects will reduce the project risk, and the City will need to plan for obstacles and disruptions in the process, preemptively. Civic leadership and community activism with their support or opposition can reduce that risk.

Boston has a unique experience with large-scale urban environmental projects. Possibly the "largest public works project in the world" (Krieger et al., 1999) was The Boston Harbor Cleanup and The CA/T and "$21 billion of public investment between 1987 and 2004" (Save The Harbor/Save The Bay, 2004). In the Leading-Edge report, Save The Harbor/ Save The Bay summarizes that the project aimed to accomplish regional goals and public investment to help catalyze private investments and the successful transformation of the Harbor (Save The Harbor/Save The Bay, 2004). In hindsight, decades after completion, it is possible to evaluate the conditions leading to the project, outline the steps taken for implementation, and assess the full extent of benefits and impacts the project had on the City. This section will describe findings from these two case studies focusing on comparable aspects to the Climate Ready Boston challenges: (1) What are the tools for implementation? What role did civic activism play in moving the project forward? (2) Which new institutions were established for this purpose? (3) How was the project funded and executed? What are the benefits of the project's spatial, economic, and environmental components?

Fig. 13 Downtown and the new Greenway 2017 (National Governors Association, 2019)

4.2 The Boston Harbor Cleanup

The Boston Harbor Project began in 1986, following a court-mandated order to modernize the wastewater infrastructure of the City and clean the Harbor. While the project was completed in 2001, the MWRA continued to improve and revamp the stormwater and wastewater system in Boston throughout the 2000s. Decades of neglect and a deterioration of the wastewater treatment infrastructure led to one of the most polluted harbors in the country, infamously called the "Harbor of Shame" (Toner, 1988). The total cost of the project was $4.7 billion, including the wastewater facilities of the Boston Harbor Project and the Combined Sewer Overflow control plan [Massachusetts Water Resources Authority (MWRA) 2014]. Today, people sail in the Harbor, swim along the beaches safely, and marine wildlife is often seen in the Harbor [Massachusetts Water Resources Authority (MWRA) 2019].

4.2.1 Civic Activism

The project took approximately 15 years to implement and to construct the required facilities, increasing pumping capacity, disposing of all solid waste, replacing pipelines, and establishing the institutional framework. While the project was completed on time, the events leading to its realization unfolded over a decade prior, with the driving force of civic leadership. Without the strong call from the local community for cleaning the harbor and modernizing the City wastewater system, this project might have taken place. Civic groups appealed to the court to require the local government to act and clean the harbor pollution that had been created from 300 years of use and neglect. Following the Federal Clean Water Act in 1972, local political leaders (City and State) submitted a waiver to the EPA and postponed action while shifting responsibilities and stagnating in bureaucratic gridlock. The push for action came from local activists, philanthropy, and public administration (Berg,

2004). Several actors led the litigation and campaign for public interest: Bill Golden, the City Solicitor for the City of Quincy, Massachusetts; the Conservation Law Foundation (CLF), an environmental advocacy group; and Save the Harbor/Save the Bay formed by the Boston Globe writer Ian Menzies, Bill Golden, and Judge Paul Garrity. The Boston Foundation (TBF), a historic community foundation rooted in Boston's civic life, supported the advocacy group work with grants (Brady, 2001). The judicial action started in 1982 when the mayor of Quincy, Massachusetts, sued the commonwealth and the Metropolitan District Commission (MDC) for the discharge of sewage into the Bay, against state law and in violation of the Clean Water Act (Levy & Connor, 1992). The Metropolitan District Commission (MDC) was the state authority responsible for wastewater treatment facilities and sewer systems. It was also in charge of state parks and recreational facilities. When it came to investing funds to modernize wastewater infrastructure, the state legislator was more inclined to redirect resources to the latter uses (Levy & Connor, 1992). In 1983, the CLF launched a court action against both the commonwealth and the EPA, the former for breaching the Clean Water Act, and the latter for failing to enforce the act (Jin et al., 2018). Although a higher court overruled state judge orders, the legislator established the Massachusetts Water Resources Authority (MWRA) in 1984 to take over the MDC wastewater responsibilities. In 1986, the federal court outlined a schedule through to 2025 with steps and instructions to build a new treatment facility (Levy & Connor, 1992). The public pressure created by advocacy groups and the court rulings were strong enough to foster a reorganization of governance and environmental resources management.

4.2.2 Governance and Funding

The challenges in acting upon the Clean Water Act can be associated with the institutional structure and limits of the MDC. Therefore, the act enabling the MWRA was a crucial moment in the Boston Harbor Project. The legislature enabled the creation of the MWRA "empowered to operate, regulate, finance, and improve the delivery of water and sewage collection, disposal and treatment systems and services, and to encourage conservation" (MWRA enabling act 1984). The independence of the MWRA as a semi-public authority allowed it to make decisions and raise funding separate from political considerations. It had the power to fund the project by collecting fees from residents and to "issue its own bonds and raise water rates as needed to cover the costs of the cleanup" (Berg, 2004).

4.2.3 Co-Benefits

Research by the Boston Foundation and Save the Harbor/Save The Bay showed the Boston Harbor Project led to private investment and development at the waterfront, totaling $2.2 billion and 60% of the City's population growth by the year 2000 (Save The Harbor/Save The Bay, 2004). A study from the Marine Policy Center at Woods Hole Oceanographic Institution and the School for the Environment at the UMass Boston looked at the ecological benefits to the Boston Harbor Project to assign a monetary value to the improvement of natural resources (Jin et al., 2018). The study combined water quality, ecosystem criteria, and value of recreation and open spaces in urbanized areas, estimating the value at $30–100 billion (the cost of the project was $4.7 billion).

4.3 The Central Artery

The objective of the Central Artery Project (CA/T) was to replace a series of deteriorating elevated highways constructed in the 1950s with a depressed system, to improve congestion and reduce air pollution. Above the tunnel in place of the viaduct, the project created 27 acres of linear open space called the Rose Kennedy Greenway. The Greenway connected the waterfront back to Downtown and the North End and allowed for new developments. Soil excavated for the creation of the tunnel went to cap landfills in the state and to Spectacle Island to cap the historic landfill and create a new park (Mass.gov, 2020b). The CA/T was substantially more complicated than the CleanUp, as it was more extensive in the spatial effort, the complexity of coordination, and the diversity of systems implemented. The project had over 100 construction contracts, with the most extensive geotechnical study in the nation, utility relocation program, and coordination with the MBTA subway tunnels. Also, one of the challenges was building 7.8 miles of roadway and tunnels across the dense urban fabric and maintaining the City fully operational with minimal disruptions. The project took three decades to complete, starting planning in 1982 with the restoration of Downtown streets in 2007 (Mass.gov, 2020a). The CA/T unfolded with more obstacles; the project took 8 years longer than planned and was error-ridden. The cost estimated in the early planning was $2.6–$5.8 billion, but the final price tag was closer to $15 billion–$24 billion with debt (Flint, 2015).

4.3.1 Civic Activism

In the early stages of the project, various interest groups in the City voiced concerns about issues from rodents to noise impact on marine life, the CLF that sued the state due to the dissatisfaction with a potential increase in traffic, and the Sierra Club litigated against air pollution (Boot, 1992). One influential organization was established in 1988 by local property owners, stakeholders, and businesses in Downtown —the Artery Business Committee (ABC). ABC's mission was to maintain the City operational while the project was

happening and influencing the plans for the benefit of the City (Luberoff, 2004). The group lobbied for funding at the local and national level and ensured the creation of the Greenway. Community outreach was part of the planning process for the use of air rights above the turnpike. The master plan, "Civic Vision for Turnpike Air Rights in Boston" (City of Boston, 2020), explored design options to repair the urban fabric and new uses above the highway. The long-term support and commitment of public groups and organizations was necessary for consensus-building in a long and complicated project.

4.3.2 Governance and Funding

Initial funding based on the estimated cost of $2.8 billion was provided (80% of) by the federal government from the Interstate Highway program. The incredible engineering challenge of building a tunnel on unstable landfill created centuries ago while the City above kept going, created unprecedented challenges, both big and small. The time added to the overall effort and the complexity of mistakes and unknowns added to the project, increased the cost. ABC, the local advocacy group lobbied the State legislature and Congress to prevent cuts in the funding (Luberoff, 2004). Massachusetts had to cover all the extra costs beyond the original estimate. The state had to increase tolls and fees and reduce spending in other places across the state (Flint, 2015).

The responsibility over the project was assigned to the Massachusetts Highway Department (MHD) in 1991.

The management team of the project was a private–public partnership between the State and an Engineering firm, Bechtel/Parsons Brinckerhoff. The agreement for the collaboration created a condition where B/PB had control over the design and was representing the state and advising it (Project et al., 2003). Public sentiment over this collaboration in lieu of the many mistakes and the cost overrun, was due to wrongdoing of the constructors and a lack of oversight (Flint, 2015). However, there was no clear record of corruption and the firm returned approximately $1 billion to cover the design flaws.

4.3.3 Co-Benefits

The original goal of the project was accomplished as it reduced congestion and allowed the flow of traffic. However, it also created more traffic than before. Taking down the elevated highway transformed the city; it connected the waterfront with the historic North End streets. Views and access points for pedestrians to the water and into Downtown revived the essence of the Harbor City. The buildings along the Greenway increased in value with the creation of an additional facade. The Rose Fitzgerald Kennedy Greenway is a lively and active place with art installations, beer gardens, and a weekend market.

4.4 Main Benefits and Takeaways

Both projects significantly improved the access and the quality of the waterfront experience. The Downtown and North End became one with the historic wharves and increased the value of properties. "The Shawmut Peninsula is some of the most sought-after and desirable urban real estate in the country" (Flint, 2015). The opportunities to develop the Seaport neighborhood in South Boston and add recreational programs along the waterfront include museums, the New England Aquarium, sailing, kayaking, and the use of the Boston Harbor Islands. The new open spaces, potentially improved water and air quality have improved the quality of life and the health of the City residents.

Both projects show different implementation processes with very different levels of engineering and management complexity. The Boston Harbor Project was overwhelmingly supported by the public and advocacy groups. Once the state realized it had to act, it established a new independent authority, which successfully drove the process. The project focused on renewing facilities without the complexities of the energetic urban fabric. On the other hand, the "Big Dig" was a gargantuan effort to transform the city while it remained active. Public opinion shifted as the project extended in schedule and budget, and the message over the final benefit for the greater metro-area community was not always coherent. The advocacy groups involved, represented one group of Bostonians and not the voices of all residents (Miller, 2012). The focus on the car and no other public transit infrastructure fostered questions of equity. There is a substantial amount of comparable experience from these projects to apply to the CRB initiative. The following discussion section will explore the overlapping issues and lessons learned from the past projects.

5 Discussion: Lesson Learned

This study aimed to compare and analyze large-scale public projects with transformational impacts on the urban environment. This exercise also attempted to extract approaches to resolve questions and challenges that have arisen in the CRB initiative. Section 3 identified four main challenge categories to be explored in the methodological comparison: civic activism and social equity, governance, regulatory practices, and funding strategies. Section 4 extracted the relevant lessons per each category from the reported history and studies. This paper used these categories as guiding issues: (1) Potential tools for implementation and civic activism's role in moving the project forward. Large-scale projects are known to be cumbersome to execute and while the urgency and need for implementation are well

established in the cases, it is hard to see any drive for implementation without a strong incentive or a political movement. (2) The scale of implementation and future operations require the establishment of new institutions and governance structures. Some of the challenges toward implementation are due to the lack of functioning or adequate institutions. Similarly, regulations and policies can be barriers to the implementation of specific project components. The change of such regulation extends the timeline of implementations; on the other hand, certain policies can incentivize actions. (3) The cost of these projects is seemingly the first and foremost significant challenge. Strategies to evaluate the benefits of a project started with the cost–benefit of the preventable loss or negative impact of the current condition. These projects all show significant benefits beyond the single utility: the spatial, environmental, and economic value that is created and extends beyond the projected.

5.1 Civic Activism, Public Participation, and Moving the Project Towards Implementation

Although in the Boston Harbor Project, what forced action was a court order, civic action, and public consensus was the instigator and the motivation to implement and push the project forward to materialization. Multiple advocacy groups backed up the same vision from their perspective. The public interest showed to drive political will and commitment to institutional change. In both cases, the actions of the TBF, CLF, Save the Harbor/Save the Bay, and ABC fostered stewardship and influenced the inception of the process and its evolution.

On the other hand, in the CA/T, the project was driven by federal political interests and available funds. The original intention to improve the public realm of downtown was admirable, however, the process failed to engage all impacted groups. Additionally, in a transportation project of this scale in a major metropolitan area and a regional business center, many stakeholders had interest in improving the outcomes. That said, missed opportunities were identified by advocacy groups that could have improved the CA/T project, if they were engaged on time. These are potential lessons that can be carried forward for the CRB initiative. For example, the CA/T project's main goal was to improve traffic and resolve engineering issues with the existing viaduct. The ABC advocated for specific spatial impacts and the design of the public realm to connect their neighborhood to the waterfront and provide better urban context to their properties. Potentially, the outreach to other commuter groups and City residents would have revealed interest in additional benefits such as public transit, pedestrian connections, bike lanes, etc. Moreover, the lack of transparency and public participation in the process exacerbated the public sentiment regarding the mishaps and schedule extensions in the construction process.

The lesson for CRB is to leverage the public support and engagement process to create community support and long-term stewardship. Public interest and support can be achieved through substantial communication of the risks, climate impact, the City's future, and the potential long-term benefits for the City's living environment. To drive the project forward and maintain a long-term commitment to the project's success, the community needs to feel invested in the outcomes. The Climate Ready Boston district planning process includes outreach to local community groups and stakeholders; however, it is not yet enough to drive the project forward to action.

5.2 Setting up Institutions with Agency and Governance Framework

Both projects were publicly funded with federal grants and fees collected from taxpayers. The way in which the responsible authority managed these funds has been a source of criticism. The overrun of the construction cost of the CA/T led to the neglect of other systems. Furthermore, the structure of the project management team and the public–private partnership raised questions from the community. For the Boston Harbor Project, the state had to form a new authority, the MWRA, with the ability to collect fees removed from the political gridlock. The establishment of a specialized authority with the capacity to implement the project and collect fees was a critical step to executing the cleanup project.

In the context of CRB—for a project of this scale, coordination and organization capacity needs to be across scales of leadership, with authority to make decisions and drive a flexible process. A governance framework could provide leadership and coordination across all necessary city and state agencies. A regulatory strategy aiming to address the identified hurdles in the current policy can streamline legislative processes. An additional takeaway can be tied to the flexibility of the project's objective. The project framework should allow flexibility under the umbrella of a vision, especially if the core purpose is to solve a problem as the project has an expanding schedule and cost. The Mayor's Harbor Vision presents a comprehensive strategy for multiple benefits beyond the resilience utility. The approach to divide the comprehensive plan to districts allows aggregation of the project and site-specific benefits.

5.3 Innovative Funding and Financing Mechanism

The main takeaway from the quantitative summary of previous studies and reports of both case study projects is that it is clear that the financial benefits and long-term economic value is more significant than projected. For long-term success, self-sufficiency, growth, and financial sustainability, these two transformative urban infrastructural projects have proven successful. Simultaneously, it is important to set the framework to ensure equitable access to this future economic growth and invest it back into public infrastructure. From this study, it is evident that the benefits of the Boston Harbor Project and the CA/T exceeded well beyond the expected and initial utility of these infrastructure projects. In essence, improvement of the urban realm and quality of natural resources catalyzes financial investment and ecosystem revitalization. From a cost–benefit perspective, thirty years down the line, the benefits outweigh the original investment as the "Boston Harbor Cleanup is about 5–16% of the total asset value of ecosystem services" (Jin et al., 2018). The Resilient Boston Harbor Vision is another opportunity to transform and improve the urban realm for the future, minimizing loss due to extreme climate events and creating additional value and benefits.

Potential strategies to support the funding and financing of the CRB projects can come from future values and benefits. These strategies can draw from future benefits and outline incremental funding mechanisms. For example, as was described by some of the CA/T critiques: the ABC as an interest group could leverage the project benefits from quantifiable value. As property owners, they directly benefited from the public investment in the project. While property owners have endured the years of construction and invested in the process—the question should be asked—should they have contributed more to the funding of the project? (Flint, 2015) This financing strategy called value capture, accounts for the future increase in property value or individual savings due to public investment. These funds can be redirected to pay for the project as a strategy for more equitable resource distribution. As Climate Ready Boston looks at waterfront strategies, the proposed alignment protects a larger area of inland properties. Therefore, concepts of resilience dividend (Rodin, 2017) and value capture can be incorporated.

6 Conclusion

The vision to transform the Boston coastline into a resilient waterfront is a complex and multidimensional effort. It is comparable in the scale, cost, and level of systemic changes necessary at the physical and institutional levels. The case studies examined in this paper offer a view into broad, long-term impacts of infrastructure projects. Beyond the stated goals of each project, the result on the ground and cascading transformation of the urban realm and built environment shows great ability for sustainability and strength. The successful transportation systems and Greenway in Downtown Boston, created after an excruciating construction process, presented a steady increase in property values, new businesses, growth of population, and improvement of urban life. The Boston Harbor Clean-Up allowed people to use the waterfront, enjoy the harbor with various recreational and commercial activities, as the city grew along the coastline with a new appreciation for the waterfront, and ecological habitats were restored. In contemporary times, the harbor is no longer used for the industry but as a recreational resource for the community. The optimistic take from the case studies—is that although it was cumbersome to implement and an expansive effort—it was well worth the trouble.

The most significant takeaway from the project studies is that this type of public project will need to be more than the sum of its parts, with a deep connection to the community and support from civic leadership. There is an opportunity to envisage the possible benefits of this project and leverage the endeavor for multiple equitable community priorities. Residents are conscious of their environments, geographic problems, and structural deficiencies, which may not be as apparent to professionals. The knowledge and ideas they provide will, in essence, promote creative solutions and strategies. Executing this project will require institutional arrangements and a change in the standard cultural perception; it will be a gradual transformation—a learning curve towards collective knowledge building.

To foster public interest and drive action, the community needs to participate beyond the standard practice. The future risk of climate change and the uncertainty of extreme weather events can be complicated and daunting to grapple. The process facilitating the CRB needs to develop a deep learning strategy and long-term stewardship across all ages and community groups. The process informs, educates, and empowers the community to develop ideas—it can bring people together and make social connections stronger. The developed networks can be developed to support long-term climate adaptation initiatives and as the basis for effective implementation. Finally, governance and the institutions created, need to fit the scale and complexity of the challenge. Institutional capacity should not be the hurdle preventing a project of this scale of importance from happening. An effective authority could support coordination between agencies and stakeholders, resolve financing issues, and drive regulatory and policy changes.

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