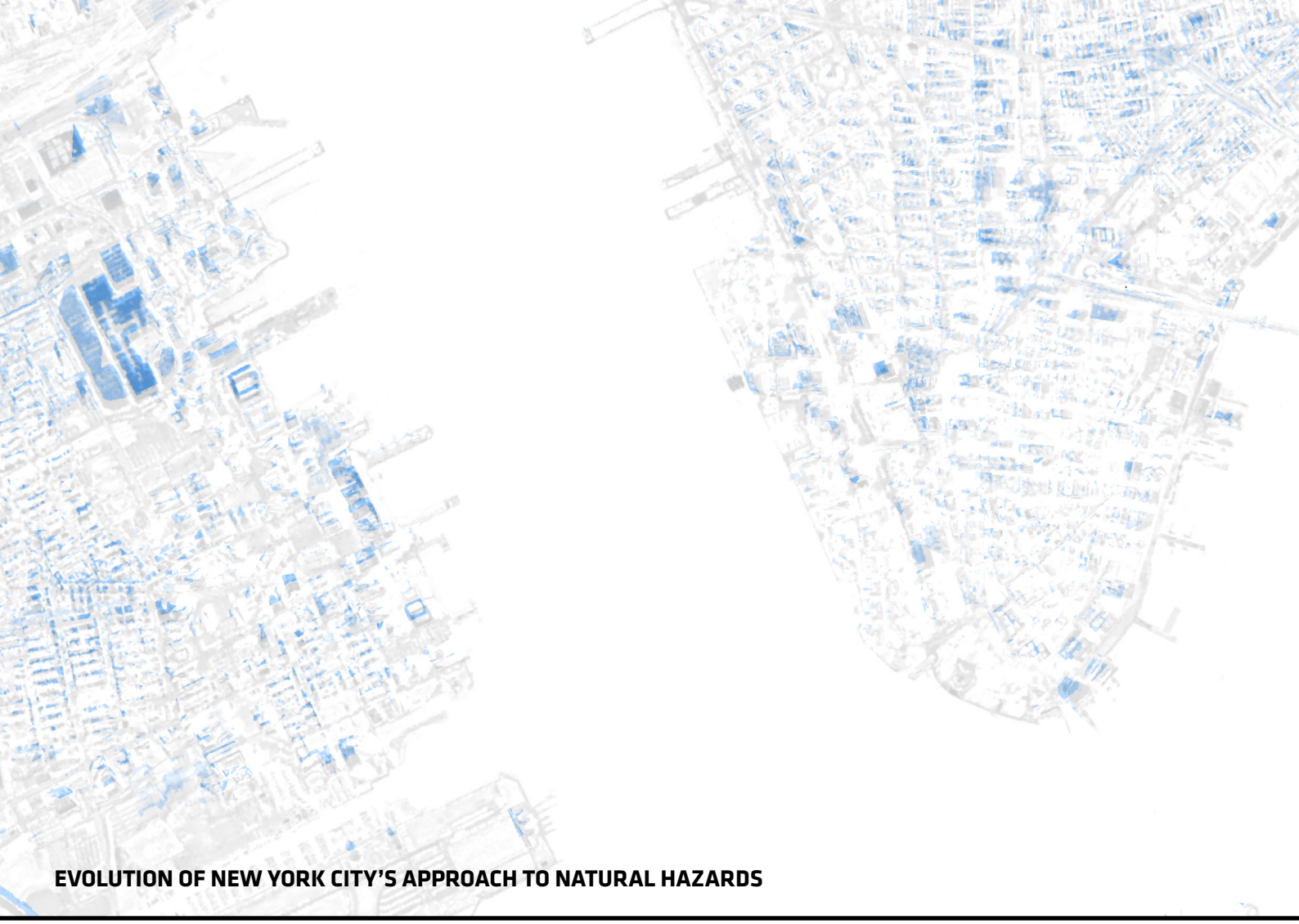

EVOLUTION OF NEW YORK CITY'S APPROACH TO NATURAL HAZARDS

ADAPTATIONS AND STRATEGIES FOR ADDRESSING FLOODING FROM HURRICANES AND STORM SURGES

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ABSTRACT

By 2050, in less than 30 years, 300 million people will become climate refugees due to the rising sea level and coastal flooding (Lewis, 2019). Inhabitants of megacities such as New York, Mumbai or Shanghai will face enormous changes within their environment. The rising sea levels, hurricanes, and floods will transform life in coastal cities and necessitate a rethink of their approach to climate change. To comprehend the different strategies adopted by coastal cities, this study distinguishes between multimillion-dollar adaptive projects and smaller-scale climate change actions by the City of New York. In addressing this global issue, the U.S. Environmental Protection Agency has provided a summary of adaptation options for coastal areas and cities. These flood prevention strategies not only highlight the vulnerability of coastal cities to climate change but also vary in their management strategies, such as building new infrastructure, relocating key facilities, or preserving natural habitats.

New York City, the most densely populated city in the U.S., has been facing flooding dated since 1788, and has a long list of historical records on this issue. The devastating superstorm of Hurricane Sandy in 2012, which flooded the streets, subways, and tunnels, caused around $65 billion in damages, and led to the loss of many homes. This catastrophic event raised global warming awareness and spurred action to protect the city's waterfronts. From using leftover oyster shells as a natural flood protection system to funding multi-billion-dollar projects, New York City began taking steps to safeguard itself from natural disasters.

In New York City's Lower East Side, Bjarke Ingels Group partnered with multiple engineers and planners to develop a proposal for a 10-mile protective zone along the waterfront. This project was conceptualized as a part of the Rebuild by Design Hurricane Sandy Competition in 2019. The central idea behind the project is to leverage elevated parklands, floodwalls, berms, and movable floodgates to shield communities and the $500 billion economic sector along the New York shore from the impact of natural disasters. Described by Bjarke Ingels "as the love-child of Robert Moses and Jane Jacobs," (Wainwright, 2015) the project represents a major step in the history of flood protection and social encouragement for residents to interact with the New York Dryline.
This project aims to merge the urban planning principles of Jane Jacobs, who advocated for natural growth without demolition, and Robert Moses, who emphasized on redevelopment. It combines innovative ideas with a rich historical background of the city to examine why New York City only responded to natural disasters after a subsequent calamity and whether the city can formulate an all-encompassing strategy for managing natural hazards by drawing on its past experiences. Besides investigating the history of natural disasters in the city, this paper provides a critical evaluation of the proposed adaptation strategies throughout its history.

RESEARCH QUESTION

How has New York City's approach to natural hazards, particularly flooding caused by hurricanes and storm surges, evolved throughout history and what adaptations have been implemented to address these challenges?

OUTLINE

1. INTRODUCTION – PREDOMINANCE OF RISK FORCING TO TAKE ACTION

A drowning statue of liberty, reminiscent of a new age of storm surges, flooding, and rising sea levels, depicting New York City's future, is showing how unprepared we are facing the ongoing climate change. The almost submerged head hitting a big wave from behind shows on the one hand the critical situation of New York City, but on the other hand gives hope that not everything is decided yet. While reading the cover from top to bottom, one is confronted with two different callings. First, invest in your retirement and provide for your own future and second, you are in deep trouble, due to "a new age of BIG STORMS threatens coastal cities like New York – and WE'RE NOT READY" (Piore, 2022). The May 2022 cover of Newsweek magazine shows the concerns of New York City residents due to flooding, storm surges, and hurricanes. Currently, it seems to be about buying Bitcoins, investing them in retirement savings, and thus securing one's future by saving and keeping money. But the question that arises when looking at it is why New York City is not ready, given the great risk and damage it faces (Piore, 2022).

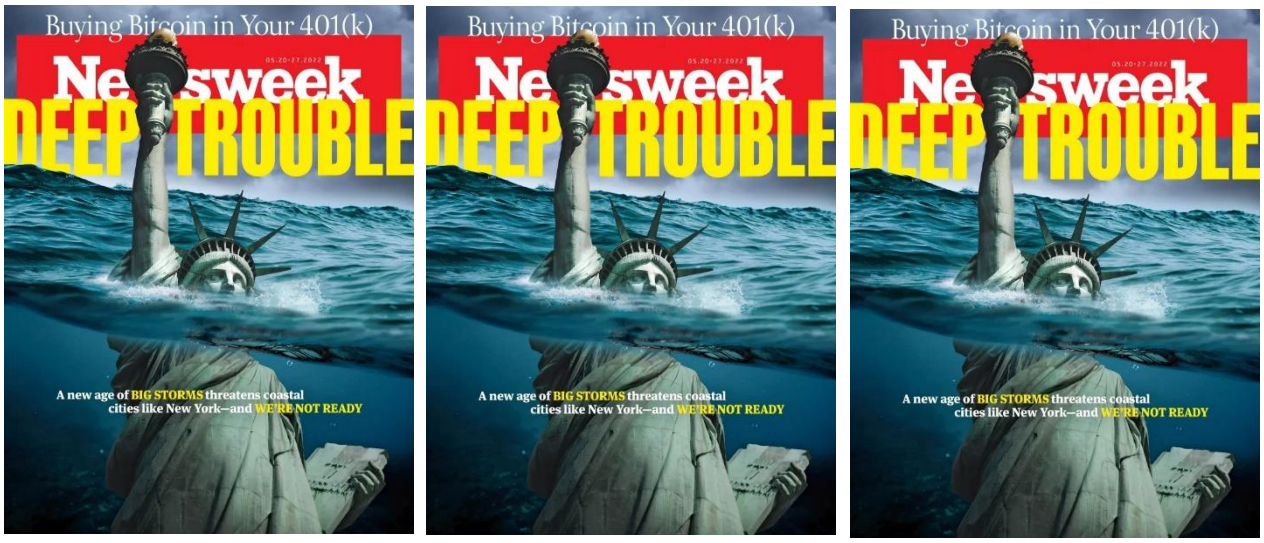

Fig.1: "Cities Brace for Apocalyptic Flooding As New Age of Super Storms Dawns" (Piore, 2022)

Since 1900, the increasing sea level has compelled coastal cities to adapt to the changing environment. New York City, situated at the Hudson River's mouth into the Atlantic Ocean, has historically faced challenges like flooding, hurricanes, and storm surges. As a result of these persistent issues, various strategies have been proposed to prevent and minimize the damage from known sea level rise, both present and future. Given New York City's location, including the high population density of Manhattan, the city's survival is at risk during and after hurricanes, floods, and storm surges. Global warming and the resulting rise in sea level have a significant role to play in the city's development. (Blakely 2012).

Throughout history, New York City has faced various natural hazards, including flooding, hurricanes, and storm surges. However, the frequency of recurring hurricanes has only become a significant issue in the city since the late 1980s. The lack of historical awareness of the potential for hurricanes in the city has resulted in a lack of preparedness and planning for natural disasters. To address this issue, it is essential to increase awareness of the risks associated with hurricanes and to implement adaptation strategies that focus on hurricane protection and preparedness. Such strategies can help to mitigate the potential damage caused by these natural hazards and protect the city's residents and infrastructure from future disasters. (Coch 1994).

Nearly 15 years after publishing a sustainability analysis and proposing various adaptation methods, Mayor Michael Bloomberg began implementing a new plan for New York City in 2007. The so called PlaNYC consisted of several recommendations for a climate plan that included infrastructure protection, specific plans for vulnerable neighborhoods, and a long-term adaptation plan. Notwithstanding the ongoing process of developing theoretical and implementing small scale strategies, New York City, as well as the New York State, has been and continues to be at risk of suffering major losses from natural disasters (Blakely 2012).

In the aftermath of Hurricane Sandy in 2012, previous methods and recommendations for various strategies proved inadequate, prompting the New York City government to update the existing PlaNYC with new protection strategies. The previously theoretical proposals and small-scale interventions are now being supplemented by an actual implementation of a design competition.
The Rebuild by Design competition and strategy challenges various architectural, structural, and engineering offices to develop a new protection barrier against flooding and storm surges. The winning project of Bjarke Ingels Group, the New York Dryline, envisions a u-shaped elevated parking loop around Manhattan's shoreline to reduce damage dimensions (Al 2018).
Regardless of the strategy to avoid financial damage from flooding, the high capital cost of the multi-billion-dollar New York Dryline project is opening awareness to already developed, less costly adaptation strategies and projects. By adopting a more hybrid solution that is easier to complete and adapt to current needs due to its smaller scale, New York City's current situation can improve faster (Aerts 2013).
The question of whether a project like the Billion Oyster Project, which works with and informs the affected residents to raise awareness of sea level rise and climate change, or whether a billion-dollar project is the best solution for New York City, remains unanswered. Whereas most implemented strategies are limiting flood damage coverage to current and projected needs the resident is left with a sense of security and neglects further developments of the rising sea level and changing climate. (Kousky 2021).

This research aims to examine past adaptation strategies proposed for New York City in response to natural hazards, considering historical data and current and future threats.
By analyzing the effectiveness of these strategies, the research seeks to identify criteria, interests, and narratives that could inform the development of new policies and frameworks for managing flood risk. Based on an analysis of New York City's history of flooding and natural hazards, and current adaptation practices, this research aims to synthesize a comprehensive set of adaptation strategies that consider financial and social considerations, as well as project-based prevention methods.

2. NEW YORK CITY'S HISTORY AND ITS RELATION TO WATER

The history of New York City is characterized by the remarkable growth and transformation, driven by its position as a global hub of commerce and culture. To gain a comprehensive understanding of New York City's history and its close association with water, it is necessary to examine its geographical features. The prominent Hudson River is a significant feature that divides the city into several distinct sections. The role of water is not only visible throughout the city but is also deeply rooted in its cultural history.

Before the arrival of European colonizers, the native inhabitants of the area of the now known New York City utilized the surrounding water bodies, including the Hudson River, for hunting and fishing purposes. In 1598, a small group of Dutch employees of the Greenland Company settled in the area known today as New York City to build shelters for the winter months, which is contradictory to the common belief that Hendrick Hudson was the first to settle and explore the area in 1609. Interestingly, Hudson, the namesake of the Hudson River, described the land, especially the abundance of water in the form of ponds and rivers, as a peaceful and thriving. Following this settlement, trade between the Netherlands, East India, and Russia began to grow in importance, making the location of the discovered area increasingly attractive. As a result, the Dutch established a colony known as "New Netherlands" in the area, leading to the eventual settlement and development of New York City as we know it today (Stone, 2015).

Due to its strategic location as a gateway for global trade between Europe and the rest of the world, the area of New York laid the foundation for New York City's future development as a bustling port and marketplace with the construction of its first pier in 1659. Its position at the heart of the eastern coastline of the United States further facilitated easy access for traders, regardless of their origin. Over time, New York City's trade and port infrastructure continued to expand, ultimately establishing the city as one of the largest and most important port cities in the world during that time. The city's relation to water, combined with its position as a global hub for commerce and industry, has played a significant role in shaping its economic and cultural history, and has solidified its status as a major player on the global stage (New York Shipping Association, n.d.).
At the turn of the 20th century, the shoreline of New York City was teeming with container ships, solidifying its position as the busiest port in the United States. This unprecedented financial success played a significant role in shaping the city into the bustling metropolis that it is known as today. As port operations and container shipping gradually shifted to locations outside the city center, New York City continued to thrive and expand, driven by the financial opportunities that came with the strategic location and economic power. "New York's importance as a port is long past" (Glaeser, et al., 2005). But despite changes in the location of its port facilities, the city's enduring success as a global center of commerce and industry has remained a hallmark of its identity and cultural heritage (Boyd, 2014).

New York City's remarkable growth and expansion over the years has been accompanied by different challenges, including noise pollution, environmental degradation, and the impacts of war. Despite these obstacles, the city has managed to maintain its resilience and continue thriving through various transformations, from its origins as a bustling port city to a center of manufacturing and finance.
Although the city has faced several challenges, ranging from the loss of waterfront biodiversity to the need to adapt to changing economic and social realities, its ability to persevere and remain at the forefront of global commerce and culture is a testament to the strength and determination of its people.
"New York's port may have been the catalyst for the city's rise, but New Yorkers were far more likely to be involved in producing manufactured goods than in working on the ships themselves." (Glaeser, et al., 2005), which led New York City to evolve from a bustling commercial center to a thriving financial and business center.

Fig.2: Aerial view of Manhattan from 1931 (left) compared to an aerial view of Manhattan from 2023 (right)

Even today, the relationship between New York City and its waterfront remains one of the most important topics for both the city and its residents. However, the focus has shifted from the historical desire to be situated close to the coast and trading hubs, to the present-day challenge of increasing the distance between the city and the coastline to mitigate the risk of flooding and combat the effect of global warming. This shift in focus reflects the city's evolving relationship with its environment and the recognition of the importance of sustainable development in ensuring the well-being and safety of its citizens.

"While New York's ability to weather past challenges has been remarkable, we cannot be certain that its future success is assured." forcing New York City to take action and constantly think of new solutions and adaptations (Glaeser, et al., 2005). The complexity and challenges associated with New York City's relationship with water have intensified in recent years, as climate change and rising sea levels continue to pose a growing threat. This has compelled residents, politicians, architects, engineers, and everyone who is involved with the City of New York to confront a range of environmental, social, and economic issues.

3. NEW YORK CITY'S HISTORY OF FLOODING – THE FIRST THREE MAJOR HISTORICAL HURRICANES

3.1 Definition Hurricanes and Tropical Storms

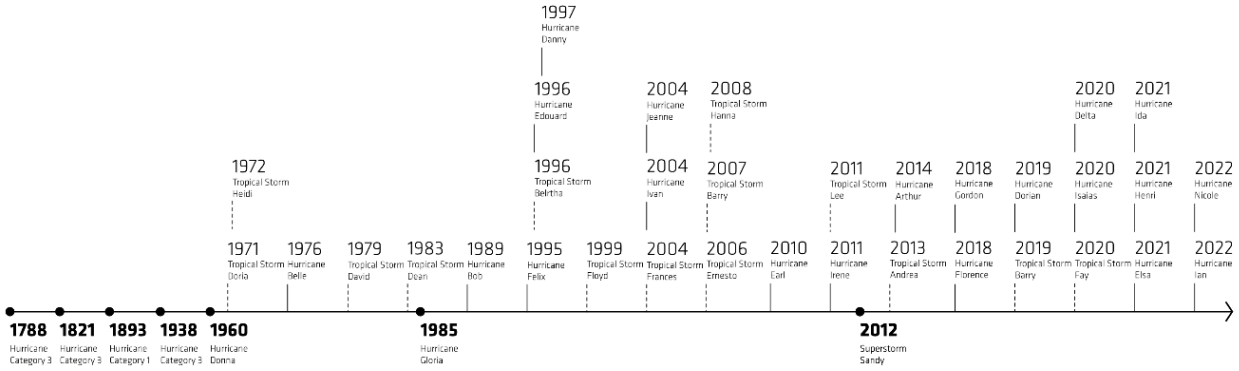

Fig.3: A Timeline of New York City's History of Hurricanes and Tropical Storms

Various historical data and analyses indicate that the coastal region of New York City has experienced severe flooding from heavy rains, hurricanes, and storm surges since 1788. After that year, notable and recurring flooding began to be a constant problem in New York City and New York State. To understand the impact of increased flooding and the accompanying strategies to avoid greater loss and damage, the history of flood management in New York City must be considered, analyzed, and studied. The following is an analysis of these notable historical natural hazards.

To understand the historical impact of hurricanes on a city, the terms hurricane and tropical storm must be defined: "Hurricanes are large-scale low-pressure systems with definite organized circulation that develop over tropical or subtropical waters "(Coch, 1994).
The formation origin is based on a tropical wave and an area of low pressure that passes through areas of high humidity, where thunderstorms and showers form. After it crosses the ocean, it begins to pick up warmer air into its storm, resulting in a low-pressure area below it, where this collection of different pressures becomes a rotating system, which is then known as a tropical cyclone or a hurricane (US Department of Commerce, 2013). During this formation of a hurricane, strong winds play a major role and determine the dimensions of its outcome based on the velocity. Which is why general categorizations can provide information about the extent of damage of a hurricane.
The Saffir-Simpson Hurricane Wind Scale divides the damage into 5 categories. From the lowest category 1, expected wind speeds of 119-153 km/h will cause some damage and hurricanes are seen as the most harmless hurricane. From category 3, major damage is caused by wind speeds of 178-208 km/h, up to category 4 with 209-251 km/h and category 5 with 252 km/h or more. (National Hurricane Center, n.d.).

Tropical storms, on the other hand, are considered the less fast and more impact-prone version of a hurricane. They begin with wind speeds of 117 mph and have the same requirements as a hurricane but cause only slightly less damage. Compared to tropical storms, hurricanes pose a higher risk of flooding from heavy rains and high tides in coastal cities. Additionally, research shows that the effect of global warming and the ongoing sea level rise is impacting the appearance and level of damages of a hurricane as well of a tropical storm. (Kemp et al., 2013)

3.2 The first major hurricanes and floods in New York City in 1788, 1821, and 1893

Looking back at the historical data of flooding regarding hurricanes and the rising sea level the year 1788 marks the first historic hurricane in New York City. Because there is no instrumental tidal data on this hurricane, the exact damage and impact of this hurricane is difficult to measure.
As reported by the New York Times, this hurricane had an intensity of at least Category 2, resulting in storm surges of up to 9 feet (2.78 m) (Schwartz, 2008).
As Ludlum describes in his Book Early History of American hurricanes: "The tide rose to a very great height, and most cellars in Front and Water streets, and a great number in Queen were filled with water" (Ludlum, 1963). The problem of flooding in New York City is not an issue that only developed it the 21 century but is existing for more than 3 decades and its "damage sustained will be very considerable. Daily Adv. (New York) 20. August 1788" (Ludlum, 1963).

Half a decade later, in 1821, the second of the seven most historic and consequential hurricanes of a Category 3 occurred. Like the previous dated hurricane, a storm surge with a height of almost 3.2 meter above the mean sea level caused extensive damage to the city and its residents (Scileppi et al., 2007).
Due to the lack of technical measurements, the wind speed and the damage caused by it can only be estimated by analyzing articles and interviews from that time.

In 1893 similar to the previous two floods, a storm surge of approximately 3 meters above the mean sea level struck New York City, resulting in significant damage within the city. (Scileppi et al., 2007). On the 24th of August 1893, the New York Times noted several boats were still driving hundreds of meters inland, due to a category 2 hurricane, leading to high flooding within the city. A day later, on August 25, 1893, the New York Times was filled with headlines about the hurricane's damage:

"The storm beat with full force on the North and East sides of the (Central) park. Striking the very tall buildings fronting on West Fifty-Ninth street, the wind was reflected back into the park with great violence. Small bushes and trees were snapped from the ground..."(Coch, 2019).

"The telegraph wires went down in every direction, like cotton strings, and New York was for a time almost completely cut off from communications with everywhere." (Coch, 2019).

For the first time, not only New York City itself was affected by a hurricane, but all residents and businesses, especially on Wall Street, were cut off from their communications with the rest of the world by the hurricane's destruction. This not only shows how vulnerable the infrastructure of New York City is but also how vulnerable this city is even to lower-category hurricanes.

Since 1920, a digitized instrumental record of each historical flooding in New York City has been available to the public through the National Ocean Survey, providing knowledge of the city's recurring struggles with storm surges, flooding, and high winds (Kemp et al., 2013). Before this "the frequency of hurricane landfalls [...][was] difficult to estimate from the instrumental and documentary records due to the relative rarity of these events and the short historical observation period" (Scileppi et al., 2007).

3.3 Hurricanes in New York City in the 20th Century

In 1938, New York City experienced yet another major hurricane, which, like previous ones, caused unexpected damage. Streets, houses, and sewage systems were flooded as "The East River flooded three blocks inland [...]" (Goudsouzian, 2004). The result of this hurricane was not expected by the city and its residents, as "one was hardly aware of anything more than a big blow" (Goudsouzian, 2004).
During that time, hurricanes were still deemed uncommon and unforeseeable events. The correlation between rising sea levels and the frequency and severity of hurricanes was not acknowledged due to limited means of communication and technology, as well as the widespread belief that such a calamity would never happen in the region. New York City and its residents had an excessive level of confidence that a hurricane would never take place. (Schwartz, 2008).

Fig. 4: Hurricane Donna floods West St and Cortlandt St

In 1960, Hurricane Donna caused extreme flooding in New York City, as shown in the image of the intersection of Cortlandt and West St. in Lower Manhattan, where the World Trade Center is now located. The residents were unprepared for the situation, and the storm surge left a height of 2.55 meters, which set the record for the highest water level at that time, leaving Manhattan, which is 1.5 meters above mean sea level, vulnerable to the impact of the disaster.
The city once again showed how vulnerable it is to tropical storm surges due in part to its geographic location and the low height of the protective seawall in Manhattan (Lin et al., 2020).

After the city recovered from Hurricane Donna, the next notable hurricane to hit New York City have occurred just 25 years later. Hurricane "Gloria was one of the strongest North Atlantic hurricanes of the century, yet the area never received the full fury of the storm", (Gigi et al. 1986) for several reasons.
At the time of the hurricane's arrival, the major landfall had already occurred, and the current low tide resulted in minimal flooding. On the other hand, studies show that New York City was lucky at the time and the expected damage Hurricane Gloria would have left behind would have exceeded all previous hurricanes in history.
Hypothetically, if the hurricane had made landfall right in New York City and its storm surge had been in addition to a high tide, flooding in the city of more than three meter above sea level would have occurred. Tens of millions of dollars in damage would have increased and more lives would have been threatened. As NOAA, the National Oceanic and Atmospheric Administration, indicates in its evacuation map, about a

quarter of the railroad tracks and major transportation routes would have been flooded as well (Gigi et al. 1986).
"For the storm of the century, it was a washout," (O'Toole, 1985). As noted in the Washingtons Post article just days after Hurricane Gloria, the precautions taken for Hurricane Gloria "were among the greatest anywhere for a hurricane in this century". (O'Toole, 1985). Emergency shelters were built and the city itself prepared for three different scenarios of Hurricane Gloria by closing skyscrapers and airports. It can be said that for the first time, New York City showed that it had learned from previous hurricanes and from its history, so it was over-prepared for a hurricane that hit less hard than expected. (O'Toole, 1985).
Many residents, confused by the unplanned exaggeration of this hurricane, were less afraid of a future hurricane, which led to a fear of "[...] that Gloria, with its less-than-expected force, may have lulled the public into a false sense of security regarding future storms" (Mcquiston, 1985).
It is not certain if the reduction in fear and severity of a hurricane of this size was in any way related to future precautions and preparations from the perspective of residents, but one thing that was inevitable is that more storms, storm surges, and hurricanes will occur and their percentage of destruction and frequency will increase, based on the known major historical hurricanes in New York City since 1788.

3.4 Super Storm Hurricane Sandy in the year 2012

"Hurricane Sandy was a sobering reminder to those of us who call New York home that it is a port city and subject to the whims of wind and water." (Abramson, 2012).

On October 29, 2012, Superstorm Sandy caused severe flooding and a storm surge in New York City that exceeded every known hurricane in New York City's history. Due to the additional above-average tide at that time, the Category 3 hurricane triggered a tidal surge of 14 feet (4.26 meters) above sea level, breaking the record set by Hurricane Donna in 1960.
This superstorm caused $50 billion in damage, and millions of people were affected not only in New York City but also around the world, as all airports in the area had to be closed. About 2 million people were cut off from electricity. Caused by the power outage, the entire supply chain in the affected area was impaired for almost two weeks.
Like previous notable historic hurricanes, the lack of risk communication and the public's reaction to it caused residents to reject the evacuation proposal and stay home because they could not afford to leave everything behind for financial reasons. Accompanying not evacuating and underestimating the situation, as Schwartz mentions in a 2008 quote from Dr. Leatherman, director of the International Hurricane Research Center at Florida International University, in his New York Times article Waiting for the Big One: "They have hurricane amnesia," he said. "You've got to keep reminding people. Statistically, we're overdue for a '38-style hurricane." (Schwartz, 2008).

Fig.5: Stuck in the floods of hurricane

Hurricane Sandy was to be expected, according to a 2011 study that mirrored and predicted Sandy's footprint (Abramson, 2012). Overall, about 17 percent of New York City's land mass was inundated by the storm surge caused by Hurricane Sandy, affecting about 433,000 New Yorkers who live in the area.

Hurricane Sandy was the superstorm that the city of New York expected but never wanted. Much the same is true for the future. New York City and other port and coastal cities know their threat will grow in the future due to climate change and rising sea levels: "a Sandy-like event [is] significantly more likely." (Letzter, 2016; Abramson, 2012; NYC Government et al., 2013).

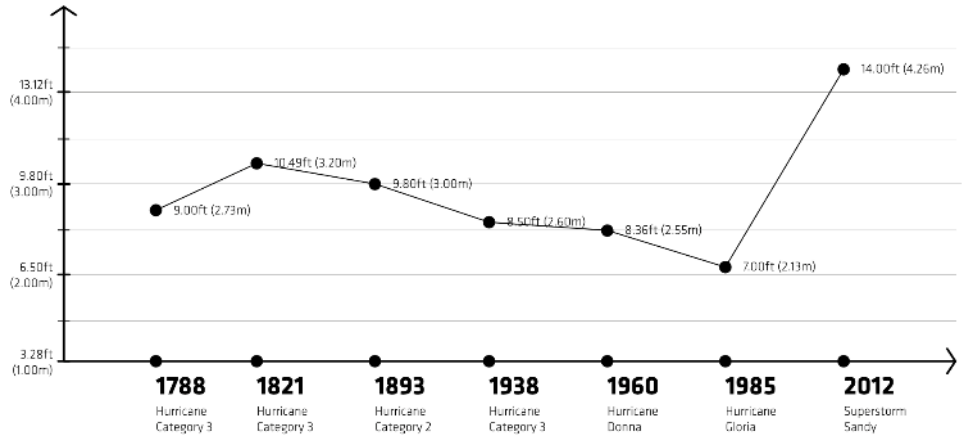

Fig.6: Overview of flood heights in New York City regarding to the seven notable hurricanes.

4. STRATEGIES FOR A BETTER NEW YORK

As one of the biggest and most heavily populated coastal cities on the planet, New York City is confronting a multitude of hazards, including the increasing threat of rising sea levels, the gradual subsidence of land, and the potential impact of natural disasters like tropical storms and hurricanes. As a result, the city is compelled to take action.

In response to the city's long history of flooding, various stakeholders including government, architects, engineers, institutions, and private organizations have proposed several strategies to prevent and mitigate flood damage. These strategies have been developed based on specific criteria after analyzing the city's infrastructure and urban environment.

"The challenges we face today are very different from those of the 1970s, but they are no less critical", if not, they are more critical than ever in the face of global warming and continued sea level rise. "Thirty years ago, a plan for New York's future would have seemed futile."(NYC Government et. al, 2007).

Looking back 30 years ago, implementing changes in infrastructure or prevention methods could have made a significant impact. Since 1920, New York City has been analyzing past floods and using that knowledge to prepare for future scenarios. By 2050, sea levels are expected to rise by 0.6-1.8 feet (0.18-0.55 meters), leading to more frequent and higher coastal floods. This will provide the framework for a storm surge, affecting approximately 120 square miles (310,000 square meters) of the city and around half a million residents (Strauss et al., 2014; SeaLevelRise.org, (n.d.).

In summary, New York City's efforts to prevent and mitigate flood damage have been ongoing for decades, with various stakeholders proposing strategies based on careful analysis of the city's infrastructure and environment. Despite the daunting challenges posed by rising sea levels and natural disasters, the city remains committed to taking action to protect its residents and ensure a sustainable future.

4.1 Adaptive Strategies – Hard and Soft Strategies

The U.S. Environmental Protection Agency (EPA) released a Synthesis of Adaptation Options for Coastal Areas in January 2009. The report details various adaptive strategies that can be employed to prevent flooding caused by rising sea levels and extreme conditions. The EPA's adaptive strategies range from constructing new infrastructure like flood barriers or relocating essential facilities to higher elevations. Other strategies include preserving habitats and retrofitting existing structures to improve backflow prevention. The debate between using soft or hard shoreline maintenance is also discussed, with hard strategies often referred to as gray structures that are engineered constructions like dikes, seawalls, and floodwalls. These interventions need to be integrated into the city's landscape to fulfill their intended purpose. Soft strategies, on the other hand, use nature-based systems like wetlands, vegetation, floating islands, and dunes to create a natural barrier against storm surges and flooding while also promoting biodiversity. Combining soft and hard adaptive strategies is often the best approach to achieve the most effective solution for each specific shoreline and coastline (U.S. EPA, 2009).

4.2 PlaNYC – A better New York City

In 2007, mayor Michael Bloomberg of New York unveiled a comprehensive strategy plan for the city's future aimed at preventing potential harm.
The primary objective of the so called PlaNYC was to develop a more sustainable and eco-friendly New York City to tackle challenges arising from rapidly increasing population, outdated infrastructure, and shifting environmental patterns. The vulnerability of Manhattan, which has shifted from a residential to commercial zone since the 1950s, is apparent. Despite this, over 1.8 million people still reside in Manhattan.

Lower Manhattan which lies at the confluence of the East River and the Hutson River, has emerged as a central business hub over the years. As the population continues to expand and the number of people susceptible to natural disasters such as hurricanes or floods grows, the climate is transforming to the city's disadvantage. A significant portion of the city's development has been constructed on low-lying land, making it additionally susceptible to flooding, storm surges, and rising sea levels (Blakely et al. 2012).

Michael Bloomberg's PlaNYC acknowledges this climate change issue as a primary concern. In February 2008, the Intergovernmental Panel on Climate Change confirmed that human activities have expedited the impact of climate change. Therefore, it is crucial to devise measures to combat global warming and its consequences.
The goal of the plan was to limit the amount of land used as the city's population continued to grow, while also addressing five key areas of interest: land use, air quality, water management, energy efficiency, and transportation. While the primary strategy for combating the threat of climate change and resulting flooding is reducing land usage, the plan also includes initiatives to improve air quality, provide cleaner energy, and enhance transportation. However, the plan's brief introduction seems to omit a critical strategy for mitigating flood damage.
PlaNYC highlights the creation of sustainable and affordable housing and emphasizes the need for public rezoning, including the regeneration of underutilized waterfronts. (NYC Government et al. 2007; NYC Government et al., 2013). The waterfront plays a crucial role as a buffer and barrier against flooding. Natural elements such as bushes are essential in creating natural flood barriers. However, there is a risk of destroying existing flood barriers when developing public spaces in these areas. "Urbanization has cost the region 85 percent of its coastal wetlands, further reducing the natural capacity of the landscape to buffer developed areas from the impact of storms" (Blakely et al., 2012).
Conversely, regenerating unused industrial areas without flood barriers provides an opportunity to incorporate new housing solutions with flood prevention measures. PlaNYC recognizes the impact of global warming, rising temperatures, and the resulting threat of floods posed by climate change.
In 2006, New York City developed an evacuation plan, employing over 34,000 people to transport residents to designated shelters during disasters. However, this alone is insufficient in preventing future storms.

"The only way to reduce the risk of violent storms in the future is to reduce greenhouse gas emissions and thus prevent dangerous climate change." (NYC Government et al., 2006).

PlaNYC, the comprehensive strategy for New York's sustainable future, emphasizes the need for various strategies to prevent flooding and storm surges caused by hurricanes. However, while the plan provides a strategy, it lacks specific and concrete adaptations to put it into action. An idea, a map, or a strategy itself won't protect a city unless it is being realized and implemented. "Up until Superstorm Sandy in 2012, however, flood protection measures were inadequate, especially considering the trillions of dollars of assets at risk." (AI, 2018).

Following the impact of superstorm Sandy on New York City in 2012, PlaNYC was revised in 2013. The recent uptake signified renewed interest in reducing the impact of flooding, storm surges, and sea level rise. The updated plan prioritized the development of resilient infrastructure and new building codes. In response to immediate needs, flood and storm surge barriers were constructed.

The revised PlaNYC outlines four adaptive strategies for coastal protection: increasing coastal edge elevations, minimizing upland wave zones, protecting against storm surges, and improving coastal design and governance.

However, it is crucial to recognize that the regeneration of numerous flooded zones will require an extended period, making them unsuitable for new housing development. (Blakely et al., 2012) To transform long-term damages into temporary inconveniences, the built and urban environment must be capable of absorbing water. (Blakely et al., 2012). To achieve long and short-term resiliency, two smaller-scale interventions are proposed in the plan. The first is to construct smaller water barriers, not just along the waterfront but also within the city. The second is to eliminate any structures such as critical support systems or electrical devices that are located within the waterway to minimize damage. While long-term strategies mainly focus on building barriers, it is essential to combine both approaches to achieve long-term resilience.

The PlaNYC, aimed at creating a greener New York, was set to be achieved by 2030. However, on April 20th, 2023, Mayor Eric Adams announced a new development of the plan called "Getting Sustainability Done." One of the achievements so far has been the installation of solar panels in public schools, generating a significant amount of solar energy for the city. Mayor Adams acknowledges the need to move beyond the previous adaptive strategies and focus on practical ways to achieve the set goals within a short timeframe. In his address, he highlights the challenges of meeting the objectives and proposes solutions to overcome them.

“Get stuff done does not mean being philosophical and theoretical on finding reasons why we must do old things the old way.” – Mayor Eric Adams (New York City, 2023).

The previous plan set forth by former Mayor Michael Bloomberg has been transformed and renewed into Plan GSD, with the aim of not only fulfilling the original plan, but also emphasizing the need for action and implementation of strategies. Mayor Adams stresses the importance of every New York resident's participation in achieving this goal. Plan GSD includes objectives such as reducing food emissions by 33%, transitioning to a zero-waste economy, promoting locally grown food, reducing air pollution, and protecting against coastal threats. (New York City, 2023).

However, it is crucial to note that the success of this plan relies on the implementation of a new mindset and lifestyle among all residents. In conclusion, it can be stated that PlaNYC has remained an adaptive strategy over the years, and due to the constantly changing environment, it remains a challenge to achieve the set goals and ambitions.

5. NEW YORK'S PREVIOUS AND PRESENT ADAPTIVE STRATEGIES

5.1 Constructing New Infrastructure – A Wall of Oysters

In 2014, the non-profit organization Billion Oyster Project partnered with local restaurants, schools, and volunteers to construct and replace an oyster wall along the harbor, as part of their flood mitigation efforts. The project not only aimed to establish a natural barrier against flooding but also to raise awareness and revitalize the natural environment in New York City's harbors. To promote environmental awareness among New York City residents, the organization collaborated with middle schools and integrated the project into the city's educational curriculum. Despite the abundance of information available on natural disasters today, including newspaper articles and the internet, the overall sense of risk may not necessarily be greater, and awareness needs to be implemented in the daily life. The Billion Oyster Project (BOP) strives to constantly remind and educate people about their surroundings.

The use of soft strategies raises the question of whether they can serve as a viable solution for preventing flooding in the harbor and potentially replace the need for expensive billion-dollar infrastructure projects that involve massive construction. When examining the history of New York City's harbor and coastline, it becomes evident that since the 16th century, around 220,000 acres of oyster reefs were present along the city's shores.
"Before the 20th century, when people thought of New York, they thought of oysters." (Billion Oyster Project, n.d.).

Fig. 7: Drawing (left) and photograph (right) of the Oyster Market in New York City

As industrialization occurred, the dumping of toxic wastewater and other pollutants into the harbor caused a significant decline in the oyster population and reefs. Although a Combined Sewer Overflow System was installed in 1845, pollutants have continued to be occasionally discharged into the harbor, hindering the natural regeneration of oyster reefs. As a result, the last commercial oyster bed was closed in 1927.
In 1972, the Clean Water Act was implemented to safeguard the environment of New York City's coast and harbor, which eventually led to the water being clean enough to support the growth of oysters by 2000.

After Superstorm Sandy caused extensive damage in 2012, the Billion Oyster Project (BOP) was established with the ambitious goal of restoring the harbor with one billion oysters by 2035 (Billion Oyster Project, n.d.). Oyster reefs serve as a highly effective soft adaptive strategy in mitigating flooding, creating a massive underwater structure that helps slow down and reduce the impact of waves during storms and hurricanes. To facilitate this effort, landscape architect Kate Orff launched the Living Breakwaters project in 2021, which provides an ideal base for oyster growth and is the first natural barrier project of its kind in New York

City. The Billion Oyster Project collaborates with existing structures and initiatives, as the reefs grow over time to serve as a buffer zone and barrier against natural disasters (Bloomberg, 2021).
Unlike hard seawall barriers that need to be rebuilt after getting destroyed in a storm, natural seawalls can rebuild themselves. However, a potential challenge is that they require shallow water and specific water temperature conditions to grow.
Nevertheless, natural protection barriers provide a longer lifetime and are "[...] the key to solving these challenges of climate change [...] [It is important to adapt] [...] human behavior, and humans aren't going to change their behavior without a direct connection to the natural world. [Pete Malinowski, the founder of the project and an aquaculture teacher at the Harbor School] (Bloomberg, 2021).

5.2 Rebuild by Design

After Hurricane Sandy reminded New York City residents of their vulnerability to floods and hurricanes, the Rebuild by Design initiative was founded to take proactive action and suggest various strategies.
This design and project-driven team aims to build resilience through collaborations. Following the 2012 superstorm, Rebuild by Design initiated a competition to design a barrier for lower Manhattan to protect against future disasters. The competition gathered engineers, architects, urban planners, residents, and organizations from around the world to develop cross-functional solutions, with a particular focus on working with local government and communities. This sparked many other resilience projects, including the allocation of billions of dollars in financial support (Rebuild by Design, (n.d.).

One of the biggest funded projects and the winner of Hurricane Sandys Rebuilding Competition, initiated by the U.S. Department of Housing and Urban Development (HUD), is the BIG U, by Bjarke Ingels Group.
In the location of the Lower East Side in New York City, Bjarke Ingels Group, in collaboration with several engineers and planners, is proposing a 10-mile protection zone along the waterfront. The idea behind the project is with the help of raised parklands, floodwalls, berms, and movable floodgates to protect the communities and the $500 Billion finance and business sector along the New Yorker waterfront.
Although construction was delayed by two years due to COVID-19, it is set to begin in Spring 2023 and is scheduled to be completed in 2026. Even before construction begins, the cost of the project "Wrapping the southern tip of the island with an emerald belt of wave-buffering wetlands and parks" (Griffin, 2019) was staggering, with a budget of 335 million USD, which makes it one of the most expensive resilience projects to date (Rebuild by Design, (n.d.).

Fig. 8: Vision of the BIG U by Bjarke Ingels Group

While a giant barrier might seem like an effective solution to protect coastal areas from flooding, critics argue that it oversimplifies the complex issue of climate change and neglects other climate-related threats. Moreover, given the rapidly changing climate, a barrier may only be useful for current conditions and become obsolete within 50 years. The proposed BIG U project has also sparked controversy, as it would require the removal of existing structures and parks to fill the land with around 8 feet (2.4 meters) of soil. However, according to Bjarke Ingels Group, the invisible flood barrier will serve as both a buffer zone for lower Manhattan and a social hub for the community. Engaging with residents during the design phase was crucial for the team, as it provided valuable insights into their experiences, needs, and priorities (Cities of Future, 2020).

"We think of it as the love-child of Robert Moses and Jane Jacobs", said by Bjarke Ingels in a New York Times interview about the New York Dryline (Wainwright, 2015).

The resilience project is incorporating the influential legacies of two major historical figures in New York City's urban planning: Jane Jacobs, who championed organic urban growth without displacement, and Robert Moses, who pursued his vision of revitalization (Walser, 2016). As part of this project, the expressway originally proposed by Moses will be transformed into a public transportation network, helping to mitigate the greenhouse gas emissions that contribute to sea level rise. "Our project must have Moses' scale of ambition, but be able to work at the fine-grain scale of the neighbourhoods. It shouldn't be about the city turning its back on the water, but embracing it and encouraging access. By taking it one conversation at a time, with the principle that everyone can get their fantasy realised, you end up getting there." – Bjarke Ingels (Wainwright, 2015).
Although some residents opposed government decisions, the design process aimed to integrate their feedback and perspectives, highlighting the relationship between Jane Jacobs and Robert Moses. Jane Jacobs, a New York City journalist, protested Moses' highway construction approach that threatened to demolish buildings and Washington Square Park (Walser, 2016). Like the BIG U project, two different parties with distinct visions for the city collided, the planners and residents. Jacobs and her colleagues presented the human-scale living in the urban environment and succeeded in defeating the new development plan.

The Resilience Project in New York City is an ambitious effort that aims to transform the city's transportation infrastructure while mitigating the impact of climate change on vulnerable communities, drawing on the legacies of Jane Jacobs and Robert Moses. The project incorporates residents' feedback and perspectives to balance the needs of different stakeholders and achieve a more sustainable, equitable future for the city.

6. A COMPREHENSIVE STRATEGY FOR DEALING WITH NATURAL HAZARDS

The question of why the city didn't take action earlier and why it required another disaster to prompt action remains unanswered.

"The city's handling of the decision-making process remained a point of contention. Residents claimed the city had failed to sufficiently convey its rationale for abandoning an earlier coastal resiliency plan, which had been developed in collaboration with community members and local stakeholders over the course of several years. "(The Architect's Newspaper, 2021)

New York city's resilience plan started after hurricane Sandy and after hundreds of years of hurricanes, sea level rise and floods. Still 10 years after superstorm Sandy are we "[...] nowhere near where we need to be," and still "[...] [s]ome communities are better protected and some are not. And we're still building in risky areas." (Menon, 2022) leaving communities unprotected.

After analyzing several strategies by the City of New York, the question of whether resilience existed in New York City before 2012 arises. New York City's coastline is a mix of industrial parks, man-made wetlands, beaches, and housing, making it extremely vulnerable. Before Superstorm Sandy in 2012, waterfront protection barriers were almost nonexistent, and there was no overall strategy for how to protect New York. Natural resilience barriers, such as Oyster reefs, were destroyed due to human impact and resulting global warming.
Mayor Michael Bloomberg made suggestions before Hurricane Sandy, but they remained suggestions. The connection of hurricanes and floodings to climate change was only made after Hurricane Sandy, and before that, hurricanes were seen as something rare that could not be changed from a human perspective. Therefore, after Hurricane Sandy, New York City started to spend millions of dollars on projects, which only addressed the short-term damages and not long-term consequences. To actively change the long-term damages, people all over the world need to change their mindset towards global warming and climate change.

New York City can be seen as a leader for other countries facing similar issues. Following its history of flooding and analyzing common influences is leading towards a comprehensive strategy to face the next big flood. While the Big U project by Bjarke Ingels Group is a positive step forward, the effectiveness of the project in the face of future superstorms remains uncertain. Therefore, a comprehensive and long-term plan should be developed based on New York City's history of flooding to ensure the city's resilience against future natural disasters.

When designing a comprehensive strategy against flooding, a city should take into consideration the social aspects, including how to include residents in the projects and how to introduce it into education. Additionally, the financial background of a city seems to be the biggest influence regarding decision making and funding multi-million-dollar projects. Smaller, cheaper, and nature-based interventions, such as the Billion Oyster project, should be supported more and taken into consideration. Restoring nature is the number one aim and goal.
Analyzing past and present flood prevention methods, a well-balanced approach to flood risk management should be the priority. By drawing on the history of New York City, a comprehensive flood prevention strategy can be developed.
Said strategy should be focusing primarily on flood risk management, which requires an understanding of the city's geography, including the history of the ground on which it is built, as well as its climate and hydrology. Once a complete risk analysis is conducted, previous prevention methods should be assessed, and any changes in the built environment that may have contributed to flooding should be identified. It is important to involve residents in the planning process, as they have valuable knowledge about the history of the area and can contribute to the development of effective flood prevention strategies.
Projects such as the Billion Oyster Project, which involve schools in their initiatives, can increase awareness and foster a changing mindset about the need for flood prevention.

To ensure the success of flood prevention strategies, it is crucial to address them not as orders from the government, but as projects developed in collaboration with affected communities. It is also important to protect all social structures, including those in financially weaker areas, by providing prevention and resilience workshops that empower residents to take action themselves. Ultimately, the goal of a comprehensive flood prevention strategy should be to increase social engagement and awareness of the historical ground on which a city is built.
Preventing flooding requires a multi-faceted approach that involves understanding the local geography, climate, hydrology and history, as well as considering the needs and behaviors of the people who live in the affected areas.

A step-by-step comprehensive strategy begins with flood risk management, by assessing flood risk using historical data such as flood maps, weather reports, and local knowledge. By identifying areas at risk, regardless of financial value, the areas that will be most affected by flooding can be identified.
The second step would be community involvement. By conducting public meetings and workshops to discuss the results of flood risk assessments, and by soliciting feedback from residents and addressing their concerns and needs, community engagement can lead to identifying valuable insights and innovative ideas for mitigating flooding. After analyzing public and private needs, a flood management plan can be developed based on the flood risk assessment and community input. This could include building new infrastructure, improving existing infrastructure, or rebuilding natural structures.
The next step is then to implement the flood management plan with community input. Working with local organizations, such as community groups or schools, residents are educated about the plan and their role in reducing flood risk. The goal should be to encourage residents to take actions such as elevating their homes or improving drainage systems in their neighborhoods, thereby raising community awareness.

After and during the implementation of the plan, the effectiveness of the flood management plan should be monitored and evaluated, which can help identify areas where improvements can be made or where additional resources are needed. Involving the community and the city's history in the planning process and implementation of actions will enhance the long-term effects of making a city more resilient to flooding and natural hazards. Learning from history rather than acting after disasters will prevent future damage from hurricanes and could have prevented the 43 deaths during Superstorm Sandy.
In conclusion, despite the devastation wrought by each historical storm since 1788, New York City lacked a comprehensive strategy for flood risk management. The city's handling of the decision-making process remained a point of contention, and it required another disaster to prompt action. While some progress has been made since then, including projects like the Big U and the Billion Oyster Project, a well-balanced approach to flood risk management that involves community engagement and a focus on restoring nature should be the priority. The goal should be to increase social engagement and awareness of the historical ground on which the city is built and to ensure the city's resilience against future natural disasters.

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LIST OF FIGURES