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Perkins+Will is an interdisciplinary design practice offering services in the areas of
Architecture, Interior Design, Branded Environments, Planning + Strategies and Urban Design.

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JOURNAL OVERVIEW

The Perkins+Will Research Journal documents research relating to the architectural and design practice. Architectural design requires immense amounts of information for inspiration, creation, and construction of buildings. Considerations for sustainability, innovation, and high-performance designs lead the way of our practice where research is an integral part of the process. The themes included in this journal illustrate types of projects and inquiries undertaken at Perkins+Will and capture research questions, methodologies, and results of these inquiries.

The Perkins+Will Research Journal is a peer-reviewed research journal dedicated to documenting and presenting practice-related research associated with buildings and their environments. Original research articles, case studies, and guidelines have been incorporated into this publication. The unique aspect of this journal is that it conveys practice-oriented research aimed at supporting our teams.

This is the thirteenth issue of the Perkins+Will Research Journal. We welcome contributions for future issues.

RESEARCH AT PERKINS+WILL

Research is systematic investigation into existing knowledge in order to discover or revise facts or add to knowledge about a certain topic. In architectural design, we take an existing condition and improve upon it with our design solutions. During the design process we constantly gather and evaluate information from different sources and apply it to solve our design problems, thus creating new information and knowledge.

An important part of the research process is documentation and communication. We are sharing combined efforts and findings of Perkins+Will researchers and project teams within this journal.

Perkins+Will engages in the following areas of research:

- Market-sector related research
- Sustainable design
- Strategies for operational efficiency
- Advanced building technology and performance
- Design process benchmarking
- Carbon and energy analysis
- Organizational behavior

EDITORIAL

This issue of Perkins+Will Research Journal includes four articles that focus on different research topics, such as open building design concept for residential building typologies, framework for resilient design, simulations and modeling for healthcare design, and urban design methods for making coastal cities more resilient to climate change.

“Developments in Residential Open Building: Analysis and Reflections of Two Seminal Case Studies” discusses open building concept for multi-family residential architecture, focusing on in-depth analysis of two specific case study buildings. The core principle of the residential open building concept is that the housing must accept change and transformation, and must include the users and building occupants in the decision-making process. By examining two specific case studies, this articles exposes the possibilities and limitations of this particular design concept. The paper also analyzes user involvement in the design process, opportunities, and the benefits of adaptable construction.

“Building Resilience: A Framework for Assessing and Communicating the Costs and Benefits of Resilient Design Strategies” discusses the development of a framework for resilient building design. The article analyzes existing resilience assessment framework for disaster mitigation, and offers a new methodology that integrates sustainability and climate change factors for developing a more inclusive framework for evaluating building resilience including economic factors. The framework has been evaluated using two case study buildings. The conclusions indicate that resilient design offers many benefits, both quantifiable and qualitative (energy savings, improved health, and productivity of building occupants), and that further research is needed that expands beyond building resiliency to urban scale.

“Simulation Modeling as a Lean Tool for Healthcare Design: Determining Room Utilization and Staffing in the Emergency Department” focuses on operational planning and simulation modeling for the design of healthcare facilities. The article outlines the process conducted for the design of an emergency department, where room utilization and staffing were examined based on the current and projected number of patients. A simulation model was developed to simulate patient flow, where patient wait times, census, and staffing rations were used as the key metrics to evaluate the efficacy of the emergency department design. The results were used to determine design scenarios that would better use the space and reduce patient wait times.

“Shrinking Wetlands, Sinking Cities: Why Preserving and Restoring Wetlands Can Help Save Our Coastal Cities” provides insight into effects of climate change and sea waters rise on coastal cities and possible mitigation through preservation and restoration of wetlands. The article includes a literature review, in-depth analysis of two case studies, and also defines next steps and necessary research for wider adoption.

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01.

BUILDING RESILIENCE:

A Framework for Assessing and Communicating the Costs and Benefits of Resilient Design Strategies

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ABSTRACT

Increasing occurrences of natural disasters and effects of climate change are creating more pressure to design resilient buildings that can withstand and adapt to changing risks, while being sustainable and creating healthy environments. A key challenge to the implementation of resilient design is perceived viability and how to incorporate and communicate the long-term benefits into the equation.

This project, by the University of Minnesota Research Practices Consortium and Perkins+Will, aims to expand existing resilience frameworks to incorporate the changing risks from global warming and the importance of sustainability for designing resilient buildings. It seeks to examine how incorporating these discourses can help to reframe the discussion of resilient design from economic factors to one of benefits and reduced risks.

The methodology for the study is based upon analyzing an existing resilience assessment framework for disaster mitigation, and integrates sustainability and climate change factors to develop a more inclusive framework to evaluate building resilience. This framework is tested using two schematic buildings, an office and a hospital located in the Midwest and uses ReLi, the resilient action list, a resilience tool in development by Perkins+Will. The result of this research is a study of resilient design strategies examining their costs and benefits.

KEYWORDS: climate change, risk, sustainable design, financial viability

1.0 INTRODUCTION

Recent natural disasters, such as Hurricane Sandy, have illustrated the growing vulnerability of the built environment, a growing urban population, and more assets located in vulnerable places to a changing climate[1]. This combination of factors is raising the average yearly cost of disasters from $50 billion per year in the 1980's to just under $200 billion per year in the last decade[2]. The interest in designing places that can adapt and respond to these changing risks is increasing, which can be seen with resilience taking center stage at the AIA Convention in 2014[3] through to city plans, such as PlaNYC[4]. These events are helping to ensure that resilience is taken into account along with sustainability. While frequently the impetus for change and the charge to design for changing risk comes after a shock, many cities and organizations are beginning to look at how to design for social, economic, or physical resilience before disaster strikes.

The discussion on resilience has been predominately led by public organizations, such as the City of Chicago, or non-profit organizations including the Rockefeller Foundation and the USGBC. This is changing, as the financial and risk analysis for businesses are increasingly being examined, such as with the "Risky Business Project"[5] launched in 2013. The financial viability of designing for resilience is still a concern, increasing interest in the costs and benefits of resilient design. This paper examines the potential costs and benefits of designing for resilience. It looks at the capital costs for a project when incorporating resilient design strategies and also highlights the current research and studies on the benefits of those design strategies.

Even with this growing global and national interest in resilience, measuring resilience is elusive because it is dependent on context. In each context, whether it is at the scale of the city or a building site, there are different stressors to respond to and this impacts how resilience is measured or framed. For a city or building that is close to the waterfront, how it will respond to flooding or storm surges is essential for measuring its resilience whereas in seismic zones, it is how it responds to an earthquake. Considerations for resilience also include the social or economic stressors within a context. Rockefeller Foundation's "100 Resilient Cities"[6] reflects this variance in measurement and the impact of context. Each 'Resilient City' identifies different stressors and issues to respond to. In Chicago, the key stressors are related to the built environment with infrastructure failure and flooding, in addition to the social concerns of endemic crime. Whereas New York's focus is on rising sea levels, coastal erosion, transportation, and heat waves. This difference in risk is reflected in both New York's and Chicago's city plans. New York's approach to resilience, with the PlanNYC[7], has a strong emphasis on coastal protection of assets, whereas Chicago focuses on its primary stressors of climate adaptation with the Chicago Climate Action Plan[8].

Due to the importance of context when designing for resilience and the potential wide range of stressors to study, this study narrowed the focus to one region. The focus of the study is on the primary acute hazards and the impact of climate change for the Midwest. While the focus of the study is on the Midwest, many of the design strategy findings and analytic approaches in this study are applicable in other regions.

This study was further refined to examine resilient design at the scale of the building and site focusing on a baseline office building and hospital. Since buildings do not exist in isolation, this study's analysis takes into account the interaction between different systems and scales. For example, sustainable design strategies focusing on improved stormwater management not only impacts the site but has broader implications for the city sewage systems and for the climate by reducing the need for treatment and subsequent greenhouse gas emissions. To incorporate these interrelationships in the analysis, a set of 28 design strategies was selected to examine. From this information, a booklet – Resilience Design Booklet: A Framework to Quantify + Assess Resilience - of those design strategies was developed to begin to compare design strategies and communicate the benefits and costs of designing for resilience.

1.1 Framing Resilience

Since resilience is a malleable term with many different meanings and interpretations, the initial research stage focused on situating this study within those ongoing discussions. The definition of resilience influences the hazards that are designed for and the design strategies chosen. In relation to the built environment, there are three predominant approaches to resilience: ecological, engineering, and an emerging concept of evolutionary resilience. Each frame is discussed further below. However, resilience is increasingly being viewed as a combination of all of these. Resilience is designing for the acute hazards, chronic hazards, the interconnectivity between systems and scales, and the influence of climate change with a focus on the way these crises fundamentally change how we live.

Engineering resilience focuses on the stability and constancy within the system that ensures the protection of physical or human assets[9]. FEMA's disaster mitigation guidance[10], the Fortified for Safer Business Program[11] and the design of stronger buildings predominately focuses on this type of approach for mitigating risk. The issue with a sole focus on engineering resilience is that it results in catastrophic failure when it does fail and can disconnect the building from its context with unintended consequences. Hurricane Katrina is a well-known instance of catastrophic failure. While the city was protected during many smaller events, reliance on one system for protection and complete trust in it created the conditions where failure of the levee had massive consequences. The flooding in Europe in 2013 of the Danube River is one example of successful resilient design with unintended consequences further downstream. Flood mitigation measures installed in response to earlier floods in Dresden allowed this city to remain unscathed, however, it made the situation worse in other areas[12].

Ecological resilience is a systems-based approach focusing on "the magnitude of disturbance that can be absorbed before the system changes its structure[13]." It is based in preserving the functionality of the system as a whole. Design strategies for ecological resilience focus on those that build in adaptability, redundancy, and diversity into the system allowing for small failures while minimizing the chance of catastrophic failure[14]. Examples of these strategies can be seen in the USGBC Building Resiliency Taskforce[15], such as incorporating renewable energy supplies to mitigate the consequences of power outages to diversifying the energy supply chain. This approach to resilience heavily incorporates sustainable design strategies. It looks at the longer term and the relationships between different systems and scales from the building to the city.

Evolutionary resilience is a more recent approach. Unlike an engineering or ecological approach, evolutionary resilience questions the assumption that the previous behavior of a system is a good indicator of future behavior. This approach emphasizes that a system transforms when exposed to stressors and can fundamentally change the behavior of the system as a whole, requiring new ways to adapt to it[16]. Evolutionary resilience views climate change as an element that is introducing a number of new stressors into the system that will transform how we live. Programs on the West Coast such as San Francisco's 'Non-potable Water Program'[17] show how the continual stress of drought is creating fundamental changes in the system from its past behavior and encouraging a new approach to how water is managed, such as rainwater capture or even use of graywater. When in designing for greater resilience in a building different approaches might be needed, or a combination of them, in order to design for the key stressors.

Instead of focusing design strategies that only respond to one framing, this study focuses on design that thoughtfully responds to the risks and the context in which the building is located and integrates design strategies from each of these ways of framing resilience. The aim for resilient design is to "pursue buildings and communities that are shock resistant, healthy, adaptable, and regenerative through a combination of diversity, foresight, and the capacity for self-organization and learning[18]."

1.2 Methodology

The study was based on a literature review examining how resilience has been framed starting from C.S. Holling's seminal text to more recent approaches, such as the "City Resilience Framework[19]." This study also builds on related literature within the fields of sustainability and green design, disaster mitigation, and climate change to identify some of the key themes and issues for resilient building design in the Midwest.

The initial framework and assessment for resilience is based upon Bruneau's existing disaster mitigation framework, "Framework for Analytical Quantification of Disaster Resilience[20]." While Bruneau's framework provided a good base for the organization of the study, since it evaluated resilience through the lens of an acute disaster, it limits resilient design primarily to an engineering framework. To broaden the scope to the additional framings of resilience and incorporate the wider range of stressors into the study, three key additional issues were identified for the literature search. In addition to disaster mitigation and acute hazards, climate change, sustainability (indicators based on LEED), and the role of the building in the community were incorporated. Table 1 shows the framework.

Table 1: Adapted Resilience Framework and Assessment incorporating key issues of climate change, sustainability, and the role of the community.

Building and Context	**Resilience Assessment**	**Adaptation + Modification**
Baseline Building	Cost Modeling	Design Strategies
Risks	Capital Costs	Benefits
Acute Hazards	Operational Costs	Costs
Chronic Hazards	Acute Disaster Indicators	
Climate Change Impact	Failure Probability	
	Time to Recover	
	Consequences from failure	
	Sustainability Indicators	
	Energy + CO2 Emissions	
	Water	
	Air Quality, Resources	
	Health + Wellbeing	
	Community Role	

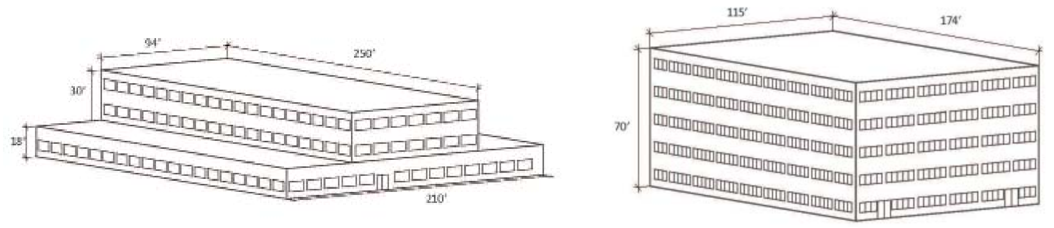
Since the scope of the research was narrowed to the Midwest, the study focuses on the key stressors of the region and a focus on acute and chronic hazards due to climate change. The National Climate Assessment was used to develop a list of the chronic hazards for the region. These include an increase in high temperatures and extreme heat days, changing seasonal precipitation patterns resulting in increased flooding and drought, and poorer air quality[21]. High winds, hail, and tornadoes were additional acute hazards incorporated into the study, as they are common stressors in the region.

Further refinement in the scope was to focus on the building and site scale to simplify the potential number of design strategies that needed to be examined. A set of 28 design strategies, described in Table 2, mitigating the hazards for the building scale were developed from ReLi, a resilient design tool in development by Perkins+Will, in addition to guidelines such as LEED[22] and FEMA[23]. ReLi is a resource and leadership tool focusing on key criteria at both the community and building scale for resilience. These design strategies were then applied to two baseline test buildings – that of a hospital and office –to evaluate the costs and benefits. The hospital was selected due to its role in contributing to a community's resilience and its role as a critical facility during an acute hazard. Since the financial implications and needs of a hospital are different than the majority of buildings, analyzing only hospitals limits the applicability of the study. An office building was incorporated to broaden the study, as it contributes to the long-term resilience of a community. Resilience is not only about responding to the acute and chronic hazards; however, it is also about everyday functionality and how that functionality returns after an acute hazard.

Table 2: The investigated design strategies and the acute and chronic hazards they mitigate including general hazard preparedness.

Design Strategy	Hazard	Description
Above 500 year Flood Plain	Flooding	Build above the 500yr flood plain, taking into account future projections due to climate change.
Backup Power (16 + 96 hrs)	Hazard Preparedness	Provision of a backup generator running on diesel or natural gas providing sufficient fuel for 16hrs (office) or 96hrs (hospital).
De-Couple Systems (DOAS)	Air Quality + CO_2 Emissions	De-couple the thermal conditioning of the building from ventilation systems installing a DOAS unit, ductwork and controls for ventilation.
Envelope Strengthening	Tornadoes, High Winds, Hail	Laminated glass window assemblies, strengthening roof systems to resist uplift, doors and windows designed to comply with wind testing loads.
Exterior Shading	Hazard Preparedness	Shading devices applied to the south and west sides of the building.
Form for Daylighting	Air Quality + CO_2 Emissions	Narrow floor plate designed for daylight with daylight sensors.
Graywater Treatment	Drought	Gray water treatment installed for use in bathrooms or as irrigation.
Green Roofs	High Temperatures	Extensive green roof.
Heat Recovery	Air Quality + CO_2 Emissions	Heat recovery ventilation system.
High Performance Envelope	Hazard Preparedness	High performance envelope: Wall R-value=25, Roof R-value= 50, Window R-value=4.5

Design Strategy	Hazard	Description
Increased Ventilation	Air Quality + CO_2 Emissions	Increasing the breathing zone air ventilation rates to occupied spaces by 30% above the minimum ASHRAE rates.
Low Emitting VOC Materials	Air Quality + CO_2 Emissions	Use of materials with low or zero emitting VOC's.
Material Specification	Tornadoes, High Winds, Hail	Avoid specifying materials that perform poorly in high winds based on FEMA recommendations.
Passive Cooling	Hazard Preparedness	Shading, operable windows, and green roof.
Permeable or pervious Paving	Flooding	Change 50% of pavement to pervious pavement.
Raise Critical Equipment	Flooding	Raise the critical equipment and backup systems above the 500 yr flood mark. This study used a mechanical penthouse.
Rainwater Catchment	Drought	Addition of storage tanks and a circulation pump.
Reduce Soil Compaction	Flooding	This study used soil amendment to reduce compaction.
Reduce Water Use, Indoor	Drought	Use of low flow fixtures (Water Sense labeled in this study).
Reduce Water Use, Landscape	Drought	Reduce landscape water use by 50-100%. This study assumed the use of native plants, taking into account changes in climate ranges.
Renewable Energy	Air Quality + CO_2 Emissions	Renewable energy (using solar panels) that makes up 5% of the total building energy.
Safeguard Toxic Materials	Flooding	Ensure toxic materials are stored above the 500 year flood plain.
Sewage Backflow Valve	Flooding	Installation of a sewage backflow valve to prevent sewage from flowing into the building in flood prone areas.
Trees and Vegetation	High Temperatures	Increase of trees and vegetation on site by 10% reducing the site temperature.
Tornado Safe Room	Tornadoes, High Winds, Hail	Tornado safe room based on FEMA 361 added to each floor.
On-site Storage	Hazard Preparedness	On-site storage for 96hrs of essential food, supplies and materials in hospital above the 500 yr flood plain.
Operable Windows	Hazard Preparedness	Each window has an operable windowpane for passive cooling when the power is out.
Water and Power Outages	Hazard Preparedness	Ensure water is available and that toilets and sinks work when the power is out. This study added a storage tank to the roof to ensure sufficient water pressure.



Office
Area: 100,050 GSF
Capital Cost: $22,877,000
Cost/GSF: $229/GSF
Glazing: 30%

Acute care Hospital
Area: 129,450 GSF
Capital Cost: $59,434,000
Cost/GSF: $459/GSF
Glazing: 30%
Beds: 50

Figure 1: Baseline buildings and initial costs.

Two different approaches were used to evaluate costs and benefits. For the costs, two generic baseline buildings were developed and are represented in Figure 1. With those baseline buildings, Mortenson Construction helped to evaluate an initial capital cost and the additional costs of each design strategy. The baseline building cost was based on five representative projects for each building type – for both the office and hospital. These representative projects were then averaged to develop a baseline building cost for each type. Figure 1 shows the cost for the two baseline buildings in addition to the parameters for the buildings.

The benefits were more difficult to determine and, instead of an exact quantification, are based on existing studies and research for the benefits of each strategy (in the Resilience Design Booklet, all the benefits and the relevant publications are stated). There were limitations within this approach, particularly in how to incorporate the benefits of an integrated design solution and how many of these strategies could result in savings in the capital costs, such as a reduction in mechanical system size.

2.0 FINDINGS

This section presents the key findings of the study, the primary issues for resilience in the Midwest and the potential costs and benefits of resilient design. This section also identifies potential areas for further research.

2.1 Resilience and the Issue of Climate Change

The Midwest will experience, and is already starting to feel the impact of climate change. Heat waves and downpours are becoming more frequent and snow and ice is arriving later and leaving earlier[24]. Depending on different emissions, climate change scenarios, and mitigation, this will influence the types and amount of adaptation strategies required in the future to respond to the increased risks. To avoid the worst consequences of climate change, the scientific evidence shows that emissions need to be reduced enough to keep temperatures from rising 2°C (3.6°F) above pre-industrial levels[25]. The amount and extremes of climate change risks can still be influenced by choices made today on addressing climate change, however, the time frame for influence is decreasing[26].

This study found that a number of design strategies implemented now influence both the adaptation and mitigation of the impact of climate change. Minnesota, Wisconsin, Iowa, and Michigan, for example, are either in the process or already have state adaptation plans for climate change. Sustainable design and passive design strategies in particular contribute to both adaptation and mitigation. Some of the strategies that adapt and mitigate climate change include: green roofs, exterior shading devices, high performance envelopes, and an increase in trees and vegetation on site. These strategies reduce the greenhouse gas emissions; however, they also ensure a level of thermal safety during acute hazards. This is especially relevant for hospitals as they are large consumers of energy in the building sector[27]. Recent disasters have raised concerns about the thermal safety during acute hazards, such as in Hurricane Katrina and extreme warming forcing evacuation[28].

There is also strong evidence of additional benefits such as improved health and productivity of building occupants[29].

2.2 Costs and Benefits of Resilient Design Strategies

Resilient strategies' initial capital costs are much easier to quantify than benefits (these estimates are approximate because this study did not have a specific site and was focusing on the regional scale). For the 28 design strategies, each of these could be quantified and the majority were less than one percent of the total capital cost of the buildings (for both the hospital and offices). The design strategies that had higher costs included the mechanical systems, such as heat recovery system, or tornado hardening. The benefits of an integrated design approach were difficult to quantify. Within capital costs, the reduction in mechanical system sizes that would result from a passive design approach were not reflected. An integrated design approach would influence the cost and reduce the capital costs associated with resilient design.

While the capital costs could be identified, the benefits presented more of a challenge. The literature is growing for the long-term benefits of design strategies, particularly for sustainable design. However, how those benefits are measured, who accrues the benefits, and the quantity of evidence varies by design strategy making it difficult to directly compare or communicate what potential benefits are for a project. For these reasons, the benefits were more loosely defined with the aim being to illustrate these complexities and at the same time begin to identify possible benefits, who benefits, incentives that might change the equation and the studies or research that information is based on. Figure 2 provides an example of one of the strategies – green roofs. The Resilience Design Booklet contains the findings for each of the 28 design strategies and this example is illustrative that for many of the design strategies, there are a number of potential benefits from acute hazard mitigation through to addressing chronic hazards; however, the quantification of the benefits depends on context, who benefits and the incorporation of a systems analysis instead of a narrow focus on the building. For

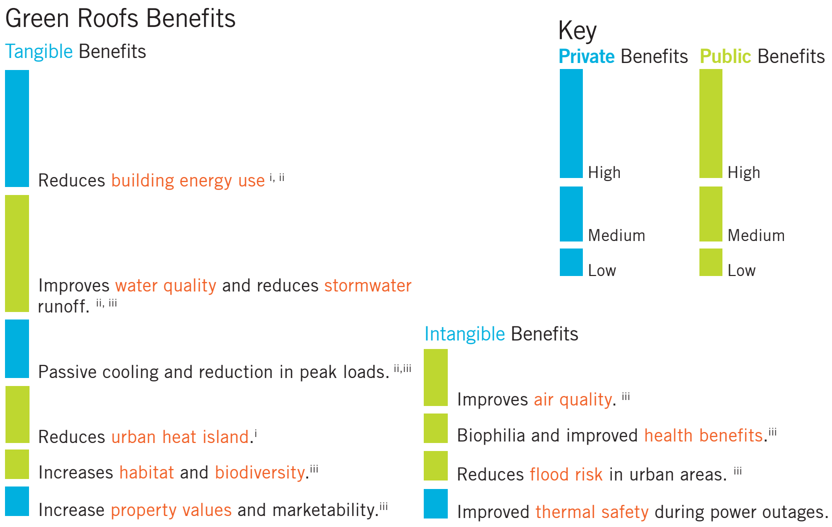


Figure 2: Example of the benefits of green roofs.

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[i] Environmental Protection Agency (EPA), (2013). "Green Roofs", On-line article, Retrieved from http://www.epa.gov/heatisland/mitigation/greenroofs.htm

[ii] Center for Neighborhood Technology (CNT), (2010). "The Value of Green Infrastructure", Article, Retrieved from http://www.cnt.org/repository/gi-values-guide.pdf

[iii] Banting, D., Doshi, H., Li, J., Missios, P., (2005). "Report on the Benefits and Costs of Green Roof Technology for the City of Toronto", Ryerson University

all of the design strategies, the benefits referenced are findings from existing studies and literature.

Even though the research for many of the design strategies have only recently begun to identify all of the potential benefits, there were a number that have already shown to provide a return on investment. Many of these are based in sustainable design and include green roofs, trees, and reducing soil compaction in addition to passive design strategies, such as shading and high performance envelopes that reduce the energy use of the buildings. Other strategies, such as permeable or porous paving, have a strong and growing body of evidence for their benefits. However, further research is needed as there are a variety of materials or approaches for permeable paving that influence the financial equation with research showing that there is a shorter lifespan and higher maintenance required, depending on the types used. The Resilience Design Booklet begins to identify the existing research and potential benefits of resilient design.

2.3 Additional Costs of Resilient Design for a Project

As mentioned, the challenge with the breadth of the study meant that the costs and benefits of an integrated design approach were difficult to incorporate. This was particularly the case with the design strategies that would impact the mechanical systems. The potential reduction in the initial sizing of the mechanical systems, due to reduced load, was challenging to incorporate without an in-depth energy analysis to determine the load reduction. Design strategies that would influence it – and would help to reduce initial capital costs – include the green roof, building form, de-coupling systems, operable windows, and shading devices. The reduced capital cost from implementation of particular strategies was not incorporated.

With the 28 design strategies quantified – shown in Table 3 - this research then applied them to both the hospital and the office baseline building to see what the potential added costs were. As the study was based in the Midwest and not at a particular site, all of the strategies - except for graywater treatment for both buildings and rainwater collection for the hospital - were included in the added cost. For this study, graywater treatment was not included due to its costs and the Midwest context. While the Midwest will have a changing relationship to water and drought conditions, severe drought is not as key of a stressor as on the West Coast. Due to the cost of the system, using graywater makes more sense in areas experiencing severe drought. In addition,

Table 3: Additional costs of resilient design strategies for the office and hospital buildings.

Design Strategy	Office: Design Strategy Added Cost	Hospital: Design Strategy Added Cost
Above 500 year Flood Plain	$0	$0
Backup Power (16 + 96 hours)	$10,000	$260,000
De-Couple Systems (DOAS)	$337,500	$685,000
Envelope Strengthening	$1,203,000	$1,320,000
Exterior Shading	$170,600	$100,000
Form for Daylighting	$262,500	$489,000
Graywater Treatment	$275,000 (not included)	Not included
Green Roofs	$200,000	$510,000
Heat Recovery	$240,000	$800,000
High Performance Envelope	$285,000	$394,000
Increased Ventilation	$162,500	$292,500
Low Emitting VOC Materials	$0	$0
Material Specification	$0	$0

Design Strategy	Office: Design Strategy Added Cost	Hospital: Design Strategy Added Cost
Passive Cooling	Costs included in specific design strategies (Exterior Shading, Green Roofs, Shading, Operable Windows, Trees and Vegetation)	Costs included in specific design strategies (Exterior Shading, Green Roofs, Shading, Operable Windows, Trees and Vegetation)
Pervious Paving and Reduced Soil Compaction	$176,000	$578,000
Raise Critical Equipment	$220,000	$400,000
Rainwater Catchment	$176,500	Not included.
Reduce Water Use, Indoor	$25,000	$424,000
Reduce Water Use, Landscape	+ $70,025 (operational savings)	+ $125,000 (operational savings)
Renewable Energy	$175,000	$1,186,500
Safeguard Toxic Materials	$0	$0
Sewage Backflow Valve	$5,000	$5,000
Trees and Vegetation	$140,000	$249,500
Tornado Safe Room	$461,500	$1,075,500
On-site Storage	$0	$0
Operable Windows	$11,000	$18,000
Water and Power Outages	$150,000	$450,000

rainwater was not included for a hospital due to varying codes and differing views on using rainwater within a hospital setting.

Additionally, on projects and with an integrated design process, not all the design strategies would be applied. Instead, the design strategies selected would be those that respond to the key risks and stressors for that particular site. There would also be an interplay between many of the strategies. To manage stormwater, for instance, a combination of strategies would probably be used and those selected would be highly dependent on context and site. In urban areas with limited space, green roofs would be a more efficient use of space to manage stormwater than wetlands. Context is key to the strategies selected and employed.

Assessing the potential added costs for a project - with the design strategies in Table 3 applied to the baseline buildings - this study found the added cost was between 15-19 percent for the hospital and office buildings, with the hospital being on the lower end of the range. However, these costs are on the high side due to the design of the study; particularly the lack of an integrated design approach and, as in many projects, a mixture instead of all the design strategies would be applied. Depending on the context, scale, and program of the building – if it is a critical facility or an office building - these will influence the costs and also design strategies selected when designing for improved resilience.

2.4 Related Evidence for Resilient Design

Other projects that illustrate the potential costs of resilient design are the rebuild of Mercy Hospital in Joplin and the “Targeting 100!” Study by the University of Washington. In the case of Mercy Hospital in Joplin, it was hit by an EF-5 tornado in 2011 where six patients died in the hospital. The new hospital was designed to be ‘virtually tornado proof’ with safe zones for each floor, laminated glass designed for EF-3 tornadoes, and in critical patient areas, hurricane rated glass, along with two protected backup generators, two independent electrical feeds, and water supplies[30]. The design of the hospital in Joplin used more extensive tornado hardening than this study proposed. The additional cost for the tornado hardening was approximately 2-3 percent of the total project cost. These measures mitigate the future consequences from a tornado and the potential costs from a tornado, as was illustrated in Joplin, range from loss of life, the loss of the building through to renting temporary facilities, staff retention, and the more intangible cost to reputation. Evaluating the full cost from a disaster is another area for additional research incorporating not only the physical asset loss, but also the costs until recovery and the intangible costs.

While Mercy Hospital is designed for resilience to acute disasters, "Targeting 100!" is a study by the University of Washington's Integrated Design Lab providing a roadmap for hospitals to achieve the 2030 Challenge with a 60 percent energy reduction, with the strategies tested in each region of the United States. Energy and greenhouse gas emission reductions are a key element in mitigating climate change and building for resilience. The "Targeting 100!" study used similar design strategies as this research; however, they used an integrated design approach early on in the process and in-depth energy modeling. Some of the design strategies to reduce energy use included: high performance envelope, 30 percent glazing area, dynamic shading, form for daylighting, and displacement ventilation with radiant panels. "Targeting 100!" found that a 60 percent reduction in energy use was possible with a three percent added cost and a nine percent return on investment[31]. Both of these examples and the difference with this study illustrate the need for further research examining the potential costs of designing for resilience – particularly on real projects.

3.0 CONCLUSION

This study indicates that there is strong evidence that resilient design offers many benefits, both tangible and intangible. The Resilience Design Booklet describes the evidence for the benefits of design strategies; however, this study has not quantified a summary figure for those benefits. This is due to the differing units of measurement used for assessing the benefits of design strategies that range from cost and operational savings through to intangibles, such as productivity or improved health. Providing a summary figure for the benefits - given the wide range and different quantifying techniques - would require a more narrowly defined site and context.

While there are benefits and designing for resilience mitigates risks, resilience is still an elusive topic and is an area where further case studies and research is needed. Sustainable design and passive design strategies offer the greatest potential for benefits from energy savings, improved health, and productivity of building occupants. The impact of these changes can be large if these strategies are adopted on a broader scale, such as Chicago's Green Roof Initiative, influencing flood risk through to stormwater systems and improved health and air quality – all issues that the Midwest will be experiencing due to climate change. While this research focused on the building scale, the analysis of the benefits of the design strategies highlighted the interrelationships between different systems and scales. The building is part of larger systems and is intimately connected to them. A building is only as resilient as the larger systems to which it is connected.

Current trends will also create change within the cost and benefit equation. Energy efficiency improvements in ASHRAE 90.1, its impacts on LEED and state codes, in addition to the declining costs of solar and renewable energy, will transform the future cost of energy and renewable systems. Through reducing energy use in a building, this can minimize exposure to changing energy costs, while mitigating the costs if an acute hazard occurs with improved thermal safety. Resilient design can offer operational and long-term savings while also building in the ability to respond to an acute hazard.

Further research will help to inform and clarify these issues; however, an important question is raised: what are the risks from waiting to adapt to and mitigate climate change? There are significant economic risks from climate change[32] and there will be additional disruptions to systems that we rely on, such as energy, food, and water. Once global warming and temperatures rise above 2°C, the opportunity to mitigate climate change will decrease with more extreme risks to design for. The key finding of this research is that the costs of designing for resilience on a project can be quantified; however, further research is needed to measure resilience and the potential costs or benefits – short-term and long-term – on a project. As these issues are based on context, this cost will likely vary based on the key risks for a specific site. Meanwhile, the risks from climate change are becoming clearer, with the IPCC report and Risky Business, and the research on potential benefits of resilient design strategies is growing with many strategies already offering a return on investment.

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02.

DEVELOPMENTS IN RESIDENTIAL OPEN BUILDING:

Analysis and Reflections on Two Seminal Case Studies

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ABSTRACT

The focus of this article is the open building concept in multi-family residential architecture. The article analyzes and examines two specific projects: the Solid Oud West in Amsterdam (2010) and the Plus Home experience in Helsinki (2005). By the analysis of these projects, the article seeks to define the state-of-the-art in open building practice, and aims to expose the possibilities and limitations that this kind of architecture offers.

The research focuses on the three main topics related to open building implementation: the possibilities of user involvement in the design process, the opportunities for an open and time-based housing design, and the benefits of an adaptable and industrialized construction. The outcome of this research seeks to inform about this trend in residential architecture and how this could affect the building industry as a whole, and architectural practice in particular.

KEYWORDS: open building, industrialization, user participation, housing, flexibility

1.0 INTRODUCTION

Open building organization is an architectural concept with growing importance in countries such as Japan, Netherlands, China, and the United States. It promotes an open and adaptable architecture aiming to fulfil the diverse and changing needs of users over time.

This article seeks to define the state-of-the-art of open building practice. To this end, it analyzes two seminal open building projects carried out in the last decade in Europe, in the specific field of residential architecture: the Solid Oud West in Amsterdam (2010) and the Plus Home experience in Helsinki (2005).

These two projects have been selected for being two of the most innovative open building projects carried out in the last decade: each of the projects has its own characteristics and they are both original in a specific way. The intention of the analysis is to expose the opportunities and limitations of the open building methodology, outlining the benefits and weak points of each project.

The article is divided in three sections. Section 2.0 explains the open building methodology and principles. Section 3.0 is the core of the research; it includes the analysis of the case studies, and reflections on the opportunities and limitations of each approach. Final conclusions and suggestions for further research are included in the last section.

2.0 OPEN BUILDING PRINCIPLES

Open building principles were first articulated by a Dutch architect John Habraken in his seminal book De Dragers en de Mensen (1962), translated and published in English as Supports: An Alternative to Mass Housing (1972)[1]. In this book, Habraken presents a paradigm shift in relation to how the housing project is conceived, that is to say, how a residential building is designed, managed, built, and ultimately occupied, pointing three key issues at the core of housing as a design problem in the 21st century: housing must be diverse, housing must accept the change and transformation, and housing must incorporate the user as part of the decision-making process.

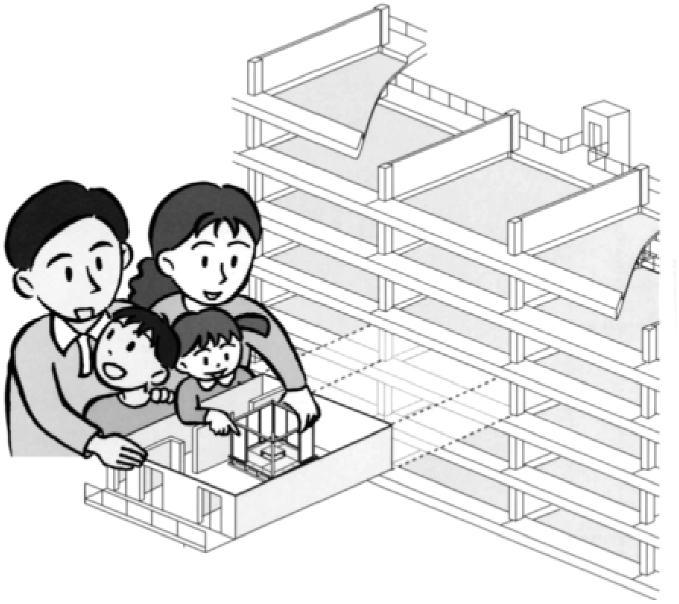

Figure 1: Support and infill separation. Image courtesy of HUDC Japan.

His proposal was based on a fundamental concept: the recognition of two distinct spheres of action and control in a collective housing building (the act of building and the act of inhabitation, separating the collective, fixed and permanent components of a residential building from components that could be transformed by individual dweller)[2]. These permanent elements - what is called the support or base building, include the structure, services, access and normally the facade; whereas the detachable units -fit out or infill- are the internal partitions, closets, bathrooms, kitchens and piping and ducts related to this equipment. Habraken proposed the separation of the design process of a residential building in two stages or construction phases. In this way, involving the user as a participant, it would be possible to respond to his/her specific requirements.

Open building proposal arises from a broader reflection on our cities and territory and it is based on three fundamental principles. The first one is the understanding of our built environment as a never-ending changing environment where buildings are transformed over time. The built environment – our buildings and by extension our cities – is a live organism, driven by rules and principles difficult to control and predict, which serves our needs through its continuous adaptation and transformation[3].

Open building principles are based on the perception of this built environment as a multi-layered structure, where five primary physical systems are recognized. Within a city, we can identify the urban structure, the urban tissue (blocks), the buildings, the infill components and the actual furniture. Each of these systems has a different life span and should be related to different levels of control and responsibility. Our built environment is sustainable to the extent that each of these systems can be transformed independently and part by part. This is the goal of open building. In short, it is about proposing an architecture able to distinguish the changeable from the permanent[4].

The second principle is based on the idea that if our built environment is to be healthy and sustainable, both users and communities need to be part of its design process. Until the 20th century, people designed and even built their houses in close collaboration with builders or skilled workers. This “natural relation” between users and built environment was broken with the modern movement -the mass housing, and the progressive “professionalization”, “institutionalisation” and “legislation” of the planning and building procedures within the last century. The appearance of new agents in the process, such as bankers, politicians, lawyers, contractors, and specialized consultants gave birth to new complex

Figure 2: Ensanche Cerda (Barcelona). Variations and transformations in the built environment. (Image courtesy of Stephen Kendall).

ways of collaborative working, which left the user out of the decision making process. The point to be made is clear: if private developers, professionals, or authorities are the only parties involved in the making of cities, the result is uniformity, where the users are excluded and cannot participate in the decision-making process related to their living environment.

The third principle is a consequence of the first two and relates to technical issues. The distinction of these two systems with different lifespan in a building (infrastructure and infill), and the requirement for equipment of the separable units, gives rise to a new sub-sector of dedicated fit-out elements. This new market is based on the open industrialization of components, which could give to the users a possibility of choice between different options of performance, quality, and cost offered by the building industry.

Within the context of a society in which major technological changes are occurring, each of the elements required in a building should be able to be changed by others. In short, it is about understanding a building as a sum of independent systems, so that each of them can be replaced and updated without affecting the others. The best example to illustrate this “technical principle” is the automobile: despite being also a complex product, its systematized production allows for the possibility of user choice and customization, as well as the continuous upgrade of its components.

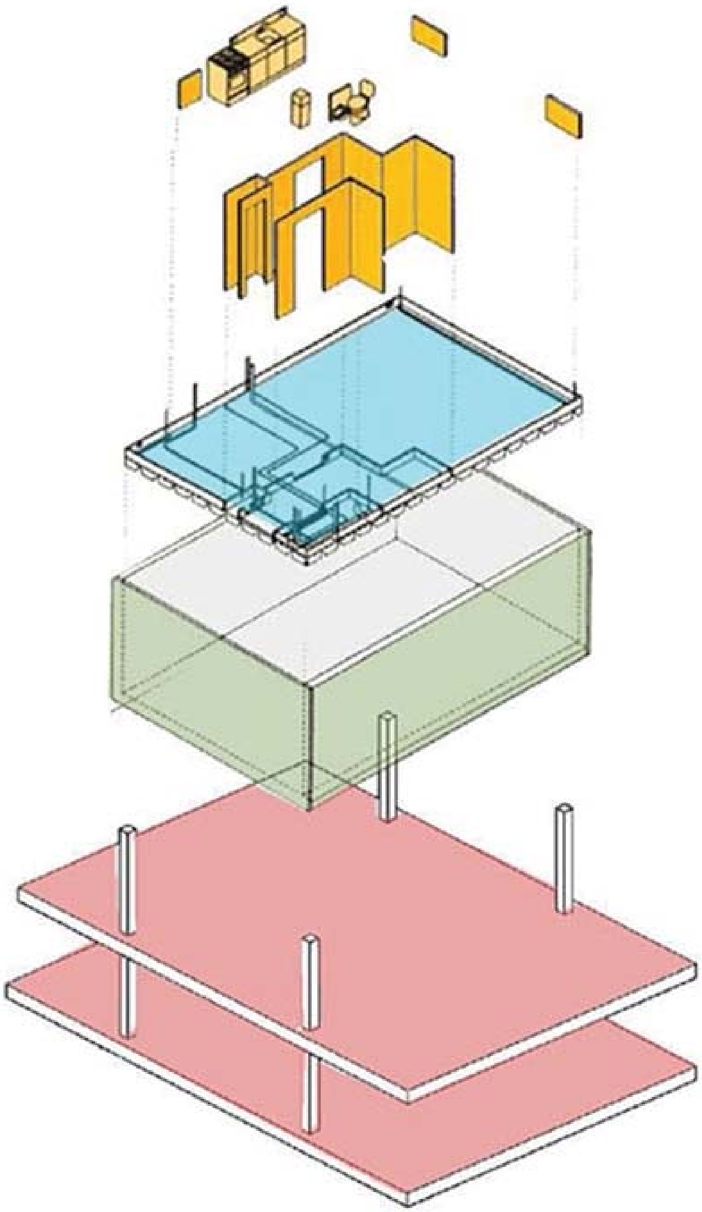

Figure 3: Separation of subsystems with different lifespan.

3.0 CASE STUDIES

3.1 Case Study One: Solid Oud West, Amsterdam (The Netherlands, 2010)

The Dutch housing corporation Stadgenoot, a non-profit private organization with links to local authorities, initiated the design and construction of the "Solids" in Amsterdam in 2010.

According to Stadgenoot, a Solid is a sustainable building constructed to be capable of lasting at least 200 years, and designed without a predetermine purpose; in fact, it should be able to accommodate any legal functionality. Solids are inspired by the 19th century New York warehouse buildings with their monumental and strong cast iron facades that are still in use today, and which for decades have been able to attract a wide variety of uses[5]. The Solid approach is based on a fundamental concept: a basic infrastructure is designed and delivered as a shell, ready to accommodate a variety of changing user-determined fit-outs over time. This enables the rented space to be designed for a whole range of purposes: living, working, cultural activities, or any combination of these functions.

Stadgenoot finished the construction of the first Solid, called Furore, in April 2011. Two other Solids were completed one month later. This article reviews Furore building, designed by the architectural practice Tony Fretton Architects. This building received the Royal Institute of British Architects (RIBA) European Award for great architecture in 2012.

Figure 4: Solid Oud West by Tony Fretton Architects. (Image courtesy of of Peter Cook and Tony Fretton Architects).

Furore is located in the Oud West district, close to Vondelpark (a central area of Amsterdam characterized by a mix of uses and never-ending activity). The complex consists of two brick constructions separated by a central atrium, which allows the access from the street into the building. The atrium connects the two volumes through the ground floor, facilitating circulation and generating a communal space. The cores are centrally located within the floor plan, connecting the ground floor with the upper levels and the garden terrace. Also, an external corridor around the atrium facilitates an alternative access to each level.

The design process was divided in two stages. The architectural task during the first phase was limited to the design of the common elements. The floor plate was then defined by the external perimeter, a neutral brick enclosure, which can accept different uses in its interior.

The structure of the building works on an eight meter column grid and is based on a precast light-weight concrete slab system, which spans from the perimeter to the central beams. This large span structural system enables a great degree of internal spatial freedom, avoiding the appearance of intermediate structural elements and facilitating an internal flexible arrangement. The generous floor-to-floor height (3.5 meters) allowed accommodation of a "thin" raised floor (about 15 centimeters), used for running wires, heating and water supply pipes, and ventilation ducts. The final three meters clear height is also suitable for non-residential uses, such as commercial and retail functions.

The final result of this first design phase was an open plan, a clear and empty floor plate that allows the users to allocate the partitions, finishes, and equipment according to their needs and economic situations.

Figure 5: Interior of Solid Oud West under construction.

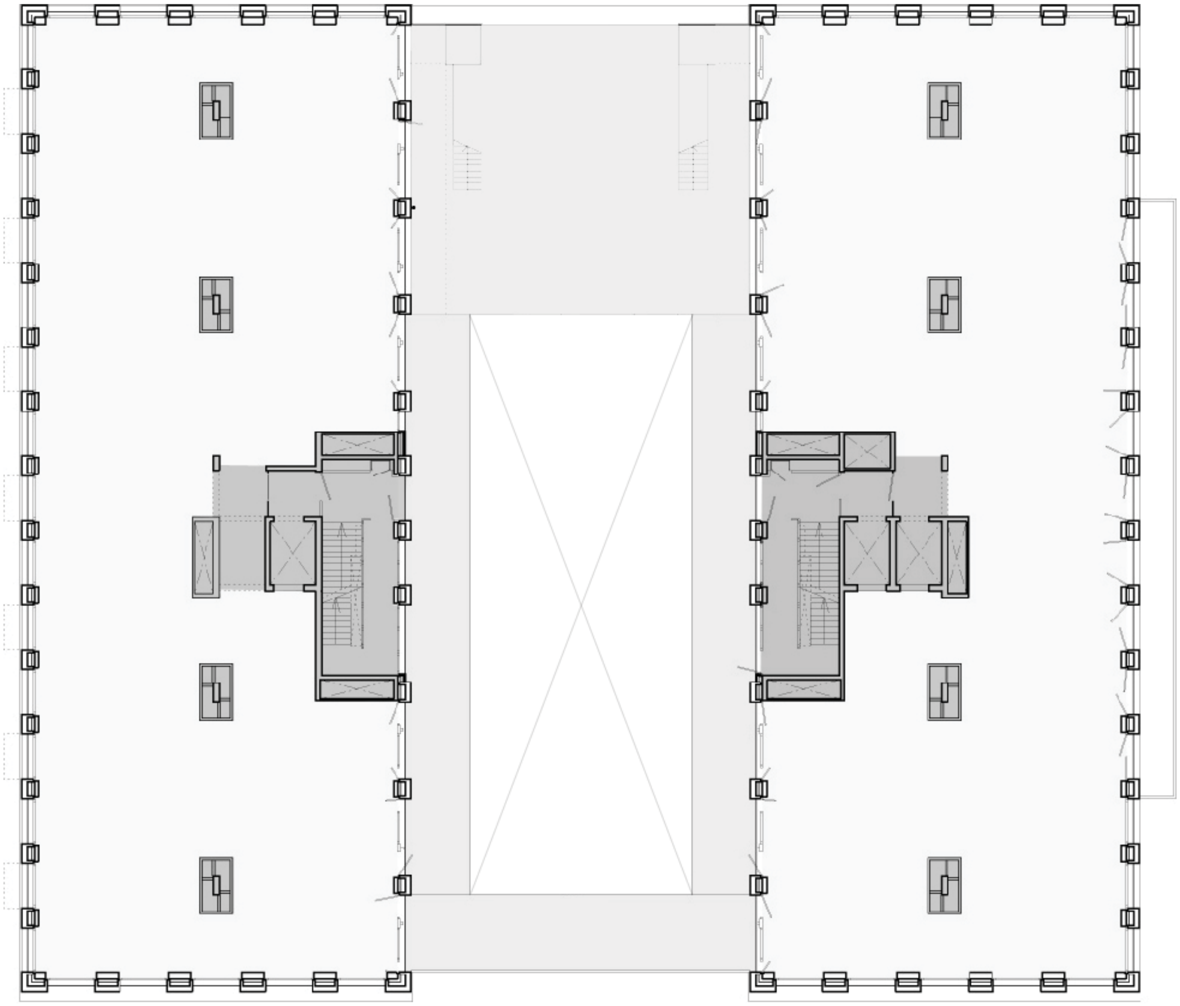

Figure 6: Solid Lv01 support plan (Image courtesy of Tony Fretton Architects).

For this second phase, the distribution of the spaces was carried out through an on-line system, where future residents chose the amount of area needed and the position of their dwelling in the complex. The challenge that Stadgenoot faced in this phase was to allocate the space in the Solids to the interested bidders. The main objective was not making profit, but to obtain a balanced functional mix between the different user types (residential, commercial, and social tenants).

The first group (residential) consisted of users who planned to live in this building, and the second group included individuals who planned to open businesses in this complex (commercial). The third group comprised low-income people (social tenants). For this purpose Stadgenoot developed a dedicated combinatorial auction system, which allowed bidders to choose the amount of space required. Therefore, the Solid was divided into 125 lots, which the residents could use and combine as building blocks to specify solid spaces[6].

Once the specific areas were assigned and the partitioning built, the flats were delivered to the users as "shells". These "shells" were provided with the insulation and demise walls between units, but did not include any internal partitions, doors, bathrooms, kitchen, or specific equipment. The design and construction of the interior of the flat was entirely up to the dweller. The developer

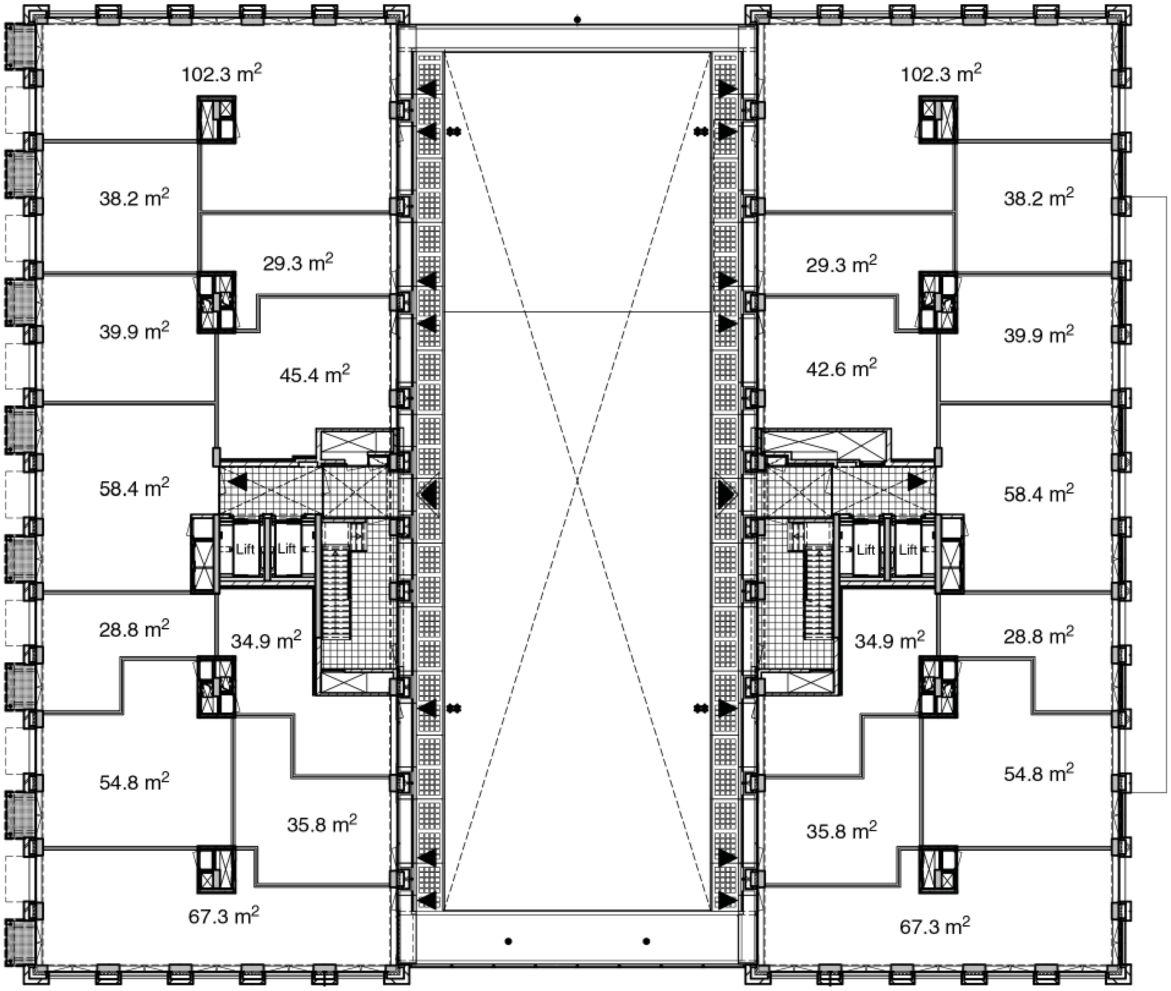

Figure 7: Solid Lv02 proposed allotment plan (Image courtesy of Tony Fretton Architects).

made available to the users different options, offering the service of suppliers of equipment, designers, and interior decorators that would propose solutions based on the user needs. Also, if preferred, the users could decide to find their own designers, subcontracting the equipment and installations.

To sum up, this two stage approach opens up a great variety of options for the users. The users can "finish" their apartments during the second phase, adapting it to their preferences and economic possibilities. This second "construction phase" can be repeated in the future, each time the needs of the users change.

From the management point of view, these two "construction phases" are associated with two levels of control and ownership. In a Solid, the developer (Stadgenoot) remains owner of the infrastructure and is responsible for the care and maintenance of the building's infrastructure. The tenants rent the infrastructure space, but is the owner of the infill unit (partitions, equipment, and finishes). If a tenant leaves, he/she can sell the interior to a next tenant. Over time, solid spaces can grow (when merged with another solid space) or shrink (when split up).

In this way, the developer recovers the initial investment based on the rents provided by the tenants over the years. Tentative calculations show that it is realistic to assume that the initial investment in adaptability can be worthy and profitable in the long term due to the savings in maintenance costs, renovations, and subsequent transformations.

3.1.1 Residential and office buildings: Possibilities and limitations of the two step approach

Through the analysis of the Solid Oud West, the open building principles have been exposed as an alternative to conventional procedures in multi-family housing buildings. Some of these principles are actually common practices in the office and commercial buildings.

At the early stage of the planning process of an office facility, the architect focuses on the integration of four parameters: the shape of the building massing and envelope, the location of the services and the structure, the relation between internal area and the perimeter, and the position of the cores in relation to the office space. These items are carefully considered in order to provide flexibility and ensure the quality and optimization of the internal space. Also, it is worth mentioning how the distinction of these two “construction moments” in commercial and office building types - has provoked the development of a new subsector of secondary components for the subdivision of the interior spaces, such as raised floors, drop ceilings, industrialized and demountable cupboards and partitions[7].

Similarly, if the housing project was approached “as an infrastructure” without partitioning, where different dwelling types can be allocated, then the general organization of the services, the location of the structural elements and even the spatial quality of the dwellings could be better. In this case, even different options of subdivisions and non-residential uses over time would be possible. Likewise, the current technologies and construction systems used in offices could be adapted to multi-family housing.

However, the design is not the only point of comparison between residential and office buildings. The division of the process in two phases and the “control and ownership system” previously described, are also procedures which could be incorporated into a new housing management system. This system would facilitate to a great extent the diversity of occupation patterns, enabling also the possibility of change and transformation of the building over time.

The multi-family housing buildings can learn a lot from the office buildings, not as a direct reproduction of the design approaches (since this would prevent us from responding to other basic requirements and representative values characteristics of the residential architecture), but as a way to appropriate and adapt to its needs some of the irrefutable advantages that from the design, management and construction point of view, this building type offers[8].

As a whole, the Solid project was assessed as a successful experience. However, due to its innovative and experimental character, a number of difficulties arose along both the design and occupancy process. One of the challenges that the developer faced was the allocation of spaces within the Solid. Drawing a good allotment is not an easy task, specially taking into account the various constraints and requirements of each group of bidders.

Some of the constraints originated from municipal and building regulations. For instance, the stairs have an emergency rescue capacity that cannot be exceeded. The rescue capacity needed for each bid depends on the surface area of the solid space and bidder’s intended function for that space. Each bid has different requirements with respect to ventilation, water, gas, and electricity (again depending on the area and the intended function). Also, the area of a solid space has size limitations depending on the use. Furthermore, a valid combination of lots must have at least one door to the central gallery and access to a utility shaft[6].

This set of preliminary parameters made the allocation process quite complex, affecting in some cases the design and quality of the spaces. Some of the final proposed lots are enclosed in tortuous shapes, including dead end spaces and corners difficult to plan as a dwelling unit. It is important that the subdivision possibilities are carefully planned well in advanced (at the base building design level) to ensure the quality of the final arrangement.

Another difficulty arose from the statutory regulation and the bureaucracy related to the “two step approach”. In this type of procedures, the final layout of the dwellings is not known at the first stage and, therefore, cannot be approved by the municipality. This issue opens up the well-known debate about the inflexibility and rigidity of some the current housing regulations in relation to the size and subdivision of the dwellings. The discussion is mainly about to what extent the building code should determine what the housing unit looks like on the inside.

This controversy is caused by an external issue: the good will from the governments to control the safety and the final results, and avoid a downgrade of the habitable space (due to the use that residents could do of it if total freedom is given).

There are two options to overcome this statutory issue: to allow for a permission of post-occupation, which should be processed after the "shells" are delivered, based on the design of the interior fit-out project or alternatively to stablish a pre-planning authorization within the first phase, based on the assumption that a certain set of conditions are accomplished. Regulations in some countries are becoming more permissive in relation to the internal fit-out (such as the Netherlands), but most of the European countries are still falling behind.

The third and last difficulty arises from the need to fit out the "shell" spaces after the first phase. The separation of the construction process in two phases implies the requirement of a dedicated interior design project and the management, and fit-out construction of each "shell". Although the housing association (Stadgenoot) assisted in this respect, the reality is that there are not many dedicated companies prepared to assist in the design of the infill units as a whole package in an efficient way –due to the fact that open building is a relatively new trend. It is hard to find companies that are able to pack the parts and deliver them in the right order and pace, including qualified and skilled workers who are present at the right time to assemble them. Logistically, it is quite a challenge to get everything from the supplier to the right place[9].

John Habraken explains in relation to this issue, "the construction sector is still organized in such a way that it involves a sequence of workers. A man for the walls, one for the electricity, the plumbing, which is a lot of fuss when occupants have to organize all that themselves. With these Solids you are dealing with a consumer-oriented project. Therefore, a criterion should be: how can you make it as easy as possible for your tenants? You must search for a balance between the best possible freedom for the occupants, without burdening them with all kinds of technical and management issues[9]."

In this sense, this type of procedure should always include a manual of technical and operational recommendations, so the dweller knows how to appropriate his/her house in the second phase. That is to say, all the tools and means needed to facilitate the fit-out should be put at user´s disposal, either through technical advice or by facilitating contact to the relevant professionals and technicians. The development of specialized infill companies along the growing implementation of open building will also help in this respect.

3.2 Case Study Two: Plus Home Experience, Helsinki (Finland, 2005)

During the last two decades, Finland has been one of the pioneers and leading countries in open building implementation. The main reasons leading up to this development are the research and teaching at Helsinki University of Technology from the beginning of 1990s, and the continuous support given by both the Finnish Technology Agency and the local authorities[10].

Within this context, Plus Home experiment stands out as a fundamental example, which combines the interactive possibilities of the internet with the principles of the open building principles. This project was the winner entry for a competition organized by the municipality of Helsinki in collaboration with Tekes (National Agency of Technology of Finland), carried out in 2002. The main objective of the competition was to promote the design of housing focused on the users, incorporating the principles of industrialized construction.

Besides the architectural proposal adequate for the site and specific context, and the technical solutions that facilitate the construction of an open system, the entries for this competition had to submit a management and data-collecting process efficient enough to meet the user requirements in a direct and individual way. Therefore, the brief of the competition was formulated to promote a multidisciplinary approach: architectural practices, developers, and data processing companies had to work together from the conceptual stage.

The winner entry was SATO PLUS HOME, a team formed by SATO-company as the leader and investor, Kahri&Co Architects as the main designer and ToCoMan Group as the cost, data, and internet consultant. The project was selected for the best new building in Finland by Finnish Association of Civil Engineers in 2005, with the main characteristcs of "remarkable architectural, structural, social, and ICT merits."

The site of the competition is located in Arabianranta Shore, a new residential development close to the seaside, five kilometers from the centre of Helsinki. The Plus Home proposal included two six-story high buildings, accommodating 77 apartments from 39 to 125 square meters, as well as retail, workspaces, and com-

Figure 8: Plus Home, Arabianranta Shore (Image courtesy of Esko Khari and Esko Enkovaara).

mon areas for the community on the ground floor. Each block is 14 meters wide, with stairs facing north to allow access to the apartments. Whereas the north elevation is made of brick with a regular composition of windows, the south façade is made of glass with generous open terraces to make the most of the sun and heat gain during the summer.

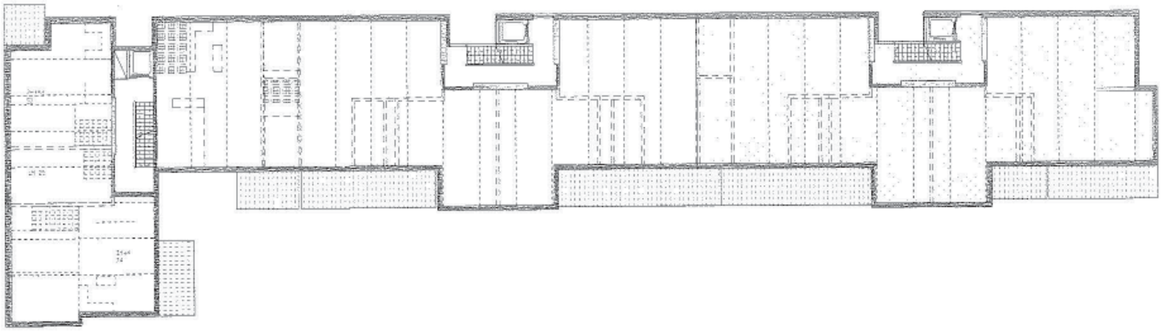

Figure 9: Typical level, support plan without subdivisions (Image courtesy of Esko Khari).

Figure 10: Typical level (cores B- C), support plan without subdivisions and Infill plan showing arrangement of apartments (Image courtesy of Esko Khari and Esko Enkovaara).

In order to enable the variety of housing types and the future adaptability, the construction of the building contained features in line with support and infill principle, which differs from the traditional way of building in Finland. For example, the load-bearing walls are located in the envelope of the building instead of in the cross-walls between the apartments in order to provide a flexible space for varying layouts on different floors. The load-bearing structure inside the walls is steel columns at maximum three meters intervals. Connected to the columns are Z-formed steel beams, which bear the concrete slabs.

Figure 11: Offsite manufacturing of load-bearing walls minimizes the construction time on site (Image courtesy of Esko Khari and Esko Enkovaara).

Most of the slabs are concrete hollow-slabs of about 10 meters span. The steel-framework makes possible to prefabricate the walls in large elements. This makes construction on site very quick. Also, the construction work is dry with very little in-situ concrete casting, which is favorable in this type of climate.

For the sanitary spaces, a two-layer slab was used, which allows flexible plumbing. The floor structure in these "wet zones" was "upside down", where the concrete slab was placed on the bottom of the steel beams, allowing plumbing and ventilation ducts to be freely positioned depending on the floor plan, after which a wooden floor layer was installed on top to close the floor cavity.

All internal walls are built in light construction with piping outside of apartments, to allow later change. The walls between the apartments are light construction with double frame, insulation and double plasterboards. The electric installations are made using an open distribution profile on the upper part of the partition walls, which provides flexibility and enables the adding of service networks.

The facade design consists of steel-structured external wall elements with almost unlimited window placement and many types of outer facing on site. The exterior is of red brick or clad with thermal plastering, some parts of profiled metal plate. The balcony slabs are made of concrete with concrete filled steel pillars. The balcony façade has an ever changing appearance, reflecting the individual variety of the residents[10].

Apart from the construction features, Plus Home was innovative as a pioneering experience in mass housing customization principles and the implementation of advanced IT and data management procedures. Tocoman, BIM software company, was part of the winning team, and developed a dedicated server tool that was accessible by all the agents involved in the project. This platform worked as the pivoting axis for the project, and included two subsystems: a BIM modelling software (Archicad) used by the design team and an interactive online system that allowed the participation of the future users.

In this manner, the architects worked together with the quantity and cost consultants on the design of the building using BIM, taking into account materials, quantities, costs, and user decisions. In this way, it is possible to keep all the documentation and data of the project centralized and not spread in different places, avoiding different versions of the same information and instantly recognizing any modifications.

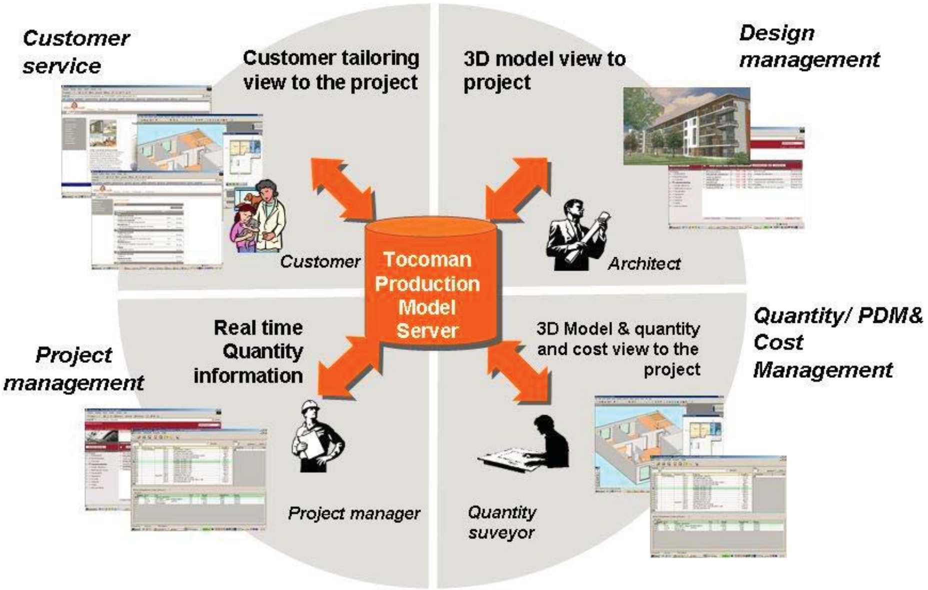

Figure 12: Plus Home, data and internet services software (Image courtesy of Esko Khari and Esko Enkovaara).

This model server enabled the coordination of the project and design process, while the residents could simultaneously start choosing between alternative floor plans in the pre-marketing stage via the internet. This online decision making process was managed by means of a five-step system, which allowed the users to personalize their dwellings. The customization started with a wide selection of floor plans offered, in terms of location of the apartment and sizes within apartments. Also, for each size, there were three possible layout arrangements, in which the position of the services and the rooms varied.

Moreover, the system allowed to choose different options of materials, finishes, and equipment. The options for a fixed price included the wood floor and the tiles with three and four alternatives for each option. In the case of the bathroom, users were able to choose among different options of color tiles and materials. Also, the glass for the windows could be selected[10].

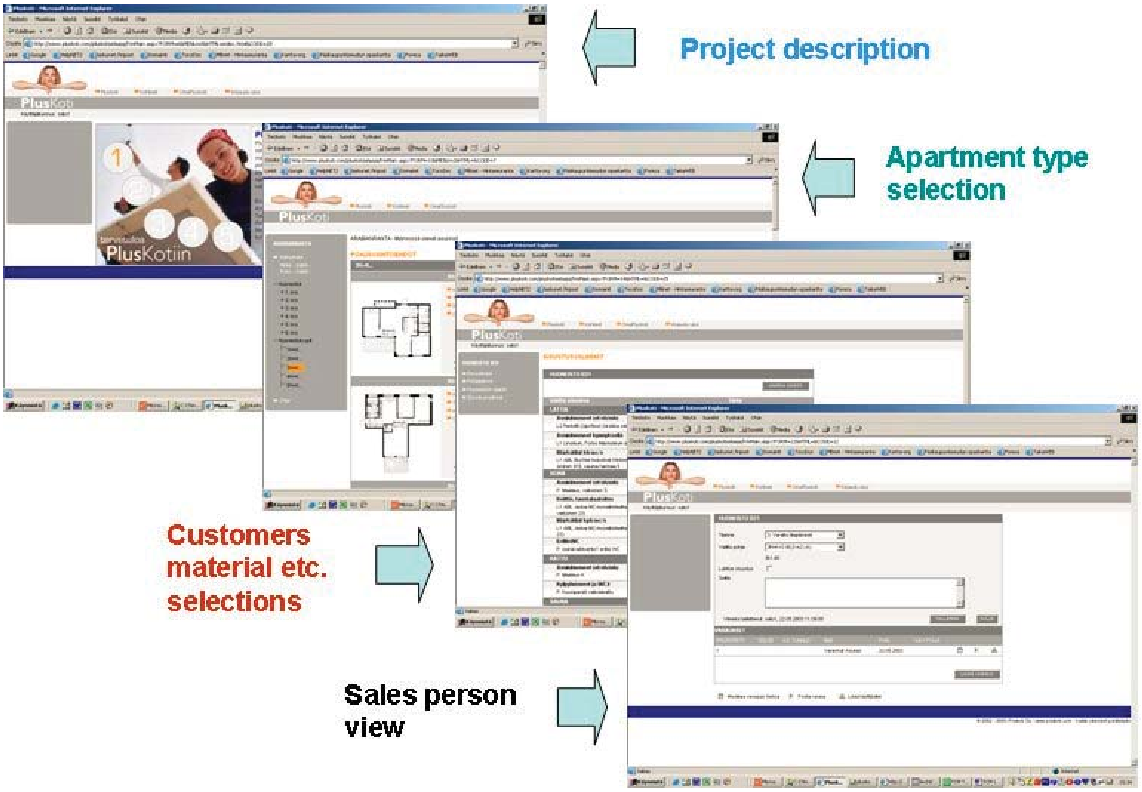

Figure 13: Plus Home, data and internet services software (Image courtesy of Esko Khari and Esko Enkovaara).

This stage was open until six months before the construction started. Then the building was completed with floor plans according to customer's choices. After this stage, the residents had three months for the final selection of surface materials, fixtures, and accessories with fixed prices. Each of the decisions and modifications later in this phase were registered in the model of the building.

In this way, the buyers could see the total price of their apartment directly after making their choices, and could also revise their choices. Once the user has finally selected all the options, the final plans, quantities, materials, and costs were available for the quantity surveyor, builder, developer, architect, and providers[10].

The Plus Home experience was a successful project. The SATO Group outlined a strategic plan concerning open building principles in 2005, using this concept for all their production of owned apartments. Since 2006, several projects have been carried out following these principles.

3.2.1 The new ways of participation: Possibilities and limitations of the Plus Home experience

During the last few years, one of the key achievements of informatics in relation to architecture lies in the capacity to optimise and organize the building processes. New BIM software programs already announce what may be a new paradigm. The use of this type of software has been limited so far (with exceptions) to the coordination work of architects, engineers, project managers, contractors, and quantity surveyors. However, few projects such as Plus Home have entered the ground of user involvement, including the users as participants in the design process.

The potential of these tools may be of great help to avoid the standards that prevent the industry from offering specific and customized solutions for each user (mass housing customization). As shown in the case of Plus Home, it is already possible to work with online platforms to optimise individual solutions at different levels of design, being worthwhile and not impacting deadlines, costs or extra-efforts for the developers[11].

In Plus Home, the mass customization principle had to allow for a certain level of standardization: the apartment sizes and their variations were pre-planned, as well as the interior selections (equipment and materials). This is at the moment, the only way to manage affordably customer choices and variations. Hence, it is required to agree to a certain level of standardization beforehand, in order to build the project data structures.

This can be seen as one of the limitations of the project: the system has its own rules and user involvement was limited to the selection process system. Further research may be needed to consider opening up the range of possibilities in a more flexible set of rules, which can be controlled in terms of cost and project management, giving the user a chance to impact the design of his/her dwelling within a wider spectrum of parameters.

Furthermore, the new technologies already offer the possibility to participate within the collective elements. By means of the social networks or the development of specific online platforms, it already seems feasible to establish internet relations with future neighbors, to agree disparities in relation to the brief and budget, the internal management of the community and the common spaces, to provide transparency to the process or even collaborate with the inhabitants of the adjacent buildings. All this could help to generate community feelings even before occupying the building physically[11].

4.0 CONCLUSION

This article analyzed two approaches to open building concept. Both case studies share characteristics in line with outlined principles: the open design strategies respond to time-based architecture, they include users as participants in the design process, and rely on industrialized and adaptable construction. Moreover, they both have compelling start-up processes in common: one project used an auction and the other used the internet.

Within these similarities, they have a different approach in relation to the support and infill separation, which turns into a fundamental difference at the organizational level of the project. In the Solids, the accommodation process was divided in two phases, with all the implications at the contractual, management, and statutory levels. In Plus Home, this separation remained just as a concept informing the design and construction throughout the project: the infrastructure and infill were conceived to be physically different construction elements, but the building process stayed as a single conventional stage.

In terms of future adaptability, both approaches are valid since the support and infill distinction at the construction level can enable flexibility in the long run. However, they offer different opportunities in relation to the first occupation of the building: in Plus Home, user participation is limited to the choice between options at the early stage, whereas in the Solids the users can have total control and freedom over the design of their dwelling, since a dedicated fit-out project is required in the second phase. This fundamental difference makes the Solids “more open”, both in terms of level of user involvement and the capacity of adaptation to non-residential uses.

In this respect, the Solids are innovative and truly ground breaking in putting forward the two-step approach, which sets the scene for the recognition of two levels of control and decision making in the residential project. As advocated by the Open Building movement, the recognition of these two levels of control is fundamental in order to achieve a sustainable built environment, able to be transformed part by part.

As a down side, it is worth mentioning some of the difficulties that arose during the project delivery due to the lack of experience in this type of procedures where the two stage approach is adopted. Further research based on realized projects may want to consider the development of methods and tools to overcome these milestones.

Plus Home, on the other hand, deals with the topic of user participation in a more limited way within a single stage conventional process, but it is original and compelling in relation to the used data and management system and the implemented technology. These aspects made it possible to respond to users in an efficient and individual way, enabling at the same time the coordination and cooperation of all parties involved in the building process. The analysis shows that further research could be done in relation to the possibility of loosening up the constraints limiting the user choices and the possibilities of participation at the collective level.

To sum up, we can state that each project is revolutionary in its particular way. Therefore, they should not be considered as rivaling or directly comparative, but as accumulative or combinative. This shows that the possibilities that open building principles offer are diverse. As shown in the analysis, to make the most of them will require adapting the housing production process (in terms of design, management, coordination between building agents, legislation, and statutory procedures), to the requirements of this new methodology. But, also it will depend to a great extent on the actual will of the parties involved in the process (authorities, developers, contractors, and designers) to make the users participants in the design process of their living environment.

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03.

SIMULATION MODELING AS A LEAN TOOL FOR HEALTHCARE DESIGN:

Determining Room Utilization and Staffing in the Emergency Department

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ABSTRACT

This article outlines the use of operational planning and simulation modeling as a lean tool within Perkins+Will, to determine the room utilization and staffing for a large trauma center, based on current and projected volumes and turnaround times. A specific area of focus was the Resuscitation Rooms and their location within the emergency department (ED). In its most recent year, this facility had 64,000 patient visits. Projections estimate that approximately 75,000 annual patient visits within 63 exam rooms will be needed in this emergency department in 10 years. This study began with a process map of the patient flow within the ED. A simulation model was built to mimic the patient flow in the design of the new emergency department. Patient wait times, census, and staffing ratios were the key metrics to assess the efficacy of the ED design. The results of this revealed that the medical resuscitation rooms that were planned were better used when integrated with the emergent rooms in the main ED versus an area decentralized and adjacent to the main ED. The results also revealed that staffing of the ED within specific staff roles (RN's and Technicians) and specific ratios could reduce patient wait times.

KEYWORDS: simulation modeling, lean, process mapping, operational planning, staffing

1.0 INTRODUCTION

This article illustrates the use of operational planning and simulation modeling as lean tools to calculate the utilization of rooms and staffing for a large trauma center. Healthcare organizations are looking at lean systems for efficient care and to minimize waste. With the principles and processes of Lean, we know how to reduce and eliminate waste, including the reduction and eliminations of errors (defects)[1]. Simulation modeling is a great tool in lean practices to assess patient flow, wait times, and analyze capacity. Simulation analysis takes into account the inherent variability in patient arrival rates, process and turnaround times and provides a fairly accurate depiction of the process flow with the planned spaces. Simulation can inform key design/operational decisions by comparing the efficiency of various design and operational concepts.

The research problem that this article addresses is how to maximize the utilization of rooms for a trauma center, while understanding the relationship between staffing and turnaround times. It is possible to locate the medical resuscitation unit in a decentralized area adjacent to the main emergency department (ED) and staff the emergency department with specific staff members, but staff utilization may decrease and patient wait times may increase significantly. Conversely, having the medical resuscitation rooms integrated with the emergent beds in the main ED may cause an increase in staff utilization and an increase in specific staff coverage, which may reduce wait times, but increase operational costs. In addressing this problem, simulation modeling was used to analyze room utilization, patient flow with wait times, and staff coverage. The following sections describe the research methodology and results in detail.

2.0 METHODOLOGY

2.1 Data Collection

To complete the simulation modeling for the trauma center, the team gathered data on current patient census, as well as projected future patient census in the trauma center. Current staffing roles and ratios were also obtained. This facility utilizes the Emergency Severity Index (ESI) level 5 Acuity System[2], where Level 1 is the highest acuity level and Level 5 is the least acuity level. The Triage area prioritizes incoming patients and identifies the "walking wounded" from the "walking critical". In some low acuity cases, patients can be triaged, assessed, and seen as a "Treat and Street" cases. The Fast-Track rooms are for lower acuity patients, such as extremity fractures and lacerations. Emergent rooms are for the higher acuity patients, such as chest pain and abdominal pain, whereas the trauma and medical resuscitation rooms are for the highest acuity patients. Table 1 shows current turn-around-time (TAT) data and the projected turn-around-time goals that were obtained, including patient arrival time patterns.

2.2 Tools and Techniques:

In developing the simulation model, a targeted workflow map for the patient flow through the trauma center, was created by areas of Triage, Fast-Track, Emergent, Medical Resuscitation, and Trauma, as shown in Figure 1. Observational studies were conducted to determine existing patient flow and processes. Process flow charts were developed to visualize the flow of patients through the various areas of the ED.

Table 1: Client's current census and goals.

2008 Client Volume: 64,218	**Current Turn-Around-Times (TAT's)**
Triage	30 minutes
Fast-Track	2 hours
Emergent	9.1 hours
Trauma	6.5 hours

	Client Goals Turn-Around-Times (TAT's)
Triage	7 minutes
Fast-Track	1.5 hours
Emergent	4 hours
Trauma	4 hours

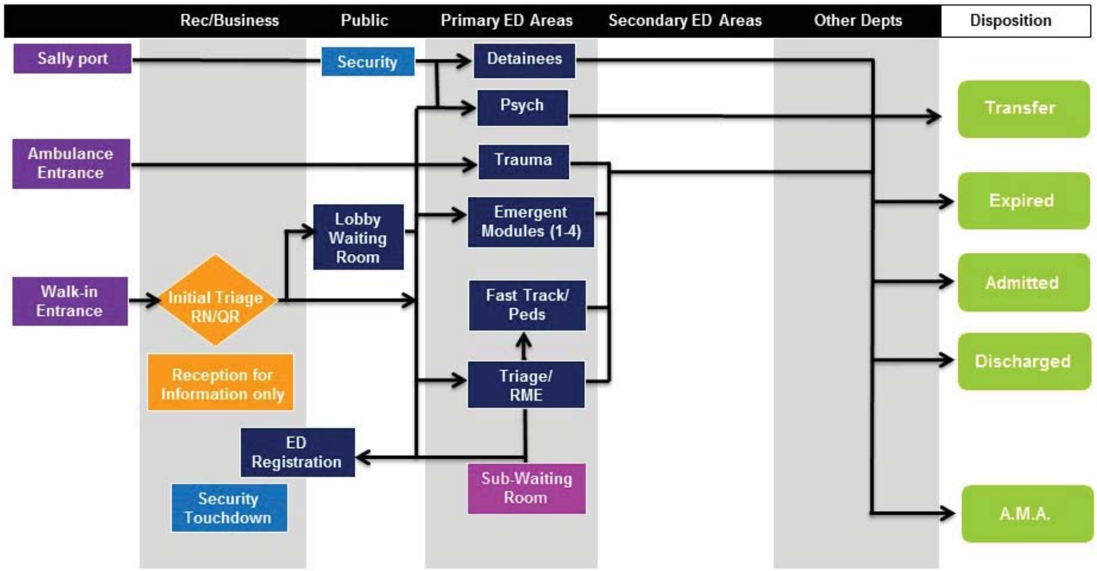

Figure 1: Targeted work flow map.

Table 2: Client 2017 Emergency Department space need projections for 74,958 visits.

Primary ED Area	Client TAT Goals (hrs.)	Projected Visits	% of Census	Reg No. of Rooms	
Trauma	4 hrs.	7,496	10%	10	
Med Resuscitation	2 hrs.	750	1%	4	38
Emergent	4 hrs.	46,474	62%	34	
Fast-Track	1.5 hrs.	8,995	12%	5	
Pediatrics	1.5 hrs.	7,496	10%	4	
Behavrioral Health	8 hrs.	3,748	5%	6	
			TOTAL	63 Rooms	

Table 2 above shows process flow, and also the percent of patients following each pathway through the process. These percentages served as probabilities in the model for simulation.

Further calculations included the time involved with movement from one area to the next based on the planned physical layout of the department.

The team determined the variables that would best represent whether the design of the emergency department would accommodate the various utilization of the rooms and staffing coverage. The team elected average patient wait time for a room by acuity, patient census, and staffing ratios as the variables for optimization in the model. Next, simulation models were built in ProModel's MedModel software[3]. The models simulate patient flow and provide statistics on the chosen variables, which can be used to measure process efficiency. In this particular simulation, the levels of acuity and staffing play a major role in the placement of patients. For the highest acuity level 1 patient, there can be no waiting time. These patients must be seen immediately by staff and placed in the trauma unit, medical resuscitation unit, or emergent rooms. In the space programming of this department, a breakdown of room requirements with their function and adjacencies was previously established with the client. All acuities had specific rooms or areas where patients were placed. The simulation model handled all "if, then" logic and provided statistics based on the patient flow.

3.0 SIMULATION RESULTS

This section describes the two scenarios simulated for room utilization, Scenario A and Scenario B:

Scenario A:

The first simulated scenario considered the medical resuscitation and emergent rooms separated, with the medical resuscitation unit in a decentralized area adjacent to the main ED. The medical resuscitation rooms and staff were drastically underutilized and may actually represent more rooms and staff than necessary (Table 3A).

Table 3A: Room utilization simulation input summary for Scenario A

Type of Room	Annual No. of Patients	Number of Rooms	TAT (hours)	Utilization
Trauma	7,496	10	4	39%
Med Resus.	750	4	2	5%
Emergent	46,474	34	4	71%
Fast-Track	8,995	5	1.5	61%
Pediatrics	7,496	4	1.5	81%
Behavioral Health	3,748	6	8	49%

Scenario B:
The next scenario integrated the medical resuscitation and emergent rooms. The integrated simulation model combining emergent and medical resuscitation areas provided flexibility for staffing purposes and improved utilization (Table 3B).

Table 3B: Room utilization simulation input summary for Scenario B.

Type of Room	Annual No. of Patients	Number of Rooms	TAT (hours)	Utilization
Trauma	7,496	10	4	39%
Combined Emergent	47,224	38	4	65%
Fast-Track	8,995	5	1.5	61%
Pediatrics	7,496	4	1.5	81%
Behavioral Health	3,748	6	8	49%

The medical resuscitation unit for the 10 year projections was simulated with current staffing ratios of 2RN's and 1 technician. The lower staff utilization with current staffing ratios shows the scope for improving staff utilization. The current staffing numbers indicated that staffing the medical resuscitation unit as a separate entity provided ample potential for flexing of staffing hours with other areas of the ED. As expected, the patient waiting times for the unit are zero to minimal owing to the abundance of staffing hours along with low utilization numbers for both RNs and technicians. However, it was noted that ESI acuity level 1 patients should never have to wait for staff due to the severity of their illness/injury. The results are shown in Table 4.

Table 4: Census with current medical resuscitation staffing ratios.

Time of Day (hours)	Average Number of Patients	Maximum Number of Parients	RN	Tech	Patient waiting time for RN or Tech (mins)	RN Utilization	Tech Utilization
7-10	1	1	2	1	0	2%	3%
10-12	1	1	2	1	0	1%	3%
12-14	1	1	2	1	0.1	5%	8%
14-16	1	1	2	1	0.28	7%	11%
16-17	1	1	2	1	0.13	6%	8%
17-19	1	1	2	1	0.12	6%	11%
19-23	1	1	2	1	0.38	5%	9%
23-1	1	1	2	1	0	4%	7%
1-3	1	1	2	1	0	3%	5%
3-4	1	1	2	1	0.14	5%	8%
4-7	1	1	2	1	0.03	3%	4%

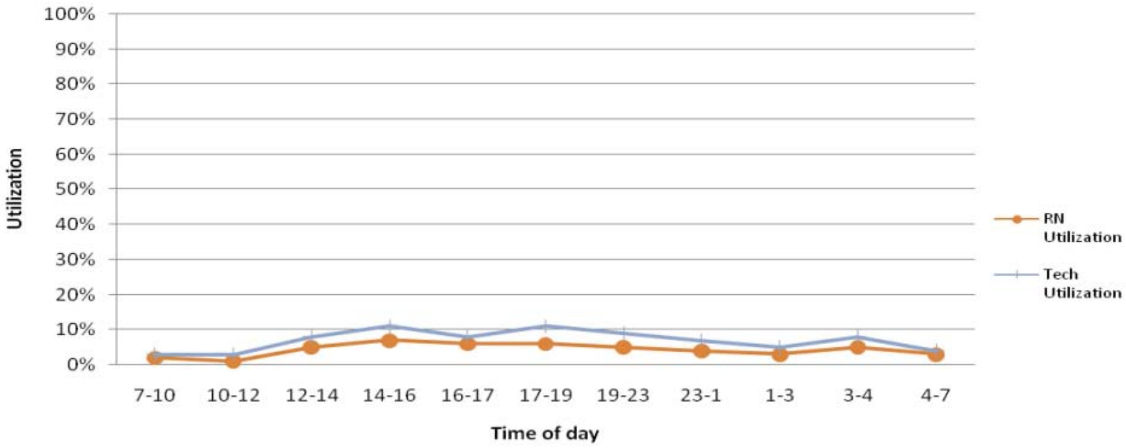

Figure 2: Resource utilization for 2017 census with current medical resuscitation staffing ratios.

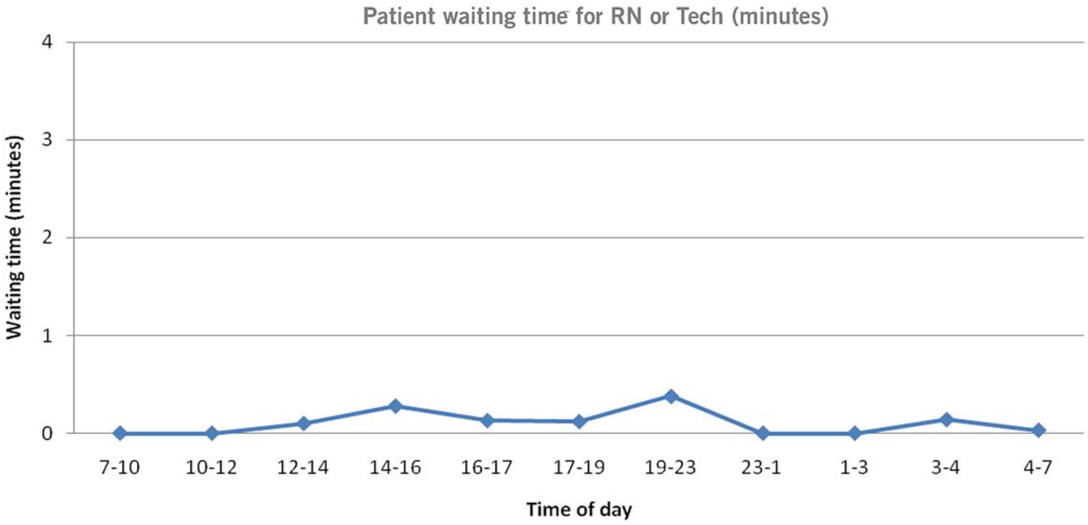

Figure 3: Patient waiting time for 2017 census with current medical resuscitation staffing ratios.

3.1 Results for Scenario 1

In this scenario, the medical resuscitation unit and emergent beds were integrated with current staffing ratios of 1 RN: 4 patients and 1 technician to 5 patients. Combining the emergent and medical resuscitation unit with staff flexing reduced the excessive waiting times and staff utilization numbers for the emergent beds. The patient waiting times were found to be significantly reduced for the combined unit dropping from an average of 112 minutes to 20 minutes. Results are shown in Table 5.

Table 5: Combined emergent and medical resuscitation unit staffing: Scenario 1.

Time of Day (hours)	Average Number of Patients	Maximum Number of Parients	RN	Tech	Patient waiting time for RN or Tech (mins)	RN Utilization	Tech Utilization
7-10	9	12	3	3	19.34	78%	72%
10-12	14	18	5	4	24.71	79%	82%
12-14	21	26	7	6	25.33	80%	80%
14-16	29	33	9	7	23.7	83%	87%
16-17	33	35	9	7	20.68	83%	88%
17-19	33	35	9	7	18.14	83%	83%
19-23	30	33	9	7	15.62	82%	85%
23-1	31	33	8	6	18.97	86%	89%
1-3	26	29	7	5	14.13	82%	87%
3-4	22	25	5	4	17.04	84%	83%
4-7	15	21	4	3	20.31	70%	70%

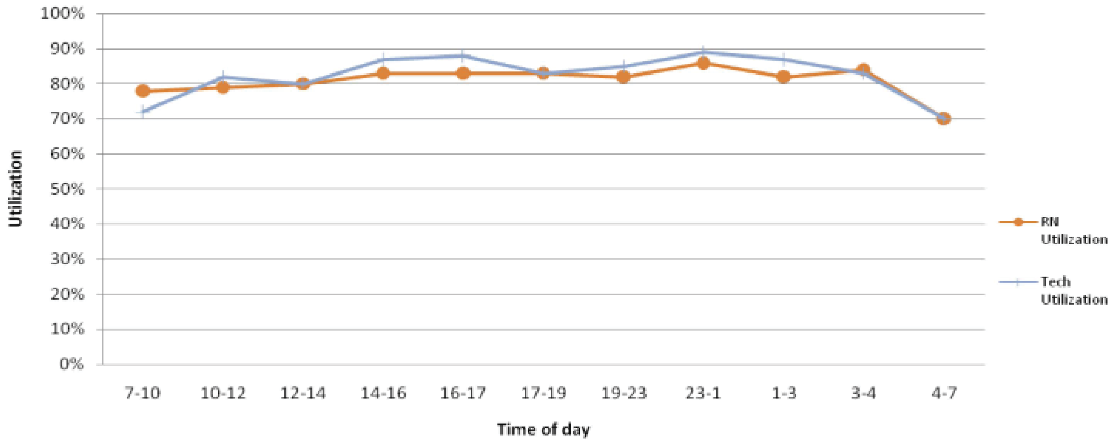

Figure 4: Emergent and medical resuscitation staffing combined: Resource utilization in Scenario 1.

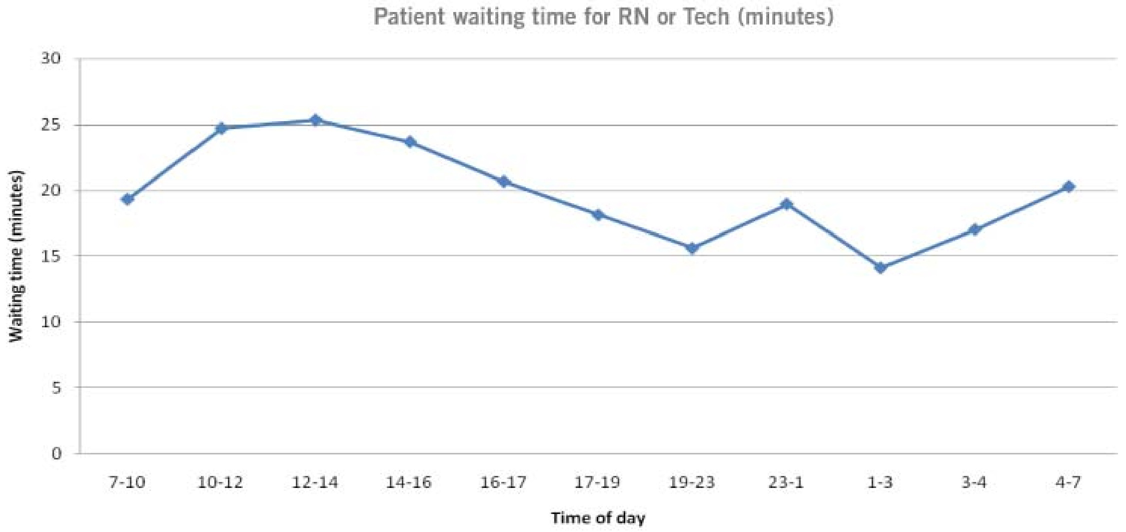

Figure 5: Emergent and medical resuscitation staffing combined: Patient waiting time in Scenario 1.

3.2 Results for Scenario 2

The team questioned the peak times in the emergency department for the combined emergent and medical resuscitation beds. Staffing in this scenario was RN/patient ratio 1:4, technician ratio 1:5, additional RN/tech during peak hours. This scenario was aimed at reducing patient waiting times for the combined model by providing additional staff hours during peak hours of demand. The drop in staff utilization was not significant compared to Scenario 1. Compared to Scenario 1, a significant drop in patient waiting times was observed with additional staffing hours (patient waiting times was an average of 10 minutes in Scenario 2 compared to 20 minutes in Scenario 1). *Note:* Considering, there is never a wait time for initial medical resuscitation assessment in clinical practice, it therefore reflected as such in the simulation. Results are shown in Table 6.

Table 6: Combined emergent and medical resuscitation unit staffing: Scenario 2.

Time of Day (hours)	Average Number of Patients	Maximum Number of Parients	RN	Tech	Patient waiting time for RN or Tech (mins)	RN Utilization	Tech Utilization
7-10	9	11	4	3	6.79	60%	67%
10-12	15	18	5	5	10.15	81%	73%
12-14	21	25	7	7	11.08	81%	70%
14-16	29	33	9	9	12.69	85%	72%
16-17	33	35	9	8	11.94	84%	77%
17-19	31	34	9	8	11.16	83%	73%
19-23	29	33	9	8	11.36	82%	75%
23-1	30	32	9	8	8.51	79%	70%
1-3	25	29	7	6	8.13	81%	74%
3-4	21	23	5	4	7.23	81%	78%
4-7	13	19	5	4	8.54	56%	51%

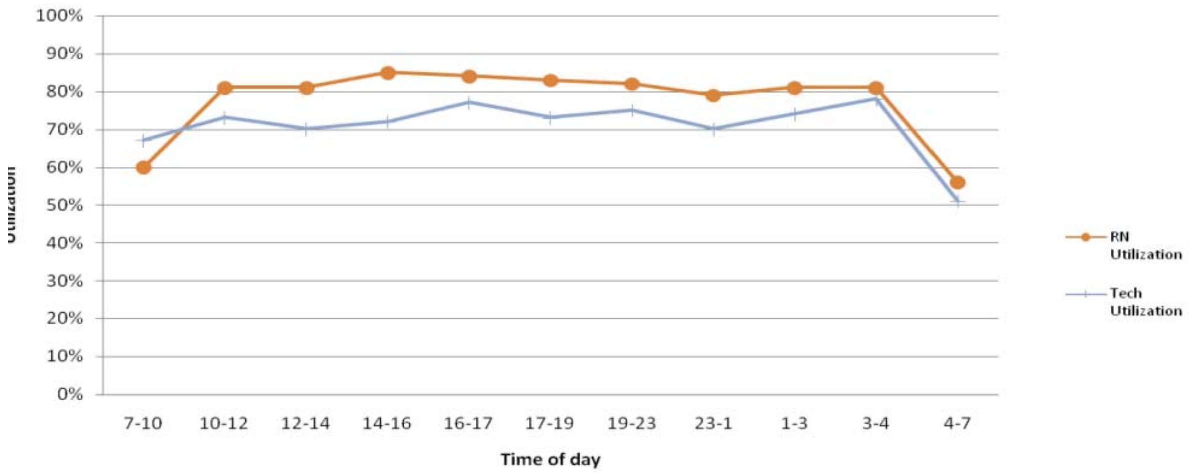

Figure 6: Emergent and medical resuscitation staffing combined: Resource utilization in Scenario 2.

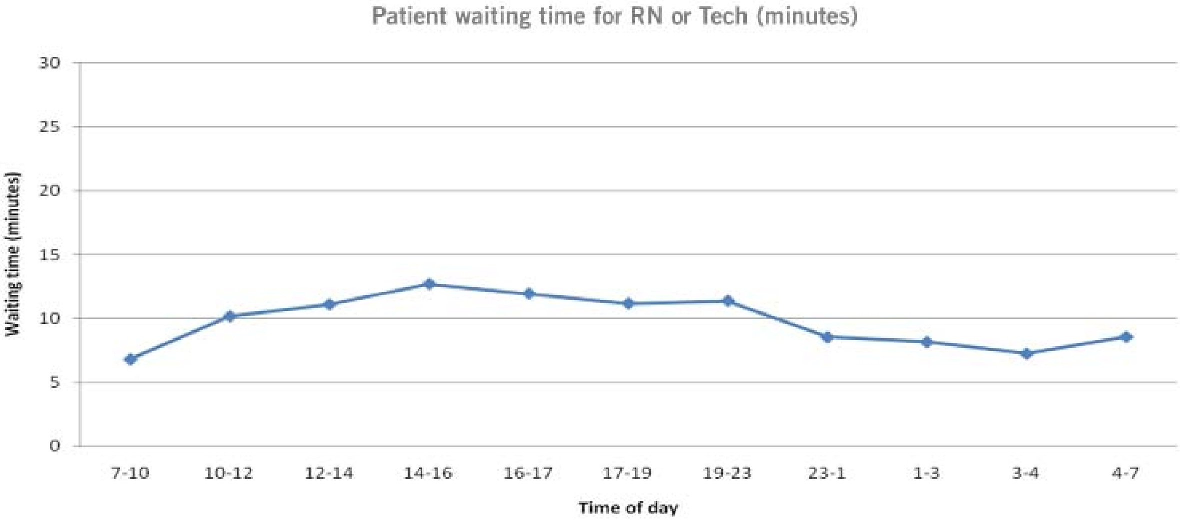

Figure 7: Emergent and medical resuscitation staffing combined: Patient waiting time in Scenario 2.

The emergent and medical resuscitation staffing simulation summary shown in Table 7 demonstrates the current staffing and results for Scenario 1 and Scenario 2.

High staff utilization could lead to increased patient wait times, staff burnout, and poor retention.

Table 7: Summary of simulation results.

Scenario	Average time patient waits for RN or Tech (min)	Average RN Utilization	Average Tech Utilization
Current	112.9	83%	100%
Scenario 1	19.8	81%	82%
Scenario 2	9.78	78%	71%

CURRENT For Medical Resuscitation, 2 RN and I Tech for all time periods
For Emergent unit, RN ratio of 1:4 and Tech ratio of 1:10

SCENARIO 1. Emergent and Medical Resuscitation as one unit, with RN ratio of 1:4 and Tech ratio of 1:5

SCENARIO 2. Emergent and Medical Resuscitation as one unit, with RN ratio of 1:4 and Tech ratio of 1:5, addition of one RN or Tech during peak hours, (Example 7:00 AM-10:00 AM for RN and 2:00 PM -1:00 AM for Tech) to reduce patient waiting times.

NOTES: 1) There is no wait for initial medical resuscitation assesment.
2) Modules would open according to need.

4.0 CONCLUSION

Simulation modeling is a powerful tool for simulating design and operations of healthcare facilities and can aid the lean design process. It assists in developing a framework for effectively using planned spaces. Developed simulation scenarios can help to understand design and space requirements before construction. Simulation results can also help determine desired outcomes for efficiency and patient/staff satisfaction. In this particular study, simulations were used to analyze room utilization, patient flow, and staffing coverage. Integration of medical resuscitation and emergent rooms provides for staffing flexibility and improves room utilization. The staffing scenarios for those rooms demonstrates effects on wait times and staff utilization. Simulation is not always needed within projects, but it is particularly useful for areas with complex arrival and queuing, such as emergency departments, obstetric unit, and surgical suites. Results can help inform key design and operational decisions for healthcare facilities. Healthcare simulation over the past few years, is going beyond the traditional role of scenarios and visualizing workflows. A simulation model can be incorporated as a component of ongoing efforts to monitor and improve performance and increase efficiency[4].

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04.

SHRINKING WETLANDS, SINKING CITIES

Why Preserving and Restoring Wetlands Can Help Save Our Coastal Cities

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ABSTRACT

As the Earth's climate changes and sea waters rise, the world's many coastal cities must get creative to stay afloat. Levees, floodwalls, and other man-made infrastructure are enormous cost burdens that continue to be overpowered by super storms and severe flooding. Planners and designers around the country are exploring methods to make coastal cities more resilient to these impending changes. One method for urban resilience that deserves more attention is the preservation and restoration of wetlands as a means to mitigate the effects of climate change. This paper aims to create an informative and comprehensive guide, and also to define the next steps and necessary research for wider adoption. Research methods that were used include literature review, in-depth review of two case studies, and interviews.

KEYWORDS: coastal resilience, landscape urbanism, climate change, soft infrastructure, urban resilience

1.0 INTRODUCTION

Wetlands are a powerful natural resource that should not only be protected, but also used as a viable method to mitigate the effects of climate change in coastal urban areas. The intent of this study is to create an informative and comprehensive guide to the current situation surrounding wetlands and climate change in coastal urban areas. The hope is that this research will serve as a platform for raising public awareness and encourage further research into these topics.

The methodology for this research begins with a brief introduction to wetlands and their significance, coastal climate change issues, and the role that wetlands can play in urban resilience. Next, a literature review of the current situation for coastal wetlands in the United States is explored: the threats they face, the laws in place to protect them, and the current research surrounding these issues. Two case studies provide a brief overview of how two very different coastal environments are dealing with wetlands and climate change. The well preserved and sparsely developed Georgia coast stands in sharp contrast to the densely developed coastline of New York City, but there are valuable lessons to be learned from the past, present, and future of both. The paper ends with a review of overall lessons learned and next steps to carry this research forward. Research methods for this paper included interviews with a diverse array of professionals and in-depth literature reviews of published sources.

2.0 SHRINKING WETLANDS, SINKING CITIES

2.1 Why Wetlands Matter

Wetlands matter a great deal to the human race, though we often fail to recognize it. The many functions of wetlands not only translate into direct economic and environmental benefits to coastal cities, but they can help offset some of the oncoming impacts of climate change.

Wetlands are the transitional zones between land and water. They are frequently inundated by surface and groundwater and support an abundance of vegetation adapted for life in saturated soil conditions. Wetlands are unique, highly productive ecosystems that are found at riparian margins all over the globe. There are many different types of wetlands, each with its own special ecology. For the purposes of this study, the focus will be on coastal wetlands, which may also be referred to as tidal marshes.

"Tidal (coastal) marshes occur along coastlines and are influenced by tides and often by freshwater from runoff, rivers, and ground water. Salt marshes are the most prevalent types of tidal marshes and are characterized by salt tolerant plants such as smooth cordgrass, saltgrass, and glasswort. Salt marshes have one of the highest rates of primary productivity associated with wetland ecosystems because of the inflow of nutrients and organics from surface and/or tidal water. Tidal freshwater marshes are located upstream of estuaries; tides influence water levels, but the water is fresh. The lack of salt stress allows a greater diversity of plants to thrive. Cattail, wild rice, pickerelweed, and arrowhead are common and help support a large and diverse range of bird and fish species, among other wildlife[1]." Forty percent of the wetlands in the continental U.S. are coastal wetlands, and 81 percent of those coastal wetlands are located in the southeast[2].

Wetlands provide many functions, all of which are extremely beneficial to urban environments. Wetlands functions can be placed into three primary categories: hydrologic, water quality, and habitat. Wetlands are complex systems that respond to a variety of processes; the functions within each category are heavily intertwined, creating a delicate balance within the ecosystem. If one function is compromised, wetlands are not able to maintain many of the other functions they provide. In other words, damage to any part of the ecosystem affects the overall performance of the entire system.

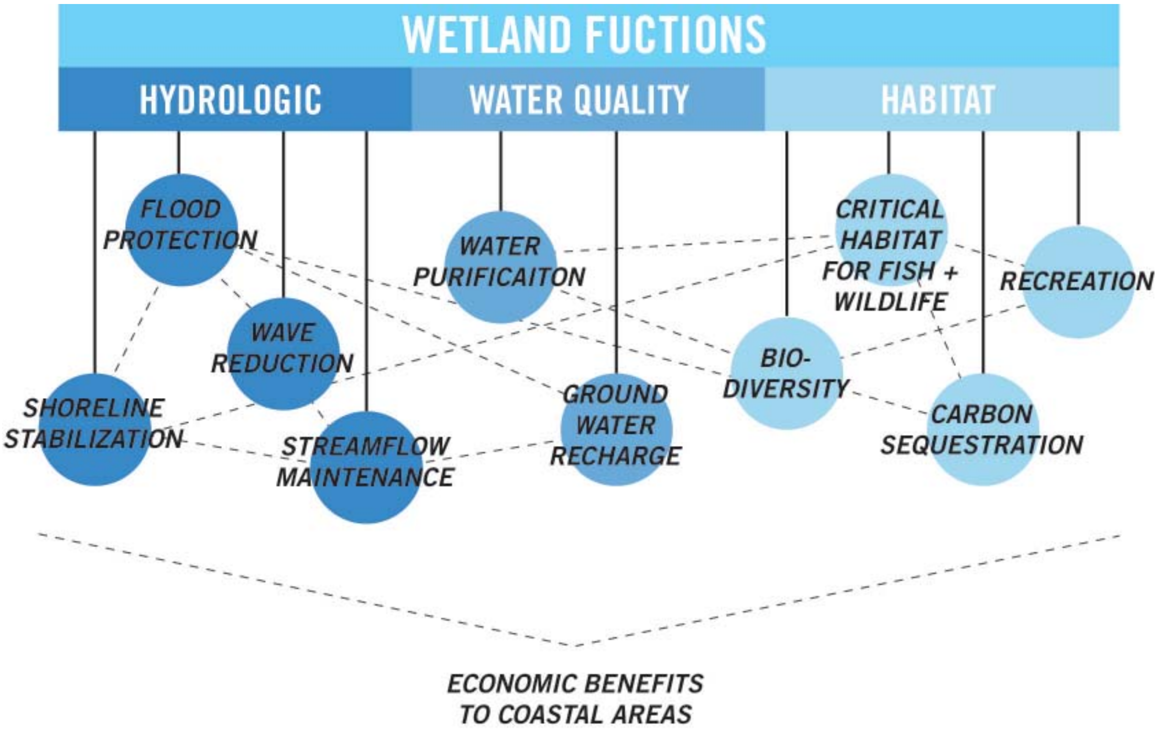

Figure 1: Diagram of wetland functions.

Climate change is affecting coastal cities on a global level through sea level rise and frequent storm events. The future of sea level rise and consequentially the fate of coastal cities is in our ability to lower global emissions. Despite the improved ability of models to reproduce historical rates of sea-level rise, some respected scientists maintain that even the new numbers are too low and the latest Intergovernmental Panel on Climate Change (IPCC) model does not account for permafrost thaw[3].

The IPCC projects three feet of sea level rise by 2100, the sea having already risen four to ten inches this past century. For every foot of sea level rise, 100 feet of flooding can be expected[4]. One third of coastal land and wetland habitats are likely to be lost in the next 100 years if the level of the ocean continues to rise at its present rate[5]. This is of primary concern because two thirds of the world's largest cities (cities with more than five million people) are less than ten meters above sea level, which equates to more than one billion people across the globe and more than half of the U.S. population[6, 7].

Due to some of this data, coastal cities are beginning to develop strategies for urban resilience. Resiliency is the capability to withstand or recover quickly from difficult conditions. Urban resilience is the ability for cities to anticipate and respond to extreme weather events. Though many of the world's major cities are at risk of sea level rise, very few are aware of, or prepared, for the potential damage that rising seas and increased flooding may bring. Many of the functions of wetlands have the unique ability to offset many of the oncoming risks climate change brings to coastal cities. However, unless wetlands are properly preserved and restored, they are also at risk of destruction.

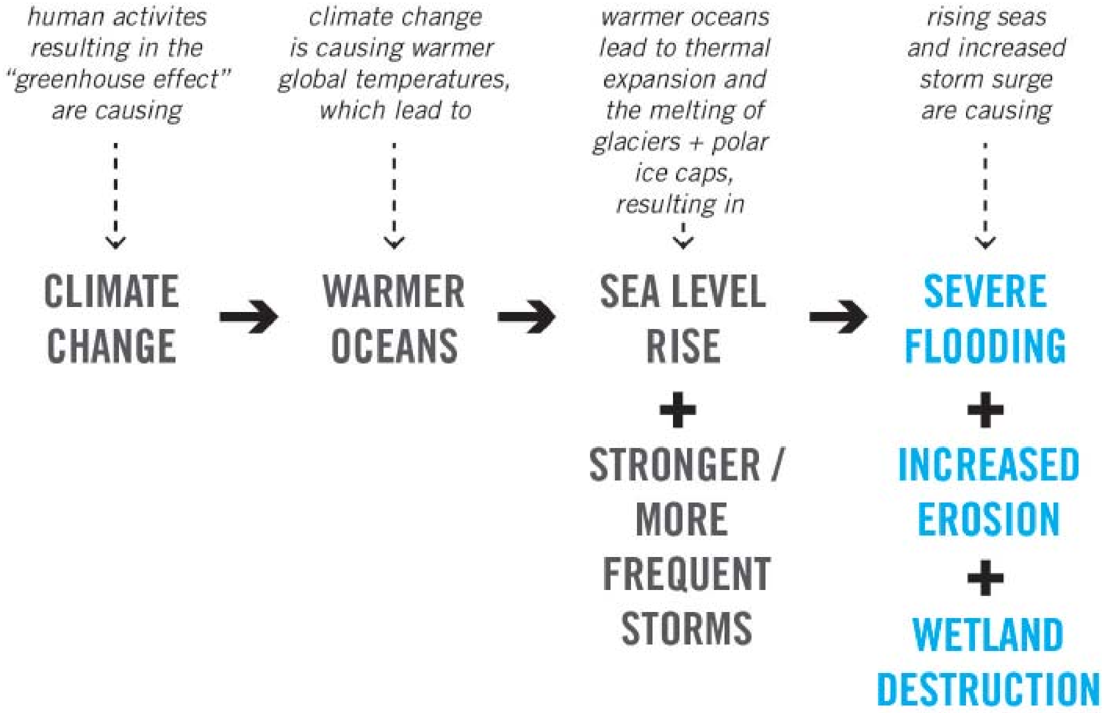

Figure 2: Impacts of climate change on wetlands[8].

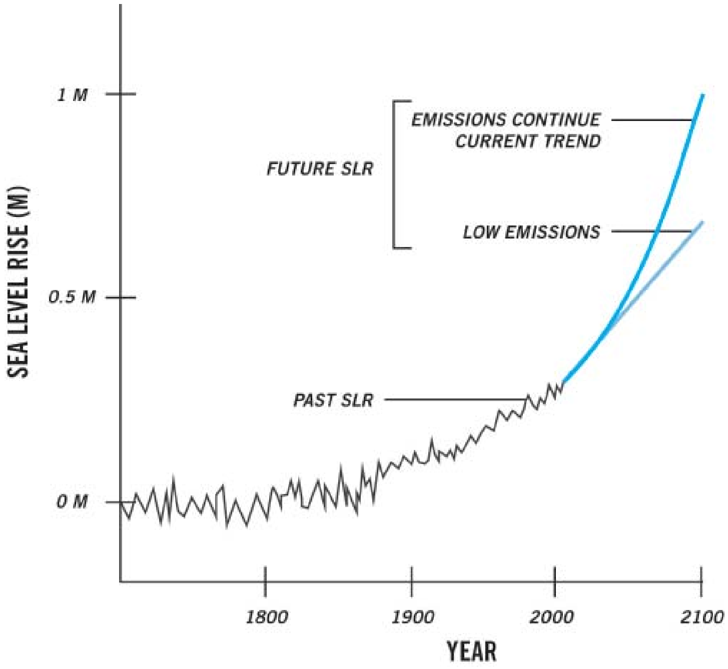

Figure 3: Projected sea level rise[4].

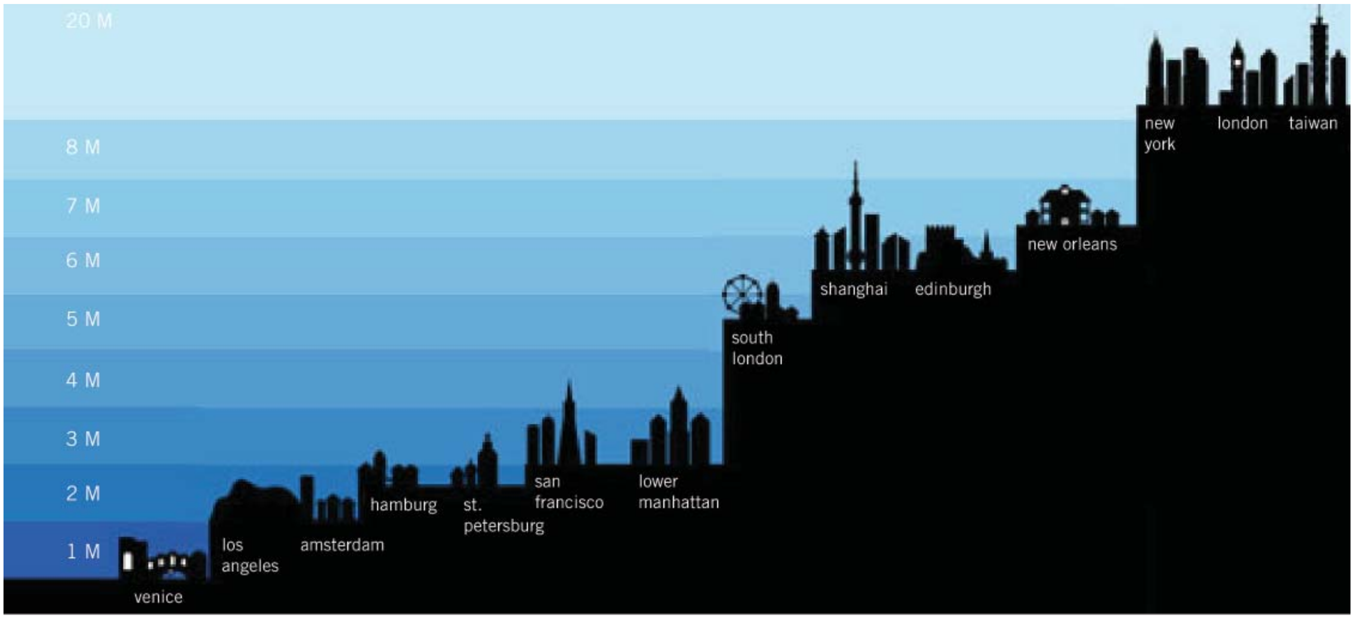

Figure 4: Sea level rise infographic[9].

2.2 Wetlands Significance

Wetlands are a complex, highly productive, and diverse ecosystem. They offer numerous ecological and economic values and benefit humans and wildlife alike. Until recently, wetlands were considered invaluable wastelands. Though our respect for wetlands has grown in the past few decades, our understanding of the complexities of wetlands is still developing. The more we discover, the more valuable wetlands become.

Wetlands provide extraordinary habitat and are some of the most biologically productive natural ecosystems in the world[10]. Often referred to as nature's kidneys, wetlands filter out toxins and pollutants and retain vital nutrients. Wetlands provide flood protection by functioning as natural sponges, absorbing and storing water and slowly releasing it. These natural functions create and save billions of dollars annually in the U.S.[11]

Though wetlands account for only five percent of the land area in the lower 48 states, they provide critical habitat for the following: 31 percent of plant species,[12] 95 percent of commercially harvested seafood (fish and shellfish),[13] 85 percent of waterfowl and other migratory birds, and 45 percent of threatened and endangered species[11]. $79 billion in annual revenue is generated from wetland-dependent species, accounting for 71 percent of the nation's commercial and recreational fishing industry. An estimated $59 billion in annual revenue is generated from wetland-related ecotourism such as hunting, fishing, bird-watching, and photography in 1991[13]. It is important to note that these economic facts are grossly outdated. Since this is the most current data found, it can be inferred that the economic importance of wetlands is highly undervalued. Wetlands purification properties can remove up to 60 percent of metals, 90 percent of sediment from runoff and 90 percent of nitrogen[14].

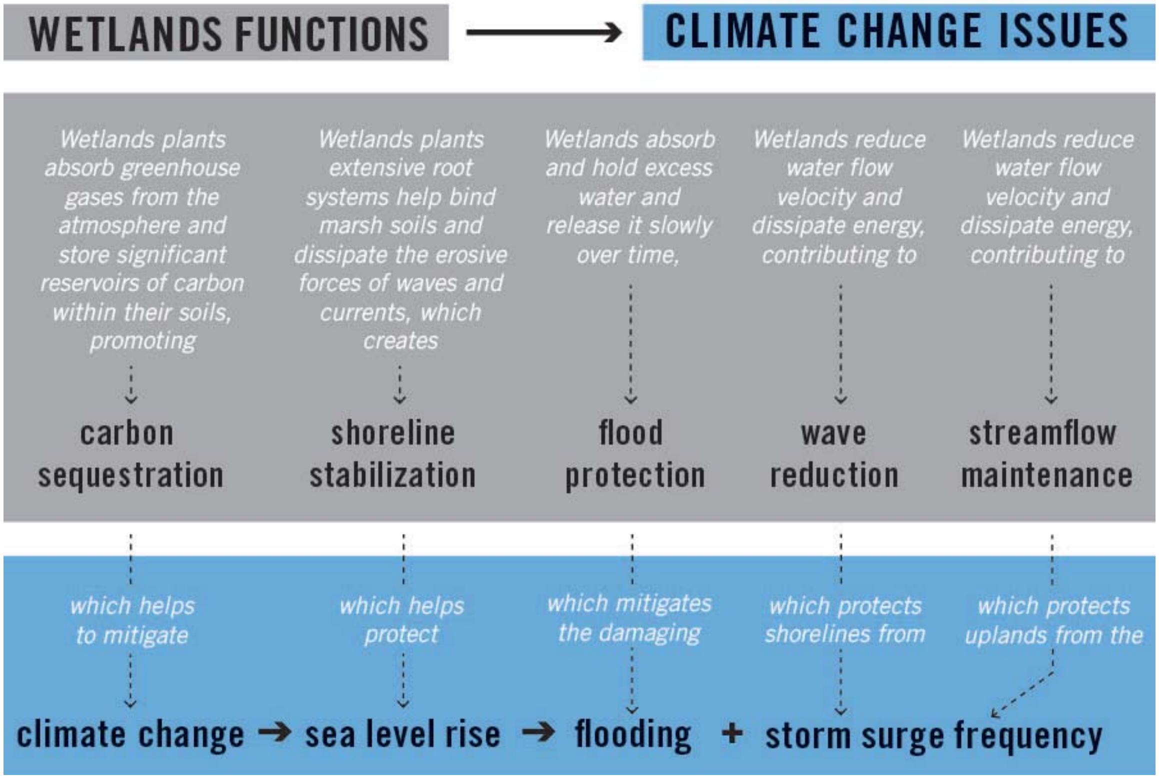

Figure 5: Wetlands and climate change.

The state of Georgia alone attributes $1 million in annual water pollution abatement costs for each 2,500 acres of wetlands[15]. One acre of wetlands can store 1-1.5 million gallons of floodwaters and maintain just 15 percent of watershed land area as wetlands decreases flood peaks by 60 percent[11]. The U.S. estimates $23.2 billion in annual savings in storm protection services due to wetlands reducing the severity of impacts from hurricanes,[16] and $5.7 million average annual increase in property damage for every loss of one-mile strip of coastal wetlands[17].

Though arguably all of wetlands functions are valuable to urban areas, the most compelling and potentially beneficial functions for coastal cities are hydrologic. Flooding in coastal areas already costs millions of dollars of damage each year (global flood damage in coastal cities is expected to reach U.S. $1 trillion per year as sea levels rise),[18] and the amount of physical and fiscal damage will only continue to increase due to climate change. Not only do wetlands help mitigate the effects of flooding, they provide a low cost alternative to other hard engineering strategies such as sea walls and flood gates while providing other environmental and economic benefits.

The most important hydrologic value wetlands provide is flood protection. "Almost any wetland can provide some measure of flood protection by holding the excess runoff after a storm and then releasing it slowly. The size, shape, location, and soil type of a wetland determine its capacity to reduce local and downstream flooding. While wetlands cannot prevent flooding, they do lower flood peaks by temporarily holding water and

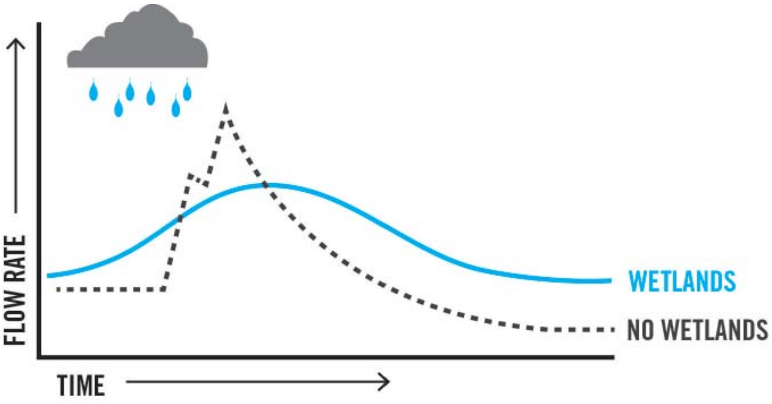

Figure 6a: Wetlands role in flood reduction[19].

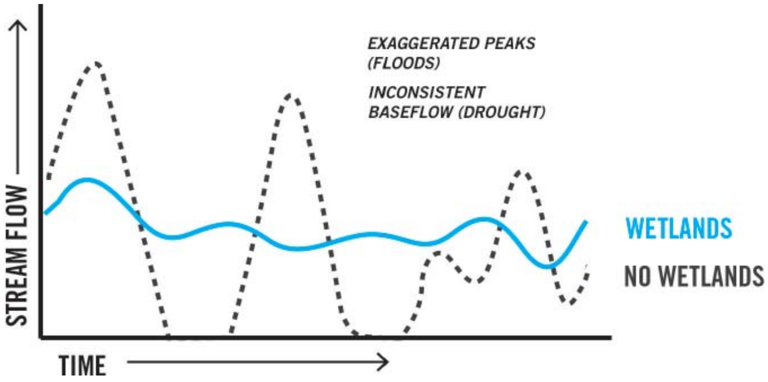

Figure 6b: Wetlands role in flood reduction[20].

by slowing the water's velocity. Wetland soil acts as a sponge, holding much more water than other soil types. Even isolated wetlands can reduce local flooding[21]." Wetlands also provide wave attenuation. Wetland vegetation decreases water velocities through friction and causes sedimentation in shallow water areas and floodplain wetlands, thus decreasing the erosive power of the water and building up natural levees. Finally, wetlands provide shoreline stabilization. Wetlands reduce shoreline erosion by stabilizing sediments and absorbing and dissipating wave energy. Wetland plants hold the soil in place with their roots, absorb the energy of waves, and break up the flow of stream or river currents. When vegetation is removed, stream banks collapse and channels widen and (or) deepen; removal of wetland vegetation can turn a sediment sink into a sediment source[22].

2.3 Wetlands Today

Wetlands today are highly misunderstood and undervalued. The public should be more informed and educated about the services and benefits that wetlands provide; particularly, more research should be done on the economic value of wetlands. Most urban areas have already destroyed a majority of their wetlands and development only continues to increase in coastal areas. In many instances irreversible damage has been done, such as landfilling. Many wetlands have been developed over, leaving little room for restored or new wetlands to grow. Wetlands also lack space to migrate inland due to rising salinity levels brought by sea level rise. Any hardened shoreline (a road or a seawall, for instance) means wetlands cannot move out of harm's

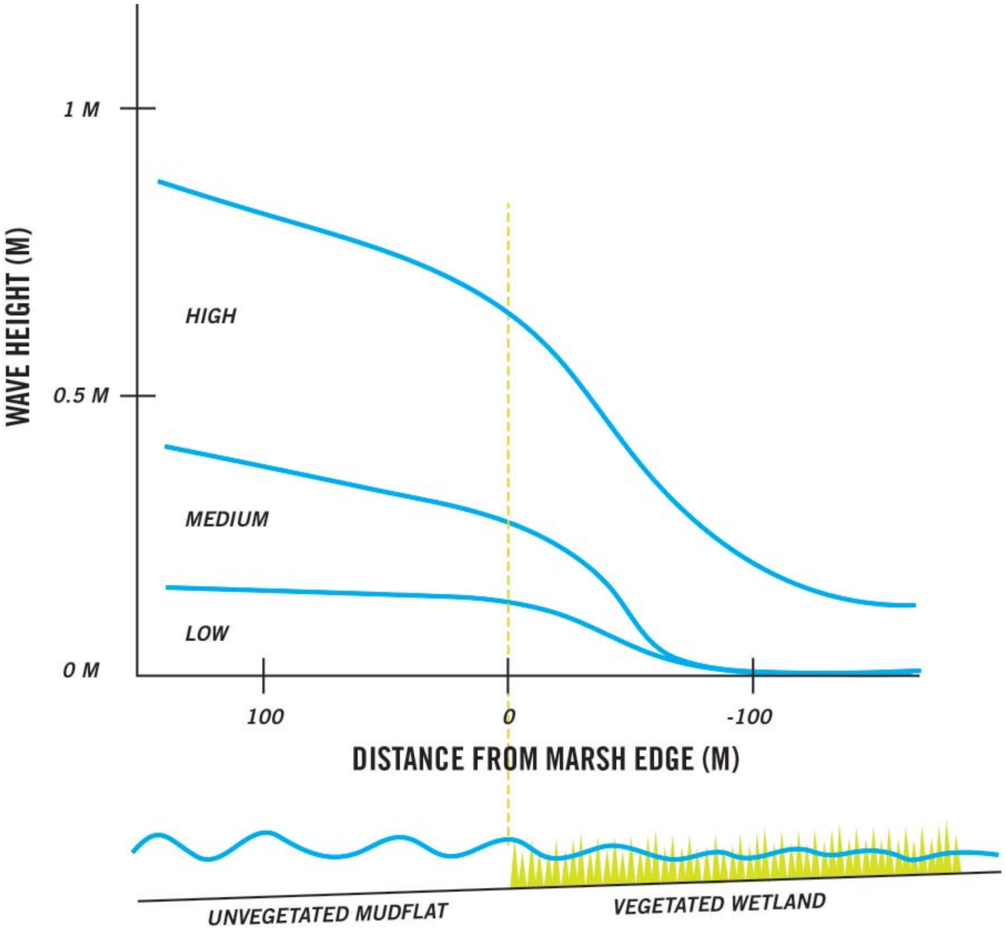

Figure 6c: Wetlands role in flood reduction[23].

way. Finally, research has been done on these topics, but the data is largely outdated and inconclusive. The bottom line is that there needs to be much more research regarding wetlands and climate change. Not only into how they can help coastal cities, but how they also can adapt to change.

Wetlands are threatened both globally and nationally. They are the second most endangered habitat in the world, behind only rainforests[24]. The U.S. estimates to have lost more than half of the country's native wetlands since 1600[25] and continues to lose 80,000 acres of coastal wetlands annually (that's the equivalent of losing one football field of wetlands every nine minutes)[26]. Between the years 1950-1970, the U.S. lost approximately 400,000 acres of wetlands per year[27].

The primary causes for wetlands loss are human activity (from urban and rural development) and from natural processes such as sea level rise and erosion. More than half of the U.S. population live in coastal areas. While non-coastal population growth has remained stable, coastal population growth rates have increased drastically over the past 30 years, with rates projected to continually increase.

Development in coastal areas puts stress on wetlands and often permanently alters the hydrology of a watershed through increased runoff and pollution[28]. "Coastal wetlands are naturally altered by high energy events such as erosion and inundation from sea level rise and storms. The impacts of these processes may be magnified by climate change and shoreline armoring. Estuarine wetlands typically protect the coastline from

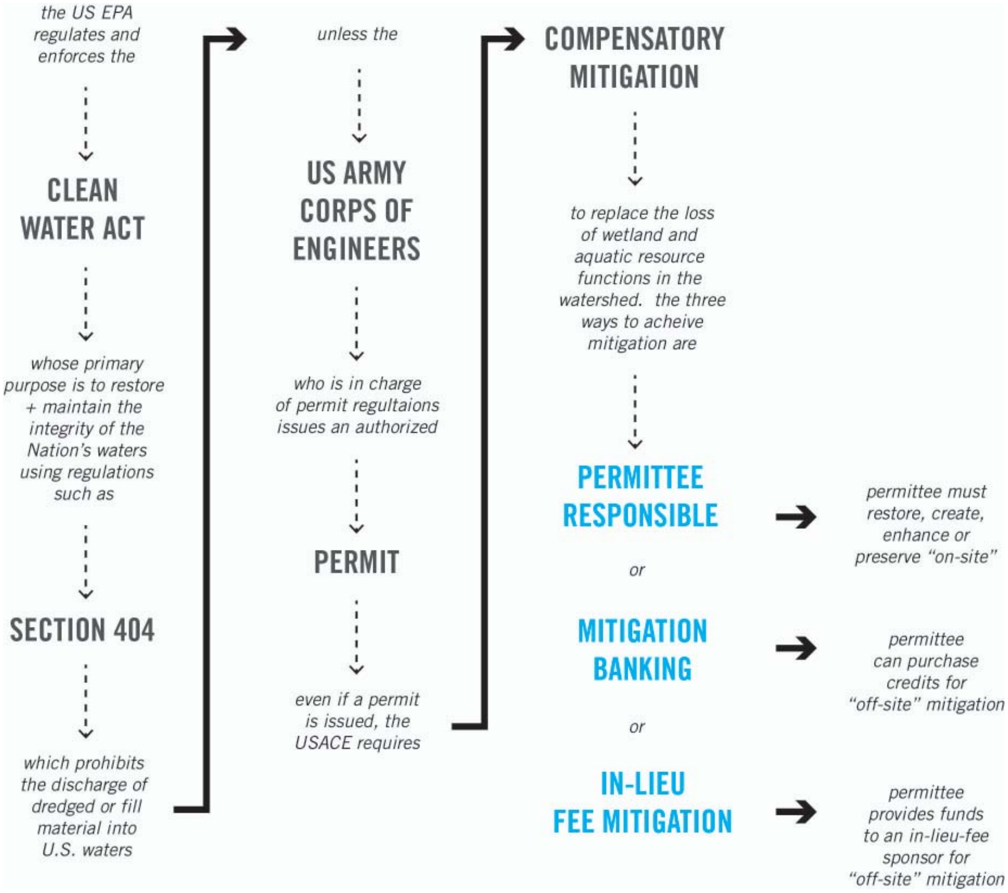

Figure 7: Wetlands protection flow chart[29].

erosion and flooding, but if sea level increases and development prevents inland migration of wetlands, more wetlands will be converted to open water[30].” In order to remain stable, marshes must either accrete sediment and organic material at the same pace as sea level rise or be able to migrate inland.

Wetlands today are protected federally and often additionally at the local level. The federal government protects wetlands through legislation, economic incentives, and acquisition. Wetlands are protected through the Environmental Protection Agency’s Clean Water Act, but the protections can be overturned through a permitting process that requires “no-net-loss” mitigation. Though federal regulations protect wetlands nationally, many states and local counties have adopted stricter regulations and laws to protect their wetlands. Though this may seem like sufficient protection, there are still many issues involved. For one, having overlapping authorities with so many laws, regulatory entities, and wetland definitions can be confusing when determining who has jurisdiction over a specific wetland or activity and what procedures must be followed. Not only can it be confusing, it can be nearly impossible to enforce. As such, many wetlands protection regulations are loosely enforced and there is a significant amount of oversight in the required compensatory mitigation practices. Finally, governmental regulations and incentives are not enough to protect wetlands. Education of the public and of federal, state and local government entities will be key in preserving remaining wetlands.

There are other federal laws in place that indirectly protect wetlands by limiting coastal development in certain areas. These include the Coastal Zone Management Act (CZMA) and many Federal Emergency Management Agency (FEMA) sponsored regulations. “The CZMA outlines two national programs, the National Coastal Zone Management Program and the National Estuarine Research Reserve System. The 34 coastal programs aim to balance competing land and water issues in the coastal zone, while estuarine reserves serve as field laboratories to provide a greater understanding of estuaries and how humans impact them. The overall program objectives of CZMA remain balanced to preserve, protect, develop, and where possible, to restore or enhance the resources of the nation’s coastal zone[31].” FEMA legislation include the Coastal Barrier Resources Act (CBRA), the NFIP Community Rating System (CRS), and the Biggert-Waters Flood Insurance Reform Act of 2012.

The CBRA, established in 1982, protects coastal areas that serve as barriers against wind and tidal forces caused by coastal storms and serve as habitat for aquatic species. The CBRA protects coastal areas from development by limiting federal financial assistance for development-related activities in designated areas[32]. The 1990 National Flood Insurance Program’s CRS is a voluntary incentive program that recognizes and encourages community floodplain management activities that exceed the minimum NFIP requirements. As a result, flood insurance premium rates are discounted to reflect the reduced flood risk[33]. The Biggert-Waters Reform Act calls on FEMA to make a number of changes to the way the NFIP is run. The new law encourages program financial stability by eliminating some artificially low insurance rates and discounts. Most flood insurance rates will now move to reflect full risk and flood insurance rates will rise on some policies. Incorporating flood mitigation strategies into the property can help lower insurance rates[34].

Wetlands scientific research developed fairly recently, with serious studies beginning in the 1970s and proliferating over the past two decades. Existing research centers include the USGS National Wetlands Research Center, the USFWS National Wetlands Inventory, and the Sea Level Affecting Marshes Model (SLAMM). “The mission of the National Wetlands Research Center (NWRC) is to develop and disseminate scientific information needed for understanding the ecology and values of wetlands and for managing and restoring wetlands, coastal habitats, and associated plant and animal communities throughout our world[35].” “The U.S. Fish and Wildlife Service’s National Wetlands Inventory (NWI) has been producing wetland maps and geospatial wetland data for the United States since the mid-1970s. The focus has been on two fronts: map or digital database preparation and delivery to the public, and projecting and reporting on national wetland trends using a probability-based sampling design. The status of mapping has been made available through various media throughout NWI’s 30-year history (e.g., state atlases, regional status maps, and now through the internet via the Wetlands Mapper online tool)[36].” SLAMM is a mathematical model developed in the 1980s that uses digital elevation data to simulate and project the potential impacts of sea level rise on wetlands and coastal areas. This valuable research tool is the first in its kind to address the future of wetlands due to climate change[37]. Although many universities and coastal research institutions have incorporated wetlands related studies into their programs, much more research is still needed to truly understand the values of wetlands.

2.4 The Georgia Coast

Georgia has 100 miles of coastline, which equates to five percent of the U.S. Atlantic coastline; however, Georgia has more than 33 percent of the remaining salt marshes on the Atlantic coast[38]. The state estimates to have 70 percent of its original coastal wetlands remaining, ranking 5th in the continental U.S. for original wetlands persevered[39]. The state links approximately $6 billion in economic benefits to the coastal marshes[40].

Wetlands loss in Georgia has been caused by coastal development, pollution, and natural processes. Coastal development has remained minimal until recent years. However, Georgia's coastal population has seen phenomenal growth in the past few decades and it continues to grow (the coastal population is expected to double between 2000 and 2030), to the detriment of wetlands[41]. Georgia is home to two major ports, Savannah and Brunswick. The manufacturing industries located near these ports have led to damaging pollution in the surrounding waterways, resulting in marsh destruction and groundwater contamination. There are 65 hazardous waste sites in Georgia's six coastal counties, 58 of which are located in port cities. There are four superfund sites along the coast, all located in Brunswick[42]. The Georgia coast has a dynamic sand-sharing system, in which natural processes of erosion and accretion take place. Though Georgia's coast experiences a lot of natural erosion, it has been exacerbated in recent years by rising sea levels, increased development, and hard infrastructure such as sea walls, bulkheads, and jetties. As such, the amount of erosion has far surpassed the amount of accretion[43].

Georgia's wetlands have benefited from favorable land ownership patterns and early public awareness, advocacy and state legislation. Coastal Georgia's land ownership patterns have resulted in many benefits for the coastal wetlands. To this day, a vast majority of coastal land remains undeveloped. Much of the coastal uplands are owned by large timber companies, and a majority of Georgia's islands are federal and state conservation areas. Only three percent of land in Georgia's coastal counties is developed; development is primarily located around Savannah, Brunswick, and St. Mary's[44]. Eugene Odum, referred to as the father of modern ecology, was a researcher and ecologist at the University of Georgia from 1940 - 1980. In the late 1960s, Odum led a campaign called "Save Our Marshes," in which he and his students educated the public about the value of wetlands. Odum's work created enough public momentum to stir up support in the Georgia legislature[45]. The Coastal Marshlands Protection Act, passed in 1970, was a direct result of this public awareness and advocacy. The Coastal Marshlands Protection Act and the later Shore Protection Act (1979) were way ahead of their time in recognizing the importance of protecting coastal ecosystems. They both acknowledge that these natural resources (Georgia's marshlands and sand sharing system) are important resources that would be costly and difficult, if not impossible, to replace if lost[46]. This foresight has led to Georgia's marshes being some of the most well preserved in the country.

Although Georgia's wetlands are well protected, there are a number of looming threats including climate change inaction, legislative roll-backs, a current lack of public awareness, increasing shoreline hardening, imprudent development decisions, and the Savannah Harbor Expansion Project (SHEP). Though there is ample evidence that Georgia's seas are rising steadily, a majority of the state does not recognize climate change as an issue. Studies of sea level at Fort Pulaski in Savannah show that the sea level is rising at a rate of approximately 0.03 meters per year, with the rate expected to increase exponentially in the coming years[47]. Georgia is one of few coastal states that has not created or adopted a climate change action plan. Because Georgia is not addressing climate change at a state level, and because coastal development is a strong economic driver for the state, the very laws that have so well preserved the Georgia marshes are now being threatened. There have been numerous proposals in the past decade to diminish and relax these laws. Advocacy organizations now have to spend their time fighting these roll-backs when their time should be spent trying to strengthen these laws. The UGA River Basin Center, part of the Eugene Odum School of Ecology, has conducted research on climate change and sea level rise and what that may mean for the Georgia coast. The center has modeled a one meter sea level rise, identifying areas of vulnerability and land cover changes. Much of the currently undeveloped drylands of Georgia's coastal counties are at high risk, with up to eight percent projected to disappear in the next 100 years. Much of this land is currently slated for future development projects[48]. The public needs to be informed of the risks associated with their properties, and future land development decisions should be based on research such as this. Another impediment, shoreline hardening, has become a popular method in Georgia to mitigate damage caused by rising water levels. Hardened shorelines, such as sea walls, increase erosion along shorelines and cause significant disruption in wetland migration. Sea walls not only increase erosion of the shore in front of them, but they cause hyper erosion of shorelines adjacent to where they end. This forces neighboring properties to either allow their land to erode, or put in place their own sea wall, thus continuing and exacerbating the cycle[49].

Although Georgia's marshes are well preserved, recent development decisions do not always follow this precedent. Georgia's marsh hammocks, small bits of marshy land barely above sea level, have been identified as one of the most endangered landscapes in America[50]. However, that does not stop developers from continually attempting to capitalize on any piece of waterfront property. The most recent example is a narrow spit on Sea Island that has been proposed for a subdivision development of eight houses. Despite being located in the FEMA floodplain and on an actively eroding beach (the shore has eroded 100 feet in the past ten years), plans are currently under review by the local city council[51]. Finally, the Savannah Harbor Expansion Project (SHEP) may have the biggest, and potentially most devastating, impact on Georgia's marshes throughout the state's history. SHEP Environmental Assessment Reports show that the harbor deepening will significantly alter the surrounding waterways and increase salinity levels. Half of the project's $652 million price tag will be spent solely on mitigating and compensating for the projected harmful effects on surrounding water quality, fisheries, and wetlands[52]. SHEP is also controversial within the community because there is no evidence that the proposed changes will actually bring in more economic activity.

Georgia's next steps in wetlands preservation should involve public awareness and community involvement, research and advocacy partnerships, policy changes, incentives, and a holistic, regional approach. The first and most important step is informing and educating the public about why these issues are important. Without public support, the Georgia coast is in dire risk. It is also important to engage local communities in conversations about the potential risks and the methods and measures to plan for and evaluate what climate change means for them. Though much more research is needed, some research is currently being conducted. Research institutions and advocacy groups should form partnerships to inform and educate the public and local governments. A scientific basis is needed in order to gain any traction; we need to be able to say that because of this data, we believe this is what should be done. An informed public voice stands a great chance of influencing local and state policy to save our coastal resources, as it has in the past. Georgia needs to strengthen current policies and propose new ones that protect precious resources and limit harmful development. Incentives such as the FEMA Community Rating System should be looked into as ways for local communities to become more resilient and save money. Finally, as with all sustainable systems, no part of the Georgia coast can be looked at in isolation. Coastal collaboration is the key to the future. Local and state governments, nonprofits and advocacy groups, research institutions, communities, private companies, and individuals must come together to create and carry forward a plan to limit imprudent decision-making and preserve the Georgia coast.

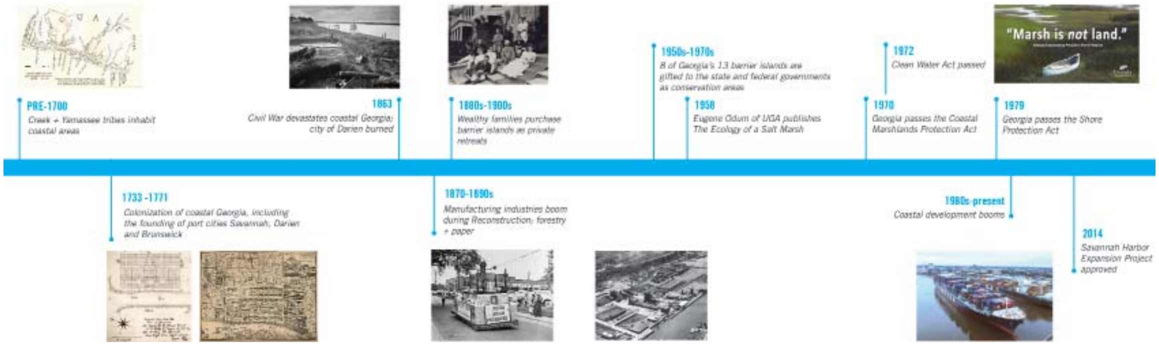

Figure 8: Georgia wetlands timeline.

2.5 New York City

New York City (NYC) has an estimated ten percent of original wetlands still remaining[53]. Nearly three million New York City residents live in flood evacuation zones[54]. Hurricane Sandy alone cost the city an estimated $19 billion in economic damage[55].

Primary causes of wetlands loss in NYC include landfilling, development, and pollution. Until the late 1970s, wetlands in NYC were regarded as additional land for development. The city began filling in wetlands as early as 1660 and these patterns of landfilling did not stop until Battery Park City was completed in 1970. A majority of NYC's flood zones are located in historic wetlands and areas that were previously water[56]. Pollution is another huge issue in NYC's waterways. NYC has a combined sewer system, which means waste water and stormwater runoff both flow through the same pipes; NYC has 490 combined sewer overflow (CSO) outfalls. In the event of heavy rainfall, these pipes overflow and the heavily polluted water flows directly into the surrounding waterways; as such, the city has never been in compliance with the Clean Water Act[57]. Wetlands can normally absorb and filter these pollutants, but if the pollutants exceed the carrying capacity of the wetlands, then the ecological functions will diminish over time. NYC now has two superfund sites, one of which is the Gowanus Canal.

Until the 1970s, protection for wetlands in NYC did not exist, which is why so few remain today. When the environmental movement brought about the notion of ecological consciousness into urban areas, nonprofit groups began to fight for the little that was left of the city's extensive historic tidal wetlands. Acquisition and preservation of the city's remaining wetlands began in the late 1970s and continues to this day; the city now owns 97 percent of its remaining wetlands[56]. After Hurricane Sandy, the city began seeking strategies to mitigate flooding brought on by extreme weather events. Wetlands are now not only being protected and preserved, but the city is exploring ways to restore historic wetlands where possible and construct new wetlands where necessary.

In 1984, Parks Commissioner Henry J. Stern founded the Natural Resources Group (NRG) with the aim to conserve and restore NYC's natural resources. This group began the trend of acquiring lands for preservation[58]. In 1987, the Trust for Public Land (TPL) and NYC Audubon began a program called "Buffer the Bay," in which they identified open space near the bay for acquisition and restoration; since then, many of the identified lands have been acquired[59]. In 2005, Mayor Bloomberg created the Wetlands Transfer Task Force to inventory city-owned wetlands and transfer them to the Department of Parks and Recreation. Today 97 percent of coastal wetlands and 79 percent of freshwater wetlands are publicly owned. The three main entities with ownership are the New York City Department of Environmental Protection (DEP), the New York City Department of Parks and Recreation (DPR) and the National Park Service (NPS)[56]. In 2007 Mayer Bloomberg released PlaNYC in an effort to make NYC more sustainable in the coming years. In 2011 an updated report was released, and in 2012 the SIRR report (Special Initiative for Rebuilding and Resiliency) was released, post-Sandy, to address resilience issues. A huge factor in the PlaNYC report deals with stormwater management and green infrastructure to reduce the amount of polluted runoff that enters the waterways. Wetlands have been receiving a lot of attention as a way to control stormwater and mitigate runoff[60]. One of the many initiatives of the PlaNYC is the NYC Wetland's Strategy to address protection and restoration issues. Key strategies include strengthening protection and acquisition efforts, developing a mitigation strategy for the city, promoting restoration projects, improving mapping and monitoring, and developing a research agenda to address wetlands challenges facing the city[56].

NYC's wetlands primary challenges are funding and space issues. Currently there is no dedicated funding mechanism for restoration projects. The maintenance, stewardship, and restoration of wetlands and natural areas require significant financial resources. Protection and restoration in New York City is particularly expensive, due to the city's high land values and limited space, ranging from $290,000 - $2,000,000 per acre. Cost-effective opportunities for restoration are increasingly difficult to find today, with high costs (and sometimes environmental impacts) of fill removal, site constraints, limited space, and competition for land. The highly developed shorelines of NYC have allowed for little to no transition area between land and water, preventing inland migration of adjacent wetlands. Even development that took place after federal or state wetland regulations were in place have not left much transition area for inland migration. State law requires a 150 foot transition area in New York City and 300 feet elsewhere; however, even recent permitted fill activity has been allowed much closer to the wetland boundary[56].

Despite issues and threats, NYC has had a number of successful restoration projects including Jamaica Bay and the Staten Island Bluebelt. Jamaica Bay, an

18,000 acre wetlands estuary, is NYC's largest remaining wetlands complex. Though surrounded by development, manufacturing, and an airport, the estuary remains richly productive and a home to diverse wildlife. In the early 1990s, the wetlands were disappearing at an alarming rate due to surrounding development and pollution; if left alone, the wetlands were projected to be lost entirely by 2025. Because Jamaica Bay is one of the last remnants of its kind in the city, it has been the focus of many preservation and restoration efforts. The city, non-profits, and community volunteers have restored hundreds of acres in the bay to date[61]. Jamaica Bay is also home to the Jamaica Bay Science and Resilience Institute, a CUNY (City University of New York) Initiative that is the first center wholly focused on the study of resilience in the world[62]. The Staten Island Bluebelt is a great example of cost effective stormwater management through wetlands preservation and restoration. The Bluebelt aims to preserve natural drainage corridors such as streams, ponds, and wetlands in order to convey, store, and filter stormwater runoff. The program saves tens of millions of dollars in hard infrastructure costs, while also preserving open space and wildlife habitat[63].

NYC also employs innovative strategies to experiment with ideas and solutions. In 2010, the Museum of Modern Art (MoMA) invited five design teams to re-imagine NYC in response to sea level rise in a project called Rising Currents. Architecture Research Office (ARO) and dlandstudio developed an "ecological infrastructure" for Lower Manhattan of green streets and a graduated edge that works within the city's existing infrastructure. The new coastal edge consists of a porous park network, wetlands, and marshes. The remaining four teams developed similar concepts of soft infrastructure approaches, such as barrier islands, oyster and subway car reefs, and wetlands[64]. One of the city's superfund sites, the Gowanus Canal, is now a pilot project for wetlands as green infrastructure. Susannah Drake's firm, dlandstudio, in collaboration with city planners and politicians have set plans for the Gowanus Canal "Sponge-Park," an 1,800 square foot stormwater management park. The small park is designed to capture and filter stormwater runoff while also creating public space to bring people closer to the water. Funded through grants by the city, the park will cost $1.5 million and serve as a prototype for green infrastructure and constructed wetlands for the city[65].

New York City's next steps in wetlands preservation and restoration should include a realistic analysis of at-risk areas, policy and funding mechanisms, and holistic, regional strategies. As climate change threats mount, it is important to reevaluate and revisit building in flood zones. High level analysis of at-risk areas should be conducted (what infrastructure will be affected, what will be lost in the event of another Sandy, etc.). The storms will continue to come; the question is, will we continue to take a reactionary stance, or will we be proactive about mitigating further losses? Wetlands restoration is incredibly expensive in NYC's dense urban environment due to issues such as high property values and constant stressors from development and pollution. Newly constructed and restored wetlands must be monitored and maintained, as they often take one to two years to mature. Current restoration efforts have been funded through grants and nonprofits, but if restoration is to make a real difference there needs to be an established funding mechanism for the city. The City of New York should develop a wetlands mitigation bank in order to make more substantial wetlands restoration

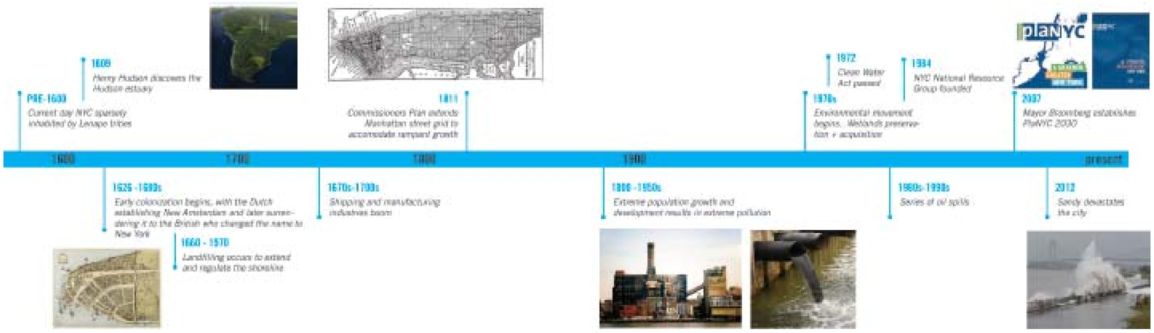

Figure 9: New York City wetlands timeline.

efforts. Mitigation banks are one way to provide a stable funding mechanism for substantial restoration projects. Finally, NYC should work together with its watershed neighbors: upstate New York, New Jersey, and Connecticut. The city is not an isolated piece of land, but part of an intricate estuary network. Climate change and sea level rise should be addressed at the larger scale in order to be more impactful.

3.0 CONCLUSION

Wetlands are a smart, cost-effective tool for urban designers and planners to use in urban areas as a means to reduce flooding, filter pollutants, create habitat, and provide open space.

The two case studies chosen were extreme situations, as most other coastal cities will fall somewhere between the two. The Georgia coast had the foresight to protect their valuable coastal resources, but now faces the risks of overturning their progress for short-term gains. We can learn from Georgia's amazing preservation strategies and their now on-going battle to continue what they started. NYC has the opposite situation. Where they were once blind to the values of their natural resources, they have come an incredibly long way in the past 40 years to shift the mindset towards preservation and restoration. We can learn from NYC's unfortunate historic decisions and now from their progressive strategies for urban resilience.

A number of conclusions have been drawn from this research. First, wetlands are still undervalued. The general public is still not aware of the many services and values wetlands provide and how they can benefit coastal areas, especially economically. Because of this, wetlands are still disappearing at a shockingly high rate, despite regulations put in place to protect them. Second, wetlands are in danger from humans and sea level rise. Wetlands are a fragile ecosystem that are upset by stressors from development and pollution. Wetlands are put at further risk from inundation due to sea level rise; ordinarily wetlands would migrate inland, but most coastal areas are highly developed and prevent this. Third, wetlands decrease the need for hard infrastructure in coastal urban areas, while saving money and improving the environment at the same time. The hydrologic values of wetlands can play a significant role in reducing coastal flooding and future investments in shoreline protection, while providing environmental benefits. Additional research is still needed to better understand and support the efficacy of flood and storm surge mitigation. Fourth, prevention is better than recovery. This is true for wetlands, which take a lot of time and money to restore, but is also true for coastal cities preparing for climate change. Much focus is placed on reactionary tactics such as adaptation strategies. More research, time, and energy should be put into preventative measures: not degrading valuable ecosystems that protect our shores, not building in floodplains, etc. Fifth, well preserved places (such as Georgia) should not be imprudent. While well preserved places will certainly not have as many issues in dealing with climate change as other more unfortunate communities, it does not mean that they have earned the right to be foolhardy. No matter the state of your coast, long-term goals should guide decision making, and never short-term profit making. Finally, poorly preserved places (such as New York City) should restore and construct. Highly developed urban coastal environments that either do not have many wetlands left or do not have ample space for wetlands should consider restoring and constructing wetlands and other soft infrastructure where possible as a means to offset the effects of climate change.

To realize success in preserving and restoring coastal wetlands, a number of next steps should be taken. Scientists and researchers should communicate information about coastal hazards and potential risks to communities and wetlands to government agencies and the public in order to heighten awareness and encourage responsible policies and decision-making. Coastal communities should plan and develop strategies for prevention and adaptation in order to mitigate further losses and build more sustainable, resilient communities. At-risk properties and infrastructure should be identified and measures and methods should be developed in order to protect these areas from future development. Government agencies should accept their responsibilities for using and providing the best information and recommendations for future land use decisions and regulations in high-risk coastal areas. Existing policies and regulations in place to protect wetlands should be strengthened and strongly enforced. Clear procedures and coordination at all levels of government are necessary. Mitigation requirements and permits should be strongly enforced and should be monitored for one to two years following implementation in order to ensure that the mitigation does in fact offset the loss and or damage done. Local and state governments, nonprofits, and communities should work together at the watershed level to develop a regional vision and approach to preserving coastal communities and resources. Collaboration across stakeholders is critical to developing impactful strategies for dealing with climate change and protecting coastal resources. Coastal areas should incentivize “the right thing” by using a combination of regulatory and economic policies, such as FEMA’s Community Rating System. In other words, communities that strive to make their cities and homes more resilient should be rewarded. Wetlands preservation and restoration could be one such incentive. Grants or legislation should provide funding to state and local governments to research and take stock of their current wetlands and to experiment and perfect mitigation and restoration practices in their areas.

Finally, the real key to success in understanding the fate and future of coastal wetlands is in more research. Though a variety of research is currently underway, much more is needed to understand the role of wetlands in urban areas and to influence public policy and funding for wetlands preservation and restoration projects. The following are specific types of research that would be incredibly helpful in this moving forward.

First, the role and efficacy of wetlands in storm surge mitigation is still unclear. Research needs to be conducted in the areas of wave attenuation and how much space (acres or miles of wetlands) are actually needed to be most effective to mitigating these issues. Second, highly developed coastal areas are exploring various edge typologies as ways to address sea level rise and storm surge. More research needs to be conducted on the effects that hardened shorelines have on surrounding areas (erosion, wetlands migration), as well as how effective “living shorelines” (shorelines with soft infrastructure) are in comparison to hard infrastructure. Third, wetlands restoration and constructed wetlands are still fairly recent sciences; experiments should be conducted to find the best and most cost effective ways to implement these measures. How long do constructed wetlands take to mature? How much space is needed for wetlands to perform well, at various scales? Fourth, monitoring and assessment needs to become more regularized. Both historic and new wetlands should be mapped, inventoried, monitored, and assessed on a regular basis. Finally, more research, such as the SLAMM model should be conducted as the effects of sea level rise on marshes are still not clearly understood. How much inundation can marshes handle? Will increased salinity levels affect performance? More localized research is needed as well; can marshes in this area migrate? Is there an opportunity for a migration corridor?

These are just a few examples of questions raised and research needed. Research and information sharing hold the answers to these questions and the key to the future of not only wetlands, but our coastal cities across the globe.

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