



Greening schoolyards - An urban resilience perspective

Leah Flax^{a,1}, Renet Korthals Altes^{b,2}, Roland Kupers^{c,3,*}, Brett Mons^{d,4}

^a New York City Transit, United States of America

^b MakeSpace4Play.com, The Netherlands

^c Institute for Advanced Study, University of Amsterdam, The Netherlands

^d The Rockefeller Foundation, United States of America

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1. Introduction: an urban resilience perspective on greening schoolyards

“Resilience, like love, is difficult to define. Yet everyone – from United Nations Secretary-General Ban Ki-moon to government agencies, company boards, and community groups – is talking about how to build or maintain it. So, is resilience a useful concept or just a fleeting buzzword?” asks Brian Walker, one of the leading thinkers on the topic (Walker, 2013). There are multiple definitions of resilience, but they largely share a common core: resilience is the capacity of a system under stress to continue functioning through adaptation and transformation. The definition of resilience underpinning this frame discussed in this paper is consistent with Kupers (2014) and Walker and Salt (2006).

Resilience has been found to be a useful concept and frame for strengthening and improving systems, in particular within the fields of urban development, disaster risk reduction, and climate action. The 100 Resilient Cities program, pioneered by The Rockefeller Foundation is an example of this. Other examples include the World Bank's City Resilience Programme or UN Habitat's City Resilience Profiling Programme. These programs have helped to raise awareness and interest in the concept of resilience. And in turn, have increased the need for practical resources and frameworks that practitioners can apply.

In this paper we will apply the “nine-box frame” (Kupers & Ching, 2016), a globally tested resilience framework, to demonstrate how the concept of resilience can be practically understood as a system-strengthening approach. Resilience is not an abstract property, but

specific to a particular system. Increasing the resilience in one system can sometimes come at the expense of another. In this paper we will discriminate between building resilience at three system scales: project, community, or city.

Among the many interventions that can be considered using a resilience framework, an important justification for this focus is the systemic potential of such interventions. Greening schoolyards impacts multiple geographic scales from entire cities to individuals, across multiple time scales from short to long-term benefits. Furthermore, greening schoolyards delivers benefits across multiple urban systems: empowering future generations to impact their surroundings, social integration, water management, air quality, and improved urban environment.

Greening schoolyards is an intervention that has historically been championed by educators but has recently grown in popularity among planners as a method to cope with extreme heat, flooding, and other increasingly disruptive climate related events. Approaching nature-based solutions through urban planning processes may also be a particularly effective approach to increase implementation (Bush & Doyon, 2019). We provide case examples from Amsterdam, Chicago, and Paris – Chicago and Paris are part of the 100 Resilient Cities network and all three cities are currently implementing green schoolyard programs as a way to cope with chronic stresses and acute shocks.

We then explain the nine-box frame and apply it to the cases of these three cities - exploring how the frame can be useful in building city resilience, community resilience, and ensuring the resilience of the project itself. We invite the reader to learn about the practice of

* Corresponding author.

¹ Leah Flax is an urban planner, former associate director at 100 Resilient Cities, and is now a government relations specialist at New York City Transit.

² Renet Korthals Altes is an architect and teacher specialized in greening schoolyards.

³ Roland Kupers is an author and advisor on complexity and resilience.

⁴ Brett Mons is an urban planner, former senior manager at 100 Resilient Cities, and is now a senior associate at The Rockefeller Foundation.

greening schoolyards, and judge for themselves the question raised by Brian Walker about the usefulness of the concept of resilience.

2. How greening schoolyards contributes to urban resilience

As primarily public assets, urban schoolyards comprise a high share of open space and engage a significant and diverse proportion of a city's population. In addition, they tend to be highly distributed geographically and relatively small in scale, at an individual level. These factors allow decision makers to be innovative and targeted with resources in order to achieve multiple benefits that work towards the goals of a given neighborhood or community.

For the purpose of this analysis, green schoolyards can be defined as multi-functional school grounds that reduce non-porous surfaces by incorporating green elements such as gardens, plants, trees, grasses and other porous surfaces. Green schoolyards better manage extreme weather events, help mitigate climate change, and serve as a natural resource for students, teachers, parents, and the community. Planners are tasked with creating great communities for all and greening schoolyards can be a multi beneficial method to promote community engagement and social cohesion, mitigate and adapt to climate change, and improve health outcomes.

2.1. Community engagement and social cohesion

As the primary user, children's influence in design or transformation of their schoolyards increases the benefit of those investments. First, adults are not necessarily the experts on what design elements children will utilize. Their contribution to the design process is critical to ensure that the final project is fun and interesting to those primary users. Second, children can gain experience and learn early on how participation in community activities can influence their environment. They are exposed to planning as a field, learn about becoming an engaged citizen, are taught the value of their opinion, and become invested in the outcome. Finally, when children are involved early in the project, they learn valuable lessons in how our actions as humans impact the environment and how to adapt their environment for the future. "It teaches students about their own impact on the environment, shows them the connections between natural systems, and empowers them to make their schoolyard an ecological asset for their neighborhood" (Danks, 2010). Research has also shown that schools that involve students in gardening help build strong communities. Students have an improved attitude about school, involve their parents more in school activities, and the school gardens provide a diversity of environmental stewardship including opportunities for science-education to learn about soil improvement and composting (Blair, 2009).

A participatory design process in which community stakeholders are involved, reaching consensus about goals and priorities, is important to build long-term stewards, who will nurture and care for their schoolyard, when children and teachers come and go (Danks, 2014). Compared with large, multi-year projects with huge budgets, schoolyard projects are better set-up to allow impactful engagement. The process of greening schoolyards, with a strong community participatory approach, could form an excellent example of citizens' ability to be part of a small scale, but very tangible and impactful decision-making process. Neighbors that know and interact with each other are more cohesive, less likely to be involved in civil disturbances, safer, and better prepared to respond and recover from acute shocks.

Schoolyards are limited in size but well distributed throughout cities. As such opening them to the neighborhood can notably increase the quantity of available public space. This in turn has the potential to impact health and social cohesion beyond the school. This benefit is further promoted when that open space is sufficiently green. Kuo et al. show that the level of vegetation in common spaces in neighborhoods predicts the use of the common spaces and the Neighborhood Social Ties (NSTs) (Kuo et al., 1998).

2.2. Mitigate and adapt to climate change

The American Planning Association adopted a Policy Guide on Planning and Climate Change in 2008 which states that "planners have the opportunity and obligation to address the challenge of global climate change." (American Planning Association, 2011) Greening schoolyards is an effective and multi beneficial tool to address climate change as a means to offset the heat island effect, absorb rainwater, and abate fine particle pollution.

Urban areas are generally hotter than their surroundings, the so-called Urban Heat Island effect. A literature review shows that green plots of land in cities reduce the temperature near such sites up to 4 degrees C during hot periods, depending on the size of the lot, the amount of trees and grass cover and the choice of the species (Shishegar, 2014). This is the result of the increase of evaporation from plants/trees, plus their own transpiration, direct shading on urban surfaces and changed air movements.

As the global climate becomes wetter and wilder, urban storm water management is increasingly becoming a priority for urban planners, water management professionals, and landscape architects. According to the National Resource Defence Council, officials tend to focus on extreme flooding events but a report from the University of Maryland urges cities to focus attention on more common and costly "chronic urban flooding due to city landscapes that cannot absorb or otherwise manage rainfall." (Center for Disaster Resilience, 2018; Weber, 2019) Urban green spaces reduce the pressure on urban drainage and flood defenses by replacing impermeable asphalt with permeable materials. Research is limited on the costs associated with urban flooding, but from 2007 to 2011, urban flooding in Cook County, IL resulted in over \$773 million in insurance claims alone (Center for Disaster Resilience, 2018). According to a literature review by the US EPA, not only do green infrastructure approaches result in multiple environmental, social, and financial benefits, these investments are typically more cost effective than grey infrastructure approaches to address urban flooding (EPA, 2013).

Green schoolyards can also play a role in combating fine particle pollution. The extent to which they can contribute to air quality improvements depends heavily on the choice of vegetation (tall or short and dense or sparse), the vegetation's distance to the source of pollution and the amount of air passing *through* the vegetation (Janhäll, 2015). According to a German research review, promising measurements suggest that local planting campaigns, even when covering small areas, can be beneficial for a reduction of particle concentrations, although further research is needed (Litschke & Kuttler, 2008).

2.3. Health and wellbeing

The positive health benefits to children of free play in natural environments is well documented. Pediatricians promote free play as an essential part of childhood, emphasizing positive impact on health and brain development. They encourage access to places for mental and sensory stimulation, privacy, or opportunities for creative play (Barros et al., 2009; Ginsburg, 2007).

Table 1 summarizes the benefits of access to natural environments for children range from improving cognitive and motor fitness, reducing gender differences, and improvements in health indicators:

3. Case studies

Amsterdam, Chicago, and Paris are three cities trying to expand green schoolyards with an explicit objective to benefit not just students - but the local communities and city overall. These cities have many things in common, including strong mayoral governance structures, leadership in climate change, and experience with both natural and human-made catastrophes. They also differ greatly in their histories, geography, and cultures. And their green schoolyard programs range in

Table 1
Summary of literature review.

Finding	Source
Children with attention deficit symptoms “function better than usual after activities in green settings...”	(Taylor et al., 2001)
Versatile play in natural environments impact motor fitness in children and significant effects can be found in balance and coordination	(Fjortoft, 2001)
Gender differences in play are less pronounced in schoolyards where children play in forested areas	(Tranter & Malone, 2004)
Increased access to green space by children is correlated with decreases in childhood obesity	(Coley et al., 1997; Kuo et al., 1998; Wolch et al., 2011)
Populations with greater exposure to green space tend to have less health inequalities and lower mortality indicators	(Hartig et al., 1991)
Green schoolyards potentially increase opportunities and reduce obstacles to a healthier lifestyle; however, these benefits may take generations to achieve reductions in some health disparities	(Tyler & Moench, 2012)

Table 2
Summary of interviewees.

Title	Organization	City	Month interviews occurred
Senior Vice President	Healthy Schools Campaign	Chicago	December 2018
Space to Grow Director	Healthy Schools Campaign	Chicago	December 2018
Chief Resilience Officer	City of Paris	Paris	November 2018
Process director Greening schoolyards project	Dept. of Education	Amsterdam	November 2018
Advisor water and climate adaptation	Municipality	Amsterdam	November 2018
Nature & Environmental Education	Municipality	Amsterdam	November 2018
Project manager Greening Schoolyards	Municipality	Amsterdam	December 2018

maturity from piloting in Paris to eight years of refinement in Chicago (Table 2).

3.1. Paris ‘Oasis’ project

All Paris parks and gardens account for 1013 acres of green surfaces. Greening a total of 700 green schoolyards of 197 acres, would increase the total green space by a fifth. Furthermore, the large majority of Parisians live less than 200 m/650 ft. away from a schoolyard, adding adjacent and distributed green oases (Mairie de Paris, 2018).

Since adopting its climate change adaptation strategy in 2015, Paris has launched several sites with the objective to “conduct a vast greening programme to cool the city.” (Mairie de Paris, 2015) The City aims to eventually implement a cooling programme for all schools, starting first with the gradual replacement of their ubiquitous asphalt with vegetation. The City envisions schoolyards as “cool refuges” welcoming community members vulnerable to heat waves during extreme weather events. The City also wants to design the schoolyards to increase output of urban agriculture to strengthen the resilience of the city's food systems, and to open the yards to the public to strengthen the social fabric of local communities.

With extensive stakeholder engagement, the ‘oasis’ schoolyard greening has been realized in 2018 in three schools (Fig. 1), with 30 more planned in 2019 and all completed by 2040.

3.2. Chicago - solving the recess drought (and preventing floods)

For nearly three decades, Chicago Public Schools did not include outdoor recess as part of the school day citing academic instruction as the priority. That changed in 2011, when Chicago Public Schools approved a policy bringing recess back to many schools, which included modest funding to repair and improve schools' playgrounds that had gone unmaintained the whole time.

Around the same time, the city's two water utilities - Chicago Department of Water Management and the Metropolitan Water Reclamation District of Greater Chicago - were looking for cost effective methods to control flooding and storm water across the city. They saw an opportunity in a partnership with Chicago Public Schools, who at the time had more than 760 acres of impermeable surfaces that did nothing to absorb rainwater or abate flooding issues (Merck, 2017). The three public entities, in collaboration with the non-profits the Healthy



Fig. 1. Paris schoolyard.
Photo credit: 100RC.

Schools Campaign and Openlands, created the Space to Grow program to transform Chicago schoolyards into green schoolyards (“Space to Grow,” n.d.).

The program enables school districts and the utilities to pool resources to transform not only schoolyards, but the wider community through increased access to recreation and park space. Space to Grow employs a participatory planning and design process over the course of several months that is coordinated by two community-based teams, a planning team and a garden team. The process aims to reduce centralized decision making by convening a biannual individual group meeting with students, teachers, school administration, parents, and the neighboring community (Children and Nature Network, 2016). These stakeholder meetings create the safe space necessary for open and honest discussion that could be inhibited by having school or community leadership in the same room.

The Space to Grow program annually calls for six schools to get \$1.5 million each to convert their concrete/asphalt surfaces into green schoolyards and engage the entire school community in the planning process. By 2019 a total of 34 green schoolyards will have been opened (“Space to Grow,” n.d.). Program funding and coordination is made possible through the Chicago Public Schools, Chicago Department of



Fig. 2. Cook Academy in Chicago's Auburn-Gresham neighborhood schoolyard before greening.

Photo credit: Space to Grow.



Fig. 3. Cook Academy in Chicago's Auburn-Gresham neighborhood schoolyard after greening.

Photo credit: Space to Grow.

Water Management, the Metropolitan Water Reclamation District of Greater Chicago, and Space to Grow (Fig. 2 and 3).

3.3. Amsterdam impulse schoolyards

In the Netherlands, the schoolyard is in the top 3 of favorite playgrounds among children. The (re) design of school playgrounds in primary education offers children more opportunities for active and diverse play, and to explore nature during & after school time, all within their own neighborhood.

For the period, 2016–2019, the Education and Green & Sustainability departments of Amsterdam's municipality provide a budget for the Amsterdam 'Impulse' Schoolyards (AIS), of up to €70,000 per schoolyard. An important condition in applying for the subsidy was that schools self-financed 20%. The program was very successful with 85 schools participating and an extension decision planned for April 2019. The program has been extended for the years 2020–2024, in which 60 more schoolyards will be greened (Fig. 4).

Characteristic for AIS is the integration of city-wide goals: stimulate active play, add 25% green per schoolyard, contribute to the rainwater absorption programme, increase nature/outdoor education, citizen participation and sustainability. In addition, the schoolyard must be accessible to the public, even after school. Funding has been combined from different departments, who have set up an interdisciplinary team



Fig. 4. Combining climate proof design with playability: wadi in Amsterdam schoolyard.

Photo credit: Ir. Renet Korthals Altes.

to ensure an integrated approach. This interdisciplinary team forms the core of the Amsterdam impulse.

4. The nine-box resilience frame

To better understand the usefulness of resilience as a concept, we now use the nine-box resilience frame to explore the cases of Paris, Chicago, and Amsterdam.

The frame was developed between 2012 and 2014 by the Resilience Action Initiative, an ad hoc coalition of leading corporations. They sought to design and test a resilience framework for cities and regions that would enable consideration of resilience as a systemic property, in multisector partnerships of cities, civil society, and companies. In addition to aiding in analysis, the goal was to create something that could be used by decision makers to articulate concrete action plans for furthering resilience (Kupers, 2014).

The nine-box frame draws extensively from the fields of systems science and ecosystem resilience, as well as the real-life experiences brought by the original multi-sector members of the Resilience Action Initiative. It has subsequently been applied globally e.g. in risk management and by the 100 Resilient Cities programme - in such contexts as hunger alleviation among migrant construction workers in Singapore, linking economic development to airport expansion in Mexico City, and medical campus planning in San Francisco.

The frame consists of nine elements – or lenses, organized around three themes (Kupers & Ching, 2016) (Table 3).

By observing the systems under consideration through each of these lenses, we can assess the resilience dynamics of a given system or scale. Specifically, we will consider how resilience can be built at the city-,

Table 3
The nine-box resilience frame.

The nine-box resilience frame		
Structural resilience	Integrative resilience	Transformative resilience
(1) Redundancy	(4) Multi-Scalar Interactions	(7) Distributed Governance
(2) Modularity	(5) Thresholds	(8) Foresight Capacity
(3) Requisite Diversity	(6) Social Cohesion	(9) Innovation & Experimentation

community-, and project-scale. While the nine-box framework can aid in decision-making and analysis, it is not an analytical but a conceptual framework. Further, we concur with (Quinlan et al., 2016) that “measuring and monitoring a narrow set of indicators or reducing resilience to a single unit of measurement may block the deeper understanding of system dynamics needed to apply resilience thinking and inform management actions.”

STRUCTURAL RESILIENCE – the systemic, infrastructure-related aspects of resilience; i.e. redundancy, modularity and requisite diversity.

- 1 Redundancy** is determined by the spare capacity in the system, by resources that are held in reserve and made available as replacement. Redundant resources may be tapped when some part of the system goes down, or when we have to deal with additional capacity demands on the system (Desouza & Flanery, 2013). A basic example is the spare tire in a vehicle or the extra capacity in an electricity network. While it can be the most straightforward way of building resilience, it is also the most costly.

City Resilience: Green schoolyards can provide added (i.e. redundant) capacity to other more established city systems. Storm water management is a good example - by retaining rainfall, green infrastructure reduces storm water discharges and combined sewer overflows. This was one of the primary goals for Chicago's green schoolyards. Similarly, schoolyards can add to a City's existing programs and capacity to handle shocks and stresses by improving air quality, social cohesion, or heat island effect.

Community Resilience: Greening multiple schoolyards within a given community creates redundancy, and ensures that if one schoolyard does not succeed, another may.

Project Resilience: There should be multiple parties sharing responsibility for operations and maintenance, enabling materials and resources to be shared between sites when necessary. Chicago's program has three capital funding partners and two managing partners, which collectively offer greater financial and political stability for the program.

- 2 Modularity** refers to loosely coupled components. A system that is too monolithic is less resilient as shocks and stresses will affect it in its entirety. Breaking it into independent smaller elements makes it more resilient, but it is no longer a system. The optimal point is a loose coupling that provides relative insulation from crisis spreading across the whole, but tight enough that it does not lose its productive capacity. Sometimes modules are in fact more solidly coupled than may be apparent: banks in the 2008 financial crisis appeared healthy individually, but weak as a system through tight synchronization.

City Resilience: The physically distributed nature of schoolyards coupled with the fact that they are all part of the school system, ensures a natural modularity with some connectivity between them. This modularity also applies to how the yards fit in with other city initiatives with similar aims.

Community Resilience: At the 34 schoolyards being greened across in Chicago, they have divided each school district into different geographic jurisdictions, and the maintenance of the sites is

dependent on those jurisdictions, which allows for more decentralized and community-based influence.

Project Resilience: Each schoolyard presents an opportunity for experimentation and learning, and the challenges faced by one, need not be repeated by all. Amsterdam has found a good balance between independent design and central control across sites. Knowledge and experience are shared by the program managers, and for the rainproof interventions via an open-source toolbox (Amsterdam Rainproof, n.d.). Through this approach the municipality increases know-how and transfers lessons learned to other schools.

- 3 Requisite diversity:** Diversity makes systems more resilient, but increasing diversity may reduce efficiency in the short term. Rather than diversity for its own sake, it is important to consider what types of diversity are relevant for particular circumstances, hence requisite diversity.

City Resilience: Greening schoolyards creates greater diversity in the urban environment by introducing more diverse natural areas. In Paris the immediate goal is to remove the uniform asphalt covering of the existing schoolyards and replace it with a porous covering, however, this is perceived as still too uniform an approach and does not fully realize the benefits of greening. Efforts are underway to introduce more diversity in design and materials, including customization by the schools themselves (e.g. with fountains and plant gardens).

Community Resilience: The schoolyards should have diversity of programming to engage multiple segments of society (children, elderly, heat-vulnerable, socially isolated groups). Engaging multiple users starts with the design process - in Chicago, from the outset, they created an inclusive design process that includes door-to-door outreach and community meetings, purposefully trying to go beyond those already affiliated with the school.

Project Resilience: Schools themselves have substantial diversity. They may be private or public, elementary or higher education, and have different leadership and reputations. This will likely enable diverse management systems to evolve. In some schools the yards may be maintained by students, others by neighborhood associations and in some cases even by professional service providers. The designs should include sufficient biodiversity in case of blight or changing weather conditions. In Amsterdam the municipality employs a diversity of experts in reviewing designs and approving funding. The process includes multiple reviews (preliminary design and final design) by a panel of four experts to ensure the design accounts for the needs of different collaborating departments: 1) (natural) education, 2) health & movement 3) urban and landscape design, 4) greening & maintenance.

INTEGRATIVE RESILIENCE emphasizes the complex interconnections of systems, i.e. multi-scalar interactions, thresholds and social cohesion.

- 4 Multi-scalar interactions** characterize the relationships of the system under consideration with other systems at different scales surrounding it. Scales can be geographic (e.g. neighborhood, city, province, nation), temporal or social (e.g. child-family-neighbors-community). From empirical studies as well as theoretical insights, it appears that the ability to understand a system at multiple scales is crucial for building resilience, both above and below the focal scale under consideration. This is because feedback loops operate across scales and have an impact on the focal scale. It is the quality of the links between the scales that strongly influences the resilience of the system.

Geographical scales: Take rainwater management, where schoolyards are one scale of intervention. Other scales include public parks, gardens, repurposed sidewalks and the traditional gutter-system itself. The relationships between the scales determine the

effectiveness and resilience of the entire system.

Social scales: Consider interactions between the schoolyard and the local neighborhood: In Chicago designers and organizers have intentionally tried to establish the schoolyard as a neighborhood park through variations in schoolyard fencing, barriers, and signage. Paris has made particular efforts to coordinate their pilots with the local neighborhood shops. In Amsterdam the schools that receive funding must be willing to open their schoolyards to the public in order to qualify for the subsidy. The impact reaches throughout diverse social scales: the children influence their parents and peers, who might spread the word among their colleagues or acquaintances. The involved teachers and the schools themselves influence other schools through sharing of best practices as well as competition among school administrators.

Temporal scales: Like the Chinese proverb says *'Teach me and I'll forget; show me and I may remember; involve me and I'll understand'*, there is great opportunity in truly involving children in the process of greening schoolyards. If children fulfill a greater role in the analysis, research, design and innovation of greening the schoolyards, they may become future change-makers. Amsterdam has several examples of schools where children have been strongly involved in the design and execution process (Fig. 5).

5 Thresholds are not often considered explicitly in policy making. While step changes are readily acknowledged in the past, future plans generally do not consider them. The obvious reason is that discontinuities generally cannot be forecast, but that does not justify ignoring them. Making a system more resilient to potential threshold effects is another way of considering them.

City Resilience: After a certain number of years/investments in green schoolyards the city will see improvements in air quality, cost savings in other programs such as rainwater detention, improved school performance, and improved social cohesion. As in many change processes, the repurposing of the yards is likely to be difficult initially, but above a certain threshold it will become established practice and reproduce more quickly. The cause of the threshold is a network effect of contagion between schools, but although it would defy forecasting ahead of time, it is nevertheless plausible in practice.

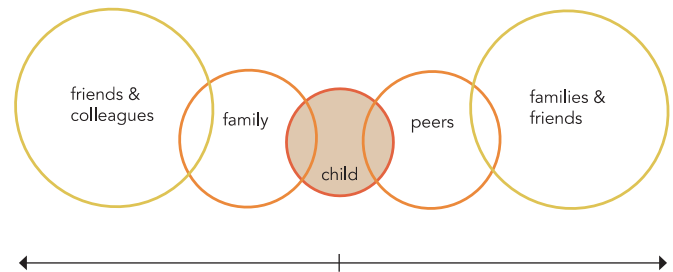
Community Resilience: In Chicago initial anecdotal evidence suggests that communities have experienced improvements including home value increases and investments in vacant land and buildings, but more research is needed. In Amsterdam research funded by the European Union is being done at 6 schools with greened schoolyards to determine the before and after effects of 'greening the schoolyards' on children's social and emotional wellbeing and school performances.

Project Resilience: In Paris, by piloting in three schoolyards, the City intends to get across the threshold for political support and funding for system-wide roll-out. The initial pilots received criticism (politicians perceived the early designs as not 'green' enough) and uncovered unexpected benefits (sound abatement providing a quieter environment). The threshold of support for wider rollout was cleared.

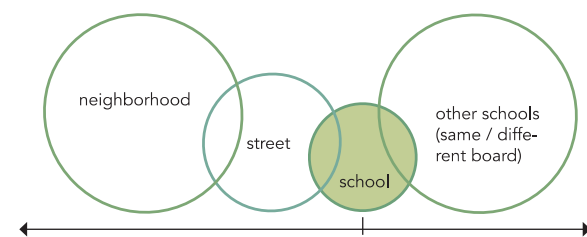
6 Social cohesion is the extent to which individuals and groups will help each other and is a fairly obvious way of building resilience. Self-organizing capabilities, social norms and trust levels within the existing system all have an impact on policy options. The challenge then becomes to understand what aspects of social cohesion build resilience and how to have more of it. Urban governance (vs. government) is positioned to strengthen social cohesion through policies that 1) attempt to integrate various departments into a unitary project organization, and 2) focus on the empowerment of residents and specific neighborhoods (van Marissing et al., 2006).

City and community Resilience: To increase social interactions and

social scale



geographical scale



temporal scale

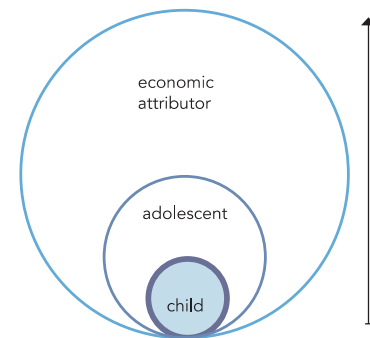


Fig. 5. Model illustrating multi-scalar interactions/influence: geographic, social, and temporal scales.

build social cohesion, schoolyards should be made accessible to the community to increase social interactions. People get to know each other, and a sense of shared identity develops. Opening access to schoolyards can be an issue, as they are generally not public space and are reserved for school usage. In Paris the vision is to open the schoolyards to the public, but this has not yet been instituted. A participatory approach with the school and engaging the surrounding community was a requisite of Amsterdam's program, and opening the schoolyards to the community is one of the strict requirements for funding eligibility. In Chicago anyone is welcome at the yards outside of school hours (summer, afternoons and week-ends). Managing partners work hard to establish programming during the summer by partnering with local community organizations - this can have a big impact on the local community as many of Chicago's greened schoolyards are in communities with little to no park access. The local community determines the use of the park and partners work with the community to post bespoke rules at each yard. They try to not post a list of "Nos", but instead try to creatively think on how best to protect the investment without making people feel unwelcome.

Project Resilience: The conversion process and subsequent management of schoolyards will only succeed by mobilizing a considerable amount of diverse social capital. The process of developing the schoolyard in collaboration with stakeholders is equally important to its result, as the final outcome.

TRANSFORMATIVE RESILIENCE focuses on broader capacity issues and longer time horizons in terms of distributed governance, foresight capacity and innovation & experimentation.

- 7 Distributed governance:** Centralized governance is inherently less resilient than distributed governance, or polycentric governance. Centralized governance has fewer checks and balances and mechanisms for including multiple perspectives (Ostrom, 2010). While centralized control is often perceived to be more efficient, it represents a classic trade-off between resilience and efficiency.

City Resilience: Whether the aim is to improve storm water management, air quality, or social cohesion, greening schoolyards tends to get new players involved in the issue. Giving new organizations, teachers, students, and local boards and communities a role in solving urban challenges creates decentralization - issues are no longer being solved by just one department.

Community Resilience: In Chicago they made sure engagement went beyond the schools to build community interest and preserve a sense of local, decentralized, ownership. They did this through early engagement with the community, site-specific design and maintenance plans for each yard, and opening the yards to community members not associated with the school.

Project Resilience: Managing a green schoolyard program centrally is unlikely to be effective, while complete decentralization will also be sub-optimal. There should be decision-making power at different levels including students, teachers, schools, communities, and the board of education. Achieving a consistent level of participation from multiple entities is difficult and depends strongly on project leadership. In Amsterdam it has been noted that the process moves forward even if there is too little participation, an obligatory participation method could better ensure the involvement of all parties.

- 8 Foresight capacity** is the competence to go beyond a culture of forecasting, to include irreducible uncertainties and the plausibility of multiple futures into the planning culture (Wilkinson & Kupers, 2014).

City or community Resilience: The city may have a regular futures process where it develops scenarios of its possible development pathways. Scenario planning can be used to scan the current reality, projected forecasts, and influential internal and external factors to produce a set of plausible potential scenarios, allowing planners to identify triggers and take action (APA, n.d.-b).

Project Resilience: Program planning goes beyond the one- or two-year horizon and gives consideration to external factors that could affect the operations and maintenance of the yards. Maintaining a regular conversation on the future evolution of schoolyards – and their inter-connection to other social and physical systems around them, will build further resilience. It may even be useful for a specific entity to become the custodian and convener of the foresight process. In Paris The Chief Resilience Officer, cognizant that greening all 750 schoolyards will take long-term commitment, is currently providing the foresight capacity to champion the project and its evolution, acting as a catalyst between the various stakeholders.

- 9 Innovation & experimentation** obviously deliver new ideas, but the process itself creates adaptive capacity making the system more resilient. The very act of innovating and exploring fosters a culture that questions the status quo and looks at how the system under consideration may be changed. Google's policy of encouraging employees to dedicate a fixed percentage of their time on personal

innovation projects is an example. It may yield some new ideas, but it will certainly deliver a more adaptive employee and corporate culture. In an urban context, experimentation offers a crucial mechanism to develop transformative knowledge and catalyze social learning (Wolfram, 2016).

City Resilience: By experimenting with greening schoolyards, cultural change and a shift in how problems are solved is possible among city institutions. In Chicago the successful implementation of the program required the Metropolitan Water Reclamation District of Greater Chicago (MWRD) to push the boundaries of what kinds of projects they do. This experiment shifted their culture and now MWRD staff “want to do more projects that have benefits that extend beyond water management.”

Community Resilience: Engaging kids and teachers in the design and evolution of schoolyards will foster creative and innovative thinking and entrepreneurship. As they experiment with making change at one site within their community, they will learn where boundaries are and what it takes to change things that have been a given for decades past.

Project Resilience: Even as a program becomes established it should continue to try new materials, designs, and programs. Gathering data along the way about park usage and performance to increase learning. Competitions and awards can be used to foster innovation and experimentation. In Chicago each school has a different independent designer and the managing partners encourage them to go beyond the standards of the city code fostering healthy competition between them. Funding new approaches can be a challenge; in Amsterdam greater innovation could be spurred with additional funding for designs that address specific challenges, such as rain-water capture or social cohesion.

5. Conclusion

Improving a project's, community's, or city's capacity to continue functioning through the shocks and stresses of a turbulent future is arguably a planner's top priority. As Norfolk's Director of City Planning George Homewood, FAICP once said “It's very simple: We are the profession that thinks about the future.” (APA, n.d.-a) However, the future is unknown and planners have limited methodologies to generate and compare preferred alternatives. Many methodologies ignore nuance, focus too heavily on cost, don't adequately incorporate community input, and don't address scale or multi-beneficial outcomes. The nine-box frame described above is a useful model to think through complexities and plan more resilient systems – urban systems are a good example as they are highly interconnected and complex.

In this paper, we demonstrated how the concept of resilience can be practically understood as a system-strengthening approach. The intent of this paper was not to comment on the design or success of the cases reviewed but was instead meant to demonstrate how resilience concepts and a systems approach can be used to improve projects, programs, and policies at any scale. We used the nine-box-frame to investigate how community leaders can assess, compare, and improve a seemingly straightforward intervention – greening schoolyards – at multiple scales. We also used the nine-box-frame to demonstrate the multi-beneficial impacts greening schoolyards can have on community engagement and social cohesion; mitigating and adapting to climate change; and improving health and wellbeing. This framework can be applied to any system or scale to aid in decision-making and conceptual analysis.

Future iterations of the greening programs in Amsterdam, Chicago, and Paris could use the nine-box frame as a planning or evaluation tool when considering improvements or expansions to their programs. The nine-box frame has been used in North America, Asia, Europe, and Latin America as a collaborative planning and evaluation tool. The frame was most recently used by 100 Resilient Cities in partnership with the University of California San Francisco to assess the current situation

and identify gaps in their Long-Range Development Plan. In the current global environment, the nine-box-frame and other resilience building tools can be used to help decision makers think through the uncertainty and endless scenarios that are possible in recovering from the devastation caused by the pandemic.

Author statement

All four authors have contributed in equal measure to conceptualization, methodology, investigation, writing – original draft, review and editing, as well as to visualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

- American Planning Association. (2011). Policy guide on planning & climate change (p. 95). Retrieved from https://planning-org-uploaded-media.s3.amazonaws.com/legacy_resources/policy/guides/pdf/climatechange.pdf.
- Amsterdam Rainproof. (n.d.). De maatregelen-toolbox - Amsterdam Rainproof. Retrieved April 8, 2019, from Amsterdam Rainproof website: <https://www.rainproof.nl/toolbox/maatregelen>.
- APA. (n.d.-a). Planning for resilience. Retrieved April 8, 2019, from American Planning Association website: <https://www.planning.org/blog/blogpost/9124762/>.
- APA. (n.d.-b). Scenario planning. Retrieved April 8, 2019, from American Planning Association website: <https://www.planning.org/knowledgebase/scenarioplanning/>.
- Barros, R. M., Silver, E. J., & Stein, R. E. K. (2009). School recess and group classroom behavior. *Pediatrics*, 123(2), 431–436. <https://doi.org/10.1542/peds.2007-2825>.
- Blair, D. (2009). The child in the garden: An evaluative review of the benefits of school gardening. *The Journal of Environmental Education*, 40(2), 15–38. <https://doi.org/10.3200/JOEE.40.2.15-38>.
- Bush, J., & Doyon, A. (2019). Building urban resilience with nature-based solutions: How can urban planning contribute? *Cities*, 95. <https://doi.org/10.1016/j.cities.2019.102483>.
- Center for Disaster Resilience. (2018). The growing threat of urban flooding. (p. 44). Retrieved from <https://cdr.umd.edu/urban-flooding-report>.
- Children & Nature Network. (2016). Building a national movement for green schoolyards in every community. Retrieved from https://www.childrenandnature.org/wp-content/uploads/2015/03/CNN_GSY_Report2016_Final.pdf.
- Coley, R. L., Sullivan, W. C., & Kuo, F. E. (1997). Where does community grow? The social context created by nature in urban public housing. *Environment and Behavior*, 29(4), 468–494.
- Danks, S. G. (2010). *Asphalt to ecosystems: Design ideas for schoolyard transformation*. New Village Press.
- Danks, S. G. (2014, February 6). THE GREEN SCHOOLYARD MOVEMENT: Gaining momentum around the world. Retrieved April 8, 2019, from Children & Nature Network website: <https://www.childrenandnature.org/2014/02/06/green-schoolyardsnearby-nature-access-for-all/>.
- Mairie de Paris. (2015). Adaptation Strategy. Retrieved April 8, 2019, from <https://api-site-cdn.paris.fr/images/76271>.
- Mairie de Paris. (2018). Strategie de Resilience de Paris. Retrieved from <https://api-site-cdn.paris.fr/images/95335>.
- Desouza, K., Flanery, T. (2013) Designing, planning, and managing resilient cities: A conceptual framework. *Cities*, Vol. 35; p89–99. doi:<https://doi.org/10.1016/j.cities.2013.06.003>.
- EPA. (2013). Case studies analyzing the economic benefits of low impact development and green infrastructure programs (No. EPA 841-R-13-004; p. 142). Retrieved from https://www.epa.gov/sites/production/files/2015-10/documents/lid-gi-programs_report_8-6-13_combined.pdf.
- Fjørtoft, I. (2001). The natural environment as a playground for children: The impact of outdoor play activities in pre-primary school children. *Early Childhood Education Journal*, 29(2), 111–117.
- Ginsburg, K. R. (2007). The importance of play in promoting healthy child development and maintaining strong parent-child bonds. *Pediatrics*, 119(1), 182–191. <https://doi.org/10.1542/peds.2006-2697>.
- Hartig, T., Mang, M., & Evans, G. W. (1991). Restorative effects of natural environment experiences. *Environment and Behavior*, 23(1), 3–26. <https://doi.org/10.1177/0013916591231001>.
- Janhäll, S. (2015). Review on urban vegetation and particle air pollution – Deposition and dispersion. *Atmospheric Environment*, 105, 130–137. <https://doi.org/10.1016/j.atmosenv.2015.01.052>.
- Kuo, F. E., Sullivan, W. C., Coley, R. L., & Brunson, L. (1998). Fertile ground for community: Inner-city neighborhood common spaces. *American Journal of Community Psychology*, 26(6), 823–851.
- Kupers, R. (Ed.). (2014). *Turbulence - A corporate perspective on collaborating for resilience*. Amsterdam: Amsterdam University Press.
- Kupers, R., & Ching, S. H. (2016). *A resilience framework for smart cities*. Civil Service College Singapore14. <https://doi.org/10.13140/RG.2.2.10084.78729>.
- Litschke, T., & Kuttler, W. (2008, June). On the reduction of urban particle concentration by vegetation & #8211; a review [Text]. Retrieved April 8, 2019, from <https://www.ingentaconnect.com/content/schweiz/mz/2008/00000017/00000003/art000002>.
- Merck, M. (2017, September 21). Chicago schools partner with water agencies to green schoolyards. Retrieved April 8, 2019, from Salud America website: <https://salud-america.org/chicago-schools-partner-with-water-agencies-to-green-schoolyards/>.
- Ostrom, E. (2010). Beyond markets and states: Polycentric governance of complex economic systems. *American Economic Review*, 100(3), 641–672. <https://doi.org/10.1257/aer.100.3.641>.
- Quinlan, A. E., Berbé-Bláquez, M., Haider, L. J., & Peterson, G. D. (2016). Measuring and assessing resilience: Broadening understanding through multiple disciplinary perspectives. *Journal of Applied Ecology*, 53(3), 677–687. <https://doi.org/10.1111/1365-2664.12550>.
- Shishegar, N. (2014). The impacts of green areas on mitigating urban heat island effect: A review (Published in 2014) (Vol. 9).
- Space to Grow: Greening Chicago Schoolyards. (n.d.). Retrieved April 8, 2019, from Space to Grow: Greening Chicago Schoolyards website: <http://www.spacetogrowchicago.org>.
- Taylor, A. F., Kuo, F. E., & Sullivan, W. C. (2001). Coping with add: The surprising connection to green play. *Environment and Behavior*, 33(1), 54–77. <https://doi.org/10.1177/00139160121972864>.
- Tranter, P. J., & Malone, K. (2004). Geographies of environmental learning: An exploration of children's use of school grounds. *Children's Geographies*, 2(1), 131–155. <https://doi.org/10.1080/1473328032000168813>.
- Tyler, S., & Moench, M. (2012). A framework for urban climate resilience. *Climate and Development*, 4(4), 311–326.
- van Marissing, E., Bolt, G., & van Kempen, R. (2006). Urban governance and social cohesion: Effects of urban restructuring policies in two Dutch cities. *Cities*, 23(4), 279–290. <https://doi.org/10.1016/j.cities.2005.11.001>.
- Walker, B. (2013, July 5). What is resilience? Project syndicate. Retrieved from <https://www.project-syndicate.org/commentary/what-is-resilience-by-brian-walker>.
- Walker, B., & Salt, D. (2006). *Resilience thinking: Sustaining ecosystems and people in a changing world*. Washington, DC: Island Press.
- Weber, A. (2019, January 15). What is urban flooding? Retrieved April 8, 2019, from NRDC Expert Blog website: <https://www.nrdc.org/experts/anna-weber/what-urban-flooding>.
- Wilkinson, A., & Kupers, R. (2014). *The essence of scenarios: Learning from the Shell experience*. Amsterdam: Amsterdam University Press.
- Wolch, J., Jerrett, M., Reynolds, K., McConnell, R., Chang, R., Dahmann, N., ... Berhane, K. (2011). Childhood obesity and proximity to urban parks and recreational resources: A longitudinal cohort study. *Health & Place*, 17(1), 207–214. <https://doi.org/10.1016/j.healthplace.2010.10.001>.
- Wolfram, M. (2016). Conceptualizing urban transformative capacity: A framework for research and policy. *Cities*, Vol. 51; p121–130. doi:<https://doi.org/10.1016/j.cities.2015.11.011>.