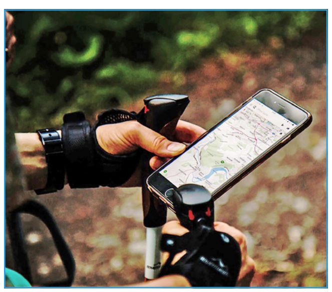

SMART Parks™: A Toolkit

UCLA Luskin School of Public Affairs
Luskin Center
FOR INNOVATION

ABOUT

The UCLA Luskin Center for Innovation presents SMART Parks™: A Toolkit, a compilation of technologies that can be used in parks to make them SMART. The toolkit is meant for park managers, designers, advocates, and anyone who wishes to learn how technology can be incorporated into parks. Some of the featured technologies are completely new. For others, the novelty may be in the use in a park setting or in combination with newer technologies. The toolkit describes each technology, how it fits into a park setting, why a park manager may decide to use the technology, and challenges that managers may face when implementing it. The toolkit also provides specific examples to help readers understand the opportunities available and how technology has been or could be applied in park settings. The document is organized by park components, representing the main features and management considerations for most urban parks: landscape, irrigation, stormwater, hardscape, activity spaces, urban furniture and amenities, lighting, and digiscapes.

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The Luskin Center for Innovation is based in the UCLA Luskin School of Public Affairs. Established with a gift from Meyer and Renee Luskin, the UCLA Luskin Center translates world-class research into real-world policy and planning solutions. Organized around initiatives, the Luskin Center addresses pressing issues of energy, water, transportation, and sustainability.

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DISCLAIMER

The UCLA Luskin Center appreciates the contributions of the many project proponents and reviewers we have listed in the acknowledgments. This toolkit does not, however, necessarily reflect their views. Any errors are those of the authors. While companies and organizations that build, sell, and/or deploy technological innovations are presented, we do not intend to advocate for or against particular companies or their products.

FOR MORE INFORMATION

Contact the UCLA Luskin Center for Innovation:
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FOOTNOTES AND REFERENCES

In this toolkit, superscripted Roman numbers indicate a footnote that can be found at the bottom of the same page. Superscripted Arabic numbers point to references listed at the end of the chapter.

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PUBLIC PARKS have been a central facet of urban life for more than a hundred years and they continue to be integral to cities. But today parks face challenges ranging from underutilization by the public to diminishing resources, such as funding for programming, maintenance, and staff. There is an opportunity, however, for park managers to address these challenges and expand their outreach by using technology and innovative management approaches. The purpose of this toolkit is to identify ways that park advocates can employ technology in new or existing parks to make them "SMART."

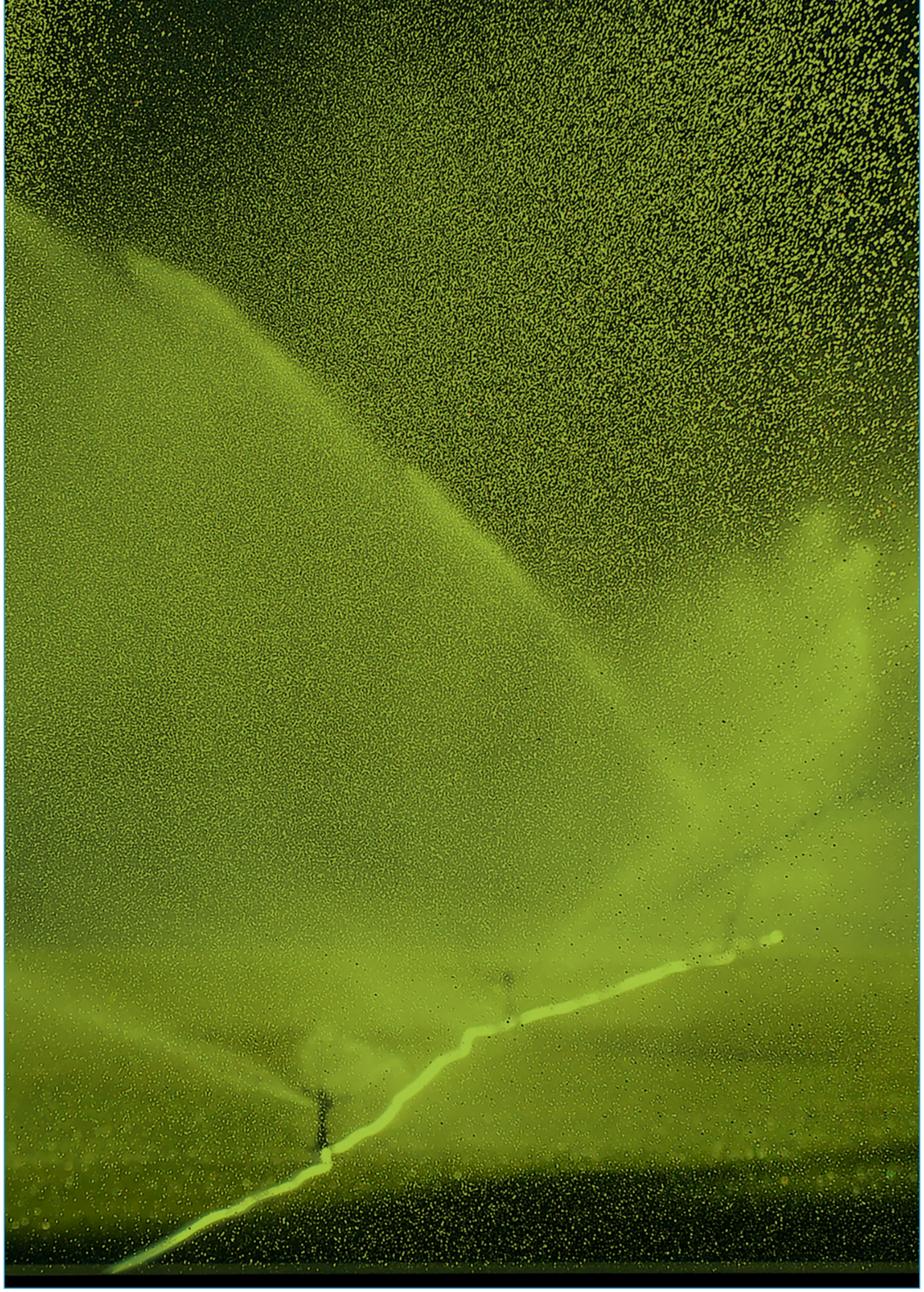
Chapter 1: Introduction

What are SMART Parks?

"SMART Park" is a new concept defined as a park that uses technology (environmental, digital, and materials) to achieve a series of values: equitable access, community fit, enhanced health, safety, resilience, water and energy efficiency, and effective operations and maintenance (see Chapter 3 for a detailed description of these Value Criteria). Based on the existing literature about parks and their many potential benefits, SMART Parks reflect and fit well in their socio-physical surroundings, are easily accessible, resilient to climate change, water- and energy-efficient, easy to maintain, and help promote the health and safety of communities. While some parks already achieve these goals, many fall short. Technological innovation can improve park performance and reduce long-term costs.

This toolkit presents technologies that can help managers create SMART Parks. Because SMART Parks are a new concept, we do not feature examples of entirely SMART Parks. Instead, we have gathered information about parks that use one or more technologies to enhance performance or reduce costs.

This chapter describes the scope, contents, and methodology of the toolkit.



Credit: Pixabay

Scope and contents of the toolkit

This toolkit is a compilation of technologies that can be used in parks to make them SMART. Some of the featured technologies are completely new. For others, the novelty may be in the use in a park setting. Some are featured because they have new applications today due to new technological developments. The technologies are organized by park components, which were identified through interviews with park managers, designers, and advocates. The components represent the main features and management considerations for most urban parks: landscape, irrigation, stormwater, hardscape, activity spaces, urban furniture and amenities, lighting, and digiscapes.

Credit: FreeStockPhotos

The toolkit is meant for park managers, designers, advocates, and anyone who wishes to learn how technology can be incorporated into parks. The toolkit describes each technology, how it fits into a park setting, why a park manager may decide to use the technology, and challenges that managers may face when implementing it. The toolkit also provides specific examples to help readers understand the opportunities available and how technology has been or could be applied in park settings. While companies and organizations that build, sell, and/or deploy technological innovations are presented, we are not advocating for or against particular companies or products. We recommend investigating which and how many products are most appropriate for each park and community. This toolkit can be a good resource to use as the foundation of long-term land use planning or to implement one technology in one park. To help park managers meet their specific goals, the toolkit ranks each technology based on Value Criteria (e.g., community fit, water conservation, etc.) presented in Chapter 3.

This toolkit is meant to serve as a resource, and it cannot replace park designers and other professionals whose expertise is necessary to ensure the development of effective parks. As a design aid, this toolkit is a starting point for park managers, landscape professionals, local government, nonprofits, and interested community members to gain information on technological innovations and their potential benefits for parks. Additional research is necessary to ensure that the selection of technologies and their benefits fit appropriately within the context of specific parks, and that technologies can be adapted to the scope and needs of the community.

Cost is always an important consideration for park improvements. This toolkit, however, does not specifically address cost for each technology. The costs vary considerably depending on location of technology purchasing and scale of park project. Plus, new technology costs often decrease over time.[i] Chapter 2 discusses cost in more detail, and Chapter 12 describes funding opportunities that may reduce upfront and/or overall costs.

While the ideas in this toolkit can be applied to state or national parks, the toolkit focuses mainly on improving and establishing neighborhood and community-scale parks in urban settings.

In most chapters we include information about programming that can multiply the benefits of implementing technology in parks. We encourage park managers to think more about how programming can be incorporated into their parks and how it can be a part of any new technology-adoption strategy.

Credit: AFS-USA Intercultural Program/Flickr

The toolkit is organized as follows:

Chapter 1: Introduction defines SMART Parks and discusses the scope and methodology of this toolkit.

Chapter 2: The Need and Role for SMART Parks provides background on the benefits and challenges of parks today, explaining how technology or creating SMART Parks can help address these challenges to ensure parks achieve the goal of community well-being. This chapter also describes the importance of integrating SMART Parks into communities and the larger region. This involves working with locals, considering their long-term needs in master planning, and using education and outreach to multiply the benefits of technology installed.

[i] Toolkit researchers can provide a snapshot of current technology cost estimates if desired. See contact information at the start of this document.

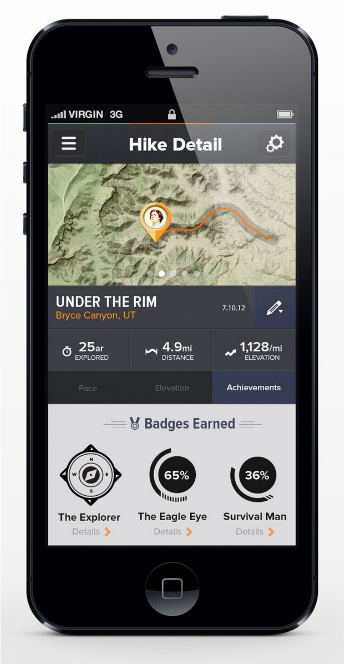
Chapter 3: Value Criteria for SMART Parks discusses common goals of creating SMART Parks and describes, in detail, the eight Value Criteria used to characterize them: Access, Community Fit, Health, Safety, Resilience, Water, Energy, and Operations and Maintenance.

Chapter 4: Landscape presents technologies for landscapes, namely the natural features in parks, including vegetation, gardens (native plant, butterfly, edible, etc.), and walking trails. This chapter features six technologies: automatic lawn mowers, near-infrared photography, green roofs, green walls, air-pruning plant containers, and vibrating pollinators.

Chapter 5: Irrigation introduces irrigation and its importance, in particular with regard to water conservation. It discusses five technologies: smart water controllers, low-pressure and rotating sprinklers, subsurface drip irrigation, smart water metering, and graywater recycling.

Chapter 6: Stormwater describes green infrastructure and the importance of stormwater management in parks. This chapter highlights five technologies: engineered soils, underground storage basins, drones, Real-Time Control and Continuous Monitoring and Adaptive Control, and rainwater harvesting.

Chapter 7: Hardscape describes the hard surfaces in parks, such as paved walking paths, seating areas, and parking lots. This chapter articulates the benefits of new surface types and features eight technologies: cross-laminated timber, pervious paving, piezoelectric energy-harvesting tiles, self-healing concrete, photocatalytic titanium dioxide coating, transparent concrete, daylight fluorescent aggregate, and carbon upcycled concrete.



Credit: Michael Koepsell/Dribble.com

Chapter 8: Activity Spaces discusses spaces for physical activity in parks and how technology and programming can improve the visitor experience. Six technologies are highlighted: interactive play structures, high-performance track surfaces, pool ozonation, energy-generating exercise equipment, outdoor DJ booths, and hard-surface testing equipment.

Chapter 9: Urban Furniture and Amenities discusses technologies for park furniture and other amenities. It focuses on seven technologies: smart benches, solar shade structures, solar-powered trash compactors, restroom occupancy sensors, smart water fountains, digital signs, and automatic bicycle and pedestrian counters.

Chapter 10: Lighting discusses efficient use that reduces energy consumption and enhances safety, thereby drawing more visitors to parks. It provides descriptions of five technologies: motion-activated sensors, LEDs and fiber optics as art, off-grid light fixtures, digital additions to LED fixtures, and lighting shields.

Chapter 11: Digiscapes discusses the prevalence of digital technology in the world today, the "digiscape," and how it might be harnessed in parks, particularly for user engagement and operational efficiency. This chapter looks at four technologies that can enhance parks: Wi-Fi, geographic information systems and services, application software, and sensor networks and the Internet of Things.

Chapter 12: Guidance on Implementation discusses park improvement prioritization and includes a table ranking each technology based on the eight Value Criteria discussed in Chapter 3. This chapter also provides a brief overview of potential funding strategies to create SMART Parks.

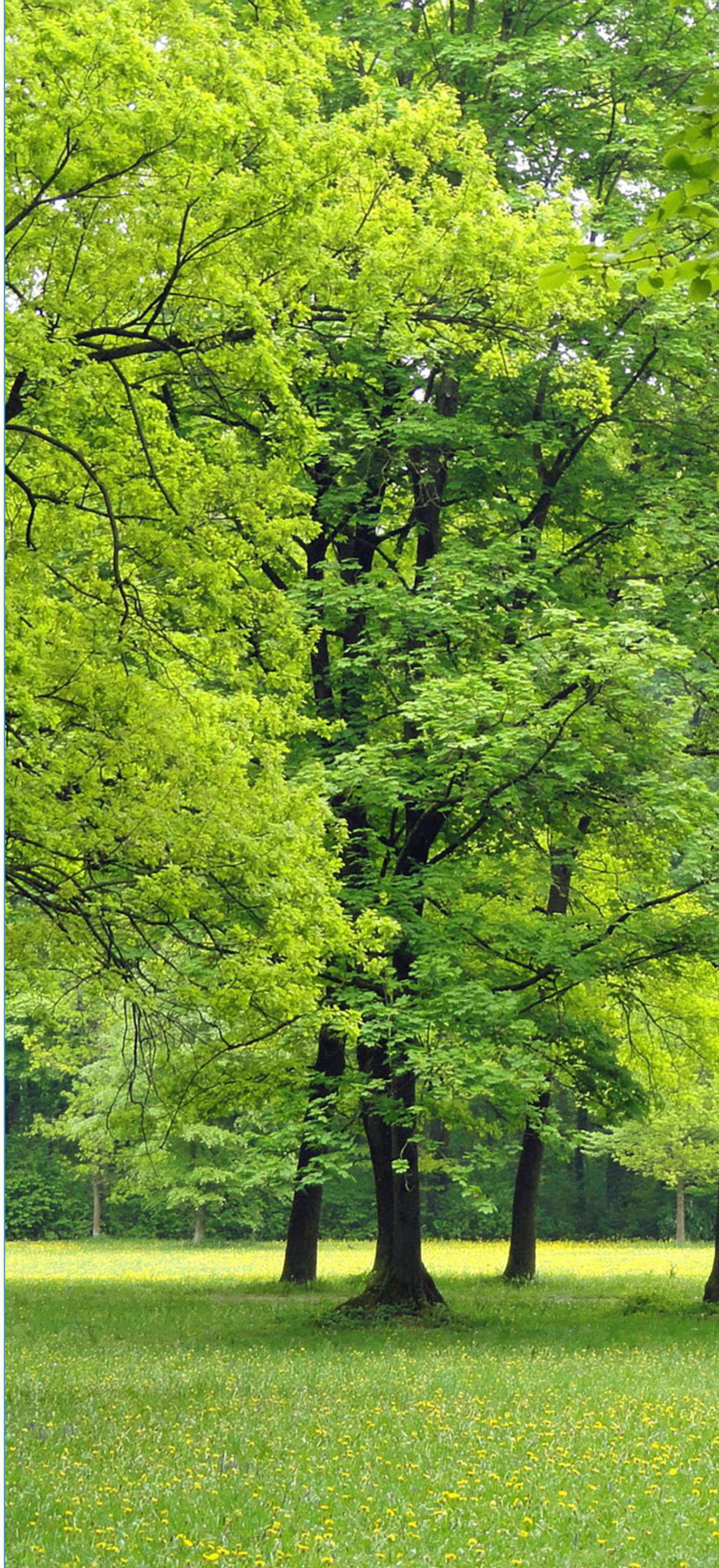
Appendices list the interviews conducted to gather information for this toolkit and the questions asked when evaluating technologies. They also provide a summary of the technology rankings based on the Value Criteria. The final appendix describes lighting materials and other details about lighting not included in Chapter 10.

Methodology

The research team reviewed the existing literature on urban parks, interviewed experts, and searched the Internet to research and compile this toolkit. The team collected information from books, articles, and the web. The literature review was focused on existing urban parks, including particular efforts to make parks more sustainable; the applicability of technologies in parks; the potential benefits and challenges associated with technology implementation; and opportunities to secure funding for implementing technological innovation in parks. Finally, for each technology presented, researchers searched for good examples of its application in a park or similar setting.

One-on-one interviews were conducted with park managers and designers, landscape architects, city officials, and staff members of nonprofits that develop parks (Appendix A) to obtain information on technologies currently used in parks, potential technology opportunities, and how to create the most useful toolkit.

To develop the eight Value Criteria used to evaluate each technology, the research team conducted a literature review on the extensive research of the many benefits of parks. Chapter 3 describes in detail each Value Criterion and why it was selected, as well as the process used to establish rankings for each technology. The technologies are ranked according to three different levels illustrated by a filled-in circle, half-filled circle, or empty circle. The researchers asked a series of questions (Appendix B) to determine the appropriate ranking for each technology. The filled-in circle indicates technologies that provide a positive benefit for a value criterion. The half-filled circle indicates technologies that represent a secondary effect on a value criterion, such as when the technology must be used with another technology to reap the benefits, or have a trade-off between their benefits and drawbacks. Last, an empty circle indicates technologies that have no effect, have a negative impact, or are unrelated to the value criterion. Chapter 3 describes these rankings in detail.



Credit: Pixabay

THIS CHAPTER

focuses on the benefits of parks, the challenges they face, and the ways in which creating SMART Parks can help address these challenges. We present the importance of ensuring that new technologies fit well not only in the park itself but also in the broader community and region. The final section presents ways for park managers to integrate technology upgrades into the larger park system, the community, and their long-term planning and vision for their parks.

Figure 2.1 Credit: Yalp Interactive

Chapter 2: The Need and Role for SMART Parks

Benefits of parks and the challenges they face

Parks represent important amenities because they provide health, environmental, economic, and social benefits to communities.[1] Parks contribute to physical and mental well-being by offering visitors opportunities for recreation, education about nature, and social contact. Parks also reduce pollution and can increase local property values.[2]

While urban parks confer numerous benefits to residents and visitors, they often face maintenance problems and under-use because of low operating budgets and a lack of facilities and programming. Therefore, it is important that urban parks be revitalized to attract more and diverse users. Technology could be central to achieving this goal. The next few sections describe in detail the most prevalent challenges facing parks.

Credit: Soofa

Figure 2.2: Soofa Smart Benches provide solar cell phone charging and collect park usage data.

Lack of Resources for Capital Improvements and Maintenance

Parks in low-income areas are often in worse shape than those in higher-income neighborhoods, as they are characterized by fewer and poorer-quality amenities and a lack of maintenance.[3,4] As local governments face more constrained budgets, there is often a reduced willingness or ability to provide enough funding for parks and recreation services.[5]

Lack of Fit With User Needs

Some parks are underutilized because their programs and services do not match the needs of the surrounding community. How the park "fits in," or is integrated within a community, is a vital consideration for enhancing community well-being and increasing park use. Parks that are integrated into their communities can encourage and improve social interactions and social bonding as well as help to build social capital.[6,7,i] Traditional parks frequently display

[i] Social capital, as defined by the Organization for Economic Co-operation and Development, is "networks together with shared norms, values, and understandings that facilitate co-operation within or

a standardized and reproducible design to accommodate multiple uses. But this does not always fit the specific cultural and social needs of the surrounding community.[8] If parks do not serve the needs of potential users, people may decide not to use them or seek alternative spaces.[9]

Inequitable Access

Park access is often both physically and emotionally inequitable. Physical barriers, such as highways or unsafe streets, can keep residents from visiting parks. Hard surfaces in parks may be uncomfortable for older adults. And minority groups may feel unwelcome if the park does not reflect their cultural preferences and recreational needs. These barriers are sometimes called "social access" barriers.[10] Some parks are underutilized because they do not appeal to a wide array of diverse users.[11] It is, therefore, important that parks provide equitable access to the people they are meant to serve and also offer programs and services that fit their needs. By expanding the diversity of users, parks can enhance the potential for social interaction, thus fostering community identity and social cohesion.[12]

Obsolescence

Parks may also attract fewer visitors because their technology and services are outdated or the community demographics have changed. As technologies develop and change fast, obsolescence is inevitable. Parks must be adaptively planned and redesigned to take advantage of technological changes.

Using technology to address challenges

While technology has historically not played a major role in park design or development and operations, new technological advances could help park managers address their greatest challenges. This section briefly describes how technology can potentially solve the challenges described above. We give more detailed information about technologies for different park components in later chapters.

Lack of Resources for Capital Improvements and Maintenance

Operations and maintenance represent a challenge for many park managers, especially if funding and staff are inadequate. Technology can help park managers efficiently maintain and operate parks while conserving water and energy resources, thus reducing maintenance costs.[13] For example, irrigation systems with "smart controllers" determine the optimal amount of watering needed (see Chapter 5); automatic lawn mowers reduce staff time and costs to maintain landscaping (see Chapter 4); and solar-powered trash compactors reduce how often trash needs to be collected (see Chapter 9).

Lack of Fit With User Needs

By collecting user data to better understand how visitors use facilities, and by offering new amenities and programs that better reflect local needs, technology and its ability to be customized can ensure that parks are SMART and provide a "good fit" for the community. For example, UCLA and California Department of Parks and Recreation (California State Parks) are developing technologies, including an interactive mobile website, to allow residents near the Los Angeles State Historic Park to provide content, such as digital murals, for the park that reflects the area's unique culture and history.[14] Considering and implementing new technologies can help park managers directly engage with community groups, offering opportunities for local input in park design and programming.

Inequitable Access

SMART Parks address inequitable access to green space by encouraging a wider range of users to visit them. In the United States, over 92% of adults ages 18 to 29 and 77% of all adults use smartphones.[15] Wi-Fi and other technologies in parks can attract users who specifically want those services. Parks can

among groups." These networks and shared beliefs help build trust and enable people to more easily work together[30].

also address inequities in access to technology by providing services like Wi-Fi. Access to broadband service is split along economic lines. Only 53% of households with annual income of less than $30,000 have broadband service, while 94% of households earning annual incomes over $100,000 have it.[15] Park managers can also utilize digital technology, such as apps,[ii] to better engage a younger generation.[16] Materials technology can also provide improved park amenities, such as path pavements that are more comfortable for the feet of older adults or lighting improvements that enhance a sense of safety. Additionally, technology can help address physical inequities in park access; geographic information systems and other mapping software can be used to create visualizations of parks and their surrounding regions. Park advocates can then use these maps to analyze residents' access to parks and improve it.

Obsolescence

Creating SMART Parks can help managers engage users and allows parks to remain relevant to different user groups and their changing needs. This is critical for avoiding obsolescence. Direct engagement with community members in planning, design, and adoption of new technologies enables the community to feel ownership of the park, which in turn reduces the chance of its obsolescence.[17]

Challenges associated with incorporating technology in parks

SMART Park development is ripe for innovation, and opportunities abound for pilot programs and projects to advance and update parks. However, there are often many unknowns associated with new technology adoption. Because many of the technologies we highlight in this toolkit are novel, they may require specialized expertise and have limited data and cost information available. Costs are also likely to change over time; typically, technology costs drop as more people adopt it. Prioritizing small pilot projects can be a great start, especially if larger updates are out of reach. Park managers do not need to change everything at once, especially since new technologies often require a trial period to evaluate performance. Technologies vary in cost and can be selected to fit park budgets and priorities. SMART Parks do not necessarily require major changes or extremely large capital investments. Small updates and retrofits can have a significant impact on operational efficiency and visitor experience without requiring fundamental shifts in management and organization or extensive expenditure.[16] Nevertheless, and as explained below, the challenges park managers are likely to face include cost, oversight and staff training needs, fast technology obsolescence, and bureaucratic inertia.

Cost

While investing in some new technologies may be costly, others are more affordable. Park managers should select technologies that meet their budget and goals, recognize that new technology costs often decrease over time, and investigate the numerous incentives that exist to provide more and better services to disadvantaged communities. Furthermore, there may be funding opportunities to reduce upfront and/or overall costs, which should be considered before deciding on adopting a new technology (Chapter 12 provides suggestions for resources and funding strategies).

Oversight and Staff Training

Park staff must regularly check equipment to ensure that it is functioning properly. Additionally, park staff may require specific training to collect data from a particular technology as well as to operate and maintain it.[18] These upfront investments in professional development can provide long-term management benefits and ensure that a technology remains effective.

Occasionally, experts may be needed to repair or adjust new technologies, and such

[ii] As an example, the app Pokémon Go brought some children into parks for the first time.[29]

Credit: The Epoch Times

Figure 2.3: Collecting user data can help park managers understand how visitors use facilities.

costs should be considered before making investments in SMART Park technologies. For example, in Philadelphia, when automatic solar-powered trash compactors malfunctioned and did not alert staff that bins needed to be emptied, the city had to hire someone with specialized experience to fix the trash sensors.[19]

Obsolescence

With the rapid pace of technological change, upgrades are needed in some technologies to avoid obsolescence. Managers should include this cost in their budgeting and consider how best to create adaptable long-term planning with community input.

Government Culture

Parks are typically run by public agencies or departments within city or local government and thus face many of the same barriers as other government sectors in adopting new technologies.[20] Government is often slow to adopt new technologies and does not quickly adapt to change for various reasons. Some include an emphasis on the status quo, limited ability to incorporate creative or innovative thinking into job duties, or bureaucratic red tape that limits the ability of government officials to adopt new technologies.[21, 22] This toolkit aims to educate park managers about some of the benefits and possibilities of SMART Parks and encourage further research so that they can then become com-

Credit: Yalp Interactive

Figure 2.4: In the Memo Activity Zone, educational interactive games can be programmed to fit the park and its visitors.

fortable advocating for change and creating a vision for their own parks, and thus lead the way in new technology adoption.

Master planning for park upgrades

Long-term planning can identify opportunities to create new or improve existing parks and can be crucial for adopting new technology. A park master plan is designed to create an overarching vision considering a park's location, natural resources, and community needs.[23] The master plan is a framework for how parks can be used and developed typically over a 20- to 30-year time frame.[23] Thus, master plans provide an opportunity for a parks agency or government to think long term and to work closely with the community. Master plans can include plans for technology upgrades in existing parks or for the incorporation of technology in developing new parks.

Technology can also play a role in the planning process itself, such as by using GIS or other mapping programs to identify parks or neighborhoods that need attention. Selecting the location of a new park or identifying which parks would benefit the most from smart upgrades is context specific. It is important to look at the larger picture and think about how and where parks, and SMART Parks, should be located. Park locations affect the equitable distribution of resources and benefits, the preservation of natural systems, and the health of park users.[18] Taking into consideration where parks are currently located, and the purposes they serve, can help determine which upgrades are more relevant or necessary in each context.

Partnerships with universities, think tanks, and tech companies can help park managers think about technology in longer terms and spark relevant ideas for inclusion in master plans. Other considerations include the fact that some parks are used jointly with other facilities, such as schools, or may result from public-private partnerships. Municipalities will need to dedicate time and research efforts to identify the best locations based on their communities' needs. Ultimately, this should be part of a master planning process that will also require creation of long-term goals and a vision for existing and future parks.

Integrating park upgrades

Parks must be integrated into communities to be effective: SMART Parks are no different and offer an opportunity to improve the connection between parks and their surrounding community and broader region.

Connecting With the Community

Park design is not one-size-fits-all, and different communities have different requirements. Parks should reflect their surrounding community's cultural and social values and needs, and can facilitate social cohesion by providing a space for everyday social interactions among neighbors and visitors.[24] The Interpretive Media Laboratory (IMLab) — a collaboration between UCLA's Center for Research in Engineering, Media, and Performance (REMAP) and the California Department of Parks and Recreation (or California State Parks) — believes technology can be an essential tool linking communities to park spaces and ensuring that they are utilized in new and beneficial ways.[14] For example, the IMLab creates interpretive technology for urban spaces (e.g., mobile websites, video, etc.) to enable community members to share their culture and history through stories.[25, 26] Fabian Wagmister, director of UCLA REMAP, described their collaborative work as "cultural civic computing," or using computers and other technology in public spaces to service the community.[17] Public involvement in creating technological systems in parks can increase the sense of ownership people feel toward parks, which can in turn ensure that the space remains relevant even if technology becomes outdated.[17]

Another benefit of increasing public input in park upgrades is that it may encourage more civic engagement in other aspects of the neighborhood and stronger support of future projects, and build trust with community leaders, who may initially be reticent about incorporating technology into parks (which have traditionally been largely technology-free).[17] Park managers should consider local residents as assets who can contribute to the planning process.

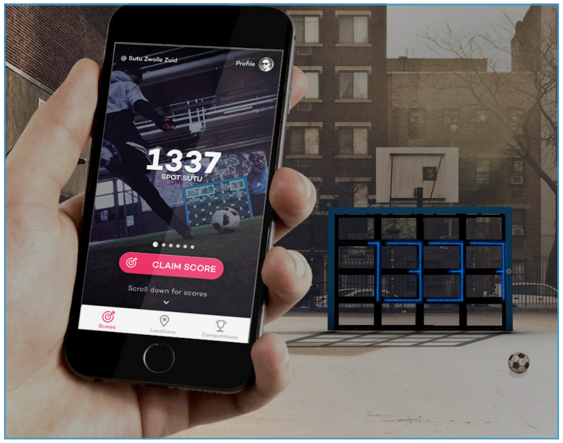
Connecting Across Parks

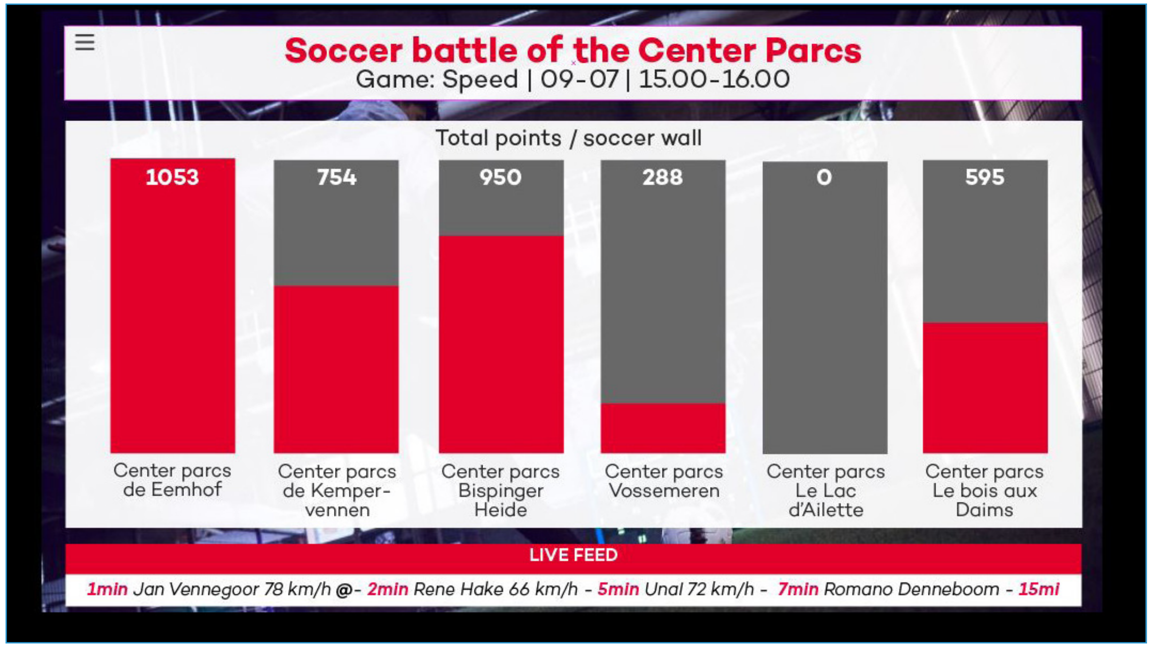
Some technologies presented in this toolkit may be best leveraged if installed and connected across multiple parks. Consider the following three examples. SMART Parks can share water or energy resources from irrigation systems and solar panels.[18] Installing smart benches (see Chapter 9) at more than one park can provide citywide park usage statistics. And when digital interactive game walls (see Chapter 8) are provided at different parks, players can compete against players at other park locations.[27]

Education and programming: Multiplying the benefits of technology

Technology in parks can provide educational benefits in two ways: through the technology itself or by adding signage, programs, or information to instruct visitors about the technology. A technology that serves as an educational tool is Yalp's Memo interactive play structure. Installed in several primary schools and public parks in Europe and Asia, Memo features interactive games that can be programmed to reflect the physical and social environment of the community[27] and to ask players questions about math, the environment, nutrition, and more.[28]

Educational signage or programs can sup-





Credit: Yalp Interactive

Figures 2.5 and 2.6: The Sutu Football Wall with app (above) and online score display (right) allows competition among players in multiple parks in an area.

plement technological upgrades by providing information to users. For example, park managers can include signage on new rainwater harvesting systems or bioswales (see Chapter 6) to teach the public about the water cycle. Park managers may wish to indicate their use of recycled water for park landscape irrigation by posting signs, which can increase awareness of recycled water and water conservation. Parks can also host educational programs such as citizen science days (Real-World Example, Chapter 6) or community gardening. And with the addition of smartphone applications, parks can become valuable tools to instruct the public on various topics such as science, technology, engineering, and math (STEM) education or environmental sustainability. For example, conservation apps can allow park visitors to identify wildlife and plant species they encounter in parks and learn more about nature conservation.[29]

Technology, and the public process of developing its relevant application in parks, can create new and unique programming opportunities. According to the Los Angeles Neighborhood Land Trust, programming is what makes a park come alive.[13] Several of the examples in this toolkit show how technology can increase use through unique and innovative exhibits, events, or other activities that engage and educate visitors. For example, Chapter 6 describes how drones have been used during citizen science days to collect water-quality samples. Chapter 11 discusses interactive trails at Los Angeles State Historic Park that let visitors explore the park's history and help plan its future. Park managers should work closely with their community to identify how technology can be used to develop useful programming that addresses local needs and desires.

By educating park visitors about the uses and benefits of new technologies, SMART Parks can self-advocate and encourage continued growth and support for upgrades.

Chapter 2

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Chapter 3: Value Criteria for SMART Parks

VALUE CRITERIA are used to evaluate the effectiveness of the technological innovations featured in this toolkit. Each of the eight criteria was selected based on the extensive existing literature that describes the many benefits of parks. This chapter describes the Value Criteria and explains in detail why each is important. Many of the benefits overlap, and therefore values may overlap. This chapter also describes the process that we used to determine each technology's ranking.

A park is "SMART" to the extent that it fulfills the following

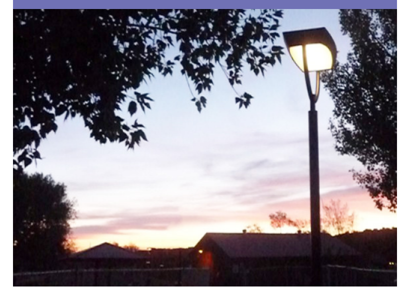
Value Criteria

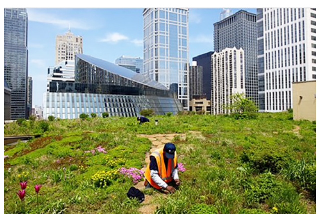
Access A SMART Park is equitably located and easily accessible, physically and psychologically, by constituent social groups.

Community Fit A SMART Park creatively utilizes and reflects its physical, ecological, social, and cultural surroundings.

Health A SMART Park facilitates healthy activities and promotes community wellness.

Safety A SMART Park provides a safe, secure, and comfortable environment for users.





Resilience A SMART Park is resilient to changes in climate, population, and land use.

Water A SMART Park utilizes strategies to conserve and reuse water resources.

Energy A SMART Park uses strategies to conserve energy resources and facilitate clean energy generation.

Operations & Maintenance A SMART Park harnesses technology solutions for streamlined and efficient operations and maintenance practices.

Parks serve communities only if they are accessible (Access) and integrated into the community (Community Fit). Once at the park, community members must feel healthy and safe (Health and Safety Criteria, respectively). The final four criteria are necessary to keep the park open and in good condition. In particular, the park must be resilient to changes (Resilience), efficiently use resources (Water and Energy), and have ongoing and effective operations and maintenance (Operations and Maintenance).

Figure 3.2 (right) illustrates the elements of well-being — physical and mental health, access to services, and social cohesion — which improve visitors' quality of life. To facilitate well-being, parks must be used, provide services, and be well-maintained. The eight criteria support these goals.

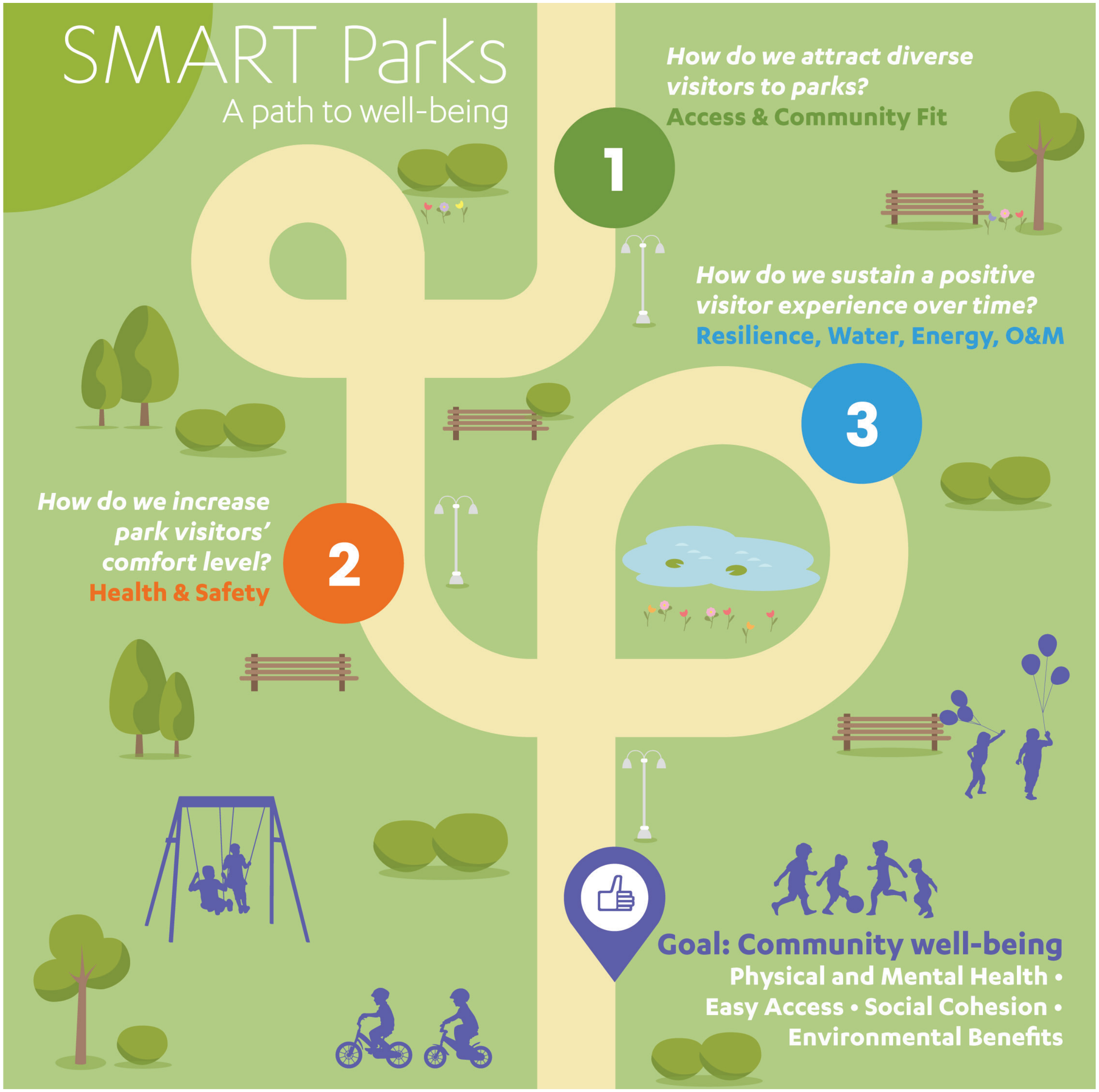


Figure 3.1 (Chapter cover photo) – Credit: Pexels
Figure 3.2, right: Credit: Christian Zarate, UCLA Luskin Center for Innovation

Access

A SMART park is equitably located and easily accessible, physically and psychologically, by constituent social groups. Physically accessible parks are close to population centers and/or connected to communities via transportation modes, and provide walkways and other design features to accommodate users of different ages and abilities. Psychologically accessible parks are those where users feel safe and welcome.

Park features and programming can improve accessibility. For example, the National Recreation and Parks Association started a Safe Routes to Parks Initiative.[1] Many local governments including Columbus, Ohio, and Miami Dade County, Florida, have their own walking to parks programs.[2,3] These programs use data (often collected through technology) to analyze park accessibility and make changes to improve it.

Some minority groups and recent immigrants perceive discrimination while in parks, see a lack of diversity in staff, and experience language barriers (with park staff, program leaders, and signage).[4] One study at Independence National Historical Park in Philadelphia, site of the Liberty Bell, found that minority communities living near the park did not feel like the park was for them. One resident said, “It is a white area.... It’s not for African Americans.”[5] In response, park managers created new informational signs and markers to show places with cultural and historic significance for the three local ethnic communities residing in the area.[5]

Rules for use may also present a barrier to some immigrants wishing to use parks. For example, requirements for advanced reservation of play fields can present a challenge for many Latinos who want to use soccer fields.[6] Within the community, soccer games are often spur-of-moment, all-day family gatherings with food. Time limits and advanced permits for fields could discourage these spontaneous uses of public space.[6]

The Access criterion is closely related to the Safety and Community Fit criteria because psychological access barriers often stem from community members feeling unsafe and unwelcome in a park. The Access criterion is also related to the Health criterion because people cannot experience the benefits of parks, such as mental and physical health, unless they can access them in the first place.

Why is access to parks important?

People can benefit from parks only if they can reach them. Access may be limited due to geographic and/or social barriers. Highways and other infrastructure can obstruct the path to a park. Also, a lack of crosswalks, pedestrian bridges, or lighting may make potential users feel unsafe, therefore discouraging use.[1] Even when there is good physical access to parks, some minority groups may face social and cultural barriers that limit their access.[7,8] Increasingly important in cities is ensuring that parks and public open spaces are welcoming to all community members, including undocumented immigrants.

Many communities face accessibility challenges, meaning they often cannot get to parks and, therefore, cannot benefit from them. Parks could provide much needed mental and physical health benefits, social cohesion, and even sanctuary from extreme weather events or disasters (the sections below describe these other benefits in detail). Therefore, physical and psychological barriers to park access are key considerations for all park advocates interested in serving communities and ensuring that parks are welcoming and open to all. For these reasons, Access is one of the Value Criteria for each technology evaluated in this toolkit.

Community Fit

A SMART Park is creatively utilized and reflects its physical, ecological, social, and cultural surroundings. We define this as “Community Fit.” Parks should use landscaping and materials that fit within their geographic location and climate. For example, native plants often require the least amount of irrigation, which is especially beneficial in areas experiencing water shortages. Management

Credit: David Moss

Figure 3.3: Park managers should be sensitive to social and cultural needs of a park's community.

must be sensitive to the social and cultural needs of a park's surrounding community and reflect it through the park services, amenities, and programs. For example, park signage must be available in languages predominant among visitors and the surrounding community. Use rules and gathering spaces should be culturally sensitive to the uses desired by groups in the community.

Park design is not one-size-fits-all, and different communities have different requirements for their parks. First, park managers must identify the different types of users. Community demographics are important as use and perception of parks vary among groups based on gender, age, race, and income.[9] Managers must identify park activities that support the local culture and norms.[10] The best way to ensure cultural relevancy or "fit" of a park is to plan the park *with* the community instead of *for* the community.[4,7,11] Collaborative park development also allows community members to take a leading role in park planning, showcase their community's uniqueness,[12] and increase "ownership" of and responsibility for the park.

Community Fit is closely related to the Access and Health Value Criteria because if people feel comfortable in a park, this can lead to enhanced accessibility and mental and physical health benefits.

Why is community fit of parks important?

How the park "fits into," or is integrated within, the community is a vital consideration for enhancing well-being and increasing park usership. Parks that are integrated into their communities can encourage and improve social interactions and community bonding.[13,14] Parks serve as a valuable asset to build social capital and create community in urban neighborhoods. Urban parks can facilitate social cohesion by providing a space for everyday social interactions among neighbors and fellow visitors.[10,15] This is especially important, as studies have shown that neighborhood social capital and social cohesion can improve the health of residents.[16,17] In particular, neighborhood poverty has been shown to have negative health effects in low-income areas but that these effects can be mediated by neighborhood characteristics such as social capital and collective efficacy.[18,19] Thus, Community Fit is an important criterion for ranking each technology in the toolkit.

Health

A SMART Park facilitates healthy activities and promotes community wellness. Urban parks can improve community health by providing settings that encourage increased physical activity and improve mental health. Parks can also encourage healthy behavior by offering healthy foods at concessions, community gardens, or through other programs.[20]

Because of the positive connection that parks have to health, Los Angeles County is working on a program for "park prescriptions," which makes local park information readily available to medical providers so they can direct patients to park resources to increase their physical activity and exposure to green spaces.[21]

Why is improving community health important?

Physical health is a major concern in the United States, especially in low-income communities, where residents suffer from disproportionately high rates of obesity and low levels of physical activity often because of a lack of financial resources for gym memberships or exercise equipment, and little access to private open spaces.[22, 23] Only 66% of teenagers from families with incomes below 300% of the federal poverty level[i] get regular physical exercise, while 75% of teenagers with family income above that level regularly engage in activity.[24] The Centers for Disease Control and Prevention indicates that creating, improving, and promoting activity spaces can increase the number of residents who exercise at least three times per week by 25%.[25]

Air pollution also has a direct impact on community health, especially in regard to people's cardiovascular and respiratory systems.[13] Trees and shrubs in urban parks can remove pollutants by absorbing nitrogen, sulfur dioxide, ozone, and carbon monoxide.[13] The Trust for Public Land estimates that public parks in the City of Los Angeles provide air pollution removal that would otherwise cost the city $1.58 million annually.[13]

Mental health is also a major concern in the United States. According to the National Institute of Mental Health, 17.9% of the U.S. adult population in 2015 suffered from some type of mental illness.[26] Parks can improve their visitors' mental health because contact with nature reduces stress and improves cognitive functioning, socio-emotional development, and feelings of personal well-being.[27, 28] Exposing young people to parks can lower stress, improve mental health, and reduce hyperactivity.[29, 30] Studies show that a "nature-deficit," especially among the young, urban poor population, has negative effects on their physical and mental health.[31] Additionally, children with Attention Deficit Disorder have improved concentration on school work after taking part in activities in green spaces.[32,33] For these reasons, Health is a criterion used to evaluate each technology in this toolkit.

Safety

A SMART Park provides a safe, secure, and comfortable environment for users. Managers can create safe parks by increasing use, improving lighting, and maintaining park facilities, including fences and signage. The Safety criterion is closely related to the Access and Operations and Maintenance criteria because poorly maintained facilities are often perceived as less safe, and perception of safety influences the psychological accessibility of parks.

Some earlier studies suggest that urban areas with vegetation may encourage crime because they allow criminals to hide and/or prevent victims from escaping.[34] But more recent research suggests that parks can actually deter crime by encouraging use of open space, thus increasing security.[34] "Eyes on the park" in the form of active visitors, staff, and residents can create a safer and more welcoming atmosphere.[35] Park activation is currently used as a public safety strat-

[i] The UCLA Center for Health Policy Research's study used the 2003 Federal Poverty Line to calculate the income threshold for 300% above the poverty line; thus the study encompassed families that were 300% above $12,384 for a family of two, $14,680 for a family of three, and $18,810 for a family of four.[24]

egy in cities. Research suggests that, rather than over-regulating design and space for security, ensuring active use and increased natural surveillance of the park is a more effective strategy for enhancing park safety.[36]

Why is safety important at parks?

People visit parks and use park features when they perceive them to be safe and do not feel at risk of crime or danger; therefore, safety is an essential factor in determining park use. Lack of safety, real or perceived, can be a significant barrier that reduces use, and thus prevents a park from enhancing community wellness. Safety is explicitly tied to inequitable park access and the additional "psychological access" barriers that minorities face when using parks. Personal safety concerns or inadequately maintained facilities are barriers to park use more often among African Americans and Latinos than among Whites.[37] Thus, having access to safe parks is essential to encourage park use and promote physical activity among urban adolescents and older adults.[38,39]

Providing parks and recreation can promote healthy activities for youth, which may reduce the appeal of criminal activities.[40] Research also suggests that the mental health benefits, including reduced mental fatigue, provided by urban green spaces may reduce violent criminal behavior.[34] One study in Philadelphia, Pennsylvania, showed that abundance of vegetation is associated with lower crime rates for assault, robbery, and burglary in a neighborhood.[34] Ultimately, safety is a vital aspect of urban SMART Parks that can influence both their accessibility and use. Thus, Safety is a criterion in evaluating each technology.

Resilience

A SMART Park is resilient to changes that may result from development, climate change, demographic change, or other forces. We use the term resilience to mean the ability to adapt to and withstand change. Some cities now have resiliency plans or initiatives in place to help them prepare and adapt to climate change, natural disasters, and other changes. Urban resiliency indicates that cities can both maintain existing operations in the face of change and also adapt to change.[41] Managers can also plan for enhancing parks' resilience to climate change as has NYC Parks, which includes resilience in its sustainability agenda.[42]

Why are resilient parks important?

In the face of climate change and increasing urbanization, cities must prepare for environmental challenges that range from rising temperatures to unpredictable precipitation, from drought to violent storms. Urban parks can play an important role in helping cities mitigate and adapt to climate change. Urban green spaces can help decrease air temperature through a "park cool island" effect, serving as cooling centers for residents, since park greenery reduces temperatures within the park.[43] Ambient temperatures in urban areas are already higher than rural or less developed areas because of the "urban heat island effect," but global warming will likely increase the need for parks as cool refuges in urban areas.[44] Parks can also balance water flows to alleviate flooding and drought, and improve local residents' resiliency by encouraging sustainable practices such as community gardens for food security.[45,46] Greenery in parks removes carbon dioxide from the atmosphere through photosynthesis — an important function as greenhouse gas emissions contribute to climate change.[43,46]

Parks can help cities achieve their resiliency goals. For example, after Hurricane Sandy, the Federal Emergency Management Agency noted that parks, open space, and green infrastructure could build physical resilience to help manage stormwater increases and community resilience by providing space for people to recover from storms.[47]

Urban parks can feature centrally in cities' emergency management plans and strategies. Parks can serve as distribution hubs for supplies and information, or as shelter areas during disasters and catastrophic events. We have identified "Resilience" as an important criterion to ensure that parks are adaptable to, and able to ameliorate, some of the negative environmental issues facing cities.

Water

A SMART Park uses strategies that conserve water resources and facilitates water capture and reuse. Water is an essential part of parks, whether as drinking water for visitors, as part of maintenance in the form of stormwater management and landscape irrigation, or as a play or aesthetic feature, such as decorative fountains.

Why is water use an important consideration at parks?

Parks could be central to the way cities use and think about water, and can be a great focus for innovative management and conservation solutions. City surfaces are typically largely paved and impermeable, thus wasting precious water resources. Parks can incorporate infrastructure to treat city wastewater, handle stormwater runoff, and also manage flows to prevent flooding. Water, for irrigation and water features like fountains or splash pads, is one of the largest operating costs for many parks; thus, water conservation can be a vital strategy for parks with constrained resources.[48] Philadelphia estimates that through stormwater management and air pollution reduction its urban parks save $16 million annually.[47]

Parks also provide a valuable opportunity for educational programming and signage when employing efficient water technologies. Visitors can learn about the technology, its benefits, and the water cycle more broadly. Based on these factors, we have identified Water use as an important criterion for evaluating each technology.

Energy

A SMART Park employs strategies that conserve energy resources and facilitates clean energy generation. Parks use energy for lighting and air conditioning, and therefore, they are good locations for adopting energy efficiency technologies. Parks also can generate their own energy by installing technologies like solar panels. Parks save energy when they can reduce use of air conditioning in park structures and surrounding areas by utilizing green space for cooling and providing shaded areas for visitors.[43]

Why is energy use an important consideration at parks?

As cities face the challenge of climate change and work to reduce greenhouse gas emissions, parks can serve as ideal locations to both reduce energy use and produce renewable energy. As mentioned in the Health criterion, urban green space has cooling benefits that reduce ambient temperatures and counteract the urban heat island effect. On average, urban parks are about one degree Celsius cooler than urban areas, which are mostly nonvegetated.[49] Solar panels and other renewable energy-generating technologies can be easily incorporated into the open space and community buildings in urban parks, thus providing clean energy and reducing emissions. Much like the Water criterion, clean energy or energy-efficient technologies in parks can help save money through lower electricity bills and also be used as educational tools to instruct park visitors on sustainability, climate change, and clean energy. Based on these factors, we have identified Energy as an important criterion for evaluating each technology.

Operations and Maintenance

A SMART Park uses streamlined, efficient operations and maintenance practices, which reduce costs, improve safety, and encourage park visits and use. Operations and maintenance are a central concern for park managers because they require a significant portion of park resources, staff, and funding.[49,50] Maintenance and upkeep are closely tied to a park's perceived safety and accessibility, therefore this criterion is closely related to the Access and Safety criteria. Lack of maintenance can hinder park use because it makes the park appear unsafe and can potentially invite crime. Better-maintained

Credit: Adam Thomas/TreePeople

Figure 3.4: Students at San Pasqual Magnet School in the Highland Park area of Los Angeles participate in a hands-on lesson about environmental planting.

facilities indicate higher levels of community and staff supervision, which can deter criminals.[34,35,51]

Why is improving operations and maintenance important in parks?

Poor maintenance of parks can be a major hindrance to use, thereby reducing park accessibility. Latinos and African Americans face personal safety concerns and inadequately maintained facilities as a barrier to park use at a higher rate than Whites.[37] Urban parks, especially in impoverished areas, often rely on limited and/or unreliable government funding, and are more likely to suffer from inadequate maintenance.[52]

More efficient management and operations can help improve parks' long-term operational viability, even in the face of funding cuts and changing recreational demands.[53] Although changes, such as the implementation of new technology, may require re-education of park staff and new maintenance skills, they can ultimately provide long-term benefits that will reduce costs, improve quality, and encourage more use. Thus, Operations and Maintenance is used as a criterion for evaluating each technology.

Technology evaluation

This section describes how each technology is evaluated in the toolkit. By asking a series of questions (see Appendix B), we determined whether a particular technology had a positive, neutral, or negative impact on each criterion. Tables at the end of each of the following chapters identify which technologies are most beneficial to which Value Criteria, thus allowing users of this toolkit to choose the most appropriate technologies to achieve their goals.

Each presented technology received one of three ratings for each criterion:

Filled-in Circle indicates technologies that provide a positive benefit for a Value Criterion. The technology is designed to deliver the primary benefit to this value criterion or it significantly improves this criterion for the park. For example, automatic lawn mowers (Chapter 4) received this rating for Operations and Maintenance because this technology significantly cuts expenses by reducing the amount of staff needed to operate mowers. Energy-generating exercise equipment (Chapter 8) received this rating for Access and Health because it provides free exercise equipment and promotes physical activity.

Half-Filled Circle indicates technologies that represent a secondary effect on a Value Criterion, such as when the technology must be used with another to reap the benefits, or have a trade-off between their benefits and drawbacks. For example, smart benches (Chapter 9) received this rating for the Health criterion. This is because benches can be outfitted with air quality sensors, which can be connected to public information displays or websites. This monitoring and citizen science engagement is an option that, if selected, could be used to inform management decisions and provide information to the public that might promote health benefits. However, not all smart benches have such sensors, and therefore, a half-filled circle was selected. Application software technology (apps) in Chapter 11 is another example. If apps disseminate information to visitors, printed materials are not necessary. This is a secondary benefit to a Value Criterion that, while worth noting, is not related to the primary purpose of this technology.

This rating was also given if there was a trade-off between benefits and drawbacks of technologies. For example, a technology such as pervious paving (Chapter 7) may provide long-term maintenance cost savings by reducing flooding, but it requires increased short-term costs upon installation. To avoid making a value judgment on whether benefits or drawbacks are more important to toolkit users, we assigned a half-filled circle to this technology.

Empty Circle indicates technologies that have no effect, a negative impact, or are unrelated to the value criterion. For example, air-pruning plant containers (Chapter 4) use more water than regular containers because holes in the pot increase plant growth and also water use. This technology received this rating for water conservation. The vibrating pollinator (Chapter 4) requires manual transfers of pollen and is very labor intensive. This requires additional staff time and, therefore, received an empty circle for the Operation and Maintenance Value Criterion.

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LANDSCAPE encompasses the natural features in parks, including vegetation, walking trails, and gardens (native plant, butterfly, edible, etc.). Not only is it a key feature that can impact park usage, but it also can provide environmental benefits, including stormwater management, air pollutant removal, increased biodiversity,[1] and reduced ambient temperatures. New technologies can be incorporated in landscape planning and design to increase operational efficiency, resource conservation, and visitor engagement. This toolkit mostly focuses on high-technology (namely new, innovative, and

Figure 4.1 Credit: Arlington County via Flickr

Chapter 4: Landscape

Figure 4.2 Credit: Wikimedia Commons

The SITES rating system is a sustainability-focused framework that ushers landscape architects, engineers and others toward practices that protect ecosystems and enhance the benefits they continuously provide communities.[2] SITES-certified landscapes reduce water use, filter and reduce stormwater runoff, provide wildlife habitat, reduce energy consumption, improve air quality, improve human health, and increase outdoor recreation opportunities.[2]

The Leadership in Energy and Environmental Design (LEED) program is a nationwide standard for constructing "green" buildings. Obtaining LEED certification requires compliance with a minimum number of criteria affecting the project, from site selection to the recycled content of building materials.[3] While LEED focuses on certifying buildings, certain categories within its standards, such as water efficiency and sustainable sites, are closely tied to landscaping decisions.[4] Park managers are encouraged to research these types of certifications to determine if they could apply, or assist with, innovative landscaping projects.

The sections that follow provide information on six technologies that can be used for landscaping: automatic lawn mowers; near-infrared photography; green roofs; green walls; air-pruning plant containers; and vibrating pollinators.

sophisticated) practices that can be applied to parks. However, there are also some low-tech, or relatively unsophisticated, options that should be considered. For example, green roofs and green walls are simple technologies that provide innovative ways to incorporate landscaping into highly developed urban areas, where it can be difficult to create new green space.

This toolkit does not provide specific planting or design suggestions and is not meant to replace landscape designers. However, we encourage park managers to consider implementing sustainable landscaping practices,[i] including using native plants,[ii] and Xeriscaping.[iii] Two certification systems — SITES and LEED — provide guidance to sustainable practices.

[i] Sustainable landscaping is land design, construction, implementation, and management of gardening activities that modify the visible features of an area and provide an environment adapted to local climate and geography. It requires fewer inputs (e.g., water, fertilizer) and is thus more environmentally friendly.[31]

[ii] Native plants are a central part of sustainable landscaping as they require less water, maintenance, fertilizers or pesticides, and attract local wildlife.[32] Landscape designers increasingly emphasize the importance of native plants, and there are many resources about them, including the national nonprofit Wild and the Theodore Payne Foundation for Wild Flowers and Native Plants. Most states have native plant societies, which can also provide helpful resources, such as plant guides.

[iii] Xeriscaping, or creative landscaping to conserve water, requires little to no irrigation and minimal maintenance.[33] Native and drought-tolerant plants are often planted in combination with using irrigation and water-harvesting technologies.[35]

Credit: Yardplex

Figure 4.3: Electric robotic lawn mowers are nonpolluting and create fine clippings that compost naturally.

Automatic lawn mowers

What is this technology?

Automatic, or robotic, lawn mowers are independent, self-moving machines that cut grass. They are controlled through programming, sensors, and sometimes remotes. Unlike many traditional mowers, which are gasoline-powered and highly polluting, automatic lawn mowers are electric and can be powered with clean energy.[5] Most are battery-operated and must be charged via a charging base plugged into an electric outlet, although some models can be solar-powered.[6,7]

How does it fit into parks?

Automatic lawn mowers can be used in parks where large areas of turf grass require regular mowing. Because the mower is automatic, it can be programmed to run every day or several times per week,[6] making it an effective weed-management tool as well as a mower. Automatic lawn mowers cut vegetation into clippings fine enough to reach the soil and compost naturally, so they do not need to be collected as green waste. Some mowers, especially high-powered ones meant for heavy-duty commercial applications, are remote-controlled rather than fully autonomous.[8]

Why choose an automatic lawn mower?

Automatic lawn mowers can improve public health, as well as reduce energy consumption and operations and maintenance costs.

Health – Automatic lawn mowers are electric and do not emit air pollutants during use. In contrast, gas mowers produce up to 5% of the air pollution in the nation.[9] By switching to an electric mower powered by renewable energy, park managers can reduce the use of fossil fuels and the emissions associated with their combustion, including particulate matter (which causes respiratory and other problems), carbon monoxide (a poisonous gas), smog-forming pollutants (hydrocarbons and nitrogen oxides), and carbon dioxide (a greenhouse gas).[9] It has been estimated that the cost of air pollution in the United States, including the health issues and mortality associated with it, is $71 billion to $277 billion annually.[10]

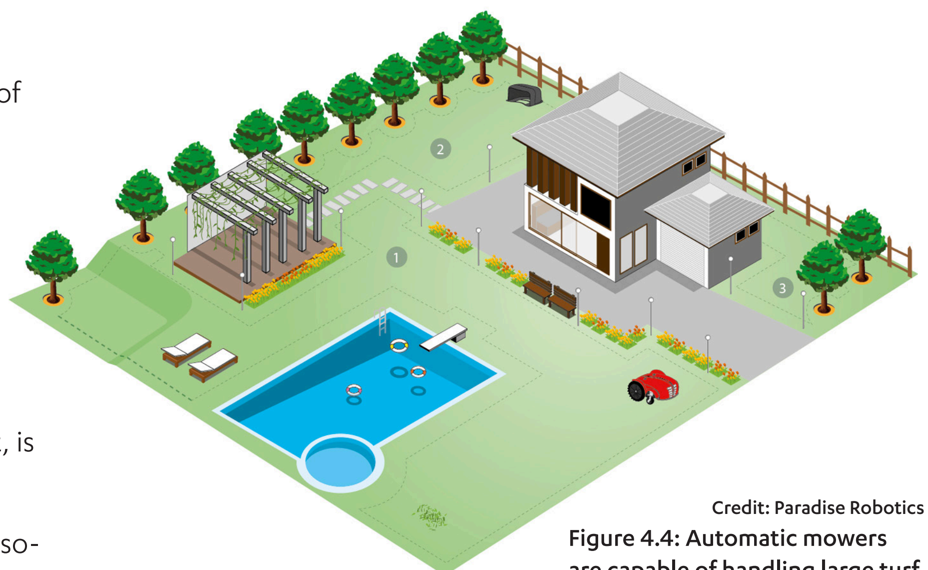
Energy – Automatic lawn mowers run on electricity instead of gasoline, potentially reducing carbon dioxide emissions.[9] Mowers powered by clean energy can decrease a park's carbon footprint.

Operations and Maintenance – Automatic lawn mowers can reduce the need for hands-on maintenance of turf lawns and be used as part of a pesticide-free weed-management strategy.

What are the challenges and trade-offs?

Necessary perimeter wiring – A low-voltage wire must be installed around the perimeter of the area to be mowed, creating an "invisible fence" to contain the automatic mower.[6]

Compatibility with park shape – Similar to household robotic vacuums, the mower takes a random path within a perimeter but avoids colliding with things in its path.[6] While this random path can provide good coverage, it may miss some areas. As a result, the automatically mowed area, especially those with irregular shapes or those



Credit: Paradise Robotics

Figure 4.4: Automatic mowers are capable of handling large turf areas, as in this rendering.

Credit: Traktor Forum

REAL-WORLD EXAMPLE

Cutting Vegetation — and Time and Money | North Carolina | 2016

Dixie Lawn Service Inc., a North Carolina landscaping services company, uses industrial remote-controlled robotic mowers (Figure 4.5, left) to maintain vegetation along highways.[8] The company can send two crew members and a mower to quickly and safely perform a job that usually took six people with weed trimmers, chain saws, and other polluting and potentially dangerous gasoline-powered equipment. The company says that switching to robotic mowers increased efficiency by 25% and halved labor costs for certain jobs.[8]

that are not contiguous, may require manual touch-ups. Mowing separated lawns may require a more advanced, multizone-capable mower or the equipment may need to be manually moved from one area to another.[7]

Compatibility with park grade – Additionally, while the mowers can cut on slopes (with some models capable of operating on up to 50- to 60-degree slopes), they may not be appropriate for very steep grades.[8]

Maintenance and supervision requirements – Although the mower can decrease the need for manual operations and maintenance, the machine may get clogged or snagged, requiring human intervention. Park employees may also be required to supervise the automatic mower for the safety of park visitors and to prevent theft or vandalism.

Takeaways

Automatic lawn mowers are an effective tool for park turf and weed management. They can improve public health, as well as reduce energy consumption and operations and maintenance labor and costs. Since the mowers are electric and not gasoline-powered, they do not emit carbon dioxide or particulate matter. Similar to some manual mowers, automatic mowers also reduce green waste by producing fine clippings that naturally compost back into the soil. However, automatic mowers require the installation of a low-voltage fence around the lawn areas, have particular maintenance requirements, and may require staff to monitor mowing during park business hours.

Credit: Public Lab

Figure 4.6: Typical photo, left, compared with near-infrared version, right, which can help determine health of trees.

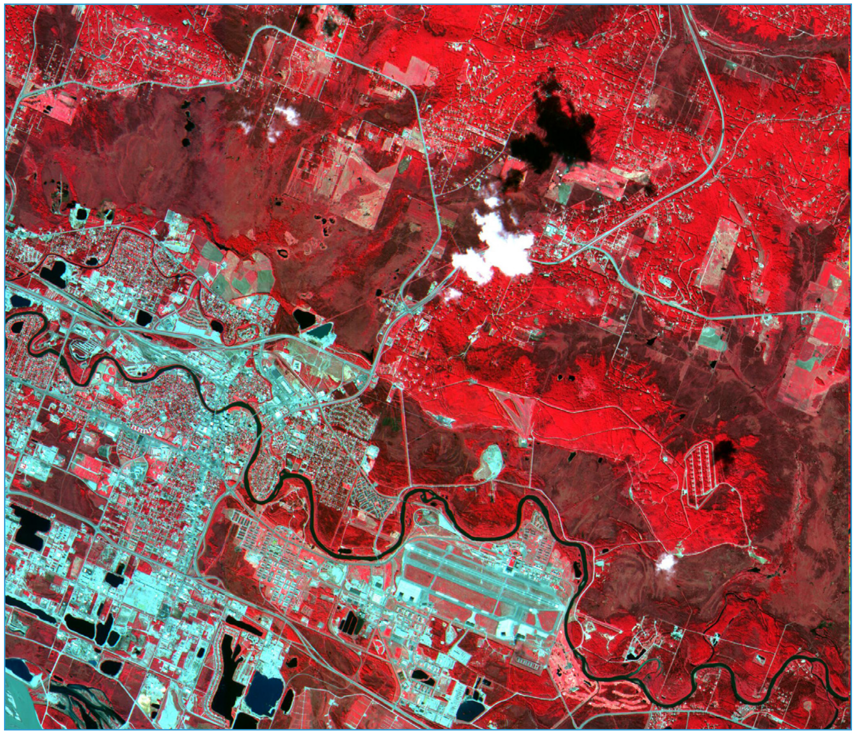
Near-infrared photography

What is this technology?

Near-infrared photography captures, in pictures, reflected light that lies outside the visible light spectrum, or what humans can see. Near-infrared light on the electromagnetic spectrum has wavelengths that are longer than visible light but slightly shorter than mid- or far-infrared.[11] Photosynthesizing plants absorb most visible light and reflect near-infrared light. Thus, a near-infrared photograph can visually show areas with high or low degrees of photosynthesis, an indicator of plant health (Figures 4.6 and 4.7).[12] The photographs can be taken with a near-infrared camera or by purchasing a kit to alter a traditional digital camera. Post-processing software can be used on the photograph to analyze plant health.[12]

How does it fit into parks?

Near-infrared photography can help determine the health of park plant life. The photographs can be used to provide visualizations of plant photosynthesis, which help park managers track vegetation patterns and health, and identify potential pollution sources.[13,14] These photos can be used on a case-by-case basis as a snapshot indicator or as part of a long-term plant-monitoring strategy. They can also help identify potential water quality concerns, high toxic chemical concentrations, or dumping, as described in the Real-World Example from Brooklyn (next page). The photographs can be particularly useful (as aerial images) for parks with extensive areas of vegetation to monitor and on a larger or more regional scale to understand vegetation patterns and landscape health in a city, county, or region.



Why choose near-infrared photography?

Health and Water – Near-infrared photography may alert park staff to water quality concerns, such as contamination or dumping.

Safety – Near-infrared photography may alert staff to reductions in tree health, allowing staff to take action to prevent trees from falling.

Resilience – Because this technology can be used to monitor plant health and response to climate patterns over time, it can inform planting palettes or irrigation needs and assist in maintaining a healthy park ecosystem. Near-infrared photography may alert park staff to vegetation damage and other issues before it is detected by the naked eye.

What are the challenges and trade-offs?

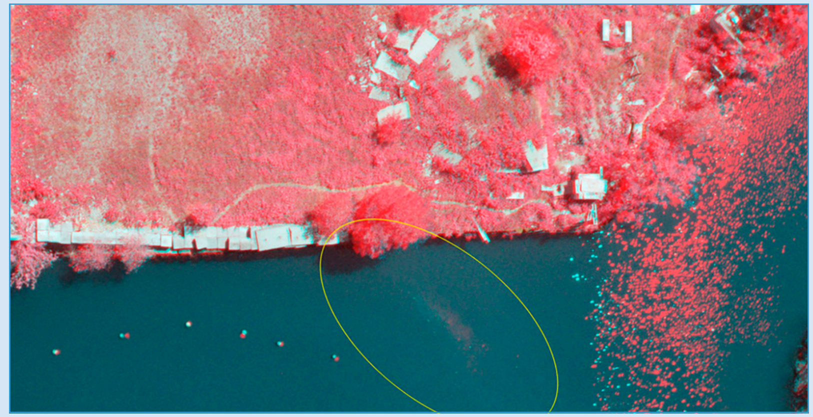
Staff expertise and training – Park staff will need to operate the cameras or hire a photographer or consultant who can take the photographs. Additional staff expertise may be necessary for photo interpretation.

Additional equipment – Near-infrared photography is most effective for analyzing landscapes when done from an aerial perspective, possibly requiring use of a drone, helium balloon, or helicopter.

Compatibility with park size – Near-infrared photography tends to be most useful for understanding the health of large-scale landscapes and may be better for parks with large landscaped areas or for regional analysis, rather than for small neighborhood parks.

Credit: Sandia National Laboratories

Figure 4.7: Vegetation shows up as red in this near-infrared photograph of Fairbanks, Alaska.



Credit: Public Lab

REAL-WORLD EXAMPLE

Citizen Science Sleuthing | Brooklyn, New York | 2011

A team of citizen scientists,[iv] students, and researchers have been using near-infrared imagery to monitor the Gowanus Canal in Brooklyn, New York, a toxic Superfund site.[v] A camera attached to a helium balloon took a near-infrared photograph that revealed a slightly pale area in the water, which could indicate decreased photosynthesis (Figures 4.8 and 4.9 above).[14] When the team inspected the area by canoe, they discovered a concealed outflow pipe that had been dumping industrial waste. The pipe likely would not have been discovered without the use of this technology.[14]

[iv] Citizen science involves the public, rather than professionals, in collecting data (and sometimes analyzing it) after training with or while working closely with a professional. This practice is beneficial to researchers because it can increase the data pool and provide low-cost samples and/or data. Most importantly, citizen science gets the public engaged in scientific research, providing educational opportunities and enhancing an awareness of scientific practices and their importance.[34]

[v] Superfund sites are contaminated areas designated by the U.S. Environmental Protection Agency for cleanup due to their risk to human health and the environment. For more information go to https://www.epa.gov/superfund.

Takeaways

This technology can track photosynthesis levels once or over time, thereby helping to monitor plant health and growth rates, as well as plant responses to climate change. Near-infrared photography is most effective at larger scales and via aerial views, so it may not be useful for small parks. It requires park staff to be knowledgeable about near-infrared photography and how to interpret its images.

Green roofs

What is this technology?

Green roofs are extensive- or intensive-planted areas located on the roof of a structure. Roofs are designed to accommodate up to a certain weight, which affects what type of green roof can be installed. An extensive green roof is the lightest type and requires minimal maintenance, relatively shallow soil buildup, and no permanent irrigation system.[15] Intensive green roofs are heavier and require more maintenance and deeper soil buildup.[15] They need regular irrigation and often include a permanent watering system but can incorporate a wide variety of plants, including shrubs and trees. Semi-intensive green roofs fall between an extensive and intensive roof in regard to maintenance, weight, soil depth, and irrigation needs.[15]

Credit: Greenroofs.com

Figure 4.10: A green roof adds visual interest and can help draw people outside.

Credit: Greenroofs.com

Figure 4:11: Green roofs naturally cool buildings because the vegetation provides shade, absorbs heat, and insulates the building.

How does it fit into parks?

Green roofs add visual interest to parks and can attract visitors. They can be installed on any park structure that can be retrofitted to accommodate their weight but are most often incorporated into new buildings. Smaller structures with lower load-bearing capabilities may be appropriate for an extensive green roof.[15] Larger structures, or structures specifically designed to bear the weight of a green roof, may be appropriate for an intensive green roof.[15] Green roofs can be designed to accommodate use, serving as locations for recreation and providing views of the park. Alternatively, green roofs can be designed without access for people, providing undisturbed ecosystems and habitats, possibly increasing biodiversity. Green roofs naturally cool buildings because the presence of vegetation provides shade, absorbs heat, insulates the building, and lowers surrounding air temperatures through evapotranspiration.[vi,16,17] This can reduce building energy needs, such as air conditioning.[17] Green roofs can also act as rain gardens, a low-impact management tool that turns an impermeable surface into an area capable of capturing and retaining stormwater on-site.[vii,17]

[vi] Evapotranspiration occurs when water enters the atmosphere by evaporating from soil and transpiring from plants.
[vii] Refer to Chapter 6 of this toolkit for more information on technologies that can improve stormwater management in parks.

Why choose green roofs?

Community Fit – Green roof design, function, and planting palette can be designed to fit any park context. A new park structure, such as a visitors' center, could be designed to accommodate a green roof, providing a unique gathering space and opportunity to teach park visitors about environmental issues like the urban heat island effect[viii] and sustainable stormwater management.

Health – Green roofs that are accessible to park visitors can increase contact with nature, which is beneficial for mental health.[18] Even if a roof is not accessible, it can increase visible green space and decrease the heat island effect, which also has positive health benefits.[18,19]

Resilience – Green roofs can be part of a low-impact strategy to retain and use stormwater on-site and reduce overflow and flooding.

Water – Green roofs can provide stormwater management benefits. While an intensive green roof requires supplemental irrigation, it can be designed to use less water-intensive native or adaptive plants.

Energy – The cooling effect of green roofs can reduce the need for air conditioning in the underlying structure.

What are the challenges and trade-offs?

Maintenance – All green roofs require more maintenance than traditional roofs, and they may not be viable for structures with low or unknown load-bearing capacity.

Space issues – Roof space may also be needed for mechanical units, emergency walkways, skylights, or other appurtenances, limiting space for a garden.

Takeaways

Green roofs can enhance park aesthetics and fit into any park context. They can be designed to provide new recreation spaces or undisturbed habitats. They can assist in low-impact stormwater management, as well as cool the underlying building and park. While green roofs can conserve water and energy and potentially improve the health and well-being of park visitors, they require buildings with proper load-bearing capacity and space and require more maintenance than traditional roofs.

[viii] The urban heat island effect describes developed urban areas that are hotter than nearby rural areas. The annual mean air temperature of a city with a population greater than 1 million people can be 1.8-5.4 degrees Fahrenheit warmer than it surroundings. For more information on heat islands go to https://www.epa.gov/heat-islands.

Credit: Joe Wolf

Figure 4.12: Chicago City Hall's semi-intensive green roof provides environmental and cost-saving benefits.

REAL-WORLD EXAMPLE

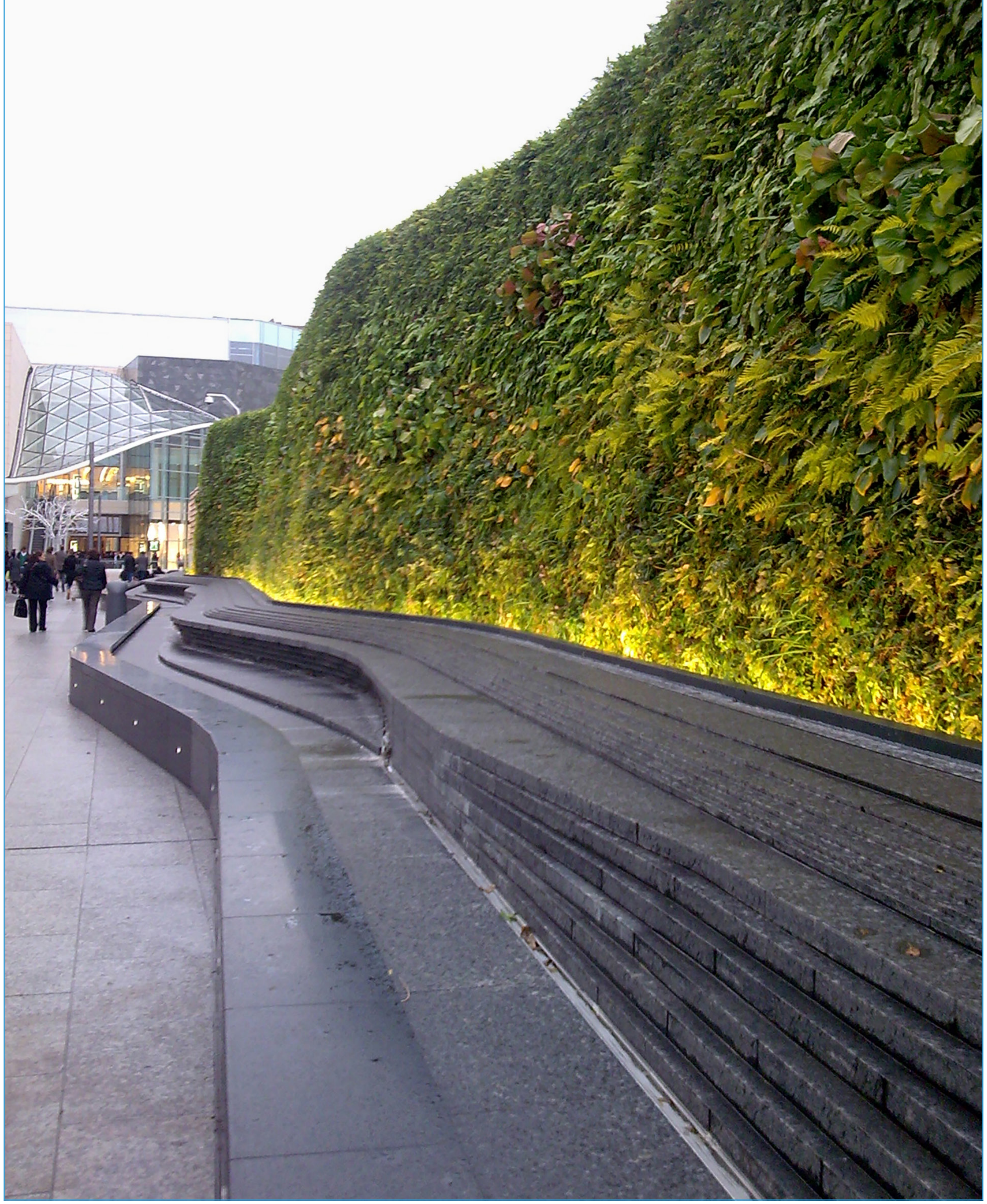
An Oasis in the Urban Skies | Chicago | 2001

Chicago's City Hall was retrofitted with a 20,290 square-foot semi-intensive green roof in 2000 as part of the city's Urban Heat Island Initiative, which was launched in response to a deadly heat wave in 1995.[17] The building was initially designed to accommodate additional stories, so it had the structural capacity needed. The green roof design was originally implemented only on one-half of the roof so that its impact could be compared to the original.[17] Ongoing monitoring shows that besides providing a beautiful and biodiverse green space, the roof is an average of 7 degrees Fahrenheit cooler than surrounding roofs, retains 75% of the rainwater that falls on it, reduces the cost of energy consumption of the building by more than $5,000 per year, and reduces noise pollution by up to 40 decibels.[17] This success led to a citywide Green Roof Initiative. Now more than 200 green roofs have been planted, including in the landmark 10-hectare Millennium Park.[17]

Green walls

What is this technology?

Green, or substrate- or soil-based, walls are a planting system that enables vegetation to cover a vertical structure, such as the façade of a building. Green walls are similar to green roofs but are installed vertically rather than horizontally. They can be soil-based, climbing, or hydroponic. Soil-based (also called substrate-based) walls use lightweight containers full of soil or other growing substrates attached to the wall, and incorporate permanent irrigation and water drainage systems.[20] Climbing green walls consist of plants that trail down off the roof or those that naturally tend to climb up, such as vines.[20] These walls allow the plants to grow naturally or have a frame to guide their growth.



Credit: Green Walls in the UK

Figure 4.13: Incorporating green walls, such as this one in the United Kingdom, onto walls or structures increases opportunities for visitors to connect with nature, which is beneficial for mental health.

Hydroponic green walls are modular like a soil-based green wall but do not use soil or growing substrate; instead the plants live on water infused with nutrients.[21] This makes the system lighter and easier to prefabricate, as the panels are often grown off-site and then attached to the wall.[22] Hydroponic green walls may or may not require permanent irrigation.

Credit: Ambius

Figure 4:14: Green walls may be appropriate where vandalism deterrence is needed, but may require higher maintenance.

How does it fit into parks?

Green walls can be incorporated onto any wall or structure in parks. A low-maintenance green wall, such as a climbing façade, may be appropriate for areas where vandalism deterrence is necessary. Some green walls require higher-maintenance, such as hydroponic or soil-based walls. These may be more appropriate for areas that are well-protected from vandalism or tampering. Green walls add visual interest to parks, may attract visitors, increase the amount of planted areas, and contribute to park ecosystems. Similar to green roofs, some green walls may provide water management benefits by capturing and treating stormwater or recycling greywater.[22]

Why choose green walls?

Community Fit – Because the planting palette, pattern, and type of green wall can be designed to fit any park context, it can reflect community needs and culture. For example, an edible herb living green wall could serve as a teaching tool and local food source.

Health – Green walls increase opportunities for park visitors to connect with nature, which is beneficial for mental health.[18]

Water – Depending on design, some green walls may assist in the treatment or infiltration of stormwater or be part of a graywater recycling strategy.[22] While a green wall may require supplemental irrigation, it can be designed to use less water-intensive native or adaptive plants.

Energy – Green walls on buildings have cooling effects and may reduce the need for air conditioning.[23]

Operations and Maintenance – Green walls may reduce graffiti or other vandalism by protecting the wall from tampering and climbing.

What are the challenges and trade-offs?

Maintenance – Substrate and hydroponic green walls require more maintenance and attention than traditional walls. Climbing green walls are relatively low-maintenance compared to substrate and hydroponic green walls, but still require more attention than a basic wall.

Damage risks – Although some green walls may deter vandalism, others can be vulnerable to damage. Green wall design and location must be carefully selected to also prevent moisture or weight damage to the underlying structure.

Takeaways

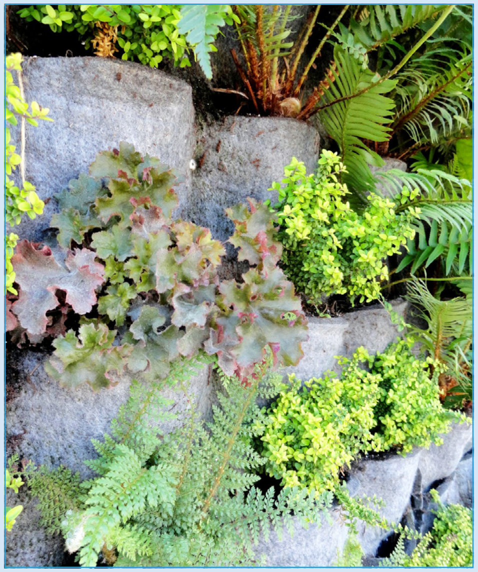
Green walls can be incorporated into any wall or structure to increase planted areas, contribute to the park ecosystem, offer cooling effects, and enhance visitor experience. Low-maintenance varieties can deter vandalism, while more complex structures may be vulnerable to damage or require more maintenance. Walls must be selected for appropriate load-bearing capacity, and consideration should be given to moisture damage prevention.

Credit: Loree Bohl | The Danger Garden

REAL-WORLD EXAMPLE

Transforming a Blank Wall | Portland | 2013

In response to a persistent graffiti problem, a local business owner commissioned a green wall in Portland, Oregon (Figures 4.15 and 4.16, above and right).[24, 25] The 75-square-foot substrate-based wall is planted with 256 individual ferns, Sweet Flag, Elephant Ears, London's Pride, Salal, and other plants. The wall turned a neighborhood nuisance into a lush, beautiful focal point for the area.[24]



Air-pruning plant containers

What is this technology?

Air-pruning plant containers are temporary planters designed to encourage healthy root growth before permanent planting. The containers force the root tips that reach the perimeter of the container to be exposed to air,[26] signaling dehydration and forcing it to split and turn inward. They can be fabric bags, containers with holes in the walls, or specially designed plastic containers shaped to optimize root growth. They can be purchased or created as a do-it-yourself strategy.[27] When a plant is grown in a conventional pot, the roots grow toward and then down the wall of the container.[27] Over time, this leads to root circling, or a dense tangle of roots around the perimeter of the pot, with relatively little root infiltration into the middle. This can kill plants if they are not repotted in a larger container.[26] Air pruning promotes larger, healthier root systems that maximize the entire growing space within the pot, not just the perimeter.[26] Healthier roots lead to healthier, more robust, and often larger plants. Air pruning may also increase the amount of time a plant can tolerate a growing container.[27]

Figure 4.17: Air pruning in specially designed containers, above, promotes larger, healthier root systems that maximize the entire growing space within the pot.

Credit: Hydroponics.co.uk

How does it fit into parks?

Air-pruning plant containers can be used to grow healthy plants in pots at parks, either as part of the landscape aesthetic or before vegetation is planted in the ground at new or retrofitted parks. Parks with existing community gardens can use air-pruning pots to improve plant growth and increase crop yields of edible food for community members. Parks may wish to have community plant sales as a new programming opportunity and could offer air-pruning containers to instruct community members on new gardening techniques.

Why choose an air-pruning plant container?

Resilience – Air-pruning plant containers can support the health of plants, increasing their robustness during stressful weather or drought events. Parks with substantial annual, rather than perennial, planting palettes can use air-pruning plant containers to enhance root health each season.

Operations & Maintenance – Air-pruning plant containers can reduce the need for frequent re-potting. Furthermore, plants with healthier root systems may require less care and attention. Parks with potted plants or trees could use air-pruning containers as permanent pots to prolong the useful life of the container, before the plant needs to be repotted.

What are the challenges and trade-offs?

Water requirements – Plants grown in air-pruning containers may require more water than plants grown in traditional containers. This is partly because of water loss through the perimeter air holes, but also because of the increased growth activity of the plants.

Credit: Wimbish Tree Farm

REAL-WORLD EXAMPLE

Room to Breathe for Trees | Oregon | 2007

A study published in Digger, a publication from the Oregon Association of Nurseries, found that shade trees grown in large fabric air-pruning containers grew healthier root systems (left in Figure 4.18, above) when compared to conventional plastic pots.[28] Each of the three tree species studied showed that those grown in fabric containers had less root circling, fewer misdirected roots, and more fibrous root systems than the trees grown in plastic containers (right in Figure 4.18, above).[28]

Takeaways

Air-pruning containers support plant health and increase their ability to withstand stress. They can also reduce the need for frequent re-potting, and thus maintenance needs. The containers can be used temporarily before permanent planting or as permanent pots within the park. Additional water may be required for plants grown using this technology, due to increased water loss through air holes and increased plant growth.

Credit: KQED

Figure 4.19: Parks with edible gardens can use vibrating pollinators as a strategy to increase crop yield. The device can also be useful in educating visitors about food production, plant biology, and the importance of natural pollinators.

Vibrating pollinators

What is this technology?

Vibrating pollinators are hand-held, battery-operated tools that vibrate near the same frequency as pollinators' wings to induce plants to release pollen, so they can then be manually pollinated.[29] In nature, when a pollinator visits a flower and stimulates pollen release, the pollinator becomes coated in pollen. The pollinator carries the pollen to the next plant it visits, fertilizing it. However, in greenhouses and areas where pollinator populations have declined, vibrating pollinators can be used to increase crop yield. Special-purpose vibrating pollinators can be adjusted to match the frequency of specific pollinators, such as those required by many edible plants, including tomatoes, peppers, squash, and blueberries.[29] Pollen released from vibrating pollinators must be manually collected and distributed for fertilization.[29] Depending on the frequency of vibration required, this low tech can be bought inexpensively or created through a do-it-yourself strategy by utilizing an electric toothbrush or tuning fork.

How does it fit into parks?

Parks with edible gardens can use vibrating pollinators as part of a strategy to increase crop yield. They may also be useful in educating visitors about food production, plant biology, and the importance of natural pollinators.

Why choose vibrating pollinators?

Access – Vibrating pollinators can be part of a local food production strategy to increase community access to healthy foods. They can also be used to educate visitors on healthy food, gardening, and the pollination process.

Health – Vibrating pollinators may be used to promote and spread awareness of local food production, which can contribute to access to healthy foods and eating habits in the community.

Resilience – Vibrating pollinators can be used to increase or salvage crop yield in the absence of natural pollinators, which could be caused by climate change and its impact on the distribution of insect and plant populations.

What are the challenges and trade-offs?

Time and labor requirements – Manually pollinating plants using vibrating pollinators is a time- and labor-intensive process. However, it can result in a significantly larger and more reliable crop yield than natural pollination alone.

Staff expertise and training – Park staff will likely require additional training to learn how to use vibrating pollinators.

REAL-WORLD EXAMPLE

Expanding Crop Yields | Louisiana | 2005

Credit: LSU AgCenter

Outside, tomatoes are naturally pollinated by bumblebees and strong winds that release and disperse pollen. Plants grown in greenhouses are not subject to wind and, therefore, cannot be pollinated in this way. Large greenhouses can sustain bee colonies for pollination, but smaller operations cannot and must be manually pollinated by growers. A study on tomatoes' crop yields grown in a greenhouse[30] found that plants pollinated with electric pollinators (Figure 4.20, above) resulted in higher yields, enough to offset the higher labor costs.[30]

Takeaways

Vibrating pollinators can be used in parks with edible food gardens to increase crop yield as well as to educate visitors about food production, plant biology, pollination, and healthy eating habits. They also enable crop yield to increase or be salvaged in the absence of natural pollinators, which may occur due to changing climate. However, using vibrating pollinators is a time- and labor-intensive process that requires manual pollen collection and distribution.

Landscape component achievement levels

Landscape technologies described in this chapter can provide a range of benefits, particularly contributing to the Value Criteria of Resilience and Health, with additional benefits for Community Fit , Water, Energy, and Operations and Maintenance. Vibrating pollinators also benefit the Access criterion, because they can improve crop yields and enhance healthy food production for communities.

	Access	Community Fit	Health	Safety	Resilience	Water	Energy	Operations and Maintenance
Automatic Lawn Mowers	○	○	●	○	○	○	●	●
Near-Infrared Photography	○	○	●	◒	●	●	○	○
Green Roofs	○	●	●	○	●	◒	●	○
Green Walls	○	●	●	○	○	◒	●	◒
Air-Pruning Plant Containers	○	○	○	○	●	○	○	●
Vibrating Pollinators	◒	○	●	○	●	○	○	○

● Indicates technologies that provide a positive benefit for a value criterion.

◒ Indicates technologies that represent a secondary effect on a value criterion or have a trade-off between their benefits and drawbacks.

○ Indicates technologies that have no effect, a negative impact, or are unrelated to the value criterion.

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Chapter 5: Irrigation

IRRIGATION is responsible for approximately 70% of freshwater use worldwide, yet half of it may be wasted because of evaporation, runoff, or infrastructure flaws such as leaking pipes.[1,2] During droughts, such as the one that affected California for much of the past five years, irrigation efficiency and effectiveness become even more important because of the existing strain on water supplies.[3] Many of the affected cities and regions have issued executive directives calling for major reductions in water usage by residents and municipal departments. This chapter describes five SMART Park technologies that can be used to enhance and improve irrigation and its related equipment: smart water controllers; low-pressure and rotating sprinklers; subsurface drip irrigation; smart water metering; and graywater recycling. Irrigation can complement other water-saving options[4,5,6,7,8] such as landscaping choices, which are discussed in Chapter 4.

California takes action toward water conservation

Efforts in the state to address wasted water and to increase conservation include:

- **AB 1881-Laird (2006)** requires the California Energy Commission to standardize performance and labeling for landscape irrigation equipment, such as controllers, sensors, and valves.[9]

- **SB X7-7-Steinberg (2009)** requires California to achieve a 20% reduction in urban per capita water use statewide by 2020, including reducing landscape irrigation demand.[10]

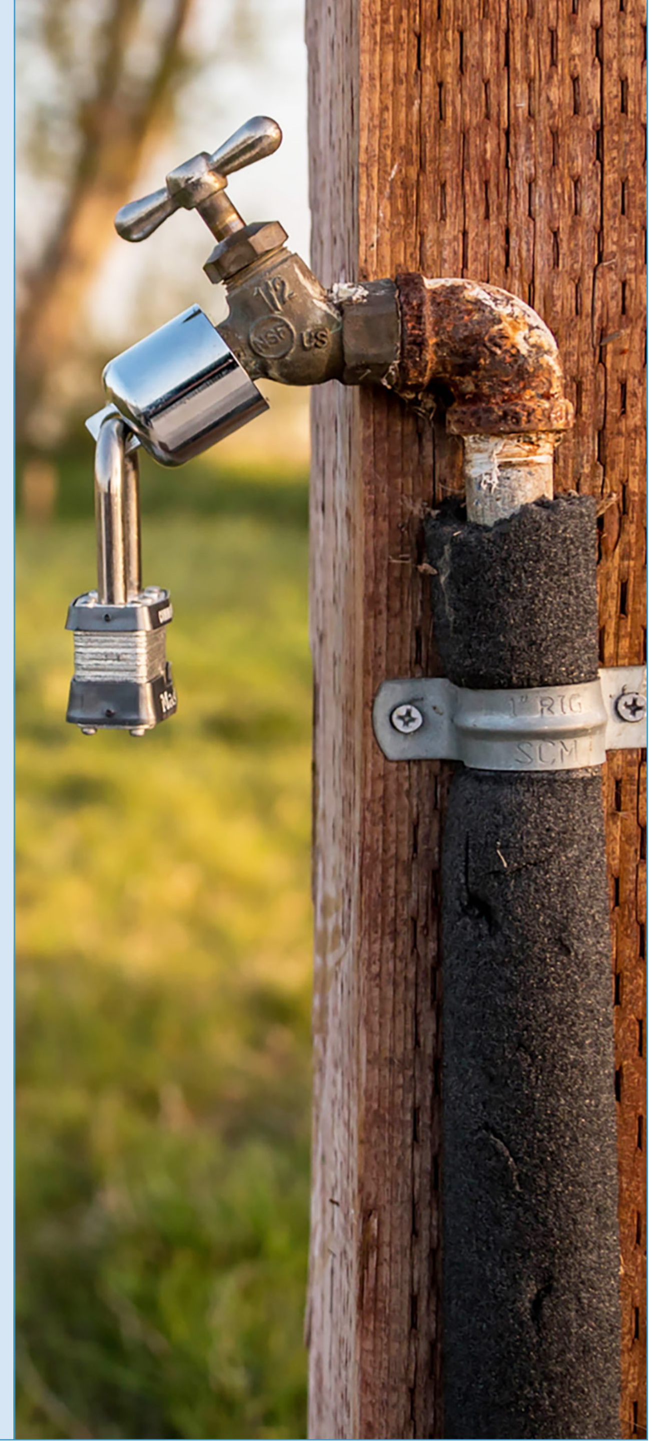
- The **Integrated Regional Water Management Grant Program,** started in 2010 as designated by California's Proposition 84, Chapter 2, allocates more than $823 million in grants toward the planning and execution of projects to help local public agencies achieve water conservation, delivery, and quality goals.[11]

- The **City of Los Angeles Executive Directive #5 (ED5),** implemented in 2014, calls for major reductions in water usage by both city departments and residents. ED5 promotes rebate programs offered by the Los Angeles Department of Water and Power to incentivize residents to conserve water and mandates water use cutbacks by city departments.[12] After the directive was implemented, the city achieved more than a 17% reduction in per capita water use by the end of 2015.[13]

- The **2016 California Water Code #13551** calls for the use of recycled water for non-potable functions, including in cemeteries, golf courses, parks, highway landscaped areas, and industrial and irrigation uses.[14]

Figure 5.1 (Chapter cover photo) – Credit: Zimmatic.com

Figure 5.2, right – Credit: Rich Lonardo/iStock



Credit: Texas A&M AgriLife Extension

Figure 5.3: Smart controllers adjust watering cycles using data from ground and weather sensors. The rectangular boxes are controller programming units; the non-rectangular pieces mounted on top of the green panel are weather sensors.

Smart water controllers

What is this technology?

Smart water controllers, also known as timers, digitally manage watering patterns of sprinklers and subsurface drip irrigation systems based on data collected through soil moisture and weather sensors.[15] Soil-based sensors measure the amount of moisture in the ground and determine how much watering is necessary based on soil type, topography, and other conditions. Weather sensors located at the park or at a local weather station can determine how much watering is needed given particular weather conditions (e.g., temperature, wind, humidity, rainfall, etc.). Weather data collected by

Chapter 5

sensors not located at the park may be relayed wirelessly to the park's controller network via the Internet of Things (IoT),[i] a digital network of sensors and devices that interact with and share data among each other via the Internet.[16]

Credit: TheBestSelling.net

Figure 5.4: Digital timers may be remotely controlled through mobile apps for easy on-the-go access.

How does it fit into parks?

Each smart water controller includes a network of sensors and control systems that can be applied to parks' existing irrigation pipes and pumps.[2] A network of multiple controllers may be digitally linked via a central control system. This unified platform can compile weather and soil data from each controller onto a single computer or an online database. Digitally storing device information and moisture data from various sources makes managing the system easier, as park employees no longer need to reference each controller separately, manually log data, or be physically on-site to monitor data and equipment.[10] Because of the remote nature of controllers, park employees can use mobile apps or Internet-based software to turn watering systems on and off.[17] Controllers can also update park employees on the status of watering cycles through text messages and email.[18]

Why choose smart controllers?

Safety – In addition to weather and soil moisture sensors, smart water controllers can be paired with motion sensors and programmed to avoid watering public areas while people or animals are present.[19]

Resilience – By using smart water controllers, park irrigation systems can adapt to daily, seasonal, and long-term changes in soil, weather, and climate conditions.

Water – Irrigation controllers can conserve water throughout parks by optimizing watering patterns in each area depending on microclimate and soil type.[20]

Energy – By automatically adjusting watering cycles based on need, smart water controllers can reduce the energy needed for motors and pumps that transport water.

Operations and Maintenance –

» Managers can remotely access controllers connected to the Internet of Things, allowing them to manage equipment, program watering cycles, and receive system alerts remotely.

[i] For more information about the Internet of Things, see Chapter 11.

» Watering patterns may be optimized based on weather data from off-site sensors. This reduces the requirements on park staff to maintain sensors and facilitates automatic adjustment of watering cycles in near-real time without requiring staff input.

» The sensors associated with smart water controllers may detect leaks, if recorded soil moisture is higher than what recent watering and weather conditions suggest it should be.[21]

What are the challenges and trade-offs?

Limited battery life – The lifetime of soil- and weather-based sensors may be lower than expected depending on how often they are activated to communicate with Internet-based information storage, or "cloud" services.[22] Furthermore, if battery maintenance or replacement is required, it may be challenging to access soil-embedded sensors, as they may be difficult to dig up, and their battery compartments may be tightly sealed to protect against water damage. Improvements in battery capacity and reliability could make smart water controllers and sensors more appealing and affordable.

Security risks – Although cloud services can be highly secured with passwords, encryption, and firewalls, IoT-enabled devices that collect and transfer data lack these security measures and may be susceptible to hacking.[22] Furthermore, some data collection agencies may sell data, possibly putting information about park operations and visitors at risk. Managers should learn what kinds of data are collected by each device, if and to whom data is being sold, and how the manufacturer secures data in both the device and cloud.

Compatibility issues – Some devices may not be compatible with existing park infrastructure, physically or digitally, making collecting viable data difficult. However, smart water controller manufacturers may bundle intercompatible hardware, software, and cloud services for easy use.[22] The reliability of IoT-enabled controllers may be hindered by the lack of Internet infrastructure and bandwidth in some regions; thus, advances in Internet connectivity are necessary to encourage adoption of smart water controllers.

Takeaways

Smart water controllers can optimize water use on a small or large scale by adjusting for soil conditions and weather patterns. To ensure that software and hardware are compatible with each other and with existing park infrastructure, it may be necessary to consult a professional to customize the system according to park needs. In areas where professional expertise is scarce, the maintenance and effectiveness of these systems can be hindered.[23]

REAL-WORLD EXAMPLES

Getting Irrigation Under Control Calabasas, California | 2014

In 2014, in response to the state's drought and dwindling water supplies, the City of Calabasas implemented a citywide smart water controller system integrating ground-based sensors, cloud network communication with satellites, National Oceanic and Atmospheric Administration data, and field observations to optimize non-potable landscape irrigation patterns. The system is notable because it updated all city-owned water controllers and replaced 1,000 spray sprinkler heads with drip irrigation emitters. It uses recycled water and collects water usage data from all city-owned parks, buildings, and streets. The system cost more than $700,000; $570,000 was funded through California Proposition 84, which sponsors public works projects that improve water conservation, delivery, and quality. The remainder was provided by the city and the Metropolitan Water District of Southern California. The city expects to regain its initial investment through water savings within five years of installation.

Credit: City of Calabasas

Figure 5.5: Calabasas' smart water controller system manages irrigation at most city-owned properties.

The city's goal was to use the system to reduce water consumption 15% to 25%. However, it has already surpassed its goal, achieving savings of 32% and 47% in 2014-'15 and 2016-'17, respectively. Operational benefits include the ability to control valves during storms and on weekends, when fewer staff may be on hand. The system also has the capability to automatically shut down broken sprinkler heads and notify supervisors. Managers learned how to run the equipment and operate the computers during a four-hour training session hosted by the technology manufacturer.[9, 24,25]

Forecasting Water Savings | California | 1982

The California Irrigation Management Information System has been upgraded several times with improved data collection and communication technology since its beginnings in 1982. This is an example of existing infrastructure newly adapted to supplement smart water controllers.[26] The system connects more than 145 automated weather systems statewide, each of which contains sensors that measure and upload environmental conditions four times a day, with digital software to analyze the data and present the results online.[27] The controllers can automatically access and use current or historical weather data from the management system to ensure that each plant in the park receives the exact amount of water required, considering humidity and evaporation rates.[ii,28] The remote data collection also ensures that managers can access up-to-date information anytime.

[ii] More information available on its website: http://www.cimis.water.ca.gov/.

Credit: Wikimedia Commons

Figure 5.6: Rotating sprinkler heads ensure watering coverage over a wide area around the sprinkler.

Chapter 5

Low-pressure and rotating sprinklers

What is this technology?

Innovations in sprinkler nozzle designs and operations optimize water use and distribution on the ground:

» Low-pressure sprinkler heads produce less fine mist than traditional heads to prevent water from being carried away by the wind.[10]

» Rotating sprinkler heads ensure 360° coverage around the sprinkler, while using a reduced flow rate and operating pressure to allow water to uniformly permeate the ground instead of running off or being carried away by wind.[29]

How does it fit into parks?

Low-pressure and rotating sprinkler heads are not new technologies; however, they have been used infrequently in parks. In some cases, it may be cost-effective to replace existing sprinkler heads because of age or incompatibility with new equipment. In other instances, they may be outfitted with a low-pressure or rotating add-on, reducing the need for new sprinklers.

Why choose low-pressure and rotating sprinklers?

Safety – Low-pressure and rotating sprinkler heads reduce the production of fine mist that can easily make walking surfaces unsafe.

Water – Compared to existing sprinkler heads, low-pressure devices require up to 39% less water to deposit 1 inch of water on the landscape. Rotating heads can independently produce water savings of 10% to 43%.[10]

Energy – Reductions in water use and operating pressure conserve energy by reducing the load on motors and pumps that transport water.

What are the challenges and trade-offs?

Some modified sprinkler heads are shaped differently than older devices, making them incompatible with existing park infrastructure. Managers should ensure compatibility by testing samples or cross-checking manufacturer information.

REAL-WORLD EXAMPLE

Rotating Heads Make the Rounds | 2013

Several municipal water districts throughout the U.S. have analyzed the water conservation impact of rotating nozzles.[30]

The Municipal Water District of Orange County in California instituted a Rotating Nozzle Rebate Program to reduce the net cost of new nozzles. Residential and commercial sites that participated in the program achieved net water savings of close to one gallon per day per nozzle.[30]

The Eugene Water & Electric Board in Oregon determined that rotating nozzles reduced water demand during peak hours and improved watering uniformity, although yearly weather patterns may have had a greater impact on water conservation than the technology.[30]

Takeaways

Low-pressure and rotating sprinklers may allow park managers to conserve water without constructing new, extensive infrastructure. Managers may be able to obtain new sprinkler heads or add-ons to existing heads at less cost than smart water controllers, meters, and recycling systems.

Subsurface drip irrigation

What is this technology?

Subsurface drip irrigation (SDI) uses ground-embedded drip irrigation tubes (or "dripline"), pumps, water-releasing emitters (exit holes along the length of the underground tubes), valves, and motors to transfer water slowly and directly to plant roots, where water and nutrient uptake is highest.[iii] This differs from overhead and rotating sprinklers, which spray water into the air that then falls on the ground, plant leaves, and plant stems.[iv,31] Compared to sprinklers, subsurface drip irrigation produces more uniform water distribution and has lower chances of evaporation and runoff.[31] SDI systems require air release and system flush valves to reduce buildup in the equipment from soil, bacteria, and other contaminants.

Credit: Wikimedia Commons

Figure 5.7: Subsurface drip irrigation inundates a relatively small area of ground surface, reducing risks of water runoff.

[iii] For information on how to retrofit a sprinkler system as a drip irrigation one, see http://civicaweb.santabarbaraca.gov/civicax/filebank/blobdload.aspx?BlobID=34294.

[iv] For more information on drip irrigation equipment and system design guidelines, see https://www.irrigationtutorials.com/drip-irrigation-design-guidelines-basics-of-measurements-parts-and-more/.

Chapter 5

How does it fit into parks?

Although forms of drip irrigation, including SDI, have been used for several decades, recent innovations, such as smart water controllers and meters and graywater recycling technology, have increased their viability for use in parks.

SDI can be used to efficiently water plants. Depending on the type of vegetation and its root depth, SDI driplines can be located at different soil depths to ensure optimal watering. For example, grassy areas with shallow root systems require driplines to be located within inches of the soil surface. In the case of mature trees, SDI driplines should be located deeper in the soil to apply water slowly over several hours so it can percolate deep into the soil. SDI also reduces risk of plant disease by minimizing contact between water and plant stems, leaves, and fruit.[12]

An efficient irrigation system may gather data from a wireless network of battery-operated sensors distributed throughout the park. Data that may be remotely monitored include soil pH, ground and air temperature, moisture and humidity, chemical content of the soil, salinity, rainfall and upcoming weather, vapor pressure, and sunlight. Furthermore, SDI systems can be continuously monitored to ensure the equipment's reliability. Data can be collected at various intervals and wirelessly transmitted to a centralized storage service, where managers or software applications can analyze it. SDI pumps and valves can be remotely adjusted in real time based on the data.[32] Even without professional consulting, consumers may be able to construct do-it-yourself electronic kits to link sensors, SDI mechanical components, and mobile software programs.[33]

SDI systems may serve as an effective means of using recycled graywater for irrigation to minimize health risks via exposure to humans by minimizing the production of fine mist. Drip irrigation is encouraged by some municipal organizations. For example, the Municipal

Credit: Texas A&M AgriLife Extension

Figure 5.8: SDI conserves water by directly targeting plant roots via drip emitters.

Water District of Orange County's (MWDOC) Public Spaces Water Smart Landscape Program incentivizes landscape improvements addressing water use efficiency at publicly owned and highly visible green spaces within the county. Improvements include converting fixed-spray sprinklers to rotating nozzles and/or drip irrigation, removing more than half of the space's nonfunctional turfgrass, and adopting IoT-enabled irrigation controllers. MWDOC provides up to $0.50 per square foot or 25% of total project cost, whichever is less, to participating cities whose renovations meet the program's participation criteria.[34]

Why choose subsurface drip irrigation?

Access and Safety – SDI eliminates the production of fine mist that can easily make walking surfaces slippery, inaccessible and unsafe.[30] Park visitors are less likely to trip on SDI dripline than on exposed watering infrastructure.

Health – SDI is an effective means of delivery for graywater, because it avoids spraying such water through the air, which can impact human health.[30]

Resilience – Deep watering prolongs plant root longevity, allowing trees to thrive even during periods of drought.[35] Traditional or shallow watering, which limits the depth of tree roots and restricts the volume of soil that each tree can use to gather water and nutrients, makes trees more susceptible to drought, disease, and uprooting.[36]

Water –

- SDI is more efficient at delivering water to plants; there is little to no loss of water to surface evaporation or runoff.[30] The lack of runoff also enhances SDI's effectiveness on uneven ground.[12]
- An SDI system can deliver water with an efficiency exceeding 95%. This means that for every inch of water pumped, at least 0.95 inch of water stays near plant roots, the area most beneficial to the plant.[30]
- SDI concentrates water delivery on a small fraction of soil volume where plant roots are located, leaving more space in the soil to absorb and contain stormwater.[30]
- With SDI, there is little to no loss of water as fine mist that gets carried away by the wind. Water can be applied with a more uniform distribution.[30,37]

Energy – SDI systems conserve energy by operating at lower pressure and flow rates than fixed-spray sprinklers, reducing the load on motors and pumps that transport water.

Operations and Maintenance –

- SDI driplines may reach areas of land plots that pivoting sprinklers cannot, such as irregular lawn shapes, dry corners, and hard-to-reach planters.[38,39]
- SDI improves physical access to plants and discourages shal-

Credit: Texas A&M AgriLife Extension

Figure 5.9: System flush valves (in blue) are necessary to periodically remove soil and bacterial contaminants from a dripline. Sediment- or bacteria-containing water is diverted out of the dripline and into the soil. The plastic container housing the valve enables convenient access to it and may limit the area inundated during a flushing cycle.

low-rooted weed growth by keeping the bare soil surface dry.[12] This allows staff and maintenance equipment to enter the area, if needed, during watering cycles.[30]

» SDI can be integrated with a wireless sensor network and smart water controllers to monitor system performance and control operations remotely, potentially reducing the workload of park staff.[31]

What are the challenges and trade-offs?

Dripline durability – Plastic SDI driplines are prone to intrusion from roots and rodents. However, new copper-lined driplines can safely replace chemicals previously used to inhibit root intrusion and may serve as a deterrent to rodent activity.[30,40]

Energy consumption – If SDI is integrated with a smart water controller system, the system's remote sensors consume power to wirelessly deliver water consumption data to the monitoring station, which increases energy use at the park. To reduce sensor activity, consumers may wish to limit readings and set longer intervals as necessary.[31]

Foreign contaminants – Air bubbles, solid debris, and microbial contaminants may gather in SDI driplines over time and can lead to equipment failure. A pressure-regulating device installed as part of a smart water controller or smart metering system may detect signs of contaminant buildup before they damage the system. Furthermore, filtration and chlorine injection may prevent buildup of soil and bacterial particles, respectively. SDI users should ensure the system's air release and system flush valves work.[30]

Issues facing novel technology – The integration of SDI with the IoT and graywater recycling is a novel concept, and system and equipment malfunctions are common when installing new technologies. Installing and maintaining SDI requires professional expertise that may not be available in some regions.[40] Maintenance challenges are among the top reasons for farmers to reject drip irrigation, although policymakers could support new technologies by developing policies encouraging SDI use.[40,41]

Compatibility with park shape – Water pressure in SDI driplines may drop over long distances or in varying soil topography. Sloped areas may require emitters specially designed to resist leakage in low portions of the dripline, even when no water is flowing.[37]

Compatibility with plant growth – Some herbicides and fertilizers require sprinkler activation that would be limited or absent after adopting an SDI system. Managers should determine whether their plants require sprinkler-activated products before adopting an SDI system.

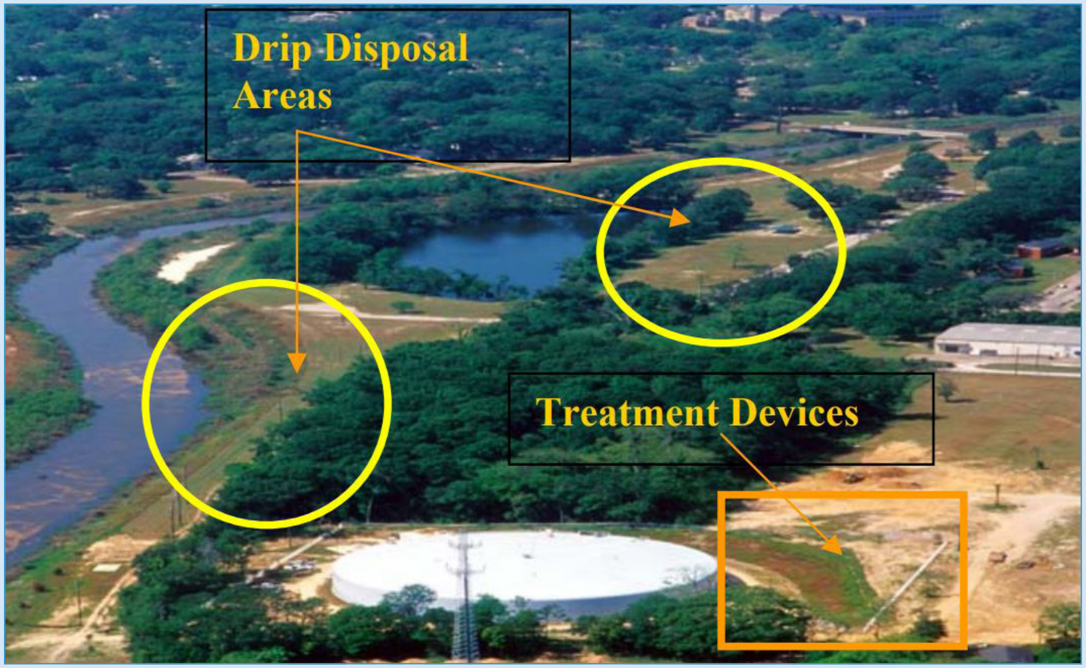
Takeaways

Although subsurface drip irrigation systems have been commercially available for some time, their viability in parks has recently increased due to opportunities to utilize emerging technologies for "smart" irrigation. Recent innovations in smart water controllers utilize Wi-Fi and Bluetooth to control SDI systems via smartphones and the Internet. Subsurface irrigation can improve water use efficiency and reduce time during which park visitors cannot access various areas due to slippery and unsafe surfaces. Because SDI system equipment is located underground, it is unlikely to suffer from vandalism or foot traffic.[42] Furthermore, SDI may improve park aesthetics because it is out of sight.[43]

REAL-WORLD EXAMPLES

Wastewater Reuse
Mobile, Alabama | 2005

To conserve drinking water and lower stress on watersheds, the Mobile Area Water & Sewer System tested the viability of reusing urban wastewater for irrigation. Forty thousand gallons of raw sewage per day were diverted from a municipal wastewater treatment facility to three stations that used mechanical filters and ultraviolet light to remove solids and microorganisms. The water was filtered and transferred to SDI systems in grassy areas along the Three Mile Creek. To minimize health concerns, a buffer zone of at least 300 feet from the nearest residence was maintained, and both influent and effluent waters were monitored for suspended solids, oxygen demand, ammonia, nitrate, phosphorus, and fecal matter. Measurements indicated that these methods could produce adequate-quality irrigating water for use in SDI systems and that the SDI system did not significantly impact groundwater quality. The experiment determined the necessity of periodically flushing SDI systems of contaminants to ensure long-term durability, and the potential for small-scale setups to rejuvenate older urban areas.[44]



Credit: Volkert

Figure 5.10: Along Three Mile Creek, thousands of gallons of wastewater that normally would be treated at a regional wastewater facility (in white) were instead diverted to small-scale treatment devices (outlined in orange) for use in nearby SDI systems (circled in yellow).

Going Underground With Irrigation
Santa Fe, New Mexico | Ongoing

Researchers from the New Mexico State University College of Agricultural, Consumer, and Environmental Sciences are using pilot projects to investigate the viability of SDI systems in improving watering efficiency. The projects at Santa Fe's The Club at Las Campanas and Albuquerque's Paradise Meadows Park irrigate half of each area with SDI and half with pop-up sprinklers and will determine whether SDI can be utilized effectively to conserve water in real-world situations. The experiment's results are expected to be compiled within three to five years.[37]

Chapter 5

Smart water metering

What is this technology?

Smart water metering combines physical water meters and digital communication components to measure water consumption and communicate the data to utilities at regular intervals through radio signals, power-line communication, satellite, and/or the Internet. Utility staff and others can access water usage data online and assume real-time control over meter reads and water flows.[45]

There are two types of smart water metering services:

» **Automatic Meter Reading (AMR),** the cheaper option, simply collects and sends basic water usage information from the meter to the utility.

» **Advanced Metering Infrastructure (AMI),** the more expensive option, utilizes ground-embedded sensors and two-way digital communications to detect infrastructure leaks, facilitate communication between users and utilities, gather data more frequently, enable remote service disconnects, and allow maintenance workers to quickly locate needed repairs.

Although communication between physical meters and the utility company does not necessarily require an Internet connection, such a connection can be used to compile, organize, and present water-use data. This allows users to easily view and analyze patterns. With AMI, an Internet platform can be used to electronically communicate with the utility company for billing, customer service, and requesting work orders.

Credit: Flickr

Figure 5.11: With smart water meters, utility staff can access water usage data online and assume real-time control over meter reads and water flows.

How does it fit into parks?

Smart water meters can replace or retrofit traditional meters currently used in parks. Traditional meters can be outfitted with an Internet-enabled digital recording device that uploads data to online cloud storage services.[46] By integrating water meters with the Internet, park managers can electronically manage billing, metering, dispatch, and customer service, reducing the need for phone calls or trips.[47] Smart water meters can remotely detect leaks within hard-to-access subsurface dripline.[48] Managers may decide to make data publicly accessible to maintain transparency and display a park's water savings.

Credit: Bmnorthamericaprod

Figure 5.12: Many smart water meters transmit data to the Internet, where websites and mobile apps analyze and translate the information into easy-to-read graphs.

Why choose smart water metering?

Resilience and Water – Smart water meters associated with either AMR or AMI identify areas of high water consumption, allowing managers to pinpoint opportunities to conserve water, especially during periods of drought.

Energy – An online platform associated with AMI can manage billing and maintenance reports digitally. This reduces the energy needed to print and distribute paper records. Reductions in water use because of smart water metering conserve energy by reducing the amount of energy needed to transport water.

Operations and Maintenance –

» Smart water meters associated with either AMR or AMI collect data frequently and at any time. They are capable of transmitting data every second, although utilities can set collection interval lengths from five minutes to one hour, or even longer, to reduce power consumption.[49,50] This technology can help managers ensure that all areas of the park are adequately watered.

» Data from smart meters is stored and presented online, allowing managers and users to easily access results remotely.

» Smart meters may be able to alert managers to leaks by detecting abnormal and sudden changes in water flow.[46] AMI alerts utilities so that they can quickly respond to needed repairs.

What are the challenges and trade-offs?

Internet infrastructure and bandwidth – While an Internet connection is not required for smart meters to collect and transmit water usage data, it maximizes the potential of AMI by establishing a user interface for park staff. In some regions, smart water meter reliability could be hindered by a lack of Internet infrastructure and bandwidth.[51] The technological viability of smart water meters may increase with advances in Internet connectivity.

Security risks – Meters may not have reliable security technology, such as encryption and firewalls, and may be susceptible to hacking.[22] Managers should learn what kinds of data various devices collect, whether data is being sold to other parties, and how the manufacturer secures data in both the device and the cloud.

Maintenance difficulties – To minimize the risk of electrocution, smart water meter batteries are sealed water-tight and generally cannot be replaced, requiring that the entire unit be replaced when the battery runs out. Electrical malfunctions in the power supply would greatly shorten the meter's effective lifetime.[52]

Compatibility issues – Some smart water meters may not be physically or digitally compatible with park infrastructure, making viable data collection difficult. However, smart water meter manufacturers can provide hardware, software, and cloud services programmed to work with each other.[52]

Issues facing novel technology – Standards of manufacturing and customer service for smart water meters are a work in progress, which has led to various quality-control, maintenance, and service inconsistencies.[53]

Takeaways

Data from smart water meters can be used internally to inform management decisions, or can be made public. Park managers must choose whether to adopt AMR or AMI; AMR is cheaper than AMI but only facilitates data collection, with little ability to detect leaks or provide communication between park managers, utilities, and maintenance workers. In some cases, AMR may be a sufficient first step toward adopting smart metering practices; the data collected could be analyzed to inform users and utilities of water usage trends and to invest in new technologies.[45] To take full advantage of AMI's digital connectivity, future innovations may seek to pair AMI with smart controller systems to ensure that each area of the park is irrigated optimally.[46] Furthermore, AMI could be combined with graywater recycling systems to determine how graywater can contribute to park irrigation effectively.

Credit: Office of the Mayor of Los Angeles

Figure 5.13: Los Angeles Mayor Eric Garcetti, holding a smart water meter, joined L.A. Department of Water and Power staff, City Department of Recreation and Parks representatives, and the city's mascot at a park in 2016 to announce the start of a pilot program to install 100 new meters in 28 parks.

REAL-WORLD EXAMPLE

Get Smart in Irrigation | Los Angeles | 2016

In early 2016, a joint effort between the City of Los Angeles' Department of Water and Power, Department of Recreation and Parks, and the Mayor's Office installed 100 smart water meters in 28 parks as part of a pilot project to test the meters' effectiveness in public spaces. The meters automatically collect and upload usage data every 15 minutes and can detect leaks much more effectively than previous non-Internet-enabled meters. The program was initiated in the wake of Los Angeles Executive Directive #5, which calls for major reductions in water use by city departments and residents.[12]

Chapter 5

Graywater recycling

What is this technology?

Graywater is wastewater that has been used once in showers, sinks, dishwashers, washing machines, or other appliances. It is distinct from blackwater, which is sourced from toilets. Graywater recycling is the filtration and utilization of graywater in place of potable water for non-potable functions such as irrigation and toilet flushing. Graywater sources are often required to be labeled unsuitable for human consumption, and graywater-carrying systems must be designed to minimize exposure to humans and pets.[54]

Credit: Aquapoint

Figure 5.14: Using recycled graywater treated by underground systems, like the one above, conserves potable water and reduces parks' water utility costs.

Graywater recycling treatments consist of several phases that mimic natural water purification processes (artificial wetlands and other natural systems that filter water can also be included in the treatment steps):

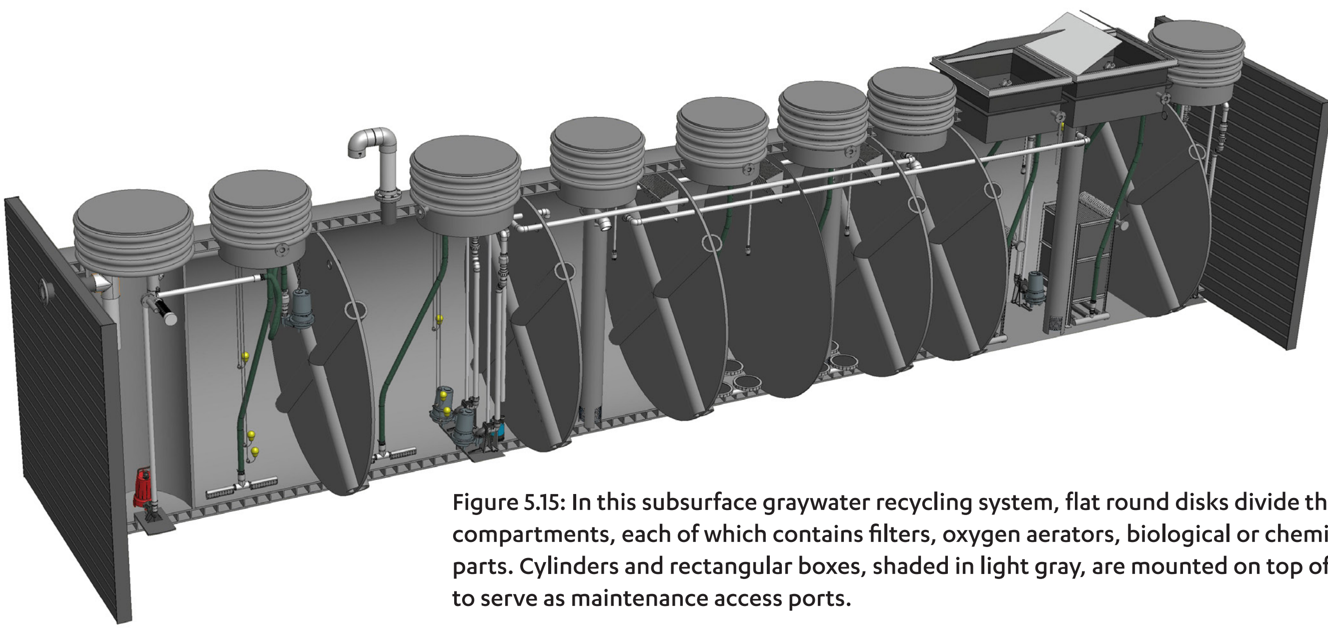
1. Primary treatment uses screens and mechanical filtering to remove solids and larger materials.
2. Secondary treatment uses oxygen reactions and naturally occurring microorganisms to consume dissolved organic molecules.
3. Further treatments may use a combination of diffusion, ultraviolet light, chlorine, and/or sulfur dioxide to eliminate remaining organisms.[55]

How does it fit into parks?

A small water recycling system may fit in parks (above or below ground) and have sufficient capacity to purify water from park bathrooms, fountains, and drinking fountains for use in irrigation. Parks may source larger amounts of graywater from municipal recycling facilities via existing pipe systems.[16] Using recycled graywater conserves potable water and reduces parks' water utility costs. Recycled graywater may be used with subsurface dripline, which would help to minimize the possibility that water would come into contact with park users. Although in some areas graywater may have better water quality than water currently used for irrigation in public spaces, non-potable water in some outdated municipal systems contains chemicals and heavy metals. These are mechanically or chemically removed from graywater.[56]

Why choose graywater recycling?

Resilience – By using recycled water, parks may be less affected when water from rainfall and snowpack is limited.



Credit: AppTech Solutions

Figure 5.15: In this subsurface graywater recycling system, flat round disks divide the system into several compartments, each of which contains filters, oxygen aerators, biological or chemical reactors, or other parts. Cylinders and rectangular boxes, shaded in light gray, are mounted on top of the system as manholes to serve as maintenance access ports.

Water – Graywater conserves valuable potable water. Additionally, using an on-site irrigation system could create a closed-loop system that requires little to no water from external sources.

Energy – By cleaning and using water on-site, graywater recycling can reduce the need, and thus the energy required, to transport potable water for park use.

Operations and Maintenance – Recycled water can contain nitrogen, phosphorous, and potassium that can enhance plant growth and reduce the need for artificial fertilizers.[57] However, if high amounts of nutrients in graywater enter natural water bodies, they may cause eutrophication, a process that can cause the die-off of plants and animals.[58]

What are the challenges and trade-offs?

Health risks to humans – Graywater may contain bacteria, viruses, and protozoa[v] that are potential human health risks. Current recycling methods use several techniques to eliminate these risks; but nonetheless, frequent monitoring is necessary to ensure safety.[58] In many cases, parks are legally required to label sources of graywater as non-potable and unsafe to drink.[54]

Risks to natural ecosystems – Salts dissolved in recycled water may be difficult to remove and can negatively impact soil health, plant growth, insects, and other organisms. Excess levels of nitrogen and phosphorous in graywater can cause algal growths, or blooms, which endanger organisms by limiting light penetration needed for underwater plant growth and deplete oxygen during decomposition. Algal blooms also taint drinking water supplies and limit commercial and recreational opportunities.[59]

Psychological effect – Park visitors may be uncomfortable coming into contact with recycled water due to perceptions of uncleanliness. A 2015 survey of adults in five American cities found that a majority were uncomfortable with the idea of drinking recycled water despite being informed that it is safe; 26% of participants believed that recycled water could not be purified enough for them to use it. This chapter is focused on non-potable uses, which may be more favorable to park visitors.[60]

Takeaways

In many cases, graywater recycling can replace the use of potable surface and groundwater sources for irrigation, extend the value of used water, and enhance plant growth by providing small amounts of nitrogen and phosphorous. To address human health and environmental concerns, water conditions must be frequently tested using remote sensors or manual observations. Park managers may wish to publicize their use of recycled water through marketing and signage. While some visitors may be unnerved by recycled water, others may be intrigued and impressed by it.

[v] Protozoa are single-celled, eukaryotic organisms (containing a cell nucleus) that can cause pathogenic and parasitic diseases, including malaria, in humans.

Credit: Wikimedia Commons

REAL-WORLD EXAMPLE

Going Gray in Irrigation | Marrakech, Morocco | 2015

A 2017 study published in the Saudi Journal of Biological Sciences tested the viability of graywater versus tap water irrigation for small-scale plots of land. Graywater from the sinks at a Moroccan primary school was separated into two batches, with one remaining untreated while the other was filtered through an artificial wetlands system using gravel, plants, and microorganisms to remove organic particles, chemicals, and pathogens (Figure 5.16, above). The treated graywater was then purified with ultraviolet light to further eliminate microbial contaminants. This water met regional microbial quality standards for use in irrigation. Both types — treated graywater and tap water — were used to irrigate small-scale areas of land. A chemical, physical, and microbial analysis showed little difference between the irrigated areas, making treated graywater a feasible alternative.

As expected, raw, untreated graywater was deemed not consistently clean enough to serve as a reliable irrigating source, and there was high variability in bacteria concentrations, such as E. coli, among samples of raw graywater.[61]

Irrigation component achievement levels

Smart irrigation technologies most effectively address the following Value Criteria: Resilience, Water, and Operations and Maintenance. This is because of these technologies' ability to conserve resources, impact water use, and automate data collection and information distribution Furthermore, Access and Safety may be enhanced by reducing the amount of water sprayed in public areas, and Health may be increased by using filtered graywater in place of municipal non-potable water, which is held to a lesser quality standard for irrigation. Finally, although digital controllers and meters use energy, their consumption is partially offset by imposing lower demands on water pumps. The table below illustrates the effectiveness of each technology in achieving the different Value Criteria defined in Chapter 3.

	Access	Community Fit	Health	Safety	Resilience	Water	Energy	Operations and Maintenance
Smart Water Controllers	○	○	○	●	●	●	◒	●
Low-Pressure and Rotating Sprinklers	○	○	○	●	○	●	◒	○
Subsurface Drip Irrigation	●	○	●	●	●	●	◒	●
Smart Water Metering	○	○	○	○	◒	●	◒	●
Graywater Recycling	○	○	○	○	●	●	◒	●

● Indicates technologies that provide a positive benefit for a value criterion.

◒ Indicates technologies that represent a secondary effect on a value criterion or have a trade-off between their benefits and drawbacks.

○ Indicates technologies that have no effect, a negative impact, or are unrelated to the value criterion.

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STORMWATER generated from rain and snow events requires attention from city planners and park managers. Poorly managed and/or excessive stormwater runoff — which can contain pollutants such as oil and heavy metals — can cause flooding. Impervious surfaces, like pavement, do not allow water to seep into soil naturally, thereby requiring human-made solutions.1 In many urban environments, stormwater management occurs in conjunction with sewage treatment, since much of the rainwater ends up in storm drains and sewers. Cities with combined sewer systems

Figure 6.1 Credit: Matthias Zomer/Pexels

Chapter 6: Stormwater

(CSS) collect both sewage and stormwater in the same pipe system.[2] Although CSS treat this wastewater and stormwater before discharging it, the system can overflow during heavy rain, when the total volume in the system is much larger.[2] If the system overflows, untreated water is discharged onto city streets and into nearby bodies of water. Separate systems for sewage and stormwater are less likely to overflow.[2] In either case, the quality and quantity of stormwater runoff can greatly impact urban areas.

Both gray and green infrastructure can be used to manage stormwater and prevent flooding. Gray infrastructure uses concrete and steel pipes, basins, etc., to capture, treat, and release stormwater.[3] Green infrastructure, such as rain gardens or bioswales,[i] mimics the natural water cycle to treat, capture, and release stormwater into the ground[1]. Green infrastructure is often more attractive to park managers than gray infrastructure, because it provides additional habitat for wildlife, enhances biodiversity, increases park aesthetics, and can be incorporated into existing park features or used to create new ones.[4]

Parks provide an excellent opportunity to develop green infrastructure, as their pervious surfaces already absorb a significant amount of urban stormwater.[1] For example, parks in the City of Los Angeles are 94% permeable, while the rest of the city is only 49% permeable.[5] The City estimates that its permeable park space provides stormwater retention benefits valued at about $8.03 million per year.[5] Park managers should consider incorporating green infrastructure in parking lots, playing fields, trails, walkways, visitors centers, wetlands,and drainage systems.[4] Not only can green infrastructure manage stormwater, but it also can create pleasing landscape designs and recreational opportunities. An initial focus on small or pilot projects in areas with high foot traffic may be a good strategy to garner support from officials and community members to incorporate more green spaces with stormwater benefits into parks.[4]

Stormwater management solutions are often low-tech, because they mimic the natural process of infiltration of water into the soil. There are opportunities, however, to supplement low-tech systems with innovations in design, management, and materials to provide additional benefits, especially in the context of parks. This chapter presents five such technologies: engineered soils, underground storage basins, drones, Real-Time Control and Continuous Monitoring and Adaptive Control, and rainwater harvesting.

Other chapters of this toolkit discuss technologies that can enhance stormwater management. Chapter 4 presents green roofs and walls, which can absorb and infiltrate stormwater. Chapter 5 describes irrigation systems that use stormwater captured in parks. Chapter 11 highlights remote sensing, the Internet of Things, and geographic information systems, which can help monitor runoff patterns, map current and potential infrastructure, and connect with community members.

Stormwater management becomes increasingly vital as climate change alters the frequency and strength of storms, and land development increases impervious surfaces and pollutants. Park managers can use the technologies in this chapter to address these challenges, while also conferring multiple benefits to users.

[i] Rain gardens are sunken areas with vegetation and permeable soil that hold and clean stormwater runoff before it infiltrates into groundwater or evaporates. Bioswales are vegetated linear channels that direct stormwater runoff to rain gardens, basins, or the sewer system. They can partially treat stormwater as it moves through the swale.[1]

Credit: denaliwater.com

Figure 6.2: Engineered soils can remove pollutants and help water infiltrate better into the ground.

Chapter 6

Engineered soils

What is this technology?

Engineered soils, used in place of on-site dirt, are manufactured from soil and organic or inorganic components such as sand, clay, or mulch.[1] They can be made of iron-coated sand, soils with higher sand content, or soil mixed with manufactured nanoparticles (see Real-World Example). These varieties of engineered soils provide differing levels of pollutant removal and/or help water infiltrate better into the ground. Engineered soils can be used in bioretention systems,[ii] such as rain gardens and bioswales, in which vegetation and soil naturally slow or capture pollutants, sediment,and/or oil in stormwater runoff.[1] Soil available on-site can often be heavily compacted or of poor quality and thus not perform these functions well. Thus, engineered soils can be added to bioretention systems to ensure they effectively manage stormwater.

[ii] Bioretention systems are another term for rain gardens, bioswales, and green infrastructure. They are soil beds with vegetation that allows stormwater runoff to filter through removing pollutants before infiltrating into the subsoil or being conveyed into drain systems or downstream.[36]

Chapter 6

How does it fit into parks?

Soil largely determines how efficiently water moves through a bio-retention system, so engineered soils allow park managers to create effective systems, even when topsoil is of low or degraded quality.[6] Soil in urban parks is often compacted from heavy use, foot traffic, construction equipment, or infill with substandard materials.[1] These compacted soils can have runoff rates similar to asphalt materials.[1] Therefore, using engineered soils can improve stormwater management and enhance the permeability of green infrastructure in parks.

Why choose engineered soils?

Safety – Engineered soils can prevent the accumulation of water on the ground, which can contribute to falls. They can also reduce flooding, and thus, safety risks, by allowing water to infiltrate into the ground.

Resilience – Engineered soils can be substituted for poor-quality soil and thus ensure effective bioretention systems. Climate change will likely impact the amount and timing of storms; therefore, more effective management of stormwater will increase resiliency.

Water – Engineered soils can improve the effectiveness of bioretention systems to treat and regulate stormwater flows. They improve infiltration of runoff and remove pollutants, thus reducing the risks of flooding and poor water quality.

What are the challenges and trade-offs?

Difficulty of selection – There are many mixes and varieties of engineered soils, and it may be difficult for park managers to determine which is most appropriate. Several studies have found that soil varieties differ in the levels of pollutants they absorb.[6,7,8]

Compatibility issues – There is also a concern that certain engineered soils may affect plant growth or the type of vegetation that can be grown.

Takeaways

Soil makeup and quality are major factors in determining the efficacy of green infrastructure at filtering, infiltrating, and managing stormwater flows. Urban areas and heavily trafficked parks often have compacted or poor quality soil that cannot be used by bioretention systems. Engineered soils or nanoparticles added to the soil can improve the functioning of green infrastructure, namely the treatment of pollutants and the infiltration of water.

REAL-WORLD EXAMPLE

Campus Pollution Cleanup | Wooster, Ohio | 2013

Osorb is a manufactured nanoparticle made of silica (glass) that can swell and absorb oil and other contaminants from water.[9] The College of Wooster in Ohio worked with ABSMaterials, which manufactures Osorb, to build bioswales with these nanoparticles around its campus.[9] The mixture absorbs pollutants from runoff and slowly releases them into the soil so microbes and plants can biodegrade them; the clean water infiltrates into the ground.[10] Plants appear to grow well in the soil mixture, and this system is two to nine times more effective at improving water quality than any previously used stormwater systems.[10,11]

Credits: Popular Mechanics

Plants appear to grow well in bioswales (Figure 6.3, above) whose soil is treated with Osorb (Figure 6.4, right).

Chapter 6

Credit: City of Redmond

Figure 6.5: A rendering of the underground stormwater detention basin in Redmond, Washington, completed in 2015. It can hold 6.6 million gallons of stormwater.[12] At the time of construction, the surface was used for parking but there are plans to construct a park on its surface.

Underground storage basins

What is this technology?

Underground storage basins (or ponds) for retention or detention are a traditional form of gray infrastructure to store and manage stormwater flows.[13] Retention ponds are also called "wet" ponds and have a permanent store of water that fluctuates based on precipitation and runoff. Detention ponds, or "dry" ponds, hold water for short periods, slowing it down during storm events.[13] Both decrease the pollutant load of stormwater runoff by allowing sediments to settle at the bottom of the ponds, so the water flowing out and into streams or storm drains is cleaner. Wet and dry ponds are appropriate in different settings, depending on the physical constraints, such as available space and groundwater table level.[14,15]

Most of these basins are built under parking lots or other paved surfaces, providing stormwater storage or flow management. The basins can be used in "treatment trains"[iii] that couple several technologies together to treat and manage stormwater flows.[13]

How does it fit into parks?

While underground storage basins are a well-established gray infrastructure solution for managing stormwater flows, they can be combined with more innovative solutions for the treatment and use of captured water.[iv] This may be particularly useful in parks, because storage basins can be built under paved areas and only require manholes at the surface.[16] Parks that do not have the space to build green infrastructure should consider underground storage basins to prevent flooding and capture stormwater for irrigation and other purposes.

Why choose underground storage basins?

Resilience – Park managers can use this technology to increase park resiliency, as storm frequency/severity and droughts may increase because of climate change. These storage basins provide flood control during storm events and capture and conserve a steady supply of water.

Water – Underground retention/detention basins capture stormwater flows to prevent flooding and for use in irrigation and other purposes.

Operations and Maintenance – Water storage technology can be used in tandem with treatment and irrigation technologies, can save money, and lower water costs at parks.

What are the challenges and trade-offs?

Gray vs. green infrastructure – To be effective beyond their traditional use as flow control or water storage, storage basins must be combined with other technologies such as filtration and/or irrigation systems. As with most gray infrastructure projects, storage basins are more expensive and complicated to construct than green infrastructure and do not confer the vegetation/recreation benefits that above-ground rain gardens or retention ponds may offer. However, they may be a good option when green infrastructure is not feasible.

Takeaways

Underground basins are a common gray infrastructure solution to stormwater management but they can be especially useful in parks if land for above-ground bioretention options is not available. When paired with rainwater capture or irrigation technologies, underground basins help manage floods while also reducing water bills.

[iii] Treatment trains are a combination of multiple stormwater strategies, such as treatment filters to basins, for more information go to https://stormwater.pca.state.mn.us/index.php/Using_the_treatment_train_approach_to_BMP_selection.

[iv] Refer to Chapter 5 for examples of irrigation technology that utilize water captured in underground storage basins.

Credits: Village of Northbrook Wescott Park Project

REAL-WORLD EXAMPLE

Wescott Park's Hidden Water Storage Gem | Northbrook, Illinois | 2016

As part of its Master Stormwater Management Plan, the City of Northbrook, Illinois, implemented about 30 infrastructure projects to reduce flooding in the city. One involved upgrading Wescott Park with a new storm sewer connected to a 7.5 million-gallon storage chamber under play fields (Figure 6.6, above).[17] Park managers also added an electronically controlled rainwater-harvesting system (Figures 6.7 and 6.8, right) enabling the stored water to be used in the new lawn irrigation system or pumped into truck-mounted tanks for watering trees or cleaning streets and sewers.[17] The project reduces water use, decreases irrigation costs, and lowers flood risk to the surrounding neighborhood.[17]

Credit: Herney/Pixabay

Figure 6.9 : Drones can efficiently sample water quality, including in hard-to-reach areas such as drainage ponds, stormwater outfalls, or bioswales.

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Drones

What is this technology?

Drones, also known as unmanned aerial vehicles or quadcopters, are remote-controlled and can be paired with cameras, sensors, or sampling equipment.[18] They can be used for a variety of tasks, including high-definition photography or videography, mapping, placement of construction materials, and data or sample collection.[19]

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How does it fit into parks?

Drones allow park managers to map and monitor stormwater infrastructure.[v] In particular, they can efficiently sample water quantity and quality, including in hard-to-reach areas such as drainage ponds, stormwater outfalls, or bioswales, which would otherwise require staff to move through thick vegetation.[20] With a variety of attachment options, drones can perform many tasks more quickly and at a lower cost than park staff.[20] Additionally, because drones can move on preprogrammed routes to consistently sample areas over time, they ensure more accurate long-term monitoring results.[21] Because the public has shown great interest in drones, they could be also used to engage visitors and promote citizen science.[vi,21]

Why choose drones?

Community Fit – Drones can be used as a tool to engage park visitors in citizen science.

Resilience – The ability for drones to consistently monitor locations over time can help park managers understand and respond to the effects of changes in climate, development, and land use.

Water – Drones can be used to monitor stormwater infrastructure and map current park conditions to help managers ensure efficient and effective stormwater management.

Operations and Maintenance – By remotely monitoring park features, drones can reduce staffing needs and enable easier monitoring of less accessible park areas.

What are the challenges and trade-offs?

Maintenance, operation, and damage risks – Drones can get stuck, broken, damaged, or lost during operation. Personnel must be trained to operate them. Additional technology (for example, water sampling equipment) may need to be added to drones depending on park needs.

Community support and privacy issues – The use of drones may cause fear or discomfort among community members, who may see them as a threat to privacy.[22] An Associated Press-National Constitution Center poll found that 35% of respondents were "extremely" or "very concerned" about the use of drones by police departments and the potential loss of privacy.[23] Some members of the community, especially undocumented immigrants, may be concerned about the surveillance capabilities of drones and thus be deterred from visiting parks that utilize them.[24] Therefore, how a local community views the use of drones should be an important consideration in any decision about their use in parks.

Takeaways

Drones can help effectively manage stormwater, especially by monitoring green or gray infrastructure or sampling water quantity and quality for regulatory compliance. Drones can help reach difficult areas and be used to establish consistent data sets. They can also be tools to engage park visitors and encourage citizen science.

[v] Drones can be used in a variety of contexts, in addition to stormwater management, and park managers are encouraged to consider their other uses.

[vi] Citizen science is where the public, rather than professionals, collect data (and sometimes also analyze it) after training with a professional. It benefits researchers by increasing the data pool and providing low-cost samples or data. Most important, involving the public in scientific research helps to educate them and make them more aware of the value of science.[35]

REAL-WORLD EXAMPLE

Citizen Science on the Lake Shores | Oakland, California | 2014

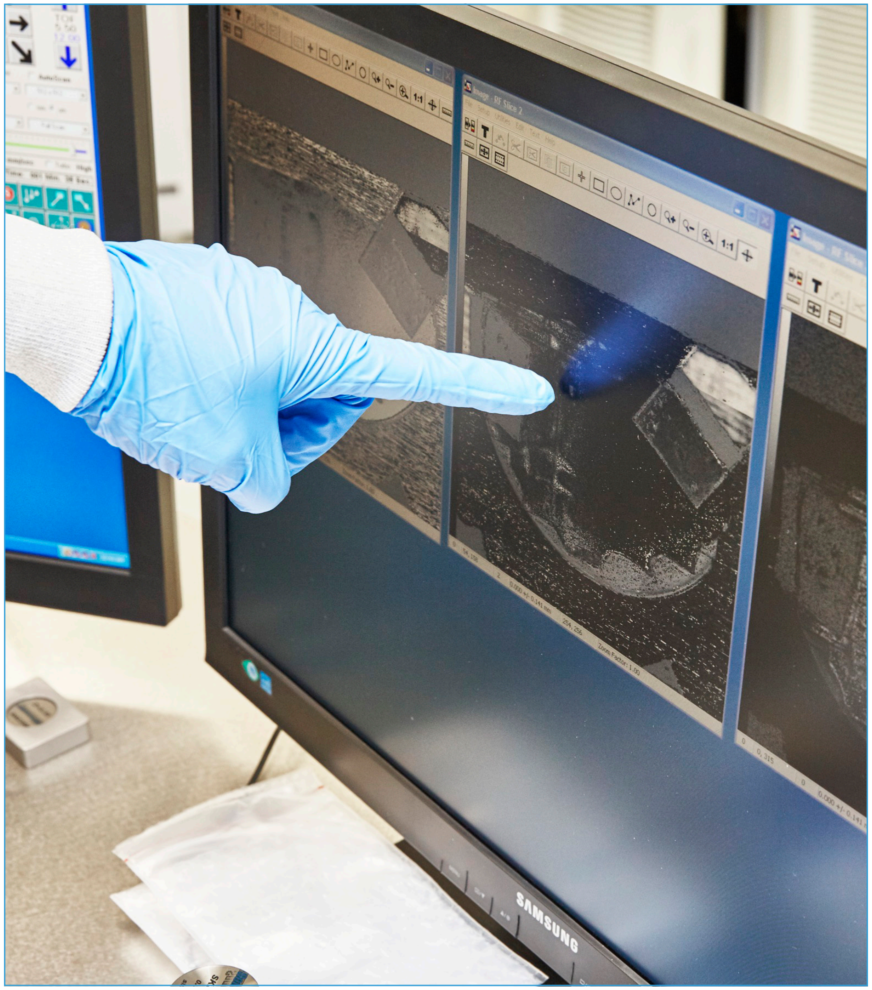
As part of a series of citizen science events across the San Francisco Bay Area called "BioBlitzes,"[25] the California Academy of Sciences invited the public to interact with drones and sample water quality at Lake Merritt in Oakland (Figure 6.9, right).[21] The drone (Figure 6.10, below) collected data by landing at multiple points on the lake, helping to create a long-term data set.[21] Event organizers noted that the drones were a big draw, attracting more than the typical number of attendees for park events.[21]

Credit: Scientific American

Credit: Bay Nature

Chapter 6

Real-Time Control and Continuous Monitoring and Adaptive Control



Credit: ENSIA

Figure 6.11: Real-Time Control sensors can improve the management and capture of stormwater flows and improve water quality.

What is this technology?

Real-Time Control involves retrofitting stormwater infrastructure with sensors, valves, actuators, and digital software to enable the system to adapt to changing conditions.[vii,26] The system can improve the management and capture of stormwater flows and improve water quality. Examples of this include rubber dams triggered to inflate and store water upstream in pipes, or to direct heavy runoff toward underused storage areas,[27] and valves that are triggered to drain ponds when a storm is forecast, creating additional storage for anticipated runoff.[26]

Continuous Monitoring and Adaptive Control (CMAC) is an application of Real-Time Control that connects to the Internet to continuously monitor stormwater flow and triggers the system to automatically respond to flow changes. Managers, or the software itself through

[vii] This software typically uses sensor networks and the Internet of Things to remotely monitor and make decisions (see Chapter 11 for more on this technology).

remote controls, can use the data obtained from the continuous monitoring to adjust the facility to meet a range of objectives, such as increased storage or improved water quality.[28]

How does it fit into parks?

Many parks already manage stormwater with gray infrastructure, which must be monitored regularly. This infrastructure is often built to be static in capacity, but changing climate and land development patterns require that these systems become more adaptable.[28] Parks may use Real-Time Control and CMAC to retrofit existing infrastructure and improve capacity without building costly new facilities. The technology also enables automatic control and monitoring of facilities, which may reduce operational needs. For example, fewer park staff members are needed when water flows in and out of ponds are automatic. Monitoring the effectiveness of stormwater infrastructure often requires a large and long-running data set of water quantity/quality samples from storm events. CMAC or other Real-Time Control equipment can make sampling easier.[28]

Why choose Real-Time Control and CMAC?

Health – Real-Time Control can improve water quality by controlling water detention for long periods. The additional holding time allows for more sedimentation[viii] and exposure to sunlight, which reduces the presence of E. coli, thus improving water quality.[26,29]

Resilience – Due to climate change, storm frequency and severity will likely change and land-use patterns will affect timing and volumes of stormwater runoff. Real-Time Control and CMAC technology can enhance the adaptability and effectiveness of existing water infrastructure to better prepare for these changing conditions.

Water – Real-Time Control and CMAC enable park managers to retrofit instead of replace existing stormwater infrastructure to improve stormwater capture, filtration, and management.

Operations and Maintenance – Real-Time Control and CMAC may reduce park operations and maintenance needs, since many actions are automatic, based on real-time data and weather predictions.

What are the challenges and trade-offs?

Oversight – Like all new technologies, Real-Time Control and CMAC equipment can malfunction and require human oversight. For example, park staff would need to ensure that automatic processes, such as inflating or deflating dams, are appropriate and accurate. Since the system bases its actions on weather predictions, it can only be as effective as the forecasts used in control operations.[28]

Debris interference – In the case of in-stream detention ponds (in which water flows into and out of a pond within a natural stream), there may be a higher probability of natural debris getting sucked into valves, hindering operation.[30] Thus, additional infrastructure, such as a trash rack, may be necessary.[30]

Takeaways

Real-Time Control and CMAC utilize sensors and software to improve existing stormwater infrastructure. These systems can control the function of infrastructure based on weather predictions and real-time data to effectively utilize capacity, capture water, and remove pollutants. However, technical difficulties require employee oversight and weather forecasts may not always be accurate.

viii Sedimentation is the process by which particles settle and deposit as sediment. Solids and pollutants sink, thereby contributing to water treatment.[37]

REAL-WORLD EXAMPLE

Bracing for Stormwater
Lenexa, Kansas | 2016

The City of Lenexa, Kansas, partnered with OPTi Technologies, a provider of CMAC technology, to retrofit four of its existing stormwater retention ponds.[30] OPTi installed solar-powered valves at each pond, which are connected via antennas to the National Weather Service forecast (Figures 6.12 and 6.13). Using a simple desktop computer application, stormwater engineers can set inflow and outflow parameters for the pond based on weather. For example, the valves can be set to release water when there is a 70% or higher chance of at least a half-inch of rain in order to lower pond levels to accept more of the predicted incoming stormwater.[30] The city also had to install extra trash racks to prevent debris from clogging the system.[30] Before the retrofit, city ponds often overflowed with stormwater.

Credits: City of Lenexa

Credit: W.S. Cumby Builders & Construction Managers

Figure 6.14: Rainwater harvesting into cisterns such as the one above can help reduce flood risk, alleviate drought, and enable park irrigation plans to adapt to changing climate.

Rainwater harvesting

What is this technology?

Rainwater harvesting captures, diverts, and stores rainwater for landscaping, livestock, fire protection, slow release into the soil, or other uses.[31] The systems vary in size and complexity but generally involve a catchment surface to collect water, a conveyance system, and storage, distribution, and treatment components.[31] In most cases, the catchment surface is a roof that directs water into pipes or gutters (the conveyance system), which leads to a cistern (a storage tank).[31] Rainwater harvesting helps manage stormwater and reduce runoff, flooding, and the cost of paying for water. [31] While traditional rainwater capture systems focus on functionality, they can also be developed into interactive exhibits that provide education benefits through signage

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or programming. Rainwater harvesting is not a new technology, but innovative opportunities exist to add interactive features or to couple the rainwater capture with smart irrigation solutions (Chapter 5).

How does it fit into parks?

Rainwater harvesting in parks was discussed previously in the underground storage basins section because harvesting can be coupled with storage to manage and use stormwater on-site. Rainwater harvesting is highlighted here for its potential as an educational and interactive tool in a park setting. In particular, creating exhibits or public art on rainwater harvesting systems can provide benefits for stormwater management, irrigation, water conservation, and community fit by creating a unique opportunity for park visitors to learn about water and the environment. The Real-World Examples that follow demonstrate how small-scale rainwater harvesting can be creatively implemented in a park.

Why choose rainwater harvesting?

Community Fit – Rainwater harvesting systems can provide opportunities for unique programming and for incorporating local art that promotes park use and creates awareness of water issues.

Resilience – Rainwater harvesting systems collect and store rainwater on-site to help reduce flood risk, alleviate drought, and enable park irrigation plans to adapt to changing climate and water availability.

Water – Rainwater capture provides stormwater management benefits and conserves water. Parks can reduce their expenditure on water if rainwater is captured for irrigation and other purposes.

Energy – By capturing and storing water on-site, rainwater harvesting can reduce the energy needed to transport water for use at the park.

What are the challenges and trade-offs?

While traditional rainwater capture systems focus on functionality, an interactive exhibit will likely require additional components, signage, or programming. This may increase costs but give park managers the opportunity to work with a local artist or an expert in creating participatory public exhibits. Such installations, however, may also have unique or added maintenance challenges.

Takeaways

Rainwater capture systems can be important components of stormwater management strategies and particularly help conserve water for park irrigation. They also provide a unique opportunity for park managers to engage and educate visitors with interactive displays. Rainwater harvesting exhibits can be a valuable opportunity to create programming that attracts and informs visitors of all ages, while fostering community knowledge of water issues.

Credits: Tim Hawley

REAL-WORLD EXAMPLE

Interacting in the Cloud (House) | Springfield, Missouri | 2015

The Cloud House in Springfield, Missouri (Figures 6.15, 6.16, 6.17), was constructed by conceptual artist Matthew Mazzotta to demonstrate the connection between food production and the water cycle.[32] Visitors enter the shed-sized barn and sit on two white rocking chairs next to edible plants growing in the windows.[32] A hidden system of gutters collects and delivers rainwater to an underground cistern. The rocking chairs are outfitted with pressure sensors to allow visitors to trigger water to be pumped toward the cloud atop the barn.[32] Water "rains" from the cloud onto the roof, into the gutters, and then is used to water the plants in the window before it trickles back into the underground cistern.[32] During dry periods, or when there is not enough rain to fill the cistern, the chairs no longer trigger watering and the plants wilt. This display of the water-cycle illustrates our fragile dependence on the natural systems that grow the food we eat, and the importance of understanding this connection in the face of climate change.[33]

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REAL-WORLD EXAMPLE

Playing with Rain Rotterdam, Netherlands 2016

Rotterdam-based designers DoepelStrijkers created the Rotterdam Watershed to demonstrate how cities can adapt to climate change and increased precipitation (Figures 6.18, 6.19, right).[34] The structure is constructed from recycled plastic rainwater pipes, half of which are filled with plants, while the other half collect rainwater, which then drips into a pond inside the structure.[34] Visitors can cross the pond on stepping stones while LED lights in the pipes illuminate the pavilion at night.[34] The Watershed is movable and in 2016 was displayed at the Edinburgh Pop-Up Cities Expo, where it was estimated that it captured more than 390 gallons of water during the event.[34] Similar to the Cloud House, the Watershed is an example of a small-scale rainwater harvesting system that, while it collects water for reuse, is explicitly designed to be an interactive public display that attracts visitors and encourages them to consider their interactions with water and nature.

Credits: Inhabitat

Stormwater component achievement levels

The stormwater management technologies described in this chapter can be incorporated into existing or new parks to provide substantial water benefits. Some also improve the resiliency of park assets, reduce operation and maintenance requirements, or enhance community fit of parks with innovative programming for visitor participation. The table below illustrates the effectiveness of each technology in achieving the different Value Criteria defined in Chapter 3.

	Access	Community Fit	Health	Safety	Resilience	Water	Energy	Operations and Maintenance
Engineered Soils	○	○	○	●	●	●	○	○
Underground Storage Basins	○	○	○	○	●	●	○	◒
Drones	○	◒	○	○	◒	◒	○	●
Real-Time Control and Continuous Monitoring and Adaptive Control	○	○	◒	○	●	●	○	●
Rain-Water Harvesting	○	●	○	○	●	●	◒	○

● Indicates technologies that provide a positive benefit for a value criterion.

◒ Indicates technologies that represent a secondary effect on a value criterion or have a trade-off between their benefits and drawbacks.

○ Indicates technologies that have no effect, a negative impact, or are unrelated to the value criterion.

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Chapter 7: Hardscape

HARDSCAPES are the human-made surfaces in parks, including paved areas, playgrounds, buildings, structures, gates, and fences. The most common hardscape materials are asphalt and concrete. Asphalt is a mixture of dark bituminous[i] pitch with sand or gravel, used for surfacing roads, flooring, and other areas.[1,2] Concrete is a heavy, rough building material made from a mixture of sand, broken stone or gravel, cement, and water.[3] It can be spread or poured into molds and forms a stone-like mass when dry.[4] Both have pros and cons; asphalt is cheaper and easier to repair but has a shorter lifespan that requires more maintenance than concrete, which is more expensive but lasts longer.[5]

[i] Bitumen is a sticky, black viscous form of petroleum used to bind road surface materials.

SMART Parks can have surfaces made of new materials and/or variants of traditional materials. Such materials can address common concerns with hardscaping, such as the urban heat island effect[ii] and lack of stormwater infiltration. Traditional pavement and surface materials are often energy-intensive to produce and also require ongoing maintenance. New technologies can provide energy and operations and maintenance benefits, address health, and improve park visitor engagement opportunities.

In this chapter, we focus on eight hardscape options: cross-laminated timber; pervious paving; piezoelectric energy-harvesting tiles; self-healing concrete; phototocatalytic titanium dioxide coating; transparent concrete; daylight fluorescent aggregate; and carbon upcycled concrete. Some of these technologies are new types of high-tech hardscape materials, while others are variations on existing materials that provide new features or benefits. For example, piezoelectric energy-harvesting tiles and daylight fluorescent aggregate are new high-tech hardscape materials, while cross-laminated timber, self-healing concrete, and carbon upcycled concrete are variants of existing materials that provide additional environmental and structural benefits.

[ii] Developed areas are typically warmer than not built-up areas due in part to the prevalence of impervious surfaces such as buildings and roads.[42] This phenomenon is called the "urban heat island effect."

Credit: Studio Roosegaarde
Figure 7.1 (preceding page): A fluorescent pigmented pebble path that glows after dark

Credit: Pavegen
Figure 7.2 (left): Piezoelectric energy-generating tiles are a new high-tech hardscape material that can provide energy and improve park visitor experiences.

Credit: Natural Resources Canada

Figure 7.3: Cross-laminated timber, created from the waste of wood mills that would otherwise be discarded, helps reduce the carbon footprint of both the original wood product and itself.

Cross-laminated timber

What is this technology?

Cross-laminated timber is a composite wood product, similar to plywood,[iii] made of lumber (often wood waste) and used in place of wood, steel, or concrete. It was first developed in Austria and Germany in the 1990s and has been used in Europe since then. It is gaining popularity in the U.S. because it has the advantages of using wood materials, including carbon sequestration,[iv] reduced

[iii] Plywood is made of sheets of wood veneer.
[iv] Carbon sequestration is the capture of carbon dioxide and its long-term storage.

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emissions, and cost effectiveness.[6] It is also a strong, fire-resistant, high-seismic performance material that can be used for larger structures typically constructed with steel and concrete.[6] Cross-laminated timber can be prefabricated with half-lips and splines (i.e., a "key and slot" to join pieces together), so it is ideal for rapid construction.[6]

How does it fit into parks?

Cross-laminated timber can replace steel, concrete, masonry, or wood and be used for floors, walls, and roofs of park buildings and other park structures. Its natural wood appearance can easily be customized or adapted to various park structures, uses, and designs.

Why choose cross-laminated timber?

Health – Cross-laminated timber, unlike other composite wood products, may be produced without added urea-formaldehyde resins;[v] thus, it may reduce exposure to formaldehyde emissions.

Energy – Cross-laminated timber creates a usable product from the waste of wood mills. Mill waste would otherwise be discarded and eventually decompose and emit carbon dioxide. This technology reduces the carbon footprint of both the original wood product and of cross-laminated timber. As with other wood, using cross-laminated timber may keep buildings cooler than steel-constructed ones, reducing the need for air conditioning, thereby minimizing energy requirements.

Operations and Maintenance – Prefabrication of cross-laminated timber allows for easy, relatively cheap, and rapid construction and repair. Cladding (or protective covering materials), varnishes, and sealing treatments can extend the life of cross-laminated timber by protecting it from moisture damage.[6]

What are the challenges and trade-offs?

Availability – Cross-laminated timber is a relatively new technology in the U.S. and may not be readily available in all locations.

Damage risk – Like all wood products, it is vulnerable to moisture damage. Proper installation, treatment, and maintenance can mitigate this concern.

Takeaways

Cross-laminated timber reduces carbon emissions and cost, and sequesters carbon. It can be used to enhance parks with a natural wood aesthetic while maintaining the structural profile of traditional steel or concrete building materials.

[v] Urea-formaldehyde resin, commonly used as an adhesive resin to produce wood panels, can emit gas, leading to exposure via the air. The EPA has classified it as a probable human carcinogen under unusually high or prolonged exposure.[43]

Credit: Wikimedia Commons

REAL-WORLD EXAMPLE

Building Blocks | Seville, Spain | 2011

The Metropol Parasol is a cross-laminated timber structure in the old quarter of Seville, Spain, that acts as a giant shade structure, gathering place, and walking destination for tourists and locals (Figures 7.4 and 7.5, above and right).[7] The bold and airy design is made possible with cross-laminated timber. Initially, engineers thought the structure was not physically feasible, but the strength of cross-laminated timber allowed for a unique design with a wood aesthetic.[7] The 90-foot-tall installation houses stores, markets, a museum, and restaurant in its base, as well as a walkway on top of the structure.

Credit: J. Mayer H. Architects

Chapter 7

Pervious paving

What is this technology?

Pervious, or permeable, paving uses material for paving roads, pedestrian pathways, and parking lots that allows for infiltration of water.[8] The material is made of coarse aggregate (stone pieces) bound together by cement or mortar. This creates its porosity, with pores over 1 mm in diameter, allowing water to permeate into the ground. This also makes pervious pavement weaker than regular pavement.[9] Traditional paving fills the spaces between aggregate pieces with cement paste, but pervious paving does not. These spaces allow for infiltration.[9]

Credit: Southeast Cement Promotion Association

Figure 7.6: Pervious pavement keeps water from accumulating and thus can help prevent falls.

Credit: Heritage Bomanite

Figure 7.7: Although not as strong as traditonal pavement, pervious pavement is suited for low-traffic parking areas.

How does it fit into parks?

Pervious paving can be used instead of traditional paving in parks to implement a low-impact development[vi] (LID) stormwater management strategy.[vii] It can be used in lieu of traditional concrete or asphalt on walking trails and other nonvehicular hardscaped areas. Pervious areas should be strategically integrated with site grading to account for the expected direction and volume of stormwater flow. Pervious pavement is not as strong as traditional pavement, so it is not ideal for high vehicular traffic areas such as driveways, but it can be utilized for parking spaces.

Why choose pervious paving?

Safety – Pervious paving prevents the accumulation of water on the ground, which can contribute to falls. It also reduces flooding, and thus safety risks, by allowing water to infiltrate through the pavement into the soil.

Resilience – Due to climate change, it is likely that cities will experience more frequent and severe storms, and more drought. Pervious paving allows parks to adapt to altered precipitation patterns by reducing flood risks and infiltrating more runoff into the ground. It may also allow the site to retain and use rainfall for irrigation during a drought.

Water – Pervious paving provides significant stormwater management benefits by allowing water to infiltrate into the water table rather than run off the site or overflow the stormwater collection system.

Energy – Pervious paving can reduce the urban heat island effect. As moisture in the pavement evaporates, it draws heat out, lowering the temperature of the pavement and surrounding area.[10]

Operations and Maintenance – While it requires more maintenance than traditional pavement, pervious pavement can prevent flooding or water damage that would otherwise require additional maintenance over time.

[vi] Low-impact development is a strategy for managing stormwater that utilizes systems that are natural or mimic natural processes. See https://www.epa.gov/nps/urban-runoff-low-impact-development.
[vii] Refer to Chapter 6 of this toolkit for more information and resources on stormwater.

What are the challenges and trade-offs?

Maintenance – Although pervious paving provides a valuable ecological service, it requires more frequent maintenance than concrete. However, the stormwater management benefits can reduce maintenance from flooding.

Location constraints – Pervious pavement is not appropriate as a replacement for all pavement uses, such as areas with high vehicle traffic or locations with high water tables. It can only be incorporated into projects in suitable areas.

Takeaways

Permeable pavement can replace traditional concrete and asphalt to enable water infiltration into the soil, which reduces the burden on the storm drain system, cools the site, and prevents flooding. While the material is weaker and needs more maintenance than concrete, it can be used in many areas and can reduce long-term maintenance costs by managing stormwater efficiently.

Credit: Santa Barbara Department of Parks and Recreation

REAL-WORLD EXAMPLE

Parking Cars and Rain
Santa Barbara, California | 2011

The City of Santa Barbara installed pervious pavement in the parking lots of several parks, including Oak Park (Figure 7.8, above).[11] The pervious pavement was installed only over the parking spaces as the driving aisles were too heavily trafficked to use this material. Although only some parts of the parking lot are pervious, they significantly increase the overall permeability of the site, decreasing runoff and increasing on-site infiltration.

Piezoelectric energy-harvesting tiles

Credit: Pavegen

Figure 7.9: Piezoelectric tiles at the Paris Marathon generated electricity from runners' footsteps.

What is this technology?

Piezoelectric[viii] energy-harvesting tiles generate electrical energy from mechanical pressure, such as walking motion. The amount of energy generated depends upon the person's weight, total deflection of the tile, and movement type. This kinetic energy is converted into electricity that can be stored in a battery or used for devices on-site.[12,13] The tiles are available in many different shapes, sizes, and colors. One permanent tile product by Pavegen Systems of London acquires a power of five watts from every footstep; within about an hour the tile can fully charge an iPhone.[14] Pavegen tiles are made from recycled polymer, including recycled truck tires, and also have wireless capabilities to analyze movement across the tiles.[12]

[viii] Piezoelectricity is electrical energy harvested from mechanical pressure such as walking motion. When pressure is applied on an object, a negative charge is created on the expanded side and a positive charge is created on the compressed side. As this pressure is relieved, electric current flows across the substance.[44]

How does it fit into parks?

Piezoelectric tiles can be installed on any walking surface in parks but are most useful in high visitor traffic areas or areas where information about visitors is needed. They are waterproof and suitable for outdoor use.[15] Piezoelectric tiles have two major functions applicable to parks: First, they can generate electricity, which can be used for a wide range of applications, such as to power outlets or site lighting. Second, they can collect information about park use based on the number of footsteps recorded.

Why choose piezoelectric tiles?

Community Fit – Piezoelectric tiles can be utilized to create interactive, educational, or cultural installations. For example, they can be used to light up different parts of an interactive wall display depending on where children step.

Health – Piezoelectric tiles can encourage physical activity by attracting park visitors to use and interact with them. For example, they can be used under athletic fields and tracks, and to power informational displays with individual fitness data.

Safety – If used as a complement to motion sensors, the piezoelectric-tile-powered lights can turn on when visitors are detected, thus improving safety after dark.

Resilience – Piezoelectric tiles can provide a temporary source of emergency power during outages or shortages.

Energy – Piezoelectric materials generate local, clean, on-site energy, which displaces the need for fossil fuel-powered electricity generation. When used as a complement to motion sensors, the piezoelectric-tile-powered lights turn on when visitors are detected and thus reduce energy costs by not powering lights in the absence of visitors.

Credit: Pavegen

Figure 7.10: Piezoelectric tile is installed in Dupont Circle in Washington, D.C.

What are the challenges and trade-offs?

Installation and maintenance – Piezoelectric tiles are more time- and labor-intensive to install and maintain than traditional concrete pavers or asphalt.

Data management – To reap the full benefit of the technology, the energy generated and data collected must be organized and managed, which may require additional training or expertise. Pavegen tiles, for example, use smart controllers to manage the tiles and devices they power. Managers can access any data collected through the tiles using a USB interface.[14]

Aesthetic appeal – Piezoelectric tiles may not fit with the aesthetic of some parks because they are not made from "natural" materials.

Takeaways

Piezoelectric tiles can be used in parks in high-traffic areas to generate electricity and collect information about park visitors. While harder to install and maintain than traditional tiles or asphalt, they can be used as interactive or educational park features to engage visitors and encourage physical activity.

Credit: Mirror.co.uk

REAL-WORLD EXAMPLE

Lighting Up the Field | Rio de Janeiro | 2014

A football field in Morro da Mineira favela[ix] in Rio de Janiero, Brazil (Figure 7.11, above), has 200 piezoelectric harvesting tiles under its AstroTurf that power field lights and enable community members to play on the field after dark.[16] Players generate energy with their footsteps, powering six LED floodlights that light the field. The generated energy is supplemented with solar energy collected during the day.[16]

[ix] Favela is a Portuguese word for slum. It is a low-income, historically informal urban area in Brazil.[46]

Chapter 7

Credit: CNN

Figure 7.12: In bioconcrete, bacteria are activated and then germinate and multiply to form limestone in the "self-healing" process, leaving a mark.

Self-healing concrete

What is this technology?

Self-healing concrete, or bioconcrete, is traditional concrete mixed with bacteria *(Bacillus pseudofirmus)* that fills micro-cracks, reducing maintenance and replacement needs.[17] When water soaks into cracks, the bacteria — which can lie dormant up to 200 years[17] — and their food source (calcium lactate) are activated. The bacteria germinate, multiply, and feed, which combines the calcium and carbonate ions. This process forms limestone and "heals" the crack.[18] When the crack is healed, a visible mark remains (see Figure 7.12, above). Self-healing concrete can be used to build new structures less prone to cracks or can repair cracks that occur over time. When applied as a liquid treatment, self-healing concrete can also repair small cracks in existing concrete.[17] The liquid treatment can be sprayed directly over a concrete topcoat, making application times shorter than other methods of concrete crack repair, such as by epoxy injection.[x,19] At present, the technology can only heal cracks that are a maximum of 0.8 mm wide.[17]

How does it fit into parks?

Self-healing concrete can be used anywhere traditional concrete is used and can also be applied as a liquid treatment to existing concrete. Its use in parks may decrease the amount of new concrete needed and lower maintenance and repair costs.[17] It is most useful for concrete that might be prone to small stress or age-related cracks rather than large cracks from shocks such as earthquakes. Self-healing concrete might be appropriate in colder areas, where water can freeze in cracks and widen them. It is important to address micro-cracks in concrete quickly because they can grow and reach the reinforcement or rebar (the reinforcing steel bars or mesh used in concrete to add strength), thus putting structural integrity at risk.[20] Since the bacteria consume oxygen, this process may have an added anticorrosive effect for steel rebar embedded in concrete.[21] Therefore, self-healing concrete can reduce long-term maintenance costs and improve the integrity of park structures.

Why choose self-healing concrete?

Safety – Self-healing concrete can prevent dangerous shifts or collapses of concrete that has been compromised with cracks.

Resilience and Energy – Self-healing concrete repairs minor cracks that occur from age, cold climates, or damage. This prevents more serious damage and prolongs the life of the structure, thus increasing its resiliency. Because this technology can reduce the need for new concrete, its use reduces the energy consumed[22] and the greenhouse gas emissions associated with its production.[17]

Operations and Maintenance – Self-healing concrete reduces hardscape maintenance and replacement needs by preventing and healing cracks. Fewer cracks can also mean fewer plants growing in them, reducing the need for labor-intensive weeding or chemical weed control. The liquid treatment can be sprayed directly over a concrete topcoat, making application times shorter than other methods of concrete crack repair, such as by epoxy injection.[19]

What are the challenges and trade-offs?

Scale of damage constraints – Self-healing concrete cannot fix extensive structural damages or remove the risk of damage from major seismic activity.

Uncertainty in varying climates – The material has been used in limited applications thus far, so it has not been field-tested in a wide range of climates and geographic regions.

Crack aesthetics and healing time frame – The healed cracks may not fit with the aesthetics of some parks, and the speed at which the concrete heals itself is not sufficient for cracks that are large (over 0.8 mm wide at present) or require immediate repair, although healing can happen in as little as three weeks.[17,23]

[x] Epoxy injection is a low-pressure injection of epoxy resin, typically used for structural repair of cracked concrete. The resin is injected through injection ports along the crack.[47]

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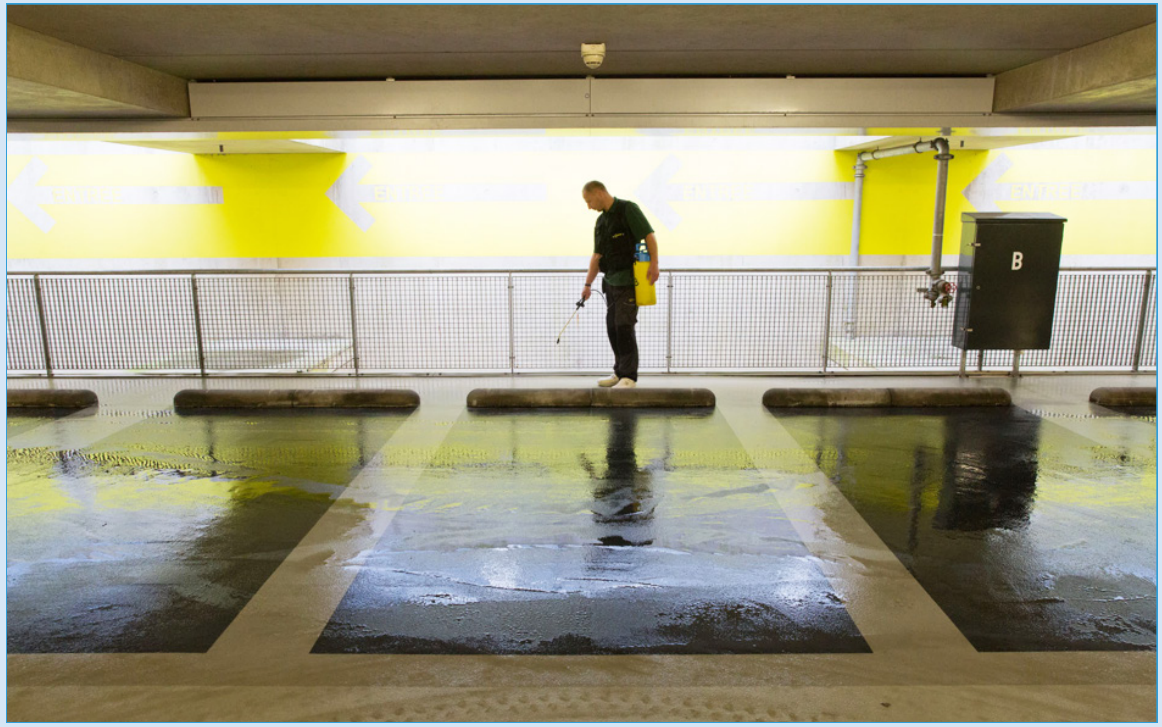
Takeaways

Self-healing concrete can prevent and heal micro-cracks in traditional concrete. Since minor cracks are common from age or cold climates and can invite unwanted weeds, self-healing concrete reduces maintenance costs, while prolonging the life of structures in parks. However, since self-healing concrete cannot fix extensive structural damages or remove the risk of damage from seismic activity, park managers must remain vigilant about inspecting the safety and integrity of park structures.



Credit: Basilisk Concrete

REAL-WORLD EXAMPLE

Leak-Proof Pavement | Apeldoorn, Netherlands | 2014

Self-healing concrete liquid repair treatment was applied to a parking structure floor in the Netherlands to prevent water penetration as well as infrastructure and vehicle damage (Figure 7.13, above).[19] The treatment can be applied over the concrete's topcoat without damaging it and requires less time to apply than traditional crack repair methods such as epoxy injection.[19] Six months after treatment, wet spots were no longer observed on ceilings where the floor above had been treated.[19]

Credit: Nanopower International

Figure 7.14: Comparison of treated (left) and untreated (right) surfaces demonstrates how titanium dioxide keeps surfaces cleaner.

Photocatalytic titanium dioxide coating

What is this technology?

Photocatalytic[xi] titanium dioxide coating (TiO_2) is an agent that can be applied as a low-concentration spray, paint, or dip coating to "self-clean" surfaces such as plastic, concrete, glass, and tiles.[24,25] It can sterilize surfaces by killing bacteria,[26] remove mold damage,[27] and purify ambient air by removing volatile organic compounds and nitrogen oxides.[25,28] Titanium dioxide is a catalyst, meaning it sets off chemical reactions when it comes into contact with UV light. The chain of reactions results in the breakup of organic (carbon-based) dirt, including bacteria and nitrogen oxides,[26] thus cleaning the surface. TiO_2 is most effective when its particle sizes are fine and when it is applied to rough surfaces.[25, 28] While there are other types of similar self-cleaning coatings made with different nanoparticles (such as zinc oxide), this section focuses on TiO_2 because it is the most common and widely used.[29]

[xi] Photocatalysis is when a photo reaction, or a reaction caused by light, is accelerated by the presence of a catalyst, which is a substance that increases the rate of a chemical reaction.[45]

How does it fit into parks?

Titanium dioxide coating can be applied to park surfaces that require frequent cleaning, such as bathrooms, windows, walls, benches, and pavement. The application of a photocatalytic coating to the interiors of restroom facilities or play structures reduces the need for maintenance and acts as a sterilizer for high-germ areas. It can also be applied to park areas that require frequent maintenance, such as windows or benches. These coatings can reduce germs on surfaces that visitors regularly come in contact with, while also reducing the maintenance costs associated with cleaning these surfaces.

Why choose photocatalytic titanium dioxide?

Access – Photocatalytic coatings can improve the cleanliness of park surfaces, which can encourage more visitors. Park users' comfort level is often closely tied to the cleanliness and maintenance level of park amenities.[30,31]

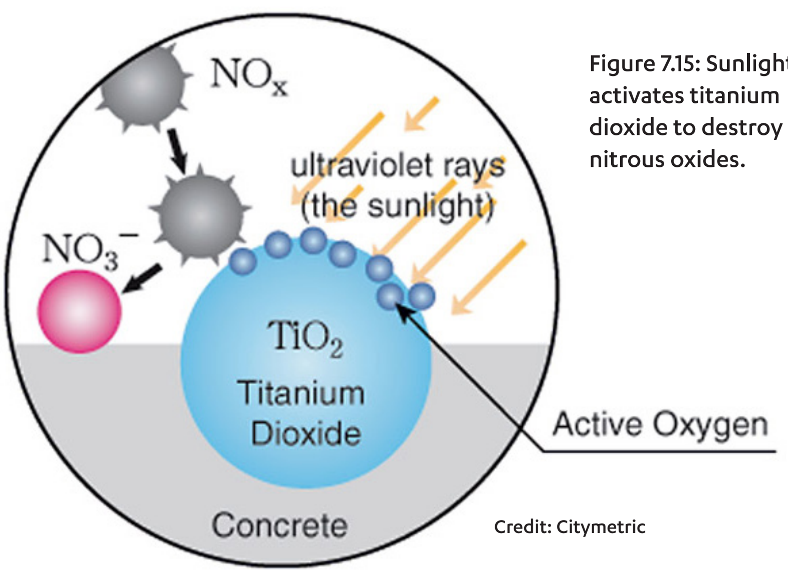


Figure 7.15: Sunlight activates titanium dioxide to destroy nitrous oxides.

Credit: Citymetric

Health – Photocatalytic coatings degrade nitrogen oxides and volatile organic compounds, improving air quality and mitigating the effects of nearby vehicle emissions.[32] The coatings also kill bacteria, thus sterilizing surfaces for improved health without requiring irritating or harmful chemical cleaners.[26]

Water – Photocatalytic coatings are self-cleaning, thereby reducing the need for water to wash surfaces.

Operations and Maintenance – Because they are self-cleaning, photocatalytic coatings reduce maintenance needs and additional costs for chemical cleaners and staff time.

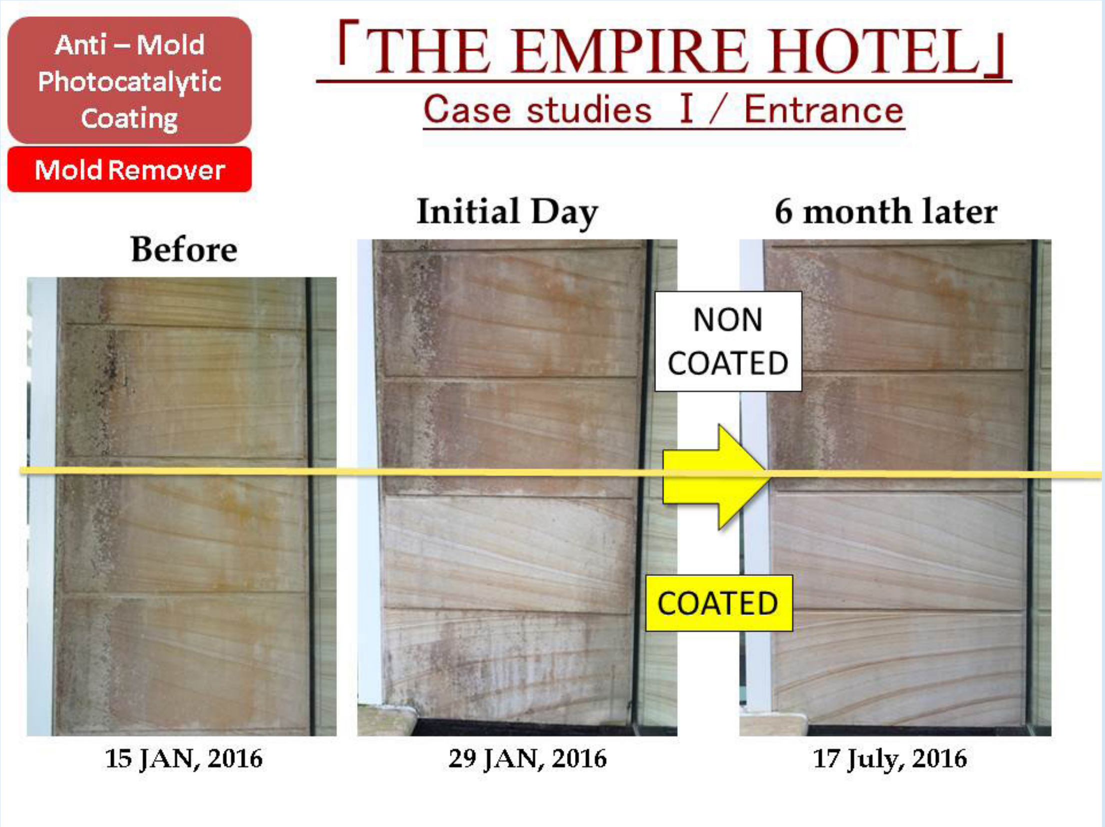
What are the challenges and trade-offs?

Variability in pollution-reduction benefits – Air pollution removal benefits vary and depend on the surface area of photocatalytic material (i.e., larger coated surface areas have more nanoparticles and therefore can remove more pollution), as well as the concentration of pollution near the material and other factors such as sunlight and wind.[32,33]

Reapplication requirements – The coating must be reapplied depending on the lifespan and use of the product. As a relatively new product, there are no accelerated weathering tests to determine exact lifespans. However, it is estimated that the coating will last two to five years.[33,34] For example, the coating used on public buses in New Brunswick, Canada, which receive frequent, heavy use, must be reapplied every two years.[26]

Takeaways

Photocatalytic titanium dioxide-coated surfaces self-clean, killing bacteria and mold while removing pollutants from ambient air.[32] This technology can reduce water use and maintenance costs with the added health benefits of surface sterilization and air quality improvement.



Credit: Coat Guard

REAL-WORLD EXAMPLE

Preventing Mold and Salt Damage | Brunei | 2016

The seaside Empire Hotel in Brunei on the Island of Borneo struggled with mold damage from ocean spray.[27] A photocatalytic titanium dioxide coating was applied to the mold-damaged wood (results above in Figure 7.16). It killed the mold colonies and prevented the proliferation of new mold on the coated surface.[27]

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Transparent concrete

What is this technology?

Transparent, or translucent, concrete is a building material with light-transmissive properties due to embedded optical elements within the concrete.[35] The technology blends small fibers that attract and transmit natural or artificial light into the concrete and make up 4% to 5% of the total concrete mixture. Transparent concrete is as strong as traditional concrete; is frost-, salt- and UV-resistant; and has fire-protection properties.[36]

Credit: DigitalPost

Figure 7.17: Despite its transparency, translucent concrete is as strong as the traditional variety.

How does it fit into parks?

Transparent concrete can have many applications in parks, including improving safety, increasing natural light in buildings, and developing creative projects. To increase safety, transparent concrete could be used for enclosing walls that provide a solid barrier without decreasing visibility. It could be used as a structural material to increase daylight and reduce the need for electric lighting. Transparent concrete may also have decorative uses. For example, transparent concrete lighting fixtures can create beautiful, unique, and delicate lighting installations, with the durability of concrete.

Why choose transparent concrete?

Community Fit – The transparency and style of the concrete can be adjusted by changing the size, number, and orientation of the embedded optical fibers, making it appropriate for a wide range of aesthetic and architectural applications.

Health and Energy – Transparent concrete allows for natural daylight infiltration, which increases well-being and productivity and decreases the need for electrical lights.[37, 38]

Safety – Transparent concrete can be used to separate park areas, while allowing visitors and potential trespassers to be easily observed. It can be used as an enclosure to help increase the feeling of safety and security for park visitors.

What are the challenges and trade-offs?

Availability –Transparent concrete may not yet be commercially available in some areas.

Lighting versatility – It may be difficult or impossible to completely dim natural light, which may be undesirable depending on how the space is used. For example, showing movies may not work well if light cannot be dimmed.

Takeaways

Transparent concrete could be used in parks to increase natural daylight and reduce electricity use in buildings. It can also provide increased feelings of safety, a unique aesthetic, and can be used to create lighting installations to engage with visitors.

Credit: Marro

REAL-WORLD EXAMPLE

Seeing Behind a Wall | Hungary | 2007

In 2007, the Cella Septichoria Visitor Centre in Pécs, Hungary, installed translucent concrete to create a unique architectural feature (Figure 7.18, above). The concrete allows natural daylight into the space and enables visitors to see the beautiful silhouettes of the trees outside.[39] At night, when the space is lit with electric lights, the center seems to glow from within to passersby outside.

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Credit: Studio Roosegaarde

Figure 7.19: Fluorescent pigments can glow up to 12 hours after just 10 minutes of natural light exposure.

Daylight fluorescent aggregate

What is this technology?

Daylight fluorescent aggregate is an impervious material that, when mixed with epoxy resin (a petroleum or plant-based coating agent), can be used to create glow-in-the-dark hardscape materials, such as bike and walking paths. The fluorescent pigments in the aggregate, which come in different colors, absorb and store natural or artificial light. They then emit that light when the light source is no longer present.[40] It takes about 10 minutes of natural light exposure for the aggregate to glow up to 12 hours.[40]

How does it fit into parks?

Glow-in-the-dark fluorescent aggregate is suitable in park areas where nighttime lighting is desired or in areas that could benefit from a unique and colorful aesthetic. It can be used in areas without electricity or on heavily shaded walking paths with minimal overhead lighting.[40] It could also serve as a glow-in-the-dark permanent art installation.

Why choose daylight fluorescent aggregate?

Access – Daylight fluorescent aggregates allow for well-lit paths, which increase park accessibility and can encourage use of facilities after dark.

Community Fit – Daylight fluorescent aggregate can be used in areas intended for dusk or nighttime use, such as amphitheaters or barbecue areas. The material can also be manipulated to create engaging, unique designs that reflect the community's culture.

Health and Safety – The use of daylight fluorescent aggregate on athletic tracks can make nighttime runners, joggers, and walkers feel safer, potentially encouraging physical activity.

Resilience and Energy – In the case of a power outage, the path will continue to provide light to the site. It does this without using electricity, thus providing a clean source of light.

What are the challenges and trade-offs?

Permeability – Fluorescent aggregate used in pathways is not permeable and therefore should not be used in areas where stormwater management is needed.

Lighting flexibility – Flourescent aggregate cannot be "turned off" so it should be used only in areas where nighttime lighting is always desired. It can work well in places that may have a sudden loss of light, such as during dusk or blackouts, or when continuous evening lighting is desired.

Takeaways

Daytime fluorescent aggregates can coat surfaces and paths to provide nighttime illumination without electricity. They can create "glow-in-the-dark" paths, which can increase access, visibility, and security in parks after dark, while also providing an engaging visitor experience. This technology also reduces electricity use and maintenance costs, and ensures lighting during a power outage or in areas without electricity.

Credit: Colossal

REAL-WORLD EXAMPLE

Light the (Bike) Way | Lidzbark Warmiński, Poland | 2016

In 2016, TPA Instytut Badań Technicznych (TPA Technical Research Institute) built glow-in-the-dark bike and pedestrian paths to increase safety for nighttime users in Lidzbark Warmiński, Poland, (Figure 7.20, above). During the day the material harvests energy from the sun, and at night it glows up to 10 hours.[41] Although many different colors of fluorescent are available, the designers chose blue as the best fit for their location.

Carbon upcycled concrete

What is this technology?

Carbon upcycled concrete, currently in the research and development phase, is a building material that can be used in place of concrete. It integrates waste carbon dioxide (CO_2) (from power plants) with calcium hydroxide (combined with aggregates and additives) via a carbonation reaction. This process, which helps make upcycled concrete nearly carbon neutral, also could give it additional strength.[22] Carbon upcycled concrete can be shaped like traditional concrete or 3D-printed, making it well-adapted to prefabrication strategies that save time.[22]

Credit: UCLA Luskin Center for Innovation

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REAL-WORLD EXAMPLE

Concrete of the Future | Los Angeles | 2016

UCLA scientists and engineers created the Carbon Upcycling Project and are working to produce carbon upcycled concrete called CO_2NCRETE. So far, they have successfully 3D-printed small samples (Figure 7.21, above) and have plans to scale up for commercial production and use.[22]

How does it fit into parks?

Once available, carbon upcycled concrete can be used anywhere traditional concrete is used in parks.

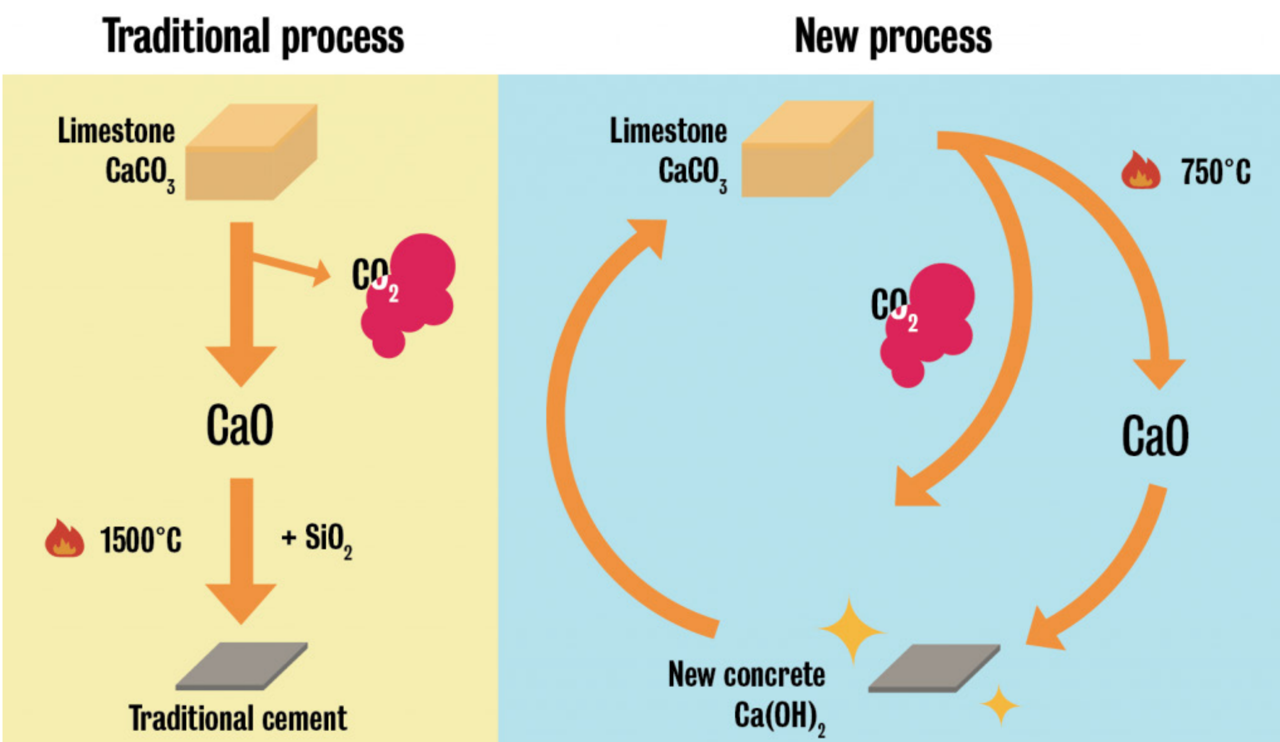
Why choose carbon upcycled concrete?

Resilience – Carbon upcycled concrete acts as a sink for carbon dioxide, mitigating the effects of climate change.

Energy – Producing traditional concrete is energy-intensive, while producing carbon upcycled concrete is nearly carbon neutral, removing CO_2 from the atmosphere.

What are the challenges and trade-offs?

Carbon upcycled concrete is not yet commercially available. As with most new technologies, there may be unexpected challenges to implementation and use and possible trade-offs between cost and strength of the material, compared to those of traditional concrete.



Credit: LeAnn Woo, Daily Bruin

Figure 7.22: The traditional concrete process emits CO_2 while the new carbon upcycling process uses waste CO_2 and embeds it in the final concrete product.

Takeaways

When commercially available, carbon upcycled concrete may be used in place of traditional concrete anywhere in parks. It is nearly carbon neutral and utilizes waste CO_2 in its production. The option to 3D-print the technology enables prefabrication and thus reduces construction time and cost.

Hardscape component achievement levels

The technologies described in this chapter confer a wide variety of benefits to parks. Several improve the safety, resilience, and energy efficiency of parks, while others produce health benefits and enhance access. The table below illustrates the effectiveness of each technology in achieving the different Value Criteria defined in Chapter 3.

	Access	Community Fit	Health	Safety	Resilience	Water	Energy	Operations and Maintenance
Cross-Laminated Timber	○	○	◒	○	○	○	●	◒
Pervious Paving	○	○	○	●	●	●	●	◒
Piezoelectric Energy-Harvesting Tiles	○	●	◒	◒	●	○	●	○
Self-Healing Concrete	○	○	○	●	◒	○	◒	●
Photocatalytic Titanium Dioxide Coating	●	○	●	○	○	●	○	●
Transparent Concrete	○	●	◒	●	○	○	●	○
Daylight Fluorescent Aggregate	●	●	◒	●	●	○	●	○
Carbon Upcycled Concrete	○	○	○	○	●	○	●	○

● Indicates technologies that provide a positive benefit for a value criterion.

◒ Indicates technologies that represent a secondary effect on a value criterion or have a trade-off between their benefits and drawbacks.

○ Indicates technologies that have no effect, a negative impact, or are unrelated to the value criterion.

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ACTIVITY SPACES

in parks, such as play structures, exercise equipment, athletic fields and tracks, and swimming pools, encourage physical activity, promote health, and can serve to educate users as well as increase visitor use. Nationwide, there is a deficiency of informal play spaces in parks, particularly in areas of high-density development and urban poverty.[1] In light of rising obesity rates[2] and park underutilization,[3] it is more important than ever for parks to provide relevant programming and welcoming activity spaces for a wide variety of users.

Figure 8.1 Credit: Playworld, division of PlayPower

Chapter 8: Activity Spaces

Credit: Kompan

Interactive play structures (shown in Figure 8.1 on the previous page and in Figure 8.2, above) can be more accessible for children with disabilities than traditional structures. Playworld's NEOS 360, previous page, includes games that children in wheelchairs can easily play, while the Kompan ICON, above, has a variety of games and structures within a single play space.

Programming brings a park space to life[4] and can bring more people into parks.[5] In addition to providing spaces and structures for physical activity, park managers should consider how technology might enhance parks through programming. For example, outdoor DJ booths, highlighted in this chapter, use technology to create a unique space for music, dancing, and community interaction that can attract new visitors and may especially appeal to teenagers.

Technologies exist to create more innovative and accessible activity spaces, including new construction materials, maintenance techniques, equipment designs, and Wi-Fi capabilities. This chapter describes six technologies that park managers and designers can utilize to enhance activity spaces: interactive play structures; high-performance track surfaces; pool ozonation; energy-generating exercise equipment; outdoor DJ booths; and hard-surface testing equipment.

Interactive play structures

What is this technology?

Interactive play structures are similar in structure to traditional play structures but have an integrated computer game system that children can interact with virtually, via buttons, sensors, lights, sounds, colors, and pictures. The structures can also gather user data and be connected to the Internet to allow for remote management. The structures come in different models and designs, and can be programmed with one or more virtual games.

How does it fit into parks?

Interactive play structures in parks can be used in addition to or in place of traditional play structures for fun, educational programming, promotion of physical activity, and to increase access and use by disabled individuals. They can be programmed to fit the needs of users and receive automatic updates of new games.[6]

For education, Yalp Interactive, a company based in the Netherlands, has developed the Memo Activity Zone, which can be programmed to ask questions on math, the environment, or other topics.[6] To promote physical activity, Yalp's Sutu ball wall creates an interactive soccer game that is connected to a smartphone application.[6] Children can track their scores and receive notifications when friends

Credit: Yalp Interactive

Figure 8.3: Yalp Interactive's Sona Dance Arch (foreground above) and Sutu ball wall (Figure 8.4 next page) are interactive structures that can promote increased activity, including by the disabled.

top their score — encouraging them to play more.

Interactive structures can gather user data, providing managers information on how often and with what games the structures are used.[6] Additionally, the structures' Internet dashboards allow for the remote control of on-off times, volume, and other settings.[7]

Interactive play structures are particularly accessible to a wide range of users, including various age groups. In addition to parks and schools, they have been installed in retirement homes, encouraging

Credit: Yalp Interactive

activity among seniors.[7] These structures may be particularly appropriate for parks that require Americans with Disability Act-compliance: All children can use them because their virtual games do not require physical ability to use. For example, the Yalp Interactive Sona Dance Arch, shown in Figure 8.3, is fully accessible to those in wheelchairs. Software is also available with audio feedback and games geared toward children with autism or other disorders.[7]

Why choose an interactive play structure?

Access – Interactive play structures can increase park accessibility for children with physical and mental disabilities. They should be designed so that their components are wheelchair accessible with interactive buttons and sensors at wheelchair height. Software geared toward children with autism and other disorders is available. The novelty of the structure may also attract children to the park.

Community Fit – Interactive play sets can accommodate a range of users and reflect community needs. Certain play sets allow park managers to adjust the languages, games, and other settings. They can also cater to multiple generations, such as grandparents playing with their grandchildren.

Health – Interactive play structures can be designed to increase physical activity through games.

Operations and Maintenance – Some interactive play sets are connected to the Internet; volume, on-off times, equipment status, and downloading new games[7] can be controlled remotely.

What are the challenges and trade-offs?

Language or visual barriers – Interactive play structures may use prompts such as numbers, words, and colors as part of a game. These prompts may be limiting for children who speak a different language, are too young to read letters and numbers, or are colorblind.

Maintenance – Often the physical components of the structure cannot be easily used without the interactive features, so if the latter break, the structure may become obsolete. Like traditional play structures and other park amenities, interactive play structures may be at risk of vandalism or damage.

Educational value – Additionally, while interactive media can engage children in new ways, some worry that digital features may distract children from learning objectives.[8]

Takeaways

Interactive play structures can increase access to parks for children with disabilities, improve health by encouraging physical activity, or serve educational purposes. As a new alternative to traditional play structures, they can increase park use and attract new visitors.

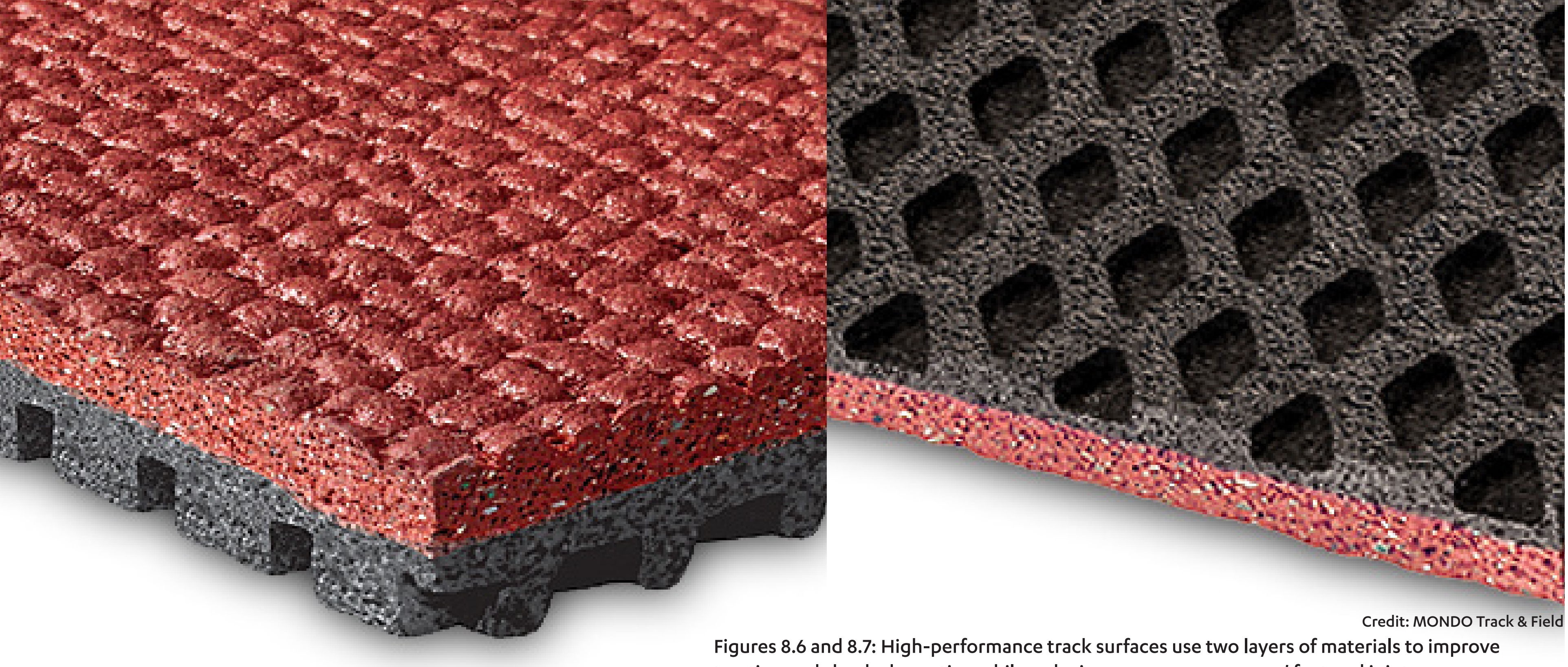
Credit: Idaho State Journal

REAL-WORLD EXAMPLE

Play Gets an Upgrade | Idaho Falls, Idaho | 2015

When the playground equipment at Tautphaus Park was stolen, the City of Idaho Falls used the insurance money to invest in a high-tech interactive NEOS 360 play structure, Figure 8.5 (above).[9] It is intended for children ages 5 to 11, but is enjoyed by all visitors. It is durable, weatherproof, and designed to withstand heavy use. While the park was already popular, the new play equipment generated publicity, attracted visitors, and received positive user reviews.[9]

Chapter 8



Credit: MONDO Track & Field

Figures 8.6 and 8.7: High-performance track surfaces use two layers of materials to improve traction and shock absorption while reducing pressure on runners' feet and joints.

High-performance track surfaces

What is this technology?

High-performance track surfaces are weather-resistant rubber running tracks made of two layers to provide efficient traction and absorb shocks.[10,11] Conventional tracks combine these into a single layer. Because the upper layer in high-performance track surfaces is relatively solid, runners' spikes do not have to penetrate the surface to gain traction, so shorter spikes can be used. Shorter spikes allow runners to transfer less of their physical energy into the track, leading to more efficient running.[10] For low-speed activities, high-performance track surfaces relieve pressure on feet and joints and increase foot comfort.[11]

How does it fit into parks?

High-performance track surfaces can be used in place of traditional track surfaces. They can be installed around the park or limited to one area, and used for local events. They perform especially well in areas with extreme weather conditions and often have longer lifespans than traditional track surfaces.

Why choose a high-performance track?

Access – High-performance tracks provide a safe, efficient, and low-pressure walking and running surface suitable for many types of users, including for high school track meets and for senior citizen fitness classes.

Health – High-performance tracks can increase performance for athletes, are easier on the joints, and increase foot comfort for recreational users. These features can attract more park visitors and encourage physical activity.

Resilience – High-performance tracks are resistant to extreme weather, making them more resilient to flooding and other extreme weather events that are caused by climate change.

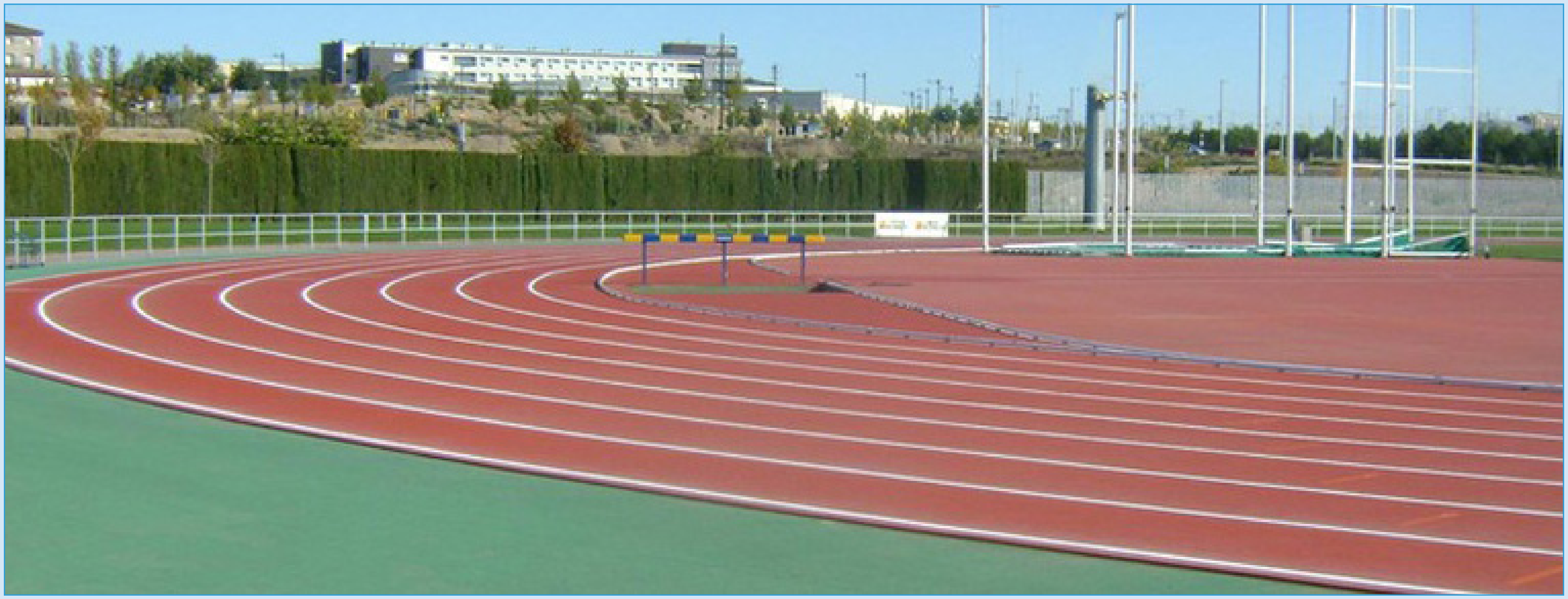
Operations and Maintenance – High-performance tracks can have a longer life than traditional track surfaces, although more intensive upfront installation and short-term maintenance is required.

What are the challenges and trade-offs?

Maintenance – High-performance tracks require attentive maintenance and cleaning, especially during the first six months to a year, to protect the rubber while it cures following installation.[12] Optimal maintenance may require specialized equipment, such as specific sweepers and pressurized washers, though maintenance is possible with hoses and vacuums.[12] However, the long life of the track surface can reduce the need for replacement, even if short-term installation needs are higher than those of a traditional track.

Takeaways

High-performance track surfaces can replace traditional track surfaces to improve access, health, and resiliency of parks. In addition to improving performance for athletes, they provide a low-impact surface that reduces pressure on feet and joints, increases comfort, and may encourage increased physical activity by older generations. The track surface is weather-resistant, reducing long-term maintenance and replacement costs. To ensure proper installation, however, the first six months to a year require extensive maintenance. Some tracks need specialized cleaning equipment.



Credit: Spazio Mondo

REAL-WORLD EXAMPLE

Tracks in Action | Zaragoza, Spain | 2012

The Aragon Sports Center in Zaragoza, Spain, replaced its 10-year-old track with a Mondotrack (Figure 8.8, above), a high-tech rubber one similar to that used in the 2012 London Olympics.[13] Approximately 1,500 people rely on the track every week, so quick installation was key. Replacing the track took about a month and a half.[13] Athletes have reported improved speed and comfort, and the track has proven to be durable.[13]

Pool ozonation

What is this technology?

Pool ozonation is a water filtration technique with two components: ozone generation and ozone management.[14] Ozone generation creates ozone particles in the water, which are a natural oxidizing agent that removes organic and inorganic compounds and sanitizes water (similar to chlorine) — without chlorine's negative health effects of eye and skin irritation[15] and exacerbated asthmatic symptoms.[16] The ozone management system then dissolves the ozone into the water, so there is no excess ozone off-gassing[i] at the pool's surface.[15] The ozone controls harmful microorganisms in water, including cryptosporidium and giardia, which can cause serious disease or infection in humans.[17] Cryptosporidium

[i] Inhaling ozone can be harmful to people's lungs.[35]

The process: how an atom destroys contaminants[18]

Energy splits targeted oxygen (O_2) into single oxygen atoms (O_1)

The single oxygen atoms form a weak bond with free oxygen molecules to create ozone (O_3)

$$O_1 + O_2 = O_3$$

Once ozone contacts contaminants, the weak bond is broken, and the oxygen atom destroys the foreign bodies/materials

The only remaining by-product from the interaction is pure oxygen (O_2)

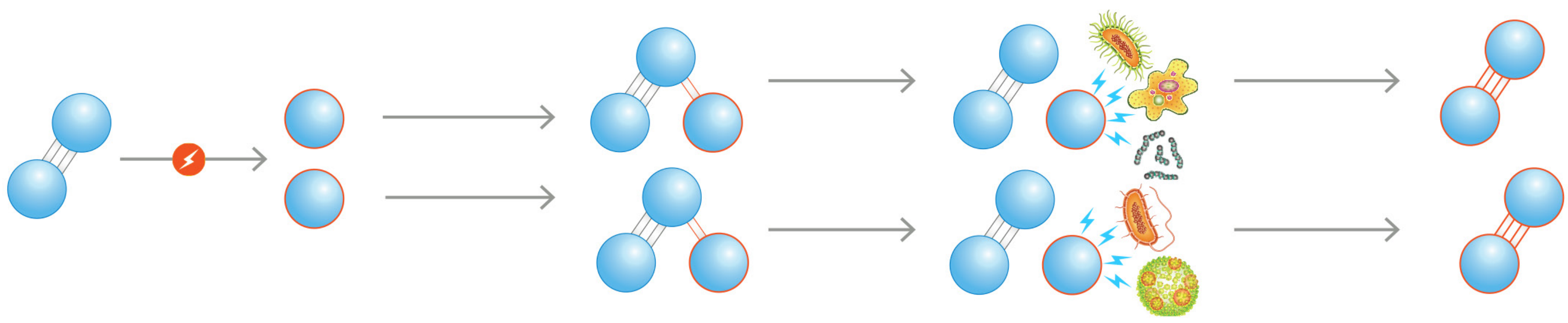


Figure 8.9 – Credit: DEL Ozone

is highly resistant to chlorine disinfectants typically used in pools.[16] Ozone can also destroy organic contamination, disinfection byproduct buildup, dead algae, and organic debris. The ozone must be well-circulated and does not remain in water for long periods, so backup sanitizers are needed in large and/or heavily used pools.[19] Thus, chlorine may still be needed, but at significantly decreased amounts.

Ozone can also be combined with other sanitizers in hybrid pool filtration systems, such as one that uses both ozone and hydrogen peroxide for water sanitation.[20] In such a combined system, the two sanitizers work together to increase active oxygen levels in the water and eliminate bacterial threats without the need for chlorine.[20]

How does it fit into parks?

The process of ozonation can be used in parks with pools and water features. While it may be particularly appropriate for smaller pools and fountains, careful system selection can make it a viable choice for full-sized pools. By reducing, or removing, the need for chlorine, ozone can reduce potential irritants and negative health effects on swimmers. Chlorine can be especially irritating for those with asthma. There is a high prevalence of asthma in disadvantaged communities, and these are often the neighborhoods most in need of public recreational facilities, such as community pools. Therefore, ozonation can be a great choice for these communities[21, 22]

Management should ensure that an ozonation system complies with federal, state, and county pool sanitation guidelines, such as the Center for Disease Control and Prevention's Model Aquatic Health Code.[23]

Why choose pool ozonation?

Health – Despite being a powerful sanitizer, ozonation does not result in harmful disinfectant byproducts,[16] many of which are suspected to be toxic or carcinogenic.[21] While some chlorination may still be needed in pools, ozonation can greatly reduce its negative health effects, which is especially important for pool users who suffer from asthma[17] or experience eye and skin irritation after swimming.[16]

Water – Pool ozonation requires less water for maintenance because backwashing (reversing the water flow through the filter to remove buildup), is not needed as frequently or for as long.[24] In some cases the water from backwashing can even be used for alternative purposes, such as landscaping.[20]

Operations and Maintenance – Pool ozonation requires less maintenance than a traditional chlorine system, since it does not require the manual addition and monitoring of chemicals, which are difficult to maintain at the proper level.[25]

What are the challenges and trade-offs?

Supplemental chlorination – Ozonation may not completely eliminate the need for chlorination in some large or frequently used pools, but it still substantially reduces the chemicals required for sanitation and has fewer maintenance requirements than traditional chlorine systems.[16]

Staff expertise and training – Park staff may not be familiar with ozonation systems, whose operation may require training.

Takeaways

Ozonation can be more effective at sanitizing pools than traditional chlorination. It offers health benefits by reducing chemicals that cause odor and irritation. It uses less water and requires less maintenance than with traditional pools. However, operating an ozonation system requires knowledgeable maintenance personnel.

Credit: Waterco

REAL-WORLD EXAMPLE

Clean and Clear Pool | Queensland, Australia | 2013

The Turtle Beach Resort in Queensland, Australia (Figure 8.10, above), which has four high-traffic swimming pools, struggled with maintenance issues, including cloudy water and strong chlorine odors. To address the problems, the resort retrofitted its pool systems with a chlorine-free, hybrid ozone and hydrogen peroxide sanitation system.[20] The pools no longer smell of chlorine; traffic to pool areas increased; and many swimmers stopped using goggles to protect their eyes from irritation.[20] Guests reported less skin irritation and asthmatic symptoms. Less time is now spent maintaining the pools, and the new systems consume less water. Additionally, wastewater from the backwash cycle is clean enough to be used for landscaping.[20]

Energy-generating exercise equipment

What is this technology?

Energy-generating exercise equipment — cardio, toning, and strength training machines[26] —generates friction (and therefore heat) while in use, which is converted to electrical energy via a generator.[27] The clean electricity produced can be used for on-site lighting, to charge devices, or can be sent to the grid for use by others. While the amount of energy generated varies with the equipment and use, an average user can expect to generate 50 to 150 watts during an hour of cycling on a stationary bike. This amount of electricity would be enough to power a television set for about an hour.[27] The equipment, which is similar to machines found in gyms, comes in indoor or outdoor varieties. Outdoor energy-generating exercise equipment is designed for durability and low maintenance.

Credit: Playpoint Asia

Chapter 8

How does it fit into parks?

Outdoor energy-generating exercise equipment can be incorporated into almost any park design. Indoor equipment can be used in recreation centers or other facilities in parks. For parks with children's play areas, it may be appropriate to locate equipment so that parents can use it while supervising their children. Outdoor exercise equipment may also be a valuable addition to parks without play areas that primarily serve adults and seniors.

Why choose energy-generating exercise equipment?

Access – Energy-generating exercise equipment in public parks gives community members free access to gym-like facilities.

The Great Outdoor Gym Co.

Figures 8.11 (preceding page) and 8.12, above: Energy-generating exercise equipment uses the friction from users to generate electricity for powering cell phones or other devices.

Community Fit – Energy-generating exercise equipment can be selected to fit a park's context. For example, machines for toning or moderate cardio exercise may be most appropriate for parks that serve a large population of older adults. The electricity generated could power the park's lights for early morning or late evening use. Parents watching children may appreciate opportunities to build strength, while also charging their phones.

Health – Energy-generating exercise equipment can encourage physical activity and facilitate healthy exercise habits. To facilitate easy use, park managers could provide an online equipment reservation system or organize classes using the equipment.

Resilience and Energy – Energy-generating exercise equipment is a source of clean energy, which can be used on-site or returned to the power grid, thereby cutting down on traditional fossil fuel-powered electricity generation, which emits greenhouse gases. The energy can help parks meet clean energy goals and teach visitors about clean energy.

What are the challenges and trade-offs?

Electrical limitations – To power lights or send clean energy to the grid, energy-generating exercise equipment must be connected to the park's electrical supply. If the equipment is not connected, the energy created will be limited to uses directly connected to the equipment, such as charging phones.

Power generation limitations – In general, the typical amount of energy generated by an average person during an exercise session (about 150 watts for an hour of cycling) suggests that the equipment would be best for powering small on-site devices.

Vandalism and damage – Like traditional exercise equipment or other park amenities, energy-generating exercise equipment could be at risk of vandalism or damage.

Takeaways

Energy-generating exercise equipment can encourage park visitors to participate in physical activity and is especially valuable for those who may not have access to other facilities and equipment. The equipment can be tailored to fit different ages. Using the equipment generates clean energy for a variety of small uses like phone charging. Using the energy generated on-site or sending it to the grid requires that the equipment be connected to the park's electrical system.

Credit: The Great Outdoor Gym Co.

REAL-WORLD EXAMPLE

A Different Kind of Workout Fuel | London | 2009

The Peckham Rye Green Legacy Gym in London (Figure 8.13, above) contains a variety of energy-generating exercise equipment, including a fitness bike and double-station leg press.[26] All equipment with moving pieces is resistance-based, and most equipment generates 50 to 110 watts on average, depending on the fitness of the user. The park manager considers the outdoor gym a "huge success": It has attracted a variety of users, including kids before school and adults walking their dogs. Users appreciate the access to a free gym, and many prefer exercising outdoors instead of indoors.[26]

Credit: Yalp Interactive

Outdoor DJ booths

What is this technology?

Outdoor DJ booths are sturdy structures that amplify and can manipulate pre-loaded beats or music from mobile phones.[28] The booths are interactive and can be charged by solar panels atop the shade structure.[28] The maximum volume and times when the machine will be on/off can be set to ensure that surrounding neighborhoods or other visitors are not disturbed.[28] Currently, Yalp Interactive is the only supplier. It designed the Fono DJ booth to provide “positive, creative, hangout spaces for teens.”[7] The company plans to connect the DJ booths to the Internet, which will allow for presenting and monitoring user statistics.[6] The DJ booths are designed to be vandalism-proof as well as resistant to mud, snow, ice, gum, liquids, and more.

How does it fit into parks?

Installing the Fono DJ Booth in parks creates a new hangout space, especially appealing to youth. This may encourage parks to allow late-night use, promote dancing as physical exercise, and attract teens and young adults. Some booths have already been installed in parks across Europe and Asia.[29]

Some parks already use outdoor speakers to create teen-friendly spaces.[30] Outdoor DJ booths allow for music amplification as well as DJ mixing features and sound effects. Park managers may wish to use the booth for programming and events such as dance nights. Some parks already host these types of events with temporary DJ booths and speakers. For example, Dance DTLA is a partnership between The Music Center and Los Angeles County that hosts a dance party at Grand Park in downtown Los Angeles with different DJs on most Friday nights during the summer.[31] The Pearl District neighborhood in San Antonio, Texas, has collaborated with Sound Cream, a mobile DJ booth housed in an airstream trailer, to host a pop-up dance club on an open public lawn.[32] The Fono DJ Booth allows parks to use music amplification on a more permanent and regular basis.

Why choose this technology?

Access – Outdoor DJ Booths attract visitors to parks and may be especially enticing for teenagers, who may not otherwise have a designated space in the park.

Community Fit – The technology enables parks to incorporate music in a way that fits community needs, while creating unique programming opportunities. The equipment can also be customized with different colors to match the park's design.

Health – By encouraging dance as physical activity in parks, the music amplification systems can help to promote health in the community in a fun way.

Credit: Yalp Interactive

Figures 8.14 (preceding page) and 8.15 (above): Fono Outdoor DJ Booth provides unique hangout spaces and opportunities for dancing for park visitors.

Energy – The booth can be solar-powered to reduce energy costs and usage.

What are the challenges and trade-offs?

Maintenance – While designed to be extremely durable, the outdoor DJ booths may still be susceptible to vandalism or require maintenance.

Potential disruptiveness – While it comes with programmable on/off times, loud music may disturb nearby residents or visitors using the park for other purposes.

Event issues – For a "pop-up" event using the booth or other temporary equipment, additional event planning, security, and coordination may be required.

Takeaways

Outdoor music in parks through use of outdoor DJ booths can provide unique programming to engage a wide variety of park visitors. While vandalism and noise concerns are important to consider, incorporating music into parks can be a fun way to encourage physical activity and provide a positive space for teenagers and other park visitors.

Credit: Yalp Interactive

REAL-WORLD EXAMPLE

Greatest Hits Outdoors | The Netherlands | 2013

The Nelson Mandelapark in Amsterdam, located in the multicultural neighborhood of Bijlmer, installed a solar-powered Fono DJ booth near its skate park and sports cage in 2013 (Figure 8.16, above). Customized with magenta, yellow, and neon colors to match the park's design, it has created a popular meeting place for all ages. Dance classes also use the Fono.[7]

Chapter 8

Hard-surface testing equipment

Credit: Trassig Inc.

Figure 8.17: Hard-surface testing equipment is dropped off a play structure to mimic a child's head during a fall.

What is this technology?

Hard-surface testing equipment is used to test the safety of hard surfaces under playgrounds, which are common sites for injuries. Instead of using an "eyeball test" to assess surfaces or rely on cumbersome lab equipment,[33] hard-surface testing equipment uses electronic sensors to mimic a child's head to provide quickly accessible data on impact, velocity, and potential for head injury.[33] The hard-surface testing equipment featured here is cordless, portable, and user-friendly. Previous equipment was very costly and park managers had to hire outside consultants to bring the equipment and perform tests. The new technology allows for lower-cost, portable devices that park managers can own and operate directly.

Data from the equipment is automatically stored and can be analyzed to identify changes in the surface's quality. Some models provide an immediate pass/fail reading from the device and then allow for the data to be downloaded to a laptop for more detailed analysis.[34] The portable equipment allows for regular testing of surfaces without hiring professionals.

How does it fit into parks?

Park playgrounds must adhere to certain safety standards to reduce the danger of head injuries from falls.[33] Hard surfaces must absorb the energy of falling objects, but over time, common playground surfaces like mulch, rubber, and gravel deteriorate because of foot traffic and other use. Hard-surface testing equipment can quickly, easily, and clearly determine the quality and safety of playground surfaces in parks. Certain models can also send a signal to park staff, when it is time to replace the surface material for safety reasons.[33]

Why choose hard-surface testing equipment?

Health and Safety – Hard-surface testing equipment can make playground safety evaluation easier and more effective, which could help reduce the frequency and severity of children's falls and concussions. Over 21,000 U.S. children aged 14 and younger are treated in emergency rooms each year for severe traumatic brain injuries after playground falls.[33]

Operations and Maintenance – Hard-surface testing equipment makes it easier for park staff to test and know when to replace playground surfaces, without requiring professionals.

What are the challenges and trade-offs?

Staff expertise and training – Installing new equipment may require park staff training, so staff know how to operate the equipment and analyze the testing results.

Safety risks – The equipment helps determine the current safety of surfaces and identifies when replacement is necessary, but it cannot prevent falls. Other safety features and supervision of children on equipment remain important.

Takeaways

New advancements in hard-surface impact testing equipment make it easier for park managers to measure fall impacts, track playground safety, and know when to replace playground surfaces. This reduces the risk of major injury resulting from children's falls.

REAL-WORLD EXAMPLE

Science for Safety for Playground Surfaces | 2015

Portable, in-field hard-surface testing equipment is still relatively new, so there are no real-world case studies yet available. The product is currently available to rent or buy. The ST Impact Analyzer CH (Figure 8.18, right) is an electronic hard-surface tester designed by Sonam Technologies. The tester determines impact attenuating characteristics of playground surfaces.[33] The device comes with a tablet computer and automatically sends collected information to an online database that park managers can use to track measurements. The company hopes to eventually set up a public database of all measurements from different parks that use the technology.[33] This would enable park managers to compare the properties and lifespans of different surfaces used in playgrounds, allowing them to make more informed decisions about which surfaces to select when building or replacing playgrounds.[33] The Free Fall (Figure 8.19, right below), created by The ParkLab, is another cordless, battery-operated impact tester. The device itself delivers a simple pass/fail indicator after each test, but more comprehensive data is saved and can be downloaded to a computer.[34]

Credit: Sonam Technologies

Credit: The ParkLab

Activity Spaces component achievement levels

Activity space technologies primarily meet the Access and Health criteria. Some of the technologies also provide Community Fit, Resilience, Water, Energy, and Operations and Maintenance benefits. The table below illustrates the effectiveness of each technology presented in this chapter in achieving the Value Criteria defined in Chapter 3.

	Access	Community Fit	Health	Safety	Resilience	Water	Energy	Operations and Maintenance
Interactive Play Structures	●	●	●	○	○	○	○	●
High-Performance Track Surfaces	●	○	●	○	●	○	○	◒
Pool Ozonation	○	○	●	○	○	●	○	●
Energy-Generating Exercise Equipment	●	●	●	○	●	○	●	○
Outdoor DJ Booths	●	●	●	○	○	○	◒	○
Hard-Surface Testing Equipment	○	○	●	●	○	○	○	●

● Indicates technologies that provide a positive benefit for a value criterion.

◒ Indicates technologies that represent a secondary effect on a value criterion or have a trade-off between their benefits and drawbacks.

○ Indicates technologies that have no effect, a negative impact, or are unrelated to the value criterion.

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Chapter 8

Chapter 9: Urban Furniture and Amenities

URBAN FURNITURE AND AMENITIES include structures and artifacts in public parks that visitors use for a variety of activities and services. These include park benches, trash cans, restrooms, and drinking fountains. Urban furniture and amenities are vital for the comfort and engagement of park visitors. In some urban public spaces, "hostile urban architecture" is employed to prevent certain uses and types of users.[1] This may include benches with dividers to prevent sleeping,[i] and bars and spikes to prevent prolonged seating. While intended for crime

[i] Some benches are designed to be uncomfortable after prolonged sitting or have separated seats or arm rests to deter people from loitering too long or sleeping on park benches.

prevention and safety, such designs often make spaces undesirable and discourage all use.[1] Increasingly, some cities have pursued a new approach of creating more livable public spaces using nimble and user-friendly urban furniture.[2] As central gathering places and locations for relaxation and recreation, community parks can also use this approach to develop more usable public spaces.

New technologies can be incorporated in parks to make them more habitable, pleasant, and easier to maintain and monitor. Many of these technologies use Wi-Fi connectivity. Chapter 11 includes additional information on how parks can use digital technologies. The present underutilization of parks, and the national push for people to be more physically active outdoors (including through the "Let's Move!" campaign launched by former First Lady Michelle Obama in 2010) should induce park managers to consider the simple technologies highlighted in this chapter that may increase park usage.

This chapter explores seven smart technologies that can help park managers rethink and redesign urban furniture and amenities in parks, enhance the visitor experience and make maintenance and operations easier and more effective. The technologies are smart benches; solar shade structures; solar-powered trash compactors; restroom occupancy sensors; smart water fountains; digital signs; and automatic bicycle and pedestrian counters.

Figure 9.1 credit: Pietro Leoni for Carlo Ratti Associati
Figure 9.2 credit: Carlo Ratti Associati

Figures 9.1 (preceding page) and 9.2 (right): Carlo Ratti's Sun&Shade canopy uses adjustable mirrors to optimize solar energy collection while providing shade. The canopy creates an artistic display by spelling out words and designs in the shade below.

Credit: Soofa

Figure 9.3: While offering Wi-Fi access and charging capability, smart benches also can provide park managers with data on noise, air quality and visitors' activities.

Smart benches

What is this technology?

Smart benches are long seats, usually for several persons, that are outfitted with technological features. Most often, they are solar-powered and contain USB-charging ports for electronic devices, while some also serve as Wi-Fi hotspots. These benches can have sensors to monitor pedestrian activity, air quality, noise levels, and other useful information about parks. Smart benches can be purchased with these features, or traditional park benches can be retrofitted to perform some of these functions.

How does it fit into parks?

Smart benches can be used in place of traditional park benches. Park managers desiring Wi-Fi connectivity without the hassle of running wires or other infrastructure can select and easily install solar-powered smart benches with Wi-Fi capability, which simply need to be anchored to the ground before use.[3] This could attract park visitors who like to work in outdoor spaces, such as freelancers or others who typically work in coffee shops or other locations with Wi-Fi.

Smart benches can also be valuable to managers who want more data on park visitors. The data can be used to evaluate park performance or make the case for additional funding and improvements. For example, some smart benches have the ability to scan the Wi-Fi enabled devices in a park to determine how many and how long people are in parks.[4] If several such benches are used, they can indicate park usage and flow patterns. The benches could also serve as a tool to engage park visitors in citizen science projects, if they are outfitted with environmental sensors for air quality, temperature, or other data, as shown in the Real-World Example.

Why choose a smart bench?

Access – Wi-Fi-enabled benches can increase Internet connectivity for park visitors who may not otherwise have Internet access.

Health – If used to collect air quality and other environmental data, smart benches could inform citizens and the government about possible health hazards in the community and/or the park.

Energy – Since most smart benches are solar-powered, they generate clean energy rather than using fossil fuel-generated energy.

Operations and Maintenance – Smart benches can track park activity, allowing for more informed maintenance decisions, like frequency of trash collection based on visitor volume and timing. The benches can also provide data to evaluate the success of community events and programming or assist in long-range planning.

What are the challenges and trade-offs?

Maintenance – Smart benches may be susceptible to vandalism or extreme weather damage. Maintenance is minimal but may be a concern, as warranties to cover defects or breakage are often limited.[ii]

Location constraints – Like most solar technologies, smart benches must be placed in areas with adequate sunlight to be effective.

Data management – While the benches can collect important information, that data is worthwhile only if effectively used.

Bench features selection – Because of the diversity of smart bench features, it is important for managers to evaluate which are most appropriate or desirable for their park. For example, installing benches that provide Wi-Fi hotspots may be unnecessary if the city already has or is planning for a public Wi-Fi network. For benches that provide public Wi-Fi, there may be a conflict between users wishing to remain connected to their devices and those who want parks to be device-free spaces.

Takeaways

Smart benches offer visitors seating and can provide access to the Internet, track park usage, and/or gather environmental data. The information can be useful to engage the community, streamline operations, and monitor park use.

[ii] As an example, Soofa works closely with its customers to address maintenance issues and allows for warranties to be purchased at $100 to extend coverage one to five years.

REAL-WORLD EXAMPLE

Take a Seat: The Village Green Project | 2013

Beginning in 2013, the U.S. Environmental Protection Agency installed eight solar-powered air quality monitoring stations on traditional park benches in parks, schools, or outside libraries and museums in Philadelphia; Washington, D.C.; Oklahoma City; Kansas City; Hartford; Chicago; Houston, and Durham.[5] The equipment, such as the one at the Kansas City Village Green Project station (Figure 9.4, right), provides readings every minute on particulate matter, ozone, wind speed and direction, temperature, and humidity. This data can be accessed by citizens, researchers, and community organizations through a website.[5] The smart benches not only provide a gathering place for the community to engage in citizen science projects but they also offer an opportunity to learn about air quality and other environmental conditions in their neighborhood.

Credit: EPA

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Credit: ParknShade Inc.

Figure 9.5: A solar shade parking structure provides cover from the sun while generating electricity for other uses.

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Solar shade structures

What is this technology?

Solar shade structures offer refuge from the sun while using solar panel technology to generate clean energy. The structures can be patio umbrellas, canopies over picnic areas, or larger solar structures over parking lots. Simple models include a solar panel in a patio umbrella, making it possible for users to charge USB devices from the stem of the umbrella.[6] More complicated umbrellas and canopies use sensors and motors to move with the sun for maximum solar energy collection and cooling benefits.[7,8] Some models of solar shade structures are portable, creating more flexible use.

How does it fit into parks?

Solar shade structures can be incorporated into the design of new parks or replace traditional shade structures in existing parks. These structures protect park visitors from the sun and heat, while also allowing them to charge their devices or generate energy for other on-site uses. Portable patio umbrellas can be easily moved to different locations based on need and demand.

Park managers can also use solar shade structures to create unique and innovative park features. For example, as part of the Dubai 2017 World Government Summit exhibit "Climate Change Reimagined," architect Carlo Ratti designed a prototype of a shade canopy that uses programmable mirrors to track the sun and cool outdoor spaces.[7] The canopy roof is made of motorized round mirrors that follow the sun to ensure optimum shade coverage. The mirrors reflect the light toward nearby solar panels creating clean, renewable energy. They can also be programmed to spell out words or design patterns in the shaded area below for an engaging user experience (see Figure 9.1 and 9.2 at the beginning of this chapter).[7]

Why choose solar shade structures?

Health – Solar shade structures provide shade, especially if the model chosen tracks the sun, which offers cooling relief to park visitors and reduces the risk of heat stress and sunburns.

Resilience – New shade structures can provide areas of cooling relief for park visitors, which may be increasingly important as temperatures rise due to climate change.

Energy – By generating solar energy, umbrellas and other shade structures can provide amenities such as cell phone charging without using energy from the grid. Larger solar canopies can generate enough electricity for on-site uses such as lighting.

Credit: ShadeCraft

Figure 9.6: The Sunflower Umbrella has Bluetooth speakers and uses sensors and solar power to automatically unfurl the shade and track the sun for optimum coverage.

What are the challenges and trade-offs?

Vandalism and damage – Solar shade structures may be vulnerable to vandalism. Free-standing umbrellas, similar to traditional patio umbrellas, are at risk of theft or damage in strong weather conditions. Umbrellas may need to be stored indoors when not in use.

Location constraints – As with other solar technologies, they must be placed in areas with adequate sunlight to be effective.

Takeaways

Solar shade structures provide protection from the sun, like traditional umbrellas and canopies, while collecting solar energy and providing services, such as cellular phone charging. By optimizing shade, generating clean power, and providing an opportunity to increase awareness of local renewable energy sources, these technologies can enhance visitors' experience in parks.

Credit: The Daily Bruin

REAL-WORLD EXAMPLE

Charging Up Under Cover | Los Angeles, California | 2017

In 2017, the UCLA Renewable Energy Association (REA), an organization dedicated to generating and raising awareness of clean energy on campus, placed four solar panel umbrellas with USB ports that can charge electronic devices with renewable energy outside Bruin Café (Figure 9.7, above). The goal was to increase awareness of sustainability efforts and solar technology on campus.[6] REA chose this location due to its high foot traffic and abundant sunlight. The umbrellas can be moved as needed, based on demand for shade and USB charging.[6]

Solar-powered trash compactors

What is this technology?

Solar-powered trash compactors are waste, recycling, or compost bins with solar panels. They crush and compress bin contents using clean energy. These bins allow for increased collection and keep pests away because containers remain closed.[9] Some compactors have sensors that track fullness and alert maintenance when it is time to empty. Others have Internet-connected software to optimize trash collection routes.[9] Solar-powered trash compactors also offer features like advertising and design options, ashtrays, and Wi-Fi connectivity.[9,10]

How does it fit into parks?

Solar-powered trash compactors can be incorporated into the maintenance plans for new parks, be placed in areas where more waste management is needed, and/or replace traditional trash, recycling, or compost bins for more efficient maintenance. Waste collection in parks is often inefficient; some bins overflow, while others are emptied too often.[9]

Advertising on the compactors could generate additional revenue, educate visitors, or help disseminate information from the city or

Credit: Wikimedia Commons

Figure 9.8: Solar-powered trash compactors like these on a Mission Viejo, California, street require less maintenance than traditional cans or bins.

parks department.[9] Custom, as well as vandalism-resistant, design options can be selected based on need. Trash compactors can also reduce the need to manage pests at waste sites.[9]

Why choose a solar-powered trash compactor?

Health – Solar-powered trash compactors can reduce health hazards by minimizing instances of waste overflow and by preventing insects and pests.

Energy – Solar-powered trash compactors use the sun's energy, thereby reducing the need for fossil fuel-generated energy.

Operations and Maintenance – Solar-powered trash compactors significantly reduce maintenance needs by compressing the waste, alerting staff when collection is needed, and optimizing trash collection routes.

What are the challenges and trade-offs?

Damage and maintenance issues – Solar-powered trash compactors, as any park amenity, are susceptible to vandalism, damage, and theft. Aluminum handles, which are on some models, can become too dirty for use or be stolen for scrap metal.[10] Models with foot pedals ensure that the units can still be opened and operated without handles. Additionally, sensors could malfunction and require software updates or specialized maintenance to ensure accurate notification of trash levels.[11]

Staff expertise and training – Park staff may be unfamiliar with the technology, making it harder to adopt and/or adequately maintain the compactors.[11]

User issues – The public may also be unfamiliar with trash compactor designs and may not know how to utilize them effectively. Proper signage and information campaigns may be required.

Takeaways

Solar-powered trash compactors can streamline collection, prevent overflows, minimize pests, and encourage increased recycling and proper waste disposal. Staff must implement a strategy to routinely check that sensors are working properly and may need to consult maintenance specialists for repairs. Park managers should select designs that are appropriate for their community.

REAL-WORLD EXAMPLE

Clean Trash Compactors
Santa Clarita, California | 2013

In 2013, the City of Santa Clarita, California, installed 34 solar-powered trash and recycling compactors in parks and other public spaces around the city (Figure 9.9).[12] Staff monitor the bins via a mobile application instead of making daily in-person trips to each can. After operating the bins for five months, the city noted that it collected 2.5 tons more recycled material than previously collected from traditional recycling bins.[12]

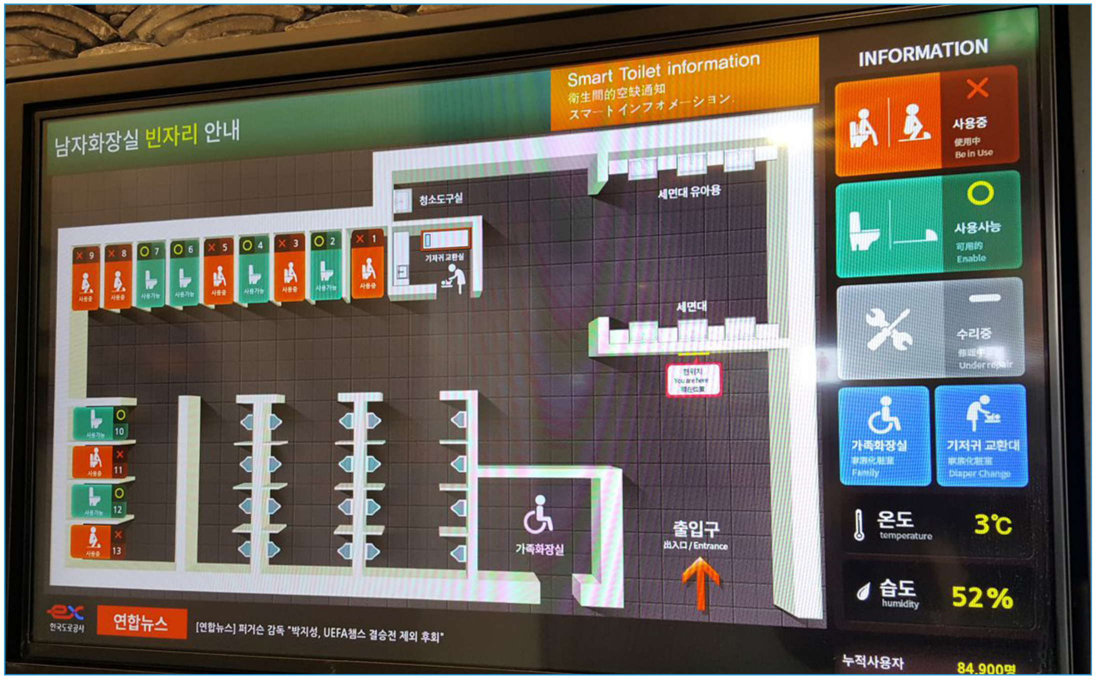
Credit: City of Santa Clarita

Chapter 9

Restroom occupancy sensors

What is this technology?

Restroom occupancy sensors detect when a stall is in use and present this information with colored lights (red for occupied and green for available).[13] The information is displayed above stall doors, in a mobile application (app) on users' cell phones, or on a monitor outside bathrooms.[14,15]



Credit: The Verge

Figure 9.10: A bathroom occupancy display in South Korea indicates which stalls are available and which are occupied in order to move people through lines more quickly.

The system consists of two components: the "smart lock" and the stall light. The lock has a sensor to determine when it is in use, and this information is then communicated wirelessly to the stall light, which displays occupancy status.[16] These sensors can reduce wait times; available traditional stalls often go unnoticed because doors appear closed or users do not notice a vacancy.[13] Additionally, the sensors and light signals eliminate the need for visitors to check underneath stalls for occupancy. This technology can also track use data to identify maintenance needs and trends[13] and whether additional facilities are needed.

How does it fit into parks?

Parks that host large outdoor events or serve as rest stops can use this technology to reduce wait times and increase privacy in frequently crowded bathrooms. Additionally, park staff can analyze use data to identify consistently unoccupied stalls, which may indicate a maintenance problem or a dirty stall.[13] By clearly indicating which stalls are available, park restroom lines can be reduced and move more efficiently. Women's bathrooms tend to be more crowded than men's, so managers wishing to pilot this technology on a trial basis should consider installation in women's restrooms first. At large venues, handicapped visitors may also benefit from seeing which bathrooms are not occupied or have available handicapped stalls, which could be identified through a different color light signal.

Why choose restroom occupancy sensors?

Access – By increasing privacy and reducing the need to check under stalls, occupancy sensors can create a more comfortable experience for park visitors and make it easier to use restroom facilities. About 10% to 15% of Americans suffer from Irritable Bowel Syndrome and more than 1 million suffer from Inflammatory Bowel Disease; both of which require sufferers' more frequent and immediate bathroom access.[17] Therefore, this technology can help visitors with these conditions feel more comfortable going to the park, since it will be easier for them to access restroom facilities.

Operations and Maintenance – Occupancy sensors for bathroom stalls with data tracking can alert staff to possible issues in consistently unoccupied stalls. They can also ensure more efficient operations by reducing wait times.

What are the challenges and trade-offs?

Size and use considerations – Restroom occupancy sensors may not be appropriate for small parks or those that do not experience overcrowding in restroom facilities.

Maintenance – As with any park amenity, the sensors or lights could be damaged, requiring money and time for maintenance.

Visual barriers – Color-blind users may have trouble distinguishing light signals indicating occupied and available stalls.[18] A potential solution is to use lights with different intensities. Parking garages using the same system often have green lights that are much brighter than red to help color-blind users distinguish between the two.[18]

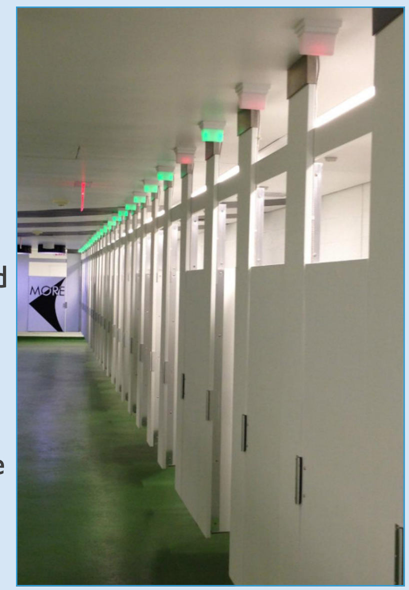
Takeaways

Restroom occupancy sensors can be helpful in parks with crowded restrooms, especially those that regularly host large events. By visually displaying which stalls are available or occupied, the sensors can increase privacy, reduce wait times, and alert maintenance staff to issues that need attention.

REAL-WORLD EXAMPLE

Keep the Lines Moving
Los Angeles, California | 2014

In 2014, the Hollywood Bowl, a music venue owned and operated by the Los Angeles County Department of Parks and Recreation, was the first to install Tooshlights, a restroom management system that lets guests "know where to go (Figure 9.11, right)."[16] The venue experienced reduced wait times and had many satisfied users, who appreciated the increased privacy and efficiency.[13] Tooshlights hopes to integrate its data into the venue's smartphone application so users can see which restrooms have the most available stalls.[13]



Credit: Andrew Bender

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Credit: Meet PAT - Products and Things Pty Ltd.

Figure 9.12: Fountains with advanced, unique features and designs encourage use, especially for park visitors with reusable bottles and those who otherwise might not have access to filtered, healthier water.

Smart water fountains

What is this technology?

Smart water fountains incorporate technology to make them more efficient and attract more usage. Technologies that can be paired with smart fountains include solar panels to chill or condense water from the atmosphere, filters to remove contaminants or improve taste, speakers to engage visitors, and sensors to monitor water quality and alert staff when maintenance is needed.[19,20,21]

How does it fit into parks?

Park visitors need to stay hydrated generally, especially in hot weather and when engaged in physical activity. Unfortunately, public trust in the quality of water from public fountains has been declining.[22] By providing new fountains with advanced features and designs, visitors may be encouraged to use them, thus making healthy, cheap, and environmentally friendly beverage choices.[22] Providing chilled and filtered water in specially designed fountains can also encourage the use of reusable bottles, which reduces waste. Many disadvantaged communities experience poor public water quality,[23] so parks can be an important access point for clean and reliable water. Some smart fountains can be interactive, encouraging park visitors to drink more water.

Why choose smart water fountains?

Access – Smart water fountains with filters can be a clean and reliable public water source, especially for disadvantaged communities that may suffer from poor quality water.

Community Fit – Smart water fountains can provide an engaging experience for park visitors to encourage water consumption (see the Real-World Example: Drink Up).

Health – Smart water fountains in parks can encourage healthy beverage choices, ensure high-quality drinking water, and provide chilled water to reduce the risks of heat stress. With rising levels of obesity in the U.S.,[24] there is an effort to promote drinking water over sugary beverages, and these fountains can help increase water consumption.

Water – Smart water fountains provide clean water and encourage park visitors to stay hydrated.

Energy – Some models of smart water fountains are solar-powered, thereby reducing the need for fossil fuel energy generation.

Operations and Maintenance – Certain smart fountains can monitor water quality and filter status to reduce maintenance needs.

What are the challenges and trade-offs?

Damage and Maintenance – As with any park amenity, smart water fountains may be at risk of vandalism or damage. These fountains may need more maintenance than traditional water coolers, such as the changing of filters.

Takeaways

Investment in smart water fountains in parks could provide clean water access, promote healthy beverage choices, save energy and money, and increase public confidence in water quality. Parks provide an ideal place for outdoor activity and, by installing smart drinking fountains, managers can encourage visitors to choose healthy options for hydration and promote physical activity.

REAL-WORLD EXAMPLES

These examples illustrate two ways smart fountain technologies can enhance parks. The first describes a fountain that engages with visitors to promote healthy behavior. The second example uses a technical approach to improve and monitor water quality.

Drink Up
New York City | 2014

In collaboration with the Partnership for a Healthier America, design collective YesYesNo designed Drink Up, a talking water fountain that encourages more water consumption.[25] When users touch their lips to the water, a pre-recorded voice gives compliments and makes jokes.[25] This encourages users to drink more water to hear the fountain talk. The smart fountain was placed in Brooklyn Bridge Park, and a promotional video with a hidden camera (Figure 9.13, right) showed footage of the amused and delighted reactions of users and passersby.[25]

Credit: Washington Free Beacon

Water Fountain Quality Assurance | Washington, D.C. | 2017

The company GrayMatter partnered with DC Water, Washington, D.C.'s water and sewer provider, to create a smart drinking fountain (Figure 9.14, left) that monitors water quality in real time.[26] Unveiled as a prototype in June 2017, the fountain uses sensors to provide data on water quality and flow that is stored online for remote access.[26] Alerts can then be sent to water managers when water quality deteriorates. The fountain can also shut off automatically when quality or flow drops below certain levels.[26] This is meant to prolong the life of the fountains, achieve lower maintenance costs, and improve both water quality and public confidence in water fountains, which has declined along with use.[26]

Credit: PRWEB

Digital signs

What is this technology?

Digital signs, such as LED screens or new LED transparent film applied to glass surfaces,[iii] can display images, text, and/or videos, which can be updated in real time. These technologies are not brand-new. In fact, LED screens are now ubiquitous in places like Times Square in New York City, where they are used for advertising. However, digital signs have not been typically featured in parks even though their capabilities have grown due to advancements in other technology (such as Wi-Fi connectivity). The signs can be simple monitors connected to a media player to display static information, such as a restaurant menu, or more complex systems connected to an online network that can be dynamically updated and incorporate video and rotating displays.[27] Dynamic signs require either a third-party service to manage and update the sign or park staff and online servers to make updates in-house. Some signs can be solar-powered, reducing energy costs.

Credit: Visix

Figure 9.15: A digital sign at a Utah transit station provides real-time information on bus schedules.

How does it fit into parks?

Parks can use this technology to disseminate important information to the public in an engaging format and/or to generate revenue by selling affordable advertisement opportunities for small businesses, as well as promote community services, events, or government information.Digital signs can provide rotating information, engaging and encouraging park visitors to read information they may have otherwise overlooked. Transit stations are beginning to display real-time transit information, which could be useful to display in parks near transit stops or where visitors often use public transit to access the park. [29]

[iii] This transparent film is a very thin self-adhesive that can be applied to glass to display images and text. It is updated via a unit controller. For more information on this new technology option see http://www.eenewseurope.com/news/transparent-adhesive-led-film-blends-digital-signage-within-surroundings

Why choose digital signs?

Access – Digital signs can provide park and local government information to citizens.

Community Fit – The signs can promote park programming or other information depending on the community's needs.

Energy – While digital signs generally increase energy consumption, some are solar-powered, which minimizes fossil fuel-generated energy needs.

Operations and Maintenance – Compared to traditional community notice boards, digital signs can be changed remotely and quickly to reflect updates and new information, eliminating the display of outdated or unrelated information.

What are the challenges and trade-offs?

Damage and maintenance issues – Like all park amenities, digital signs could be at risk of vandalism and damage. Additionally, signs connected via an online network could be hacked to display unauthorized information. It is therefore important that proper security systems be in place.[28]

Sign updates – Some signs may require a third party to update them, making it more difficult to provide timely changes or identify maintenance problems.[29] Managing the sign in-house requires staff knowledge and additional technological infrastructure such as servers.[31]

Staff expertise and training – All new technologies require park staff to adapt and learn how to use them effectively.

Aesthetics – Finally, since digital signs are often associated with urban settings, some park users may object to having digital signs in the more natural environment of a park.

Takeaways

As central gathering places for the community, parks have a unique opportunity to disseminate information to the public. Digital signs allow for real-time or frequently updated information to be presented in an engaging way. Software requirements, security concerns, and community needs should be considered when selecting or deciding to purchase digital signs. The location of the digital sign (possibly near park entrances or integrated on park building walls) should be carefully considered to maximize communication capacity but minimize adverse aesthetic impacts.

Credit: Soofa

REAL-WORLD EXAMPLE

A Sign of the Times | Boston, Massachusetts | 2016

In 2016, the City of Boston installed a solar-powered digital sign known as the Soofa Sign in Samuel Adams Park to provide information about local events, city services, and public transit (Figure 9.16, above).[30] The 32-inch sign encourages visitors to engage with the city via social media. Boston, and the nearby City of Cambridge, have since installed new 42-inch Soofa signs. This new model can be updated using the Soofa Talk website application and can feature upcoming events, maps, local artists, and advertisements.[31] The sign also allows for public engagement campaigns such as those using QR codes, which direct users to websites when scanned on a smartphone.[31]

Automatic bicycle and pedestrian counters

What is this technology?

Automatic bicycle and pedestrian counters collect data about the number of bicycles or pedestrians that pass by a given location during a specified time. There are a number of different types of counters, which can be battery-powered and located underground, on posts, or at street level. They use sensors, video cameras, or inflated tubes or metal strips (that detect bicycles or people passing over them) to obtain user counts.[32,33] Each is best-suited to particular locations and types of infrastructure.

Figure 9.1 – Credit: Eco-Counter

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Credit: Eco-Counter

Post (Figure 9.17, preceding page), pneumatic tube (Figure 9.18, above left) and plate (Figure 9.19, above right) are different types of counters that track bicyclists and pedestrians.

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Automatic counters track daily, monthly, or annual data that can be aggregated and displayed on location or on a website. The data can be especially helpful to planners and government officials who need to evaluate the status of infrastructure or advocate for improvements.[34] Without counters, officials must rely on intermittent clipboard surveys and census data, which tend to undercount biking and walking.[34] Some counters use visual displays to present how many bikes have passed. These displays could be located next to bicycle stations with air pumps or other bicycle maintenance equipment to create a more bicycle-friendly street or path that encourages active transportation.[34]

How does it fit into parks?

Park managers may wish to collect data about specific bike or walking paths. Such data can give them information about park use and help them plan operations, programming, and other services. Counters in parks could be part of a larger citywide effort to track bicycle usage. Additionally, counters can creatively engage visitors with interactive displays that encourage more physical activity, while anonymously collecting data.[34]

Automatic counters that rely on sensor strips, plates, or inductive loops[iv] can be located underground, while those that utilize video cameras or other sensors can be mounted on posts, streetlights, and

[iv] Inductive loops are installed in the pavement and can detect and count when something metallic moves over them. They are used for counting cars in the road or bikes on bike paths. They do not count pedestrians.

other equipment in parks.[33,34] Some counters, such as air-inflated pneumatic tubes, which temporarily stretch across bike lanes, can be moved as needed.[33]

Why choose a bicycle or pedestrian counter?

Community Fit – If coupled with an interactive display, automatic bicycle and pedestrian counters can engage visitors and promote community interest in biking, walking, and other active utilization of park facilities.

Health – Visual displays or websites showing the prevalence of bicycling and walking in the area can encourage use of these modes of transportation. When people are aware of the number of bikers and walkers, they may be inspired and more likely to participate themselves because decisions to walk and cycle are influenced by social considerations such as attitudes, norms, and perceptions.[35] Counters may also raise awareness about active transportation by demonstrating that the infrastructure already exists to make bicycling or walking a viable transportation option.

Operations and Maintenance – Using sensors in place of traditional clipboard counts, commonly used by cities or park staff to evaluate bike usage, can free up staff time and produce more accurate data that is easier to collect.

What are the challenges and trade-offs?

Damage and maintenance issues – Like other park amenities, automatic bicycle and pedestrian counters could be at risk of vandalism, theft, and damage. The counters often come with a warranty[v], so replacement of failed units after the warranty expires could require expert maintenance assistance.[33]

Battery life – Some models have specified battery lives, after which replacement is necessary.[33]

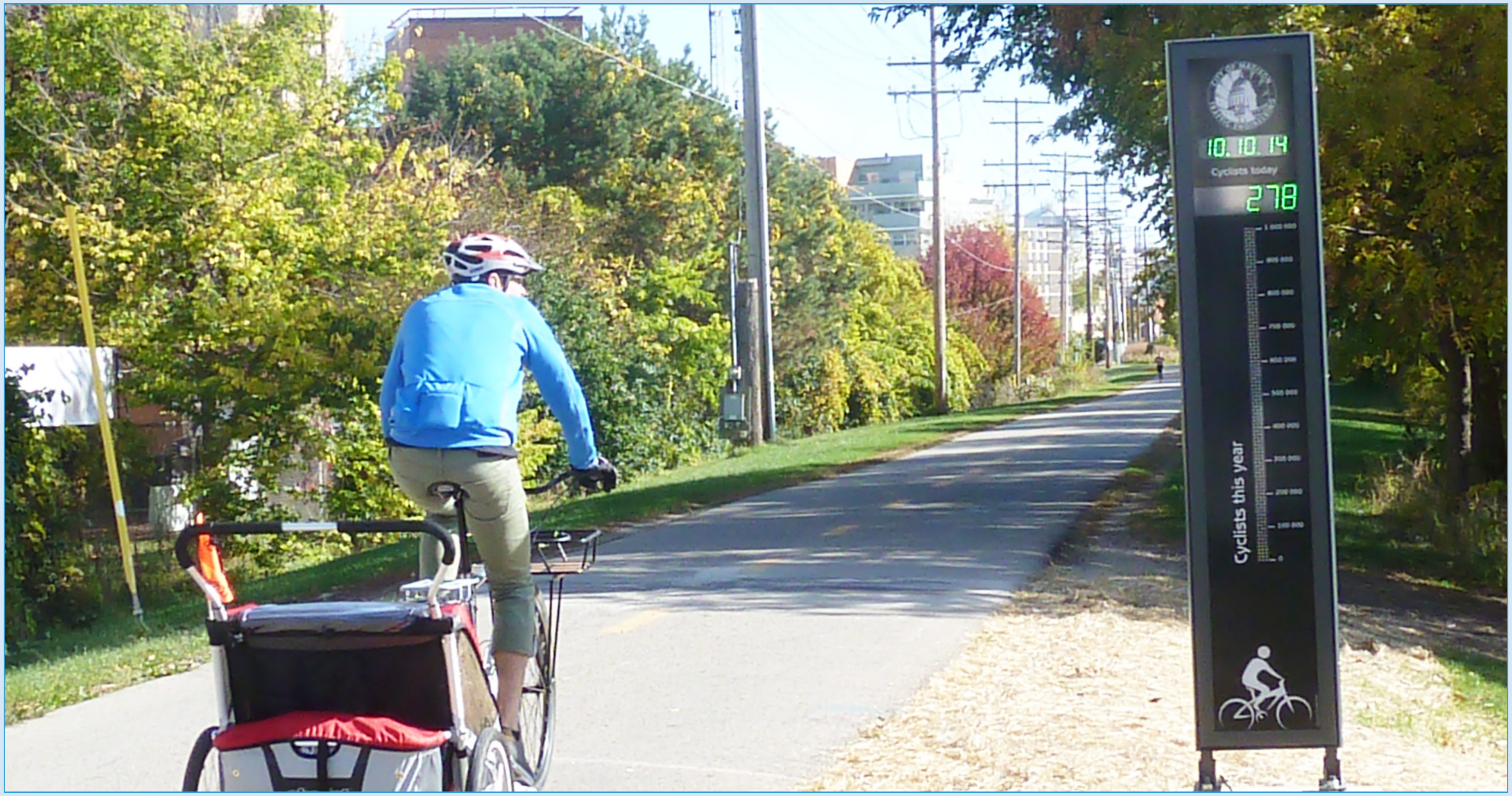
Sensor sensitivity – It is important to ensure that sensors are accurate and do not miscount traffic or become falsely triggered.

Data management – Counter displays can encourage park visitors to bike or walk more often. The data can help park management make decisions about which paths or trails are used most and to identify where upgrades may be needed. Park management will need to dedicate staff time to data collection, cleaning, and analysis. If managed effectively, the data could also be used to advocate for funding or new infrastructure at the local government level.

Takeaways

Automatic bicycle and pedestrian counters can be an effective way for park managers to track usage of parks and paths. In combination with visual displays and websites, counters can also serve as a public engagement tool to encourage physical activity and active transportation. In places where clipboard surveys or census data were previously utilized, counters can reduce staff time and improve data reliability. Data collection can enable performance evaluations of existing infrastructure by demonstrating how much use bicycle and pedestrian infrastructure receives, which may lead to support for new projects.

[v] EcoCounter's visual display comes with a two-year warranty.



Credit: Arthur Ross, City of Madison

REAL-WORLD EXAMPLE

Tallying Up Bike Riders | Madison, Wisconsin | 2014

In 2014, the City of Madison, Wisconsin, installed an automatic Eco Counter for bicycles with a visual display on a bike path near a busy intersection (Figure 9.20, above).[36] The city previously tracked bicycle usage with counters, but none included a visual display. Now riders can see the daily and annual number of riders that use the path as they pass by and on a website that aggregates and displays the data in a Google Maps-style interface.[36] The website is updated daily to highlight bicycling trends over time and space. The data can be compared with other Eco Counters across the city or globally.

Urban Furniture and Amenities component achievement levels

Depending on the technology selected, park managers and visitors can enjoy a variety of benefits, particularly under the Access, Health, Energy, and Operations and Maintenance Value Criteria. The table below illustrates the effectiveness of each technology presented in this chapter in achieving the different Value Criteria defined in Chapter 3.

	Access	Community Fit	Health	Safety	Resilience	Water	Energy	Operations and Maintenance
Smart Benches	●	○	◐	○	○	○	●	◐
Solar Shade Structures	○	○	●	○	●	○	●	○
Solar-Powered Trash Compactors	○	○	●	○	○	○	●	●
Restroom Occupancy Sensors	●	○	○	○	○	○	○	●
Smart Water Fountains	●	◐	●	○	○	●	◐	●
Digital Signs	●	●	○	○	○	○	◐	●
Automatic Bicycle and Pedestrian Counters	○	◐	◐	○	○	○	○	◐

● Indicates technologies that provide a positive benefit for a value criterion.

◐ Indicates technologies that represent a secondary effect on a value criterion or have a trade-off between their benefits and drawbacks.

○ Indicates technologies that have no effect, a negative impact, or are unrelated to the value criterion.

Chapter 9

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Chapter 9

Chapter 10: Lighting

LIGHTING can help extend the hours of park use as it greatly influences individuals' willingness to visit a park after sunset. The combination of programming and lighting can increase park access, community fit, safety, and health. Many cities have implemented programs that extend park hours and appeal to families. While a major facet of these programs is the additional resources, events, and classes available, the central role of lighting in encouraging increased community use of park spaces is also a critical factor.

Park managers must comply with city, county, and/or state lighting standards and make decisions about the materials, types, and color rendering index (CRI)[i] of light bulbs for their parks. These decisions may directly impact safety in parks.

[i] The color rendering index (CRI) measures the ability of a light source to reveal the colors of objects faithfully compared to an ideal or natural light source. See Appendix D for more information on the CRI.

Well-lit areas experience less crime and make visitors feel more comfortable using them.[1, 2,3] Different types of light bulbs provide a different quality of light and have varying lifecycle impacts on the environment. Appendix D provides more information on the different types of light bulbs available.

Lighting choices also play a crucial role in addressing light pollution, which is the inappropriate or excessive use of artificial light that can cause adverse consequences for humans, wildlife and the climate.[4] LEDs (light-emitting diodes),[ii] discussed in this chapter, can be beneficial for energy use and cost but may increase light pollution because they produce brighter and more intense light than other bulbs.[5] The increasing adoption of LEDs, especially in developing countries, has contributed to a 2% increase worldwide in the brightness and geographic spread of artificial light shining at night in each of the past four years. Proper outdoor nighttime lighting choice and design, such as proper shielding, can reduce these effects (light shields are discussed later in this chapter).[4]

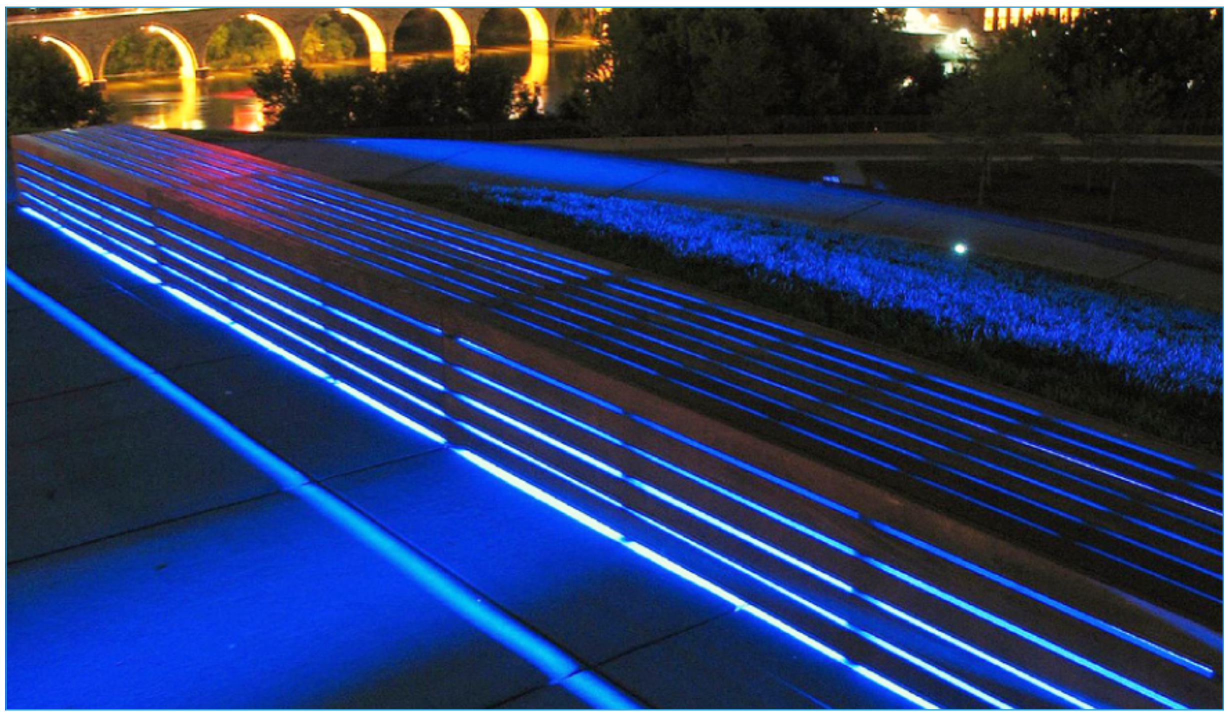
Lighting must be energy efficient. In 2016, the California Energy Commission adopted new standards calling for small-diameter directional lights, which are lights that have a diameter of 2.25 inches or less and point in a single direction, and general-purpose LEDs to have a minimum lifetime of 25,000 hours and an efficacy of at least 80 lumens per watt.[6] Powering park lights with renewable energy and programming lights to turn off when not needed can help increase lighting reliability and resiliency, decrease fossil fuel-generated energy use, and increase independence from the local power grid.

This chapter provides information on five technologies that can be used to enhance and improve lighting equipment in parks: motion-activated sensors; LEDs and fiber optics as art; off-grid light fixtures; digital additions to LED fixtures; and lighting shields. Some new hardscape materials, including piezoelectric energy harvesting tiles and daylight fluorescent aggregate, may also produce light, but these are covered in Chapter 7.

[ii] LEDs are semiconductors that release light when influenced by an electric current or field.

Credit: LA Discover the Pier/goldmedalpark.org

Figure 10.1, preceding page: Programmable LEDs light up Santa Monica Pier.



Credit: goldmedalpark.org

Figure 10.2, right: Benches lit with blue LEDs face the Guthrie Theater in Gold Medal Park, Minneapolis, Minnesota.

Motion-activated sensors

Credit: Pexels

Figure 10.3: Motion-activated sensors in park lighting can reduce energy use and light pollution by turning on only in the presence of visitors rather than remaining on at all times.

What is this technology?

Motion-activated sensors detect movement, via microwave or ultrasonic energy, and then activate a mechanical (e.g., a door opener), auditory (e.g., an alarm), or visual (e.g., a light) response.[7] The sensor sends out a burst of energy, which bounces off the nearest object and is reflected back toward the sensor. When someone moves into the path of energy emitted from the device, the sensor detects a change in infrared, or heat energy, the amount of reflected light, or the response time of the reflected light; it then triggers a response. This section focuses on the use of motion sensors with park lights.

Chapter 10

How does it fit into parks?

Motion sensors can be used anywhere in parks, including pathways, plazas, and buildings. They may be paired with park light fixtures ("motion-activated lights") to illuminate areas in use. Existing lights can be upgraded to use this technology, and new lights can include preinstalled sensors. Motion sensors can also help reduce light pollution by limiting the time that lights are active when not needed.[4]

Why choose motion sensors?

Safety – Motion-activated lights ensure that visitors can continuously pass through lit areas. Sudden activation of lights may deter potential criminal activity and make users feel safer.

Energy – Motion sensors could automatically dim lights when paths are empty, reducing energy consumption and costs.[8]

Operations and Maintenance – Motion-activated lights automatically turn on when visitors pass, thereby reducing staff time to operate lights manually.

What are the challenges and trade-offs?

Safety issues – Motion-activated sensors do not guarantee safety and should be used in conjunction with other safety measures. For example, motion sensors deactivate after not detecting change for a given time. This could present an opportunity for criminals to lie in wait.

Visitor comfort – The lights may turn off when visitors are idle, which could startle some users. However, a simple action such as waving an arm or walking around will reactivate them.

Takeaways

Motion-activated lights can increase security in parks, but should not be solely relied upon for safety. The use of motion sensors may deter criminals or aid in their capture. Sensors work passively and automatically, reducing energy costs and time spent by park staff managing lights.

Credit: Citelum

REAL-WORLD EXAMPLE

Smart Street Lights | Barcelona | 2012

Barcelona's Smart City initiative includes the Barcelona Lighting Masterplan (2012), which set and met the goal of installing LED bulbs on 1,100 lampposts (Figure 10.4, above) by 2014.[8] The city integrated motion sensors on lampposts to monitor pedestrian traffic and to automatically dim when streets were empty. Fifty percent of the city's lighting power is now controlled remotely, and the initiative reduced the lighting system's energy use by 30%.

LEDs and fiber optics as art

What is this technology?

This section focuses on two different technologies that can be used to create lighting designs: LEDs and fiber optics. LEDs (light-emitting diodes) are semiconductors that emit light when connected to an electric current or field. Fiber optics are thin, flexible fibers of glass or other transparent solids used to transmit light and telecommunications signals. They do not produce their own light, do not carry electricity, and do not emit heat or ultraviolet light, and therefore, can be safely used in wet conditions. Each technology can be computerized and variably shaped to create unique visual displays through a wide variety of physical arrangements and color combinations. They can also be used together: LEDs as the light source, which is then transmitted via fiber optics.

Credit: Amardeep M. Dugar

Figure 10.5 Fiber optics portray Michigan's constellations at Rosa Parks Circle, Grand Rapids.

How does it fit into parks?

LEDs and fiber optics can be used anywhere in parks to form artistic expressions and enhance space quality. This includes indoor and outdoor venues, such as pathways, fields, buildings, and seating areas.

Why choose LEDs and fiber optics?

Community Fit – Creative lighting may enhance the space and provide artistic expression to increase visits and strengthen community identity through place-making.[iii]

Safety – Lighting displays may attract visitors to previously underutilized areas of the park, thus contributing to park use and safety.[9] Fiber optics may be safely used in wet conditions and in public areas without risk of electrocution and ultraviolet light exposure.

Energy – Fiber optics can distribute light widely from a few active bulbs without requiring electricity themselves, therefore reducing the amount of energy consumed.

Operations and Maintenance – Artistic light displays formed of LEDs and fiber optics may be computerized to automatically change color at various times with minimal supervision.

What are the challenges and trade-offs?

Maintenance and damage – Small LEDs and fiber optics are often fragile. If they break, they require costly maintenance or replacement. Furthermore, in displays when many small lights are inactive simultaneously, it can be difficult to determine if all need replacing or if only a small handful are blocking power to the others. A digital monitoring system may make maintenance more efficient, but with an added cost. LEDs and fiber optics should be covered with glass, transparent plastic, or a metal frame to deter vandalism.

[iii] Place-making is the concept of creating public spaces that are at the heart of a community, improving neighborhoods, cities, and regions. See https://www.pps.org/reference/what_is_placemaking/.

Credit: Echelman

Figure 10.6: Computerized LEDs on Her Secret is Patience, an aerial sculpture in Civic Space Park in Phoenix, Arizona, change color seasonally.

Takeaways

Smart lighting technology can enhance aesthetics, while minimizing energy consumption in parks. LEDs and fiber optics may be used separately or together to enhance a park's aesthetic quality; increase its safety; and provide an opportunity to engage local artists and reflect community culture. Furthermore, unique art may allow a park to stand out among others, attracting media attention, donations, and increased local funding.

Credit: LA Discover the Pier

REAL-WORLD EXAMPLE

Reinventing the Wheel | Santa Monica, California | 2016

Pacific Park, consisting of 12 rides and 14 midway games, is a central attraction of the Santa Monica Pier (Figure 10.7, above). The park hosts the world's only solar-powered Ferris wheel.[10] When the Pacific Wheel opened in 1996, it was illuminated by 5,392 red, white, and blue incandescent bulbs.[11] In 2008, the city replaced the bulbs with 160,000 programmable LED lights, saving 75% of energy use.[12] In 2016, as part of the park's 20th anniversary celebration, the city replaced the already eco-friendly bulbs on the Ferris wheel with newer LEDs that save 6% more energy[12] and increase the potential color combinations from eight to 16.7 million and the imaging speed from three to 24 frames per second.

Off-grid light fixtures

What is this technology?

Off-grid light fixtures are independent of the local power grid and efficiently powered via renewable energy-generating devices, including solar panels and wind turbines.

How does it fit into parks?

Off-grid light fixtures can be installed anywhere in parks where there is access to a sufficient source of renewable energy. For example, solar panels on structures can provide clean power to the buildings and lights on nearby pathways, parking lots, and plazas.

Why choose off-grid light fixtures?

Safety – Lights powered by renewables could operate during a power outage, whereas those connected to the local power grid would be compromised.

Resilience – When outfitted with both solar and wind energy collectors, lights can operate in a variety of climate conditions.

Energy – Renewable energy reduces dependence on the local power grid, which is often powered by fossil fuels that emit greenhouse gases.

Credit: Philips, The Future of Light

Figure 10.8: Off-grid light fixtures, powered by renewables, enhance park safety because they could operate during a local power grid outage.

Chapter 10

Operations and Maintenance – Solar panels and wind turbines integrated into lighting fixtures eliminate the need to connect the light to the power grid, thereby reducing utility and installation costs.[13]

What are the challenges and trade-offs?

Operating conditions – Lights that are dependent on renewable energy are impacted by weather conditions. Current research and development in off-grid light fixtures focuses on increasing efficiency by expanding the range of operable conditions, including brightness thresholds for solar power and wind speed requirements for wind power.

Maintenance and damage – Inclement weather may damage solar panels or wind turbine parts. Solar panels may also be targeted by thieves seeking copper and other metals; therefore, a physical deterrent or barrier surrounding the light fixture may be necessary.

Takeaways

Powering efficient lighting fixtures with renewable energy sources can reduce or eliminate the need to draw power from the local grid. Initial installation costs of off-grid lighting may be much cheaper than that of traditional lighting. Park managers should consider whether their park has enough exposure to wind and sunlight before committing to a purchase. Managers can request an on-site analysis from industry professionals or representatives to identify the best park sites and positioning for renewable energy collection.

Credit: Leah/discoverairdrie.com

REAL-WORLD EXAMPLE

Off the Grid in the Park
Airdrie, Canada | 2014

Chinook Winds Public Park in Airdrie, Canada, installed off-grid LEDs on its pathways in 2014 (Figure 10.9, above). The wind turbine and solar panel on each light fixture produce 1 kilowatt-hour (kWh) of energy per day, enough to power the lights at night. Choosing off-grid lights cut installation costs by 50% and provided 80% more energy reliability than traditional grid-connected streetlights, based on energy storage and weather conditions. A custom site analysis was conducted to ensure lights were exposed to as much wind and sun as possible to efficiently produce energy.[13]

Chapter 10

Digital additions to LED fixtures

What is this technology?

LED fixtures illuminate when a semiconductor chip converts electricity into light. Each chip serves as a mini microprocessor with a circuit board to which sensors can be connected. Other light fixtures do not have circuit boards and therefore cannot connect to additional digital technology,[14] such as fiber optic sensors and Wi-Fi routers. These digital technologies can record and track light, noise, weather, water use and availability, air quality, pedestrian and vehicle traffic data, and also help increase Internet connectivity. They can be added to LED fixtures or purchased with preinstalled digital additions.

Fiber optic sensors use optical fibers to measure light intensity, temperature, sound, pressure, or air quality. These measurements are determined by light detectors in the optical fibers, which recognize variations in light signals caused by changes in light intensity, temperature, etc. These signals are then translated by the sensor into measurements that can be analyzed.[15]

Wi-Fi routers are devices that create wireless Internet connectivity by converting a wired Internet connection into a wireless signal that can be accessed by personal computers and smartphones.[16]

Credit: Cisco

Figure 10.10: Digital sensors enclosed within plastic cylinders on light fixtures can measure light intensity, temperature, sound, or air quality and transmit that data for analysis.

Chapter 10

How does it fit into parks?

Digital additions can be used with any LED fixtures in parks, such as along pathways, in plazas, and mounted on buildings. Fiber optic sensors can be installed to gather data on resource use for improved operations and maintenance. Wi-Fi routers can be attached to light fixtures to improve connectivity throughout the park.

Why choose digital additions to LED fixtures?

Community Fit – Integrating LED lampposts into park Wi-Fi networks could increase Internet coverage and allow visitors to connect to digital networks. They can potentially diversify opportunities for interactive programming, such as digital scavenger hunts that use smartphones' Internet connections to track users' real-time progress.

Safety – Audio sensors may be programmed to contact authorities upon detecting a particular decibel threshold or noise pattern, such as that of breaking glass or disruptive late-night gatherings.

Water – Digital sensors can track humidity, informing management decisions and reducing unnecessary irrigation.

Energy – Digital sensors can track ambient light levels and prevent fixtures from consuming energy when sufficient natural light is available.

Operations and Maintenance – Computerized lights can be remotely monitored, automatically alerting park managers when repairs are needed. Park managers and local agencies may use data collected by fiber optic sensors to make decisions, such as alerting authorities when the sound of breaking glass is detected; in day-to-day planning, such as deactivating sprinklers when rain is forecast; and in long-term planning, such as determining where to plant trees to improve air quality.

What are the challenges and trade-offs?

Toxicity – Some digital additions to LED fixtures may contain rare and toxic materials including arsenic and lead.[17]

Maintenance and damage – Sensors may be targeted by thieves seeking rare metals, therefore, a physical deterrent or barrier surrounding the light fixture should be used. A catch net could be installed to minimize breakage if the add-on falls during a storm or earthquake, or because of improper installation.

Data management and privacy – Data may require analysis from a third-party source, whose services could be expensive. Gathering and storing certain types of park usage data may raise privacy concerns among visitors because of potential exposure to hacking or the sale of data to third parties.[18]

Takeaways

LED fixtures in parks offer a number of opportunities to add sensor and communications technologies. With these additions, managers can collect and analyze information on crowds, noise, weather, resource use, air quality, and pedestrian and vehicle traffic throughout parks. Purchasing preinstalled add-ons to LED fixtures, or installing these additions to existing fixtures, might require extensive and costly setup. Staff might need to be trained to use the technology correctly. Park managers should be mindful of visitors' privacy when gathering and storing real-time data, as well as post a clear notice of what types of and for what purpose data are being collected.

REAL-WORLD EXAMPLE

Sensing the City Through Street Lights | Barcelona | 2012

Following its Lighting Masterplan adopted in 2012, the City of Barcelona installed LED bulbs on 1,100 lampposts (Figure 10.11, right).[8] The LED lampposts are hollow and contain fiber-optic signal transfer cables. Each lamppost has a unique digital identification code and serves as a telecommunications port that provides Wi-Fi and a platform for sensors that can monitor crowds, noise, weather, and traffic. These sensors streamline public services; for example, if there is a disturbance at night, the police are notified with the precise decibel level.[19]

Credit: Joan Thomas/Fortune

Chapter 10

Credit: U.S. Air Force

Figure 10.12: Light shields such as the flat version above focus the illumination, thus reducing light pollution and glare that can irritate the eyes.

Lighting shields

What is this technology?

Lighting shields are opaque fixture covers, often made of metal or plastic, that restrict the shine angle of a light source. By partially enclosing light fixtures, illumination is less diffuse and more focused, reducing light pollution by redirecting light downward. This provides increased illumination below, lessening the need for additional light sources. It also reduces glare, or light that emanates horizontally from the source and irritates eyes without illuminating the ground. Shields can be lined with reflective material (see the Real-World Example), which can increase lighting intensity by redirecting light that would otherwise be absorbed by the shield. Lighting shields come in various shapes and sizes, such as flat and rectangular (Figure 10.12, above) or domed (Figure 10.14). Some fixtures come with lighting shields preinstalled; others can be refitted with shields later.

How does it fit in parks?

Lighting shields may be used on new and existing fixtures in all areas of the park, by placing a cover around each light source. Light shields can be an important part of a strategy to reduce light pollution, since they reduce glare and target light more effectively to the area requiring illumination.[4] According to the National Park Service, 50% of the emitted light from unshielded fixtures shines directly into the atmosphere and scatters off molecules and aerosols before being reflected toward the ground as sky glow, a distinctive light over cities. Up to 30% of total outdoor lighting in the United States enters the atmosphere unused, and the corresponding resources wasted in generating sky glow and light pollution may total up to $1.7 billion per year.[20]

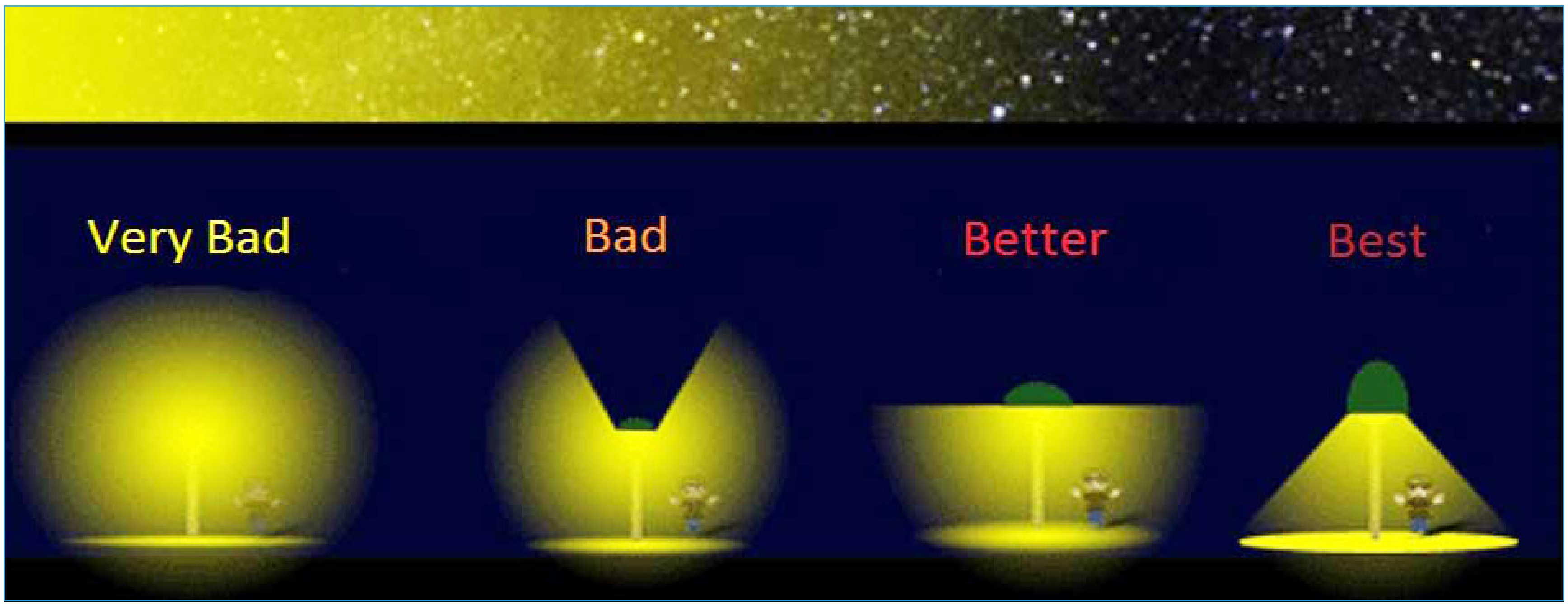
Why choose lighting shields?

Community Fit – Reduced glare and light pollution may make it easier to view the nighttime sky, providing opportunities to expand informal or programmed stargazing in parks.

Health – Lighting shields reduce secondhand exposure to blue light, a type of light that some LEDs produce in concentrations sufficient to disrupt sleep cycles and eye health.[21]

Safety – Reducing glare and providing more focused light offers increased color rendition and visibility, both of which allow park users to better identify details of park features and other visitors.

Energy – Lighting shields on low-power fixtures provide more efficient illumination, thereby saving energy.



Credit: National Park Service

Figure 10.13: Different degrees of shielding determine the amount of light that enters the atmosphere unused.

Operations and Maintenance – Lighting shields allow light sources to efficiently illuminate the ground, thereby reducing the need for new fixtures.

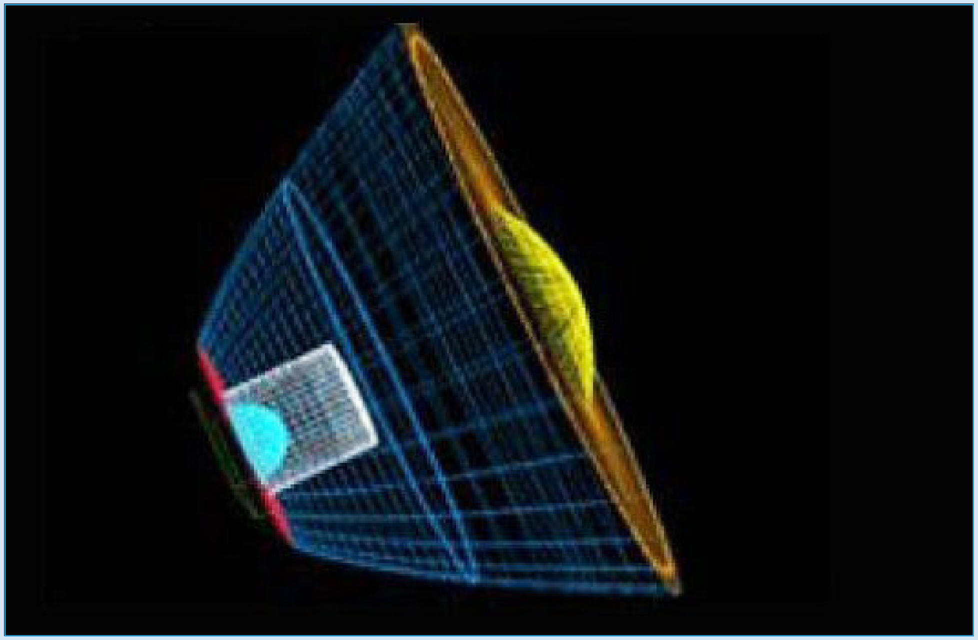
What are the challenges and trade-offs?

Visibility – Light absorbed by shields may not reach the ground, reducing visibility. Reflective coatings can help address this.

Safety – A shield's weight may pose added risk of falling and breakage; however, this risk is minimal on new light fixtures due to manufacturer safety precautions.

Takeaways

Lighting shields on park fixtures can refine light quality at relatively low cost. For existing lights especially, adding shields can reduce or eliminate light pollution and glare, ensuring higher-quality illumination. Continued research and development into lighting shield design using a variety of materials may further optimize the quality of illumination.



Credit: New Atlas

REAL-WORLD EXAMPLE

Shedding Light on a New Shield Design | 2013

Figure 10.14 , above, shows a shield design created in 2013 by researchers at Taiwan's National Central University and Mexico's Universidad Autónoma de Zacatecas.[21] LEDs were equipped with reflective lenses that focused light into parallel rays. The inside of the shield was also lined with a reflective material to prevent light from scattering. Finally, light was filtered to reduce glare. This new lamp and shield met the researchers' goal of using energy efficiently to project a uniform rectangle of light over a given area, while limiting areas of increased glare and light pollution.[21]

Chapter 10

Lighting component achievement levels

SMART parks use lighting technology to enrich park safety, programming, and operations while minimizing energy consumption, light pollution, and other environmental impacts. Light fixtures may be outfitted with shield covers, Wi-Fi, and/or digital sensors to optimize directional efficiency, connectivity, and operations and maintenance. Lights can be arranged creatively: not only to direct park visitors but also to showcase artwork and/or illustrate a unique cultural or physical element of the area. The table below illustrates the effectiveness of each technology in achieving the different Value Criteria defined in Chapter 3.

	Access	**Community Fit**	**Health**	**Safety**	**Resilience**	**Water**	**Energy**	**Operations and Maintenance**
Motion-Activated Sensors	○	○	○	●	○	○	●	●
LEDs and Fiber Optics as Art	○	●	○	●	○	○	◒	◒
Off-Grid Light Fixtures	○	○	○	◒	●	○	●	●
Digital Additions to LED Fixtures	○	◒	○	●	○	◒	◒	●
Lighting Shields	○	◒	●	●	○	○	●	●

● Indicates technologies that provide a positive benefit for a value criterion.

◒ Indicates technologies that represent a secondary effect on a value criterion or have a trade-off between their benefits and drawbacks.

○ Indicates technologies that have no effect, a negative impact, or are unrelated to the value criterion.

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"DIGISCAPES"

describes digital technologies[i] and applications (apps) that collect data that can be used to enrich park access, safety, programming, operations, and interactions between park managers and users. This chapter presents four digital technologies that could help park managers: Wi-Fi; geographic information systems and services (GIS); application software (apps); and sensor networks and the Internet of Things (IoT).

[i] Digital technologies are electronic tools, systems, devices and resources that generate, store or process data. These include social media, online games and applications, multimedia, productivity applications, cloud computing, interoperable systems and mobile devices. More information can be found at: http://www.education.vic.gov.au/school/teachers/teachingresources/digital/Pages/default.aspx.

Chapter 11: Digiscapes

The use of digital technologies has become widespread in urban areas in the United States.[ii] As of 2018, 9,000 hotspots were provided in municipalities across the U.S., a 49% increase since 2013.[1] Given the ubiquity of digital technologies, smartphones, and social media among modern city dwellers, the availability of public Wi-Fi and the opportunity to use digital apps can increase the appeal of urban parks. Mobile device users tend to spend more time in public spaces than nonusers,[2] suggesting that park visitors may be more likely to use mobile devices. Contrary to some concerns, digital communication in public spaces does not necessarily hinder interaction among people; it can facilitate conversations about the news of the day, encourage shared social activities, and allow park users to share experiences via photos and videos.[3] Therefore, park managers should consider how best to reach these users.

Many modern mobile devices and sensors are compatible with the Internet of Things (IoT), a network of electronics and software that enables communication between digital devices and the remote collection, storage, and sharing of data through the Internet. Applying the IoT to automate processes and increase labor productivity may generate up to $4.6 trillion over the next 10 years for public sector services,[4] including parks.

[ii] In the United States, 77% of adults use smartphones (92% of those ages 18 to 29 and 88% of those ages 30 to 49),[74] and 69% of adults use social media.[2]

Credit: Iamlivingit.com

Figure 11.1 (preceding page): Apps can quickly provide park information on location and give real-time directions.

Credit: Wikimedia Commons

Figure 11.2: A street-side sign in Seattle provides instructions to connect to the city's free wireless network.

Wi-Fi

What is this technology?

Wi-Fi allows personal electronic devices to connect to the Internet without a wired connection.[5] Modems and network hardware devices enable Wi-Fi by transferring data to and from the Internet and Wi-Fi-capable devices such as smartphones, computers, digital audio players, cameras, watches, and printers.[6,7]

Wi-Fi can serve multiple people over wide areas, called "hotspots," if used with routers, wireless access points (WAPs), and switches. Routers allow multiple devices to connect to the Internet simultaneously through a single modem, also acting as a decoder to translate the modem's signal into usable data for multiple Wi-Fi- capable devices.[6,8] The router and modem together create the central hub for Wi-Fi connectivity. A WAP is any device that allows other devices to connect to the Internet wirelessly. Thus, all wireless routers are WAPs.[9] WAPs can extend the reach of routers giving a wider area access to Internet connectivity.[9] Finally, switches enable communication between multiple connected devices.[10] They are beneficial for directing the traffic of incoming information from each device to specific destinations, instead of allowing information to be shared among all connected devices, which can otherwise slow performance and increase security risks. Routers contain some switches; however, additional switches may be wired to routers as necessary to handle a large amount of information and/or devices. While useful for areas with high user traffic, switches are especially applicable to sensor networks and the Internet of Things, described later in this chapter.[11]

Credit: Pexels

Figure 11.3: Parks that provide free Wi-Fi may attract visitors wishing to enjoy the outdoors while staying connected to social media.

How does it fit into parks?

Managers can create free, public Wi-Fi hotspots anywhere in parks by installing a central hub, or modem and router, and a system of WAPs. Wi-Fi hotspots eliminate the need for park visitors to pay for or link to nearby networks.[iii] While many digital technologies have

[iii] Managers could opt to charge users for Wi-Fi access (as they do in some New York City parks; see https://www.nycgovparks.org/facilities/wifi). However, free Wi-Fi may attract more park visitors.

been widely adopted, access to the Internet at home is divided inequitably between low- and high-income households.[12] Parks can provide an important service by making Wi-Fi free and available to all visitors. Some urban furniture, including smart benches and solar-powered trash compactors, described in Chapter 9 of this toolkit, may serve as WAPs. Weather-proof WAPs can be inconspicuously mounted on light poles or building roofs to provide Internet connectivity outdoors.[4]

Wi-Fi hardware infrastructure, including routers, may be available through municipalities, companies, and community organizations for free or for a small fee. For example, the City of Los Angeles' park Wi-Fi system was installed by the American Park Network and paid for entirely by Toyota.[13] Park visitors may use Wi-Fi to work, study, watch videos, or instantly share pictures, videos, and other media of their experiences at the park.[14]

Why choose Wi-Fi?

Access – The availability of free Internet access may attract a wide variety of users, including those working and those using the park as a backdrop for social activities and networking. A joint study by the Hispanic Heritage Foundation, Family Online Safety Institute, and National Research Center for College and University Admissions found that nearly 50% of all high-school students surveyed said they were unable to complete a homework assignment because they did not have access to the Internet or a computer.[15] The Pew Research Center has found that African-American and Hispanic households are less likely to have a high-speed home connection compared to Caucasian or Asian households. Adding Wi-Fi to urban parks, especially those in predominantly Hispanic and African-American neighborhoods, can greatly benefit students.[12,15] Additionally, park users may use Wi-Fi to access park-related digital schedules to plan activities and reserve facilities.

Community Fit – Park users may use Wi-Fi to create and share digital content, such as pictures and videos, that capture their experiences in the park.[16] Wi-Fi may also enable park- and community-specific digital programming (see the example of Los Angeles State Historic Park later in this chapter).

Safety – Wi-Fi may improve reliability of communication between park personnel, users, and emergency service providers. Modern phones may use Wi-Fi to make calls when cellular networks are not available, and Wi-Fi-enabled devices may be easily located within parks, allowing for quicker emergency response.

Operations and Maintenance – Park managers can use Wi-Fi on-site to access administrative services and instantly upload and download data on water quality, plant health, or the number of park visitors.

What are the challenges and trade-offs?

Safety and privacy concerns – Public Internet access must have strong security, user policies, and manager oversight to ensure that the service is not used maliciously. Connection to digital networks is not always secured by password, and information from one device may be intercepted by another.[17] Thus, Wi-Fi users may risk their privacy.[18] Content filters and data encryption, however, can fortify Wi-Fi and protect users from hacking. Managers should develop clear language in user agreements to educate consumers about hacking, privacy loss, and other dangers.[19] To protect counties or municipalities from hacking, networks in parks should be separate from other government networks.[18]

User disruption – The proliferation of Wi-Fi and Internet access may disturb park visitors, who see the outdoors as an escape from digital technology. This may, however, be a larger issue for wilderness areas and exurban state and national parks that are more secluded than urban public spaces. Internet access could be confined only to the more public areas of the park, while leaving other activity spaces more secluded.[20]

Disposal concerns – Disposal can also be an issue for Wi-Fi, because some equipment contains metals or substances in potentially toxic concentrations. Managers should check manufacturer information for proper disposal.[21]

Wildlife impacts – Wireless device signals could hinder the health and behavior of wildlife species. Prolonged exposure to Wi-Fi radiation has been shown to discolor garden cress and hinder their growth.[22] An article in *Science* magazine concluded that pollinating bees may pick up on electrical fields from flowers and use these to determine which flowers to visit.[23] Wireless devices' signals could interfere, causing bees to become lost or disoriented.[24] Therefore, Wi-Fi equipment should be placed at least 3.5 feet away from sensitive flora.[25]

Takeaways

Free public Wi-Fi has high potential to attract new users to parks, including those seeking to work and study, create park-related content, or simply relax. Wi-Fi may also provide reliable communication during an emergency and when cellular networks are unavailable. However, public Internet access must be effectively secured and encrypted, and managers must weigh its potential impact on wildlife and visitors who do not wish to see digital technology entering the park's natural setting.

Credit: Ed Yourdon/Flickr

REAL-WORLD EXAMPLE

Parks Go Digital

Many parks around the country have added Wi-Fi. A 2010 study surveyed laptop users at seven urban parks (Bryant Park (Figure 11.4, above) and Union Square in New York, Rittenhouse Square and Reading Terminal Market in Philadelphia, Union Square in San Francisco, and Dundas Square and Nathan Phillips Square in Toronto) that offer Wi-Fi. The study found that 25% of laptop users had not visited the park at which they were surveyed before Wi-Fi became available. Of those who had previously visited, 70% reported that they visited more often since Wi-Fi had become available, and none reported that they visited less frequently.[14] Nationwide statistics on Wi-Fi availability in parks is limited, but some information is available for individual cities, including New York, Los Angeles,[13] and San Francisco.[26,27]

Credit: Wikimedia Commons

Figure 11.5 Data may be visually represented with GIS in 3D by overlaying various areas with blocks of unique shape and color.

Geographic information systems and services

What is this technology?

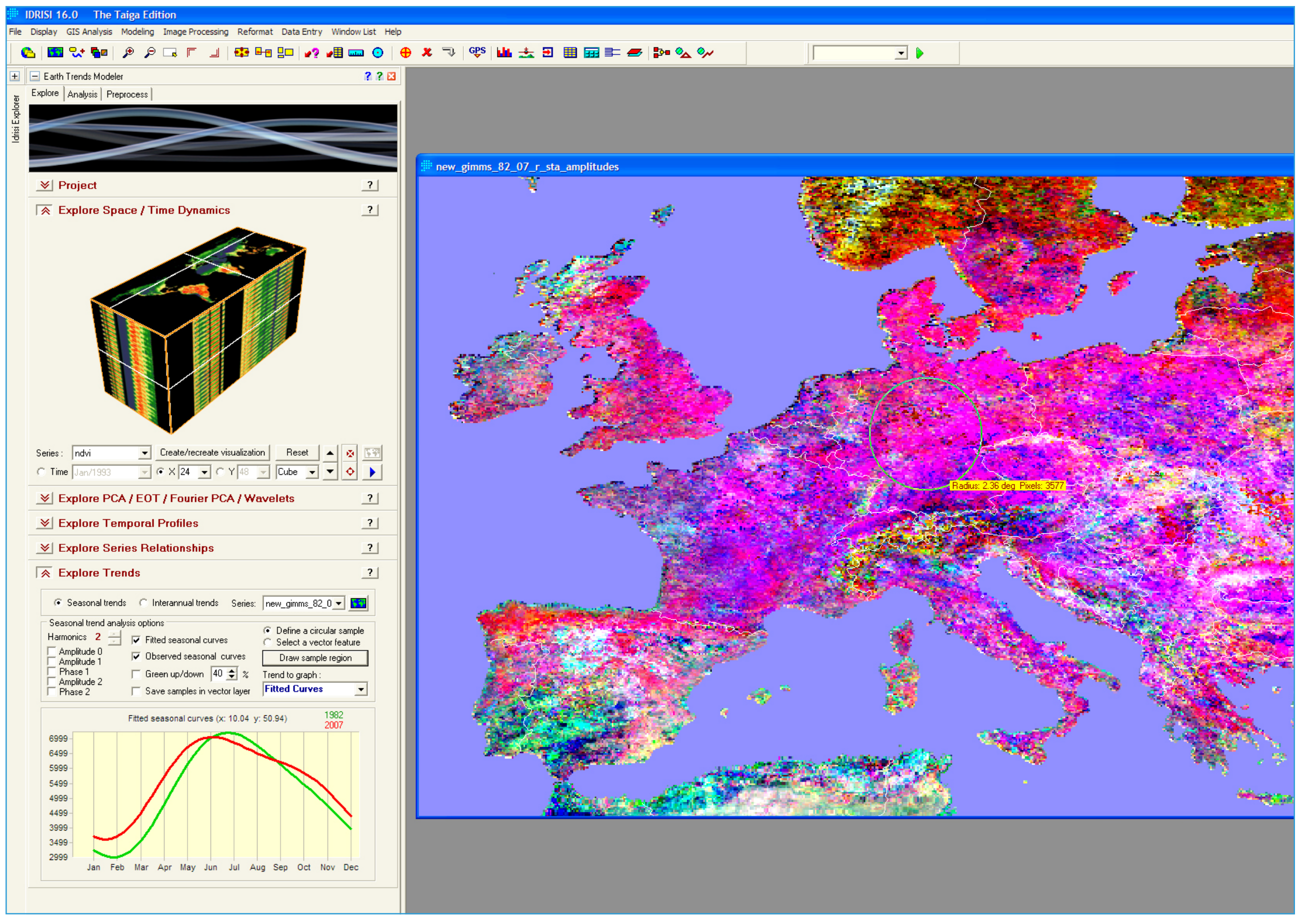
Geographic information systems and services (GIS) use digital software to capture, store, manipulate, analyze, manage, and present geographical data.[28] GIS is notable for how it displays information; each different data parameter, such as climate, air quality, and human health, is presented as an individual, uniquely colored layer of information overlaid on top of a two- or three-dimensional digital map. When viewing the map on a computer screen, each layer may be toggled visible or invisible such that any number of layers may be simultaneously viewed. By observing how layers overlap, and by noting the measurements of multiple parameters at a specific point on the map, potential trends and relationships may be drawn between land use, socioeconomic factors, environmental factors, etc.[29]

Information to be presented on a GIS map may be originally organized as tabular data; i.e., in rows and columns. Tabular data is useful for tracking changes in recorded measurements over time, as each row generally represents a measurement taken at a unique instant. To be presented on a GIS map, however, tabular data must be merged with spatial data, or information that identifies geographic locations through latitude, longitude, and topographical coordinates. This conversion may occur in several ways:

- GIS users may manually select a point on the map that corresponds to the location where data was collected.
- Sensors, cameras, and other devices that collect GIS-compatible data may contain built-in tracking devices that can relay their location to GIS software via radio waves and Wi-Fi signals.
- Computerized data from satellite images may already be associated with a specific geographic location, and this information may be transferred to the GIS software through functions built into the program.

Once tabular and spatial data are merged, GIS can summarize geographic data, compare measurements at a specific location, and measure geographic features such as the distance between two points on the map.

Data-collecting devices and GIS software may be downloaded or purchased from various retailers. GIS users may learn how to navigate the program through tutorials built into the software or professional training. Although an Internet connection is not required for all GIS services, it is often invaluable for storing backups of digital data.



Credit: Wikipedia

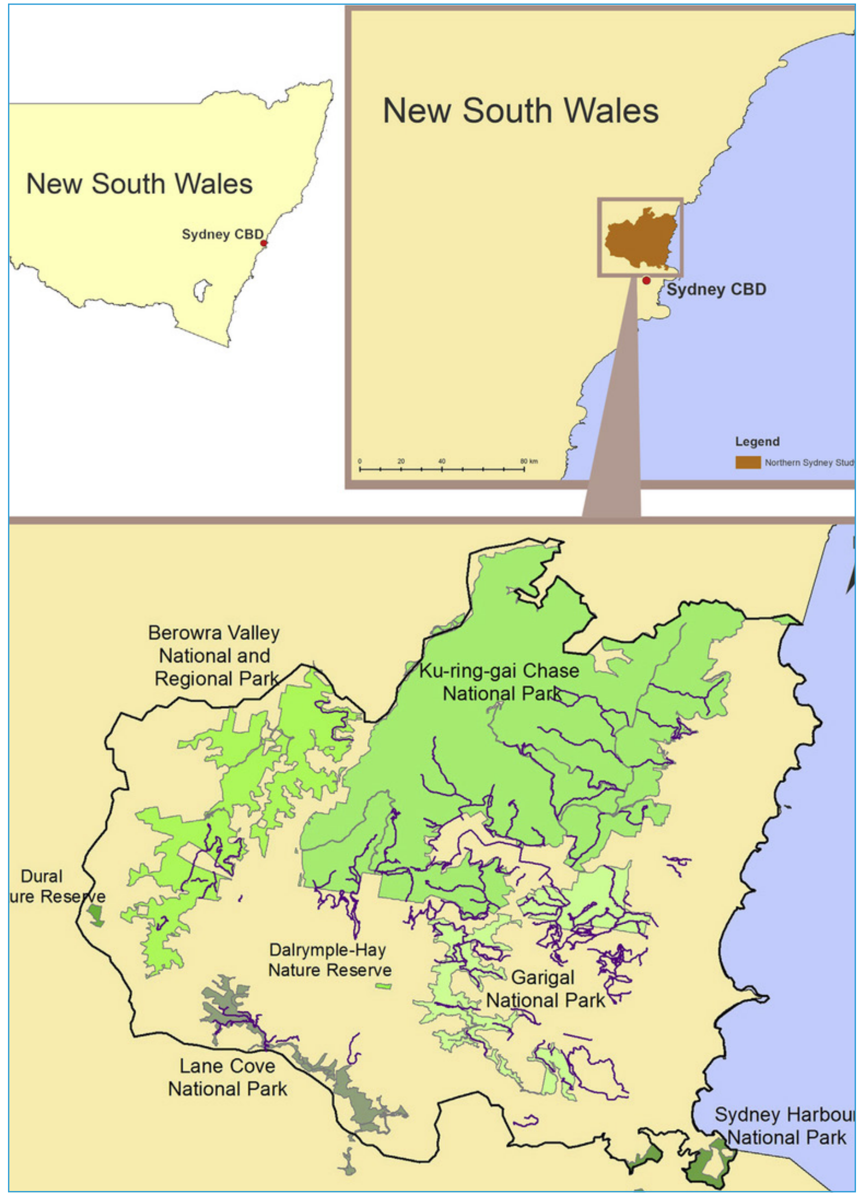
Figure 11.6 GIS software can provide various settings to display and graph data from different times and spaces.

How does it fit into parks?

GIS can be a useful planning and assessment tool for park managers and occasionally can provide opportunities for park visitors to contribute information about the park and its use. GIS can help managers identify locations for new parks or display an existing park's physical features. Physical park data that can be mapped and analyzed in GIS include the location of infrastructure, such as light fixtures and irrigation pipes,[30] and natural landmarks, such as plants and water sources. GIS can also display community population density; vegetation and soil distribution; wildlife habitat; sites that produce pollution and those that are sensitive to various types of pollution;[29] buildings and archaeological landmarks; wireless signals from cellular towers, mobile devices and Wi-Fi equipment; land and property values within and surrounding the park;[31] air, water, and soil quality;[32] water distribution, watersheds, and stream flows,[33] among others.

Management decisions can be informed by GIS findings. For example, park managers may use GIS to determine suitable habitat to accommodate wildlife.[32] To do so, map layers tracking vulnerable species of flora and fauna could be overlaid with those illustrating spatial distributions of predator species and climate. After determining the necessary habitat conditions for various endangered species, a map of all areas matching the requirements can be created allowing managers to see where these species could thrive.[34] GIS can also inform decisions about optimization of artificial watering patterns, light fixture placement, soil fertilization, and other components based on park characteristics as measured by manual field observations or digital sensors.

Park managers working with GIS can provide opportunities for park visitors to learn more about parks and/or to participate in creating educational and social media content for users. For example, the University of California, Davis Arboretum maintains GIS and digital maps linked to information about plant collections, including gene-



Credit: Researchgate.net

Figure 11.7: Maps, such as the above, can be used in public participation GIS exercises. In Sydney, Australia, professional researchers used GIS maps to show park visitors specific locations where they could identify park activities.

alogy, propagation date, propagation success rates, and geographic range.[35] The maps are publicly accessible to visitors, students, and researchers, allowing users to find plants by location and name, or to create custom maps before their visit.[36] Some park data, such as topography and plant health, could be contributed by visitors as they explore the park. This method is called public participation GIS.[iv,37]

Why choose GIS?

Access – GIS data can help determine physical barriers to access (i.e., roads and parking availability) and psychological barriers (i.e., safety). It can map the linear distance between parks and residents as well as well-lit and safe routes (based on lighting and crime data) that pedestrians, cyclists, drivers, and transit users could take to access a park.

Perceived accessibility to parks may be a more reliable predictor of park use than geographic distance.[38] Park managers can use GIS as a tool to improve access to parks or determine locations of future parks. For example, a Korean study assessed the spatial distribution of Seoul's urban parks using GIS.[33] The study revealed an unequal distribution of park space that favored the southern area of the Han River.[33]

GIS could also be used to map the distribution of mobile hotspots, including smart benches and solar-powered trash compactors (see Chapter 9), and Wi-Fi strength, so that park managers can spot and address areas that lack wireless Internet coverage or have unnecessary hotspot overlap.

Community Fit – Public participation GIS, which collects data directly from park users, allows participants to express their opinions about how well the park provides benefits to its surrounding community and also to suggest how it can better serve visitors. GIS can also be used to track changes in property values and crime in the area surrounding the park by showing these statistics spatially on maps at different times.[29] This could help determine the impact of a park on its community.[31]

Health – By combining layers of a GIS map, park managers may simultaneously view spatial distributions of air quality data gathered by remote sensors, wireless signal data collected in field tests, human health data self-reported by park users, and plant health data mapped by near-infrared plant photography (see Chapter 4). Overlaps between layers can help identify causes of health problems. For example, if an area is marked as having a high concentration of both wireless signals and plant disease, managers may hypothesize that electronic equipment is negatively affecting plant health and can take steps to separate signal emitters and plants. As GIS data shows changes over time, managers can later determine whether the previous actions effectively restored plant growth.

Resilience – Managers can use GIS to plot plant, weather, and topographic data to reveal how species may be impacted by drought or flooding and select the most appropriate landscaping in the face of climate change.

Water – Park managers can use GIS maps to identify watersheds and model stormwater runoff patterns[39] to help determine where and what to plant, as well as how to manage runoff. GIS can be paired with soil, weather, and other sensors to manage and use water more efficiently in parks.

Energy – GIS can map the locations of artificial lights and areas of concentrated light pollution to reveal which light sources are contributing to light pollution and therefore wasting energy.[40] Managers

[iv] Public participation GIS (PPGIS) directly involves the public in data collection, submission, mapping, and other projects using GIS. Through PPGIS, marginalized social groups and grassroots organizations may gain hands-on technical experience, while playing an integral role in community decision-making. Furthermore, PPGIS enables a high volume of collected data by using large numbers of volunteers and participants. For more information, see http://www.mapcruzin.com/community-mapping-gis/ and the PPGIS electronic forum (http://www.ppgis.net/).

can use the results to develop policies to reduce the use of some lights or add motion-activated sensors and lighting shields to use energy more efficiently (see Chapter 10).

Operations and Maintenance – GIS conveniently automates data collection and mapping, which can be used to streamline park operations. When GIS mapping technology is paired with sensors to provide data in near-real time, managers can track changes in park conditions without dedicating staff to manually collect field data.[29] Park managers can also use GIS to easily view multiple data sets as separate layers of a single digital park map. For example, data on light fixture type and intensity can be overlaid on a map of foot traffic to determine if the park is adequately lit.[29] Furthermore, 3D maps, which can be drawn by GIS software, can pinpoint locations of underground infrastructure to allow maintenance workers to navigate areas needing repairs.[41]

What are the challenges and trade-offs?

Operations and data management – GIS technology requires human oversight and management, but can be paired with sensors and other technology to collect and display real-time data. However, these sensors may require more hands-on work to install, operate, and maintain, while increasing energy use. GIS automatically presents and summarizes data, but the data must be analyzed to make informed decisions on watering, event planning, plant selection, etc.[42,43] To address this, GIS mapping software may be calibrated with other digital programs to automatically adjust lighting and watering in real time. Park managers should determine the goals and desired level of complexity of the GIS system to avoid investing in excess or unnecessary equipment.

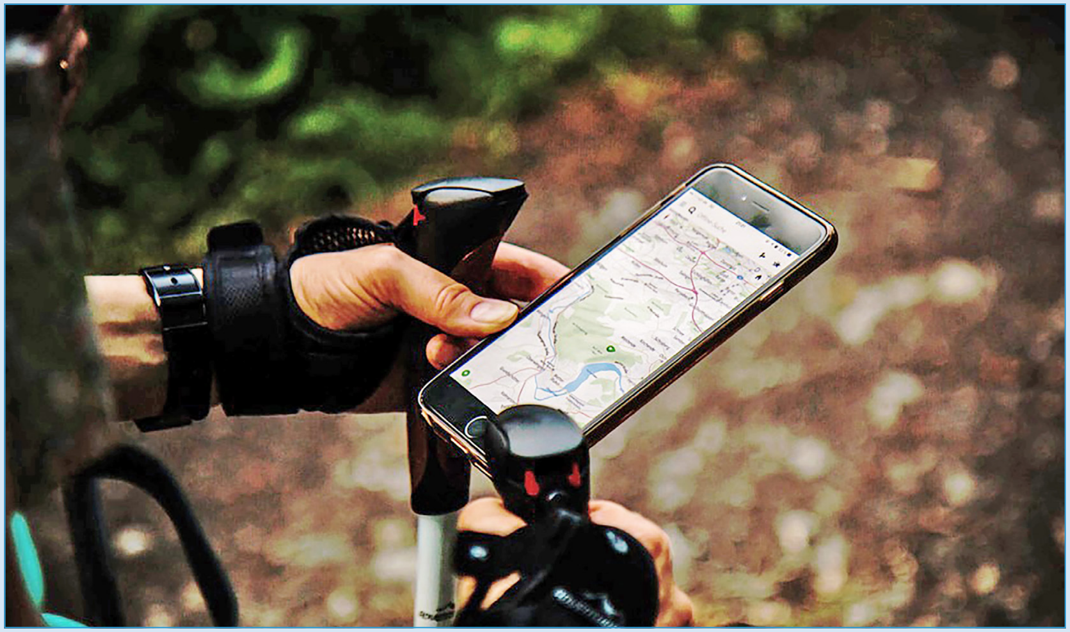
Disposal concerns – Disposal can also be an issue for GIS, because some sensors contain metals or substances in potentially toxic concentrations. Managers should check manufacturer information for proper disposal.[21]

Takeaways

GIS mapping technology has a high potential to streamline collection, analysis, and presentation of many types of data that can be used to improve parks' accessibility, landscaping, community involvement, health benefits, and park management. It may require extensive setup with sensor systems, and dedicated and observant managers to act upon collected data.

REAL-WORLD EXAMPLE

Mapping the Park | Campbelltown, Australia | 2012



Credit: Pixabay

In 2012–13, researchers at the University of Queensland, Brisbane, and the University of South Australia used Internet-based public participation GIS to survey park users in Campbelltown, Adelaide, South Australia.[44] They aimed to map the distribution of user activities in parks to determine how urban park type and size impact physical activities and distribution of park benefits.

Public participants used digital pushpins to mark locations with icons representing park activities and benefits, and text to provide additional notes.[44] This was used to identify where and how they use parks on a Google Maps-type interface (Figure 11.8, right). The activities surveyed varied in intensity, ranging from sitting to brisk cycling. Benefits were split into four types: environmental, physical, social, and psychological.

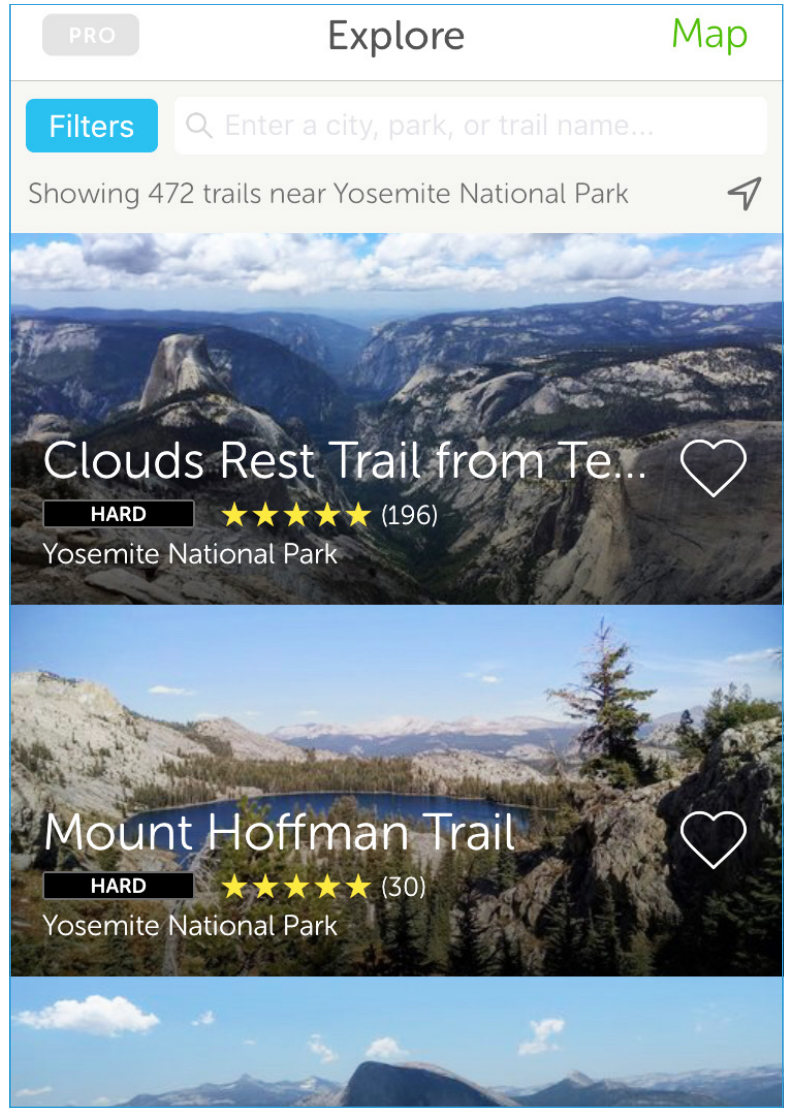
The survey included a digital map to delineate park boundaries, which allowed respondents to quickly identify parks and accurately mark the spaces that they used the most.[44] Digital data entry made it possible for participant responses to be quickly compiled on a single online platform, saving time and cost. Having park users submit their own data also saved time and money that would have been spent observing visitors' actions over time. Data about the types of benefits experienced in the park and the intensity of physical activities were presented as visually concise, separate layers on an interactive map, allowing the distribution of each to be viewed independently or together.[29] This allowed decision-makers to understand how parks of various sizes and features contributed to community health, which areas encouraged certain types of activity, and which areas were underused.[44] The results could be used by city planners to ensure equitable access to different activities, services, and benefits provided by various types of parks.

Application software (apps)

What is this technology?

Apps, short for "application software," are software that can run on computers, tablets, smartphones, or other electronic devices. Apps may or may not require an Internet connection, but those that do can retrieve real-time data, store user content, or enable two-way communication. There are many different types of apps, and they can perform a multitude of functions, such as maintaining calendars, making phone calls, taking pictures, organizing data through spreadsheets, viewing maps, gaming and entertainment, and graphic design. Each of these functions may be fulfilled by a distinct app, or one app may combine several services for the user's convenience.

Existing apps that may streamline user activities can be downloaded for free or for a small fee from online marketplaces, such as Google Play for Google-based devices and the Apple App Store for Apple-based devices. New apps may be created from computer code to fulfill a specific need. While this toolkit aims to inspire readers to creatively employ app technology in parks, the details of programming, constructing, and designing apps are beyond the scope of this document. We encourage readers to seek further information on whether to design an app specifically for a park manager's purposes.[v]



Credit: AllTrails

Figure 11.9: The app AllTrails displays park-specific trail information based on user location.

[v] For one of many guides to creating mobile apps, see https://www.allbusiness.com/12-step-guide-to-building-your-first-mobile-app-11193-1.html.

How does it fit into parks?

Apps have the potential to enhance park visitor engagement, streamline park administration, create content, collect data, engage users in citizen science, and explore community identity. Apps can enhance visitor engagement by quickly providing park information on location and giving real-time directions and parking availability, which can connect users with the most accessible outdoor opportunities at any given time. Apps may also increase user engagement by providing two-way communication so that park visitors and managers may discuss questions, complaints, and suggestions through digital suggestion boxes.

Park managers may use apps to provide a convenient and less time-consuming platform for visitors and staff to manage scheduling, memberships, event registration, facilities reservations, equipment rentals, and donations. For example, in June 2012, the Mississippi Department of Wildlife, Fisheries, and Parks began using apps and a new website to centralize wild game reporting, permit registration, sales records, campground reservations, and vehicle license renewals.[45] The new system increased efficiency and flexibility for the department for selling licenses, processing registrations, and contacting customers.[46]

Apps can serve as a hub for content creation and sharing. For example, park users or staff may take a picture of themselves and/or a park feature or activity, customize the picture, and immediately post it to their social media profiles. Digital content creation further benefits park management through publicity for their park.

Mobile apps may be used with GIS technology and other data collection and mapping services. The ubiquity of smartphones, along with their enhanced camera and geospatial capabilities, has lowered the barrier for amateur scientists to interact with spatial data.[47] For example, students attending Maryland's James Madison University can take a field course in Ireland where they use mobile apps to collect data and observations of rocky outcrops. The data is recorded on iPads in the field, combined with other students' data, and compiled on a desktop program. The composite data on rock formations forms a highly detailed geological map of the mountain ridge that can replace or supplement existing maps produced by professional geologists.[48]

Apps can be used to engage park users in citizen science or public involvement in scientific research,[vi] which can create increased awareness of and a close bond with parks.[49] For example, eBird, an app developed by the Cornell Lab of Ornithology and the National Audubon Society, allows bird enthusiasts and ornithologists to record and track avian observations on their smartphones in real time all over the world.[50] Erin Crotty, executive director of Audubon New York, says usage of smartphones and apps can provide "individuals of all ages [with] easy and rewarding bird watching."[50] Apps also allow tech-savvy bird-enthusiasts to contribute scientific data, which is stored online and forms GIS maps of avian populations that change over time. Scientists may study these maps to determine whether some species are becoming endangered and to prioritize conservation efforts.[50]

Location-based apps allow park visitors to share and explore their community identity. For example, the Interpretive Media Laboratory (IMLab), a collaborative project between California State Parks and the UCLA Center for Research in Engineering, Media, and Performance, developed LASHP Trails, a GPS-based mobile app that delivers interactive walking, jogging, and cycling tours to the app's users, allowing visitors to learn about the history and future of the area as they pass natural and historical landmarks in the Los Angeles area.

[vi] Citizen science resources are available through the National Geographic Society, National Wildlife Federation, California Academy of Sciences, Scientific American, Citizen Science Alliance, citizenscience.org, and others.

These digital trails are created through text, pictures, and oral stories contributed by the community, encouraging collective creativity and exploration of identity. The trails are also customizable, as users can request information about nearby activities and places to eat while using the app. LASHP Trails is the beginning of a planned citywide interconnected network of interactive routes called Trail City LA.[51,52,53]

Why choose apps?

Access – Managers can use apps to improve user experience, safety, and engagement. Efficient scheduling through mobile apps may make it easier for park visitors to reserve park facilities and participate in park-related activities. Apps providing information on location, weather, air quality, real-time directions, and parking availability can improve the user experience. Finally, certain applications can encourage new users to visit parks, interact with nature, and/or interact with others using the same app.[54]

Community Fit – Apps can provide parks with temporal and cultural context. Data collection through apps can track park changes over time, and by recording statistics such as visitor demographics and park programming attendance, managers can track how well the park serves its community. App interfaces may be designed to publicize or market specific aspects of parks to adjacent communities. Apps can also provide a platform to display the unique characteristics of the park, the surrounding community, and its residents, as seen in IMLab's Trail City LA and LASHP Trails projects explained earlier. Finally, content creation and sharing can improve community engagement and participation in park development. Often this leads to neighborhood cohesiveness, improving overall well-being.[16]

Health – Apps can incentivize physical activity and exploration within the park through prizes, such as raffle tickets or virtual badges, which mark recipients as dedicated park visitors that may be desired by those seeking to distinguish themselves from other app users. The popular app Pokémon Go, in which users collect fictional creatures called Pokémon, led to short-term increases in physical activity among participants and has encouraged users to seek out parks, where the likelihood of finding certain types of Pokémon is higher.[54,55]

Aside from incentivizing healthy activities, mobile apps can help park users plan, organize, and initiate events.[56] Furthermore, apps can be used to send notifications to users about park conditions (i.e., air quality, temperature, etc.), which allows the public to make informed decisions about whether to spend time outside.

Safety and Resilience – Park managers can post weather and safety information, including crime, health, and warnings, to quickly update app users and community members, even during power outages or other emergencies.

Water – Some apps may be used with digitally connected irrigation and stormwater equipment, allowing managers to easily control watering patterns and stormwater flows to prevent wasting water (see Chapters 5 and 6).

Energy – Distributing information about park activities through apps reduces the energy consumption and costs associated with printing and mailing brochures. Some apps may be used with light fixtures, allowing managers to easily control fixture activation and light intensity to conserve energy when not needed (see Chapter 10).

Operations and Maintenance – Apps can reduce the time managers spend publicizing events, processing permits and payments, tracking facilities and equipment reservations, and collecting data. Managers can program apps to automatically distribute event reminders, emails, or social media posts to more easily maintain a public presence with park users and the public. Apps that provide digital two-way communication can allow managers to receive and respond quickly to pressing visitor questions, complaints, and suggestions.

Mobile apps can also be used to efficiently crowd-source detailed field data for GIS, compile all data into an aggregate master file using desktop software, and easily resolve data discrepancies.

What are the challenges and trade-offs?

Park-specific app creation – The proliferation of apps may be overwhelming, and park visitors may be unlikely to download a park-specific app.[57] Therefore, park managers should determine the audience they wish to target and decide if a park-specific app is appropriate and useful. Once a park manager decides to develop an app, it requires both technical expertise and knowledge of park features. It may be necessary for park managers to consult a third-party platform to design an app customized for their park or to modify templates used by other civic departments. Users may lose interest if apps do not accurately display real-time information, reflect changes in programming, or provide two-way communication between users and managers. A staff member or associate should be assigned to update the app and communicate with users.

Security and privacy – Security can also be a concern with app use. Any app that stores visitor data must have strong security, user policies, and manager oversight so it is not used maliciously. Data encryption and firewalls may help to reduce risk.[19]

User disruption – Like other technologies in parks, mobile apps may disturb visitors who see the outdoors as an opportunity to escape from their digital devices. The recent proliferation of the Pokémon Go application led to some concerns that app users were being loud or otherwise interfering with the activities of other visitors at parks, museums, cemeteries, memorials, and places of worship.[58] Although this behavior may be a characteristic of the app's users, rather than a quality of the app itself, any app that makes disruption more frequent should include clear user agreements discouraging behaviors that upset other park users. Park managers concerned about disruptive app use should also post clear signage within parks asking app users to be mindful of others.

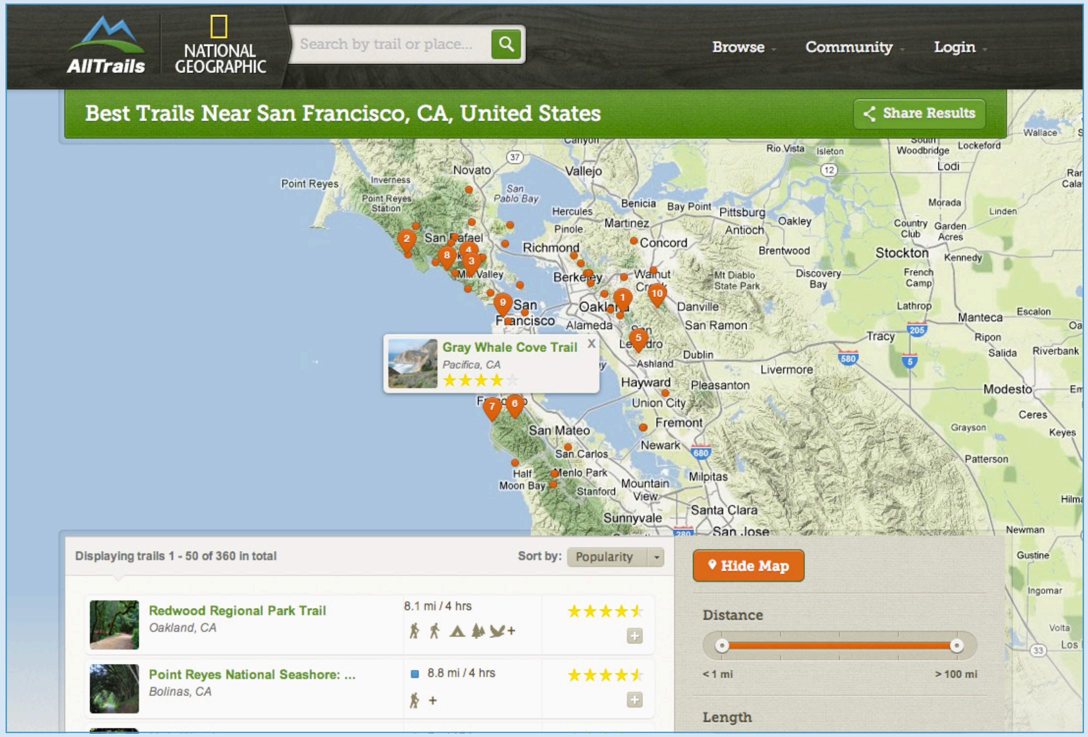
Internet connectivity – Finally, while many apps do not require Internet access, most are more effective with continuous Internet connection. Apps may store real-time information about specific parks and trails on an Internet server instead of within the app. This reduces the app size, which lowers loading times and frees up space on the host device to hold other information, and users need not spend time to continuously update the app. However, users would likely be unable to use these apps without access to an Internet connection.

Takeaways

Apps may be used for many park-related purposes. They can provide basic park information, improve data collection, enhance educational and social media content creation, and facilitate collaboration and two-way communication between users and staff. While critics of park-related apps may argue that their use contradicts the traditional purpose of parks as an escape from technology, apps may in fact help preserve parks by fostering community stewardship across users of all ages.[16] To encourage healthy, active participation, managers should carefully consider the app's desired purpose, scope, and target audience, and discuss with park visitors whether the app effectively meets their needs, and how its services can be improved.

REAL-WORLD EXAMPLES

Apps in Action for Parks



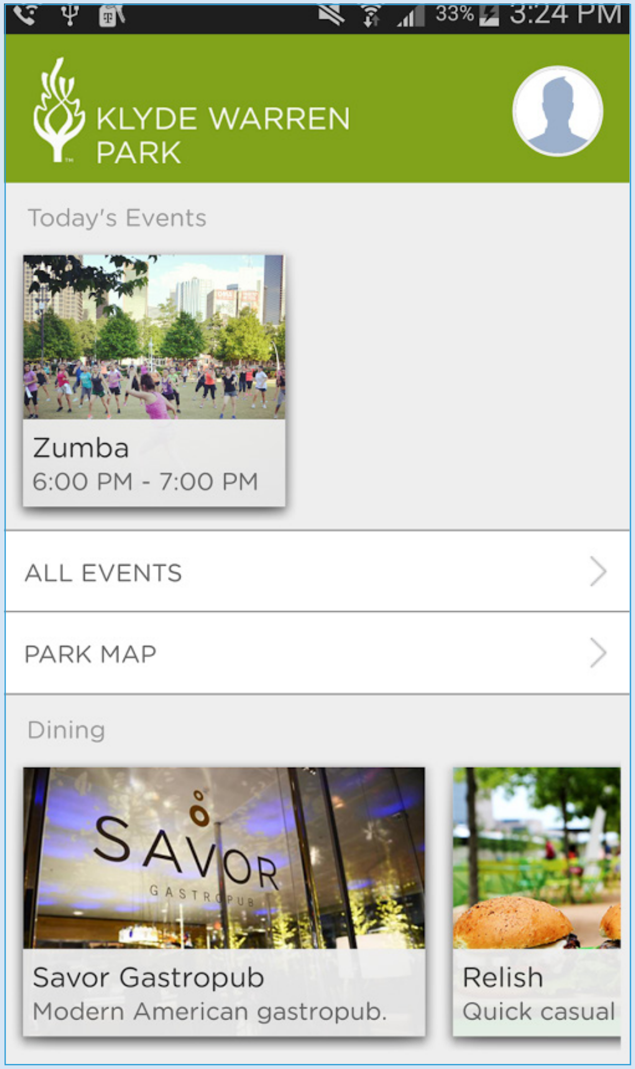
Credit: Techcrunch.com

AllTrails is a free app that follows the location of Internet-enabled devices such as smartphones to provide a list of nearby trails for hiking, running, and biking (Figure 11.10, right). The list, which draws from an online database containing thousands of trails, is updated continuously as the user's location changes. One of AllTrails' hallmarks is that it allows users to submit data about trails, such as reviews, photos, maps, foot traffic, and information on flora and fauna. Some of this content may be "geotagged," or assigned, to a specific location on the trail, to appear automatically in the app when users approach the location. Users may search for trails based on their specifications, such as trail difficulty, length, child- and dog-friendly, views, or allowed activities. Once a trail is selected, the app can provide driving directions and progress toward the location.

App users may interact with each other through shared content including location geotags, trail reviews, and photos, which spread enthusiasm for trail exploration. The app uses "Reputation Score," a prestige system that indicates the most active users of the app, to bring the community's attention to those who actively create content.[59] The above features are provided by the free app, while the "Pro" version, which requires a paid annual subscription, offers more trail options and information, enables offline app use, and increases the capability to create and share maps. While AllTrails is geared toward users of larger parks, similar features could be incorporated into apps for small urban parks.

The **Agents of Discovery** app is free and used at city, state, and national parks, including at the Los Angeles County Department of Parks and Recreation, to increase children's cultural, historical, and scientific knowledge about local parks and their surrounding communities. App users pursue virtual missions to find and learn about various locations within parks.[60] Users who finish tasks win virtual points and badges, which young participants gather in competition with each other. The app encourages children to explore the outdoors, which improves mental health and spatial awareness, and engage in physical activity, which helps address childhood obesity.[18]

In 2015, park managers at **Klyde Warren Park**, a 5.2-acre park in Dallas, Texas, collaborated with Pariveda Solutions, a third-party technology firm, to produce a mobile app to provide and update park-related events in real time (Figure 11.11, right).[61] The app offers a high level of convenience to visitors and may strengthen their connection to the park. The app includes a digital map of amenities, a programming schedule, and the food and beverage listings of visiting food trucks. Users can register to receive updates for daily programs including fitness, music, and child-friendly events, and receive notifications when program scheduling changes. On the Google Play marketplace, reviews for the app are overwhelmingly positive. However, the app has been downloaded fewer than 1,000 times, which pales compared to the park's claim of 1 million visitors per year.[61,62] This may imply that the app is most appealing to a specific, limited audience, such as those who frequent parks, attend events regularly, are tech-savvy, and/or see Klyde Warren Park as their primary option for outdoors space becasue of its proximity to their home or workplace, or available programming.



Credit: Google Play

Sensor networks and the Internet of Things

What is this technology?

Digital sensors can record, store, and wirelessly transmit information about light intensity, temperature, moisture, air and water quality, resource consumption, motion, and other factors. Multiple sensors may be interconnected, with or without wires, to create a sensor network that collects data over a wide area. Depending on the sensor device used, the network can generate various types of data, such as numbers, text, images, and audio. Digital software can compile and analyze this information.[63]

The versatility and applications of sensor networks are enhanced by the Internet of Things (IoT), which connects physical objects through networks of electronics, software, and the Internet. Devices connected through the IoT, including cameras, phones, digital identification tags, sensors, and Wi-Fi equipment, communicate digitally with one another and with users, collecting and sharing information via radio waves and online software. IoT can create integrated systems of devices that were

Credit: Bosch

Figure 11.12: Sensors embedded in parking spaces can be linked to the Internet of Things to provide active parking management that can alert drivers to available spaces.

previously isolated. For example, sensors that track resource consumption may trigger an automated text or email message upon detecting a specific condition, such as when the water level in a storage tank reaches a certain height. IoT is similar to GIS, described earlier in this chapter, in that both services handle large amounts and multiple types of data. They are slightly different in that IoT uses wireless communication between devices, whereas GIS only requires these devices to communicate with mapping software and not necessarily with each other. Furthermore, IoT can enable action based on data through automated decision-making, whereas GIS prioritizes mapping data for convenient viewing by decision-making authorities.

The infrastructure associated with connecting multiple devices through IoT can be highly complex and technical.[63] It requires Internet access or radio or cell phone signals to support data collection from sensors and mobile devices, data formatting and transport to the Internet, and Internet infrastructure such as servers, websites, and database management systems. Additional software may be required to make all data secure and compatible with each other, although these programs may be included with the purchase of physical sensors.[64]

How does it fit into parks?

When sensor networks are connected to the IoT, park managers can access data remotely with an Internet connection.[65] The data can be used for predictive analysis to avert a crisis before it happens, to make quick real-time decisions such as reducing artificial light intensity when few visitors are nearby, perform day-to-day planning such as optimizing waste collection routes, and engage in long-term planning.[18] Some park equipment, such as those used for communication, irrigation, and lighting, can be linked to sensors through IoT and be automatically adjusted according to real-time data. This can increase the quality of existing services and reduce the operational costs of public departments.[66]

IoT sensors and networking devices can be used in all park components featured in this toolkit. The following are examples of how this technology could be implemented at parks:

Landscapes – Soil sensors can measure acidity, salinity, and water quality and levels.[18] Sensors and cameras facing trees can monitor tree health based on water intake and physical changes in tree shapes.[18] Cameras can cover a wide area so that a unique camera or sensor is not needed for each tree. Data from both types of equipment can be aggregated through IoT software and automatically warn managers if a tree is likely to fall, leading to actions to stabilize or remove the tree.

Irrigation – Sensors can detect leaks and collect general data allowing park managers to track water use in specific areas over time.[66] Soil moisture and weather sensors can determine how much watering is necessary. When linked to irrigation controllers via IoT, this information can be used to remotely operate irrigation valves to control water flow.[67] For example, sensors and automated irrigation are used in 68% of public parks in Barcelona thanks to the Smart City Barcelona Initiative, which seeks to enhance the efficiency of public services with digital technology. Since implementation, water conservation has increased by 25% and the city has saved about $555,000 on water annually.[68]

Stormwater – IoT allows measurements of available capacity at water storage facilities to be compared with weather predictions and readings from soil moisture sensors to create strategies for the capture, retention, processing, and release of rainwater runoff in varying rainfall conditions.[69,70,71] For example, Real-Time Control software uses the IoT to adapt stormwater management to changing weather patterns (see the Real-World Example in Chapter 6).

Hardscapes – Sensors embedded in parking lots can notify users, through digital signage and mobile apps, which parking spots are available.[41] Digital identification tags embedded in cars can be linked to park managers' and nearby parking enforcement officers' phone numbers through IoT to efficiently send a text notification if parking fees have not been paid or to ensure parking rules are followed. For example, cars registered to nonresidents of the area should not be parked in resident-only parking areas.[65] The City of Barcelona implemented this technology at its parks in 2014 and has since increased parking fee revenue by $50 million annually.[4]

Activity Spaces – Through IoT, motion sensors in swimming pools can be linked to lifeguards' phone numbers and possibly prevent drowning by sending a text alert to lifeguards and staff after detecting a sudden change in movement patterns.[18] Sensors can also help monitor park usage, detecting which times the park is busy, which equipment is most popular, and how long equipment is used, which can inform future park improvements.[72]

Urban Furniture and Amenities – Sensors can monitor trash containers for remaining capacity and, through IoT-enabled communication with utilities, notify staff when the container is full. Additional software may optimize the garbage collectors' routes, based on which containers are full.[65,41] Park benches can also be outfitted with sensors to measure pollution, noise, and foot traffic.[41]

Lighting – Similar to urban furniture, light fixtures are convenient locations to mount fiber optic sensors and communications devices to provide Wi-Fi and record noise, weather, air quality, and pedestrian and vehicle traffic data that can be stored online via IoT software.[68,41] Lights may customize output intensity using data from sensors that track time of day, ambient light, weather, and the presence of people.[65]

Digiscapes – IoT-enabled sensors are compatible with other technologies mentioned in this chapter. Data collected from sensor networks are often mapped and presented with GIS. Data from sensors that track foot traffic, park popularity, peak visitation hours, and equipment use can be stored online in IoT software and trigger an automatic notification in an app when the park is not busy, encouraging visitors to come at nonpeak times.[18] Alternatively, data can be used by a park app that incentivizes outdoor play and physical activity by awarding points to children who engage with various park features.[72]

Why choose sensor networks and the Internet of Things?

Access – Optimized parking management in and around the park can notify visitors when and where parking spots are available, thereby making the park more accessible by car.

Health – Sensor data combined with park apps can encourage physical activity.[72] Air quality sensors, which collect data that can be used to inform park managers whether air is unclean, can be easily installed on light fixtures and urban furniture.[65]

Safety – Predictive analysis, a feature of IoT, is valuable for mitigating safety hazards: IoT enables digitized stormwater management, which can help prevent flooding; motion sensors in pools can reduce the risk of drowning; and input from cameras, weather data, and soil monitoring sensors can notify managers of a tree's risk of falling.

Resilience – Citizens can analyze publicly accessible IoT data and participate in developing and implementing strategies to maintain the park during and after droughts and storms, and when budget cuts are required.[65,16] A Smart City Barcelona Initiative called "Open Government" facilitated two-way communication between municipal government and citizens.[4] Its "Citizens Attention" kiosks broadcast information from government programs and initiatives, and an online "Open Data" portal provides citizens and corporations with tools to develop apps addressing resident needs.[4] Sensor networks provide large amounts of data that park managers can use to form resource conservation strategies.

Water – IoT-enabled sensors can minimize wasting water. Sensors in stormwater capture containers can control water flows to prevent the flooding of underground ecosystems and minimize the amount of toxic runoff entering natural water bodies. Weather data can be combined with soil-based moisture sensors to determine precise amounts of irrigation needed in each area of the park, while IoT-enabled water meters can detect which areas of the park use the most water. IoT-enabled sensors may also reveal pipe leaks by detecting water flow when no faucets, sprinklers, or fountains are active.

Energy – Sensors can conserve energy in creative ways. IoT-connected light fixtures may save energy by automatically dimming when they are not needed. Optimized parking and waste collection, enabled through IoT, can improve route efficiency for cars, thereby reducing energy use.

Operations and Maintenance – IoT-enabled devices are automated and store data online, both of which present several operational benefits. Remote, automated data collection can streamline operations around the clock, even when no manager is on-site. Managers can also view and act upon data remotely, making it easier to respond to problems. Additionally, sensors can be placed in spots that would otherwise be inconvenient to access, such as underwater or along underground pipes.

What are the challenges and trade-offs?

Compatibility – Devices used by different municipal departments or produced by different companies might be incompatible with each other or existing communication infrastructures. However, some IoT platforms can reformat data to improve compatibility.[65]

Data management – Data collected by IoT systems typically need to be managed and analyzed by park staff. This may require additional training and/or staff time, and data might still be misinterpreted. Future platforms may have increased capabilities to automatically act on data and adjust watering or lighting patterns to streamline park operations.[65]

Privacy – IoT faces the same issues as other digital technologies regarding privacy. Park managers should fortify sensors with data encryption and firewalls, and provide clear user agreements about the types of and reasons for collecting any IoT data.[73]

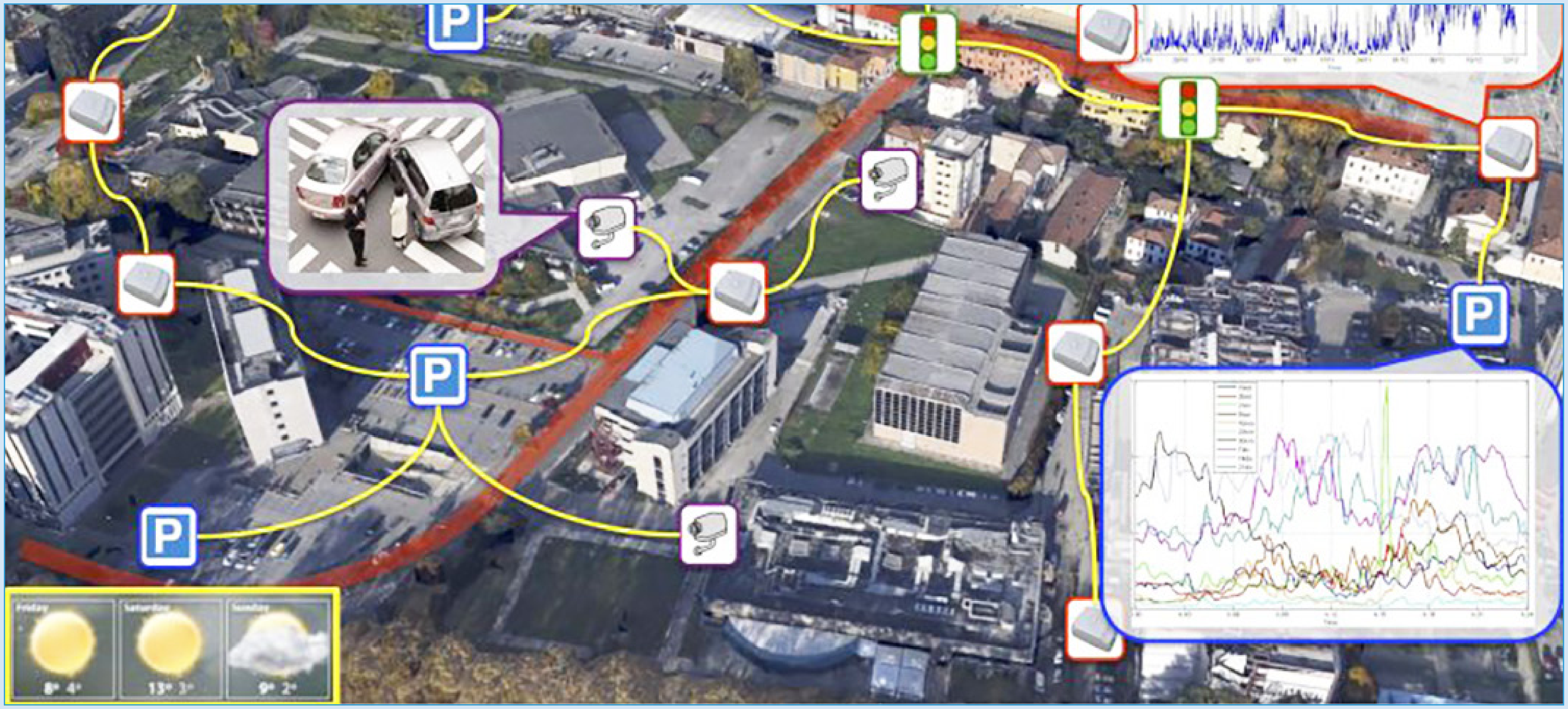
Environmental impacts – IoT and sensor networks can potentially affect wildlife and the environment. Sensors' wireless signals may have the same effects on plants, bees, and other species as Wi-Fi equipment. Therefore, sensors should be placed away from sensitive flora and fauna.

Disposal – Disposal can be an issue for IoT if sensors contain metals or substances in potentially toxic concentrations. Managers should check manufacturer information for proper disposal.[21]

Issues with novel technology – IoT is evolving, meaning best practices to create an IoT network have not been established. Furthermore, no clear business model exists to attract investors. However, successful implementation of some services such as smart parking, which can provide immediate benefits to civic operations, can promote further development of IoT networks.

Takeaways

Because sensor networks and IoT are relatively new technologies, their implementation in urban parks has been limited. However, the massive amounts of data they collect can help enhance park services. Procedures to create infrastructure, link devices, and notify users of data collection have not been established. Until methods are developed, managers should promote transparency with park visitors when using these devices.



Credit: Human Inspired Technology Research Centre

REAL-WORLD EXAMPLE

Birth of a Smart City | Padua, Italy | 2014

In 2014, the Padua Smart City project brought together government sponsors, University of Padua researchers, and corporate backers at Patavina Technologies to promote the use of IoT systems in public administration.[65] An experimental sensor network (Figure 11.13, above) including 300 nodes, or unique points, was deployed at the university and was used to draw correlations between weather and air quality. Each node was placed on a streetlight and included temperature and humidity sensors, and one node also included an air-quality sensor. Data collection lasted seven days. Researchers noted a simultaneous spike in air pollution and humidity along with decreases in light intensity and temperature.[65] The researchers concluded that a rainstorm had caused the changes in weather readings and led to increased traffic congestion, which generated more air pollution. This case study is a good example of using data from different types of sensors to determine potential correlations between issues such as weather and air quality.[65]

Digiscapes component achievement levels

"Digiscape" technologies most effectively meet the Access, Community Fit, and Operations and Maintenance Value Criteria. This is largely due to the appeal these technologies have to new types of users, content creation capabilities, and automated data collection and information distribution. Also, park Resilience can be enhanced through data analysis and by providing platforms for increased community involvement. Additionally, park Safety may be increased through quick dissemination of warnings and gathering of real-time data. Finally, GIS may offer greater insights into effective resource management. The table below illustrates the effectiveness of each technology in achieving the different Value Criteria defined in Chapter 3.

	Access	Community Fit	Health	Safety	Resilience	Water	Energy	Operations and Maintenance
Wi-Fi	●	◒	○	◒	○	○	○	●
Geographic Information Systems and Services (GIS)	◒	◒	◒	○	◒	◒	◒	◒
Application Software (Apps)	●	●	◒	◒	◒	◒	◒	●
Sensor Networks and the Internet of Things	◒	○	◒	◒	◒	◒	◒	●

- ● Indicates technologies that provide a positive benefit for a value criterion.
- ◒ Indicates technologies that represent a secondary effect on a value criterion or have a trade-off between their benefits and drawbacks.
- ○ Indicates technologies that have no effect, a negative impact, or are unrelated to the value criterion.

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Chapter 12: Guidance on Implementation

THE TECHNOLOGIES presented in this toolkit can help managers, designers, and advocates transform existing parks into, or create new, SMART Parks. Because each park has a unique community, needs, budget, and existing infrastructure, this chapter presents issues and contexts to be considered during planning and implementation. To help managers prioritize, we offer guidance on how to best use the Value Criteria in Chapter 3. Finally, we share strategies and sources for securing funding. While many of these suggestions could apply to all park upgrades, we specifically highlight opportunities that are unique to SMART Parks.

Planning new and existing-park SMART upgrades

Before adopting new technology, managers should determine what would best fit their parks by considering the neighborhood and regional context, and by evaluating park benefits, budget constraints, and the broader planning process. It is outside the scope of this toolkit to discuss these issues in detail, but we briefly describe each. Other resources, such as reports and toolkits from organizations like the National Recreation and Park Association[i] or individual state or city government guidelines for park master plans,[ii] provide more information on these topics.

[i] See http://www.nrpa.org/uploadedFiles/nrpa.org/Publications_and_Research/Research/Papers/.Rejuvenating-Neighborhoods-White-Paper.pdf

[ii] For examples, see http://www.in.gov/dnr/outdoor/2603.htm.

Credit: FreeStockPhotos

Figure 12.1, preceding page: Community meetings and other opportunities for engagement are an essential part of any park planning process.

Credit: Pexels

Figure 12.2: Park managers should evaluate conditions of their parks to determine where upgrades should be focused. The Value Criteria in this toolkit can be a helpful guide in identifying areas for improvement and which upgrades might best serve a diverse array of users.

Neighborhood and Regional Context

Managers should consider how their park fits into the network of parks across their community, city, and region. How is the park unique? Does it serve particular community needs that other parks do not? Does it effectively serve the community because of its connection with other parks in the area? The answers to these questions will help managers determine which technologies will best fit their park. Some technologies may be best utilized across several parks. For instance, smart benches highlighted in Chapter 9 track user data and can provide a regional perspective of park use when installed in multiple areas across a city. Certain parks may also face unique challenges in implementing new technology due to their location or physical infrastructure.

It is critical that managers regularly engage with the communities surrounding parks to understand and keep up-to-date on their needs and preferences. For example, the Los Angeles Neighborhood Land Trust employs a community organizing team focused on directly engaging residents at each stage of the park development process.[1] Similarly, the Trust for Public Land engages the community through a guided and participatory design process for creative place-making, a community-based process that reflects local identity through the arts, culture, and creativity in planning and designing new and upgraded parks and open spaces.[iii,2] Ongoing outreach and community engagement are critical to any park's success.

Credit: Pexels

Figure 12.3: Essential to the implementation process is identifying budget constraints, which can influence which technology options can be considered.

The types of upgrades and services a park provides should be dependent upon the community it serves. Some key questions to ask when considering which technologies to implement in parks include: What are the demographics of the people who live near the park(s)? What language do they speak? Do children, adults, seniors, and those with limited mobility come to the park in large or small groups? What facilities do they use, want, and need at the park(s)? How well does the park(s) serve its community? Is the community interested in opportunities for family events, education, or increased physical exercise?

Evaluating Park Benefits

The Value Criteria presented in this toolkit were developed based on interviews with park professionals and advocates during which they identified park priorities. The criteria should be used as a guide to evaluate the effectiveness of parks in providing services (access for all, community integration, health, safety, etc.). Once the most important and relevant criteria for a particular park(s) have been identified, park managers can assess how well the park meets these criteria. For example, if building resilience against climate change is the most significant criterion a park manager chooses to address, then he/she should consider implementing the landscape and stormwater management technologies featured in Chapters 4 and 6, respectively.

Ongoing community outreach and engagement are critical components for determining park priorities, which can change over time.

[iii] For more information, see http://creativeplacemaking.t4america.org/what-is-creative-placemaking/.

Budget Constraints

The cost of technologies discussed in this toolkit range greatly and will likely be the limiting factor in implementing SMART Parks. With that said, we recommend thinking creatively about projects and considering the funding strategies described later in this chapter.

There are a few technologies which budget-constrained managers should consider because they are small-scale, have low initial costs and long-term cost-saving benefits, and/or provide multiple benefits and uses.

Small-scale technologies with low initial costs:

» Investing in air-pruning plant containers (Chapter 4) is a low-cost investment that can improve plant growth and save landscaping costs.

» Using pervious paving (Chapter 7) in park areas that must be paved or repaved is a small-scale change that can confer water, safety, and maintenance benefits.

» Solar umbrellas (Chapter 9) can be a small-scale investment to provide shade for visitors and renewable energy for powering their devices.

Technologies that provide maintenance benefits resulting in long-term cost savings:

» Smart water controllers (Chapter 5) use weather and site conditions to automatically adjust watering to optimize efficiency, which can reduce water use and costs.

» Applying photocatalytic titanium dioxide coating (Chapter 7) to surfaces in parks can lower maintenance costs over time as it reduces the need to clean surfaces.

Technologies that are cost-saving due to multiple benefits:

» Smart benches (Chapter 9), depending on the model, can provide visitor tracking data, solar-powered device charging, and Wi-Fi hotspots.

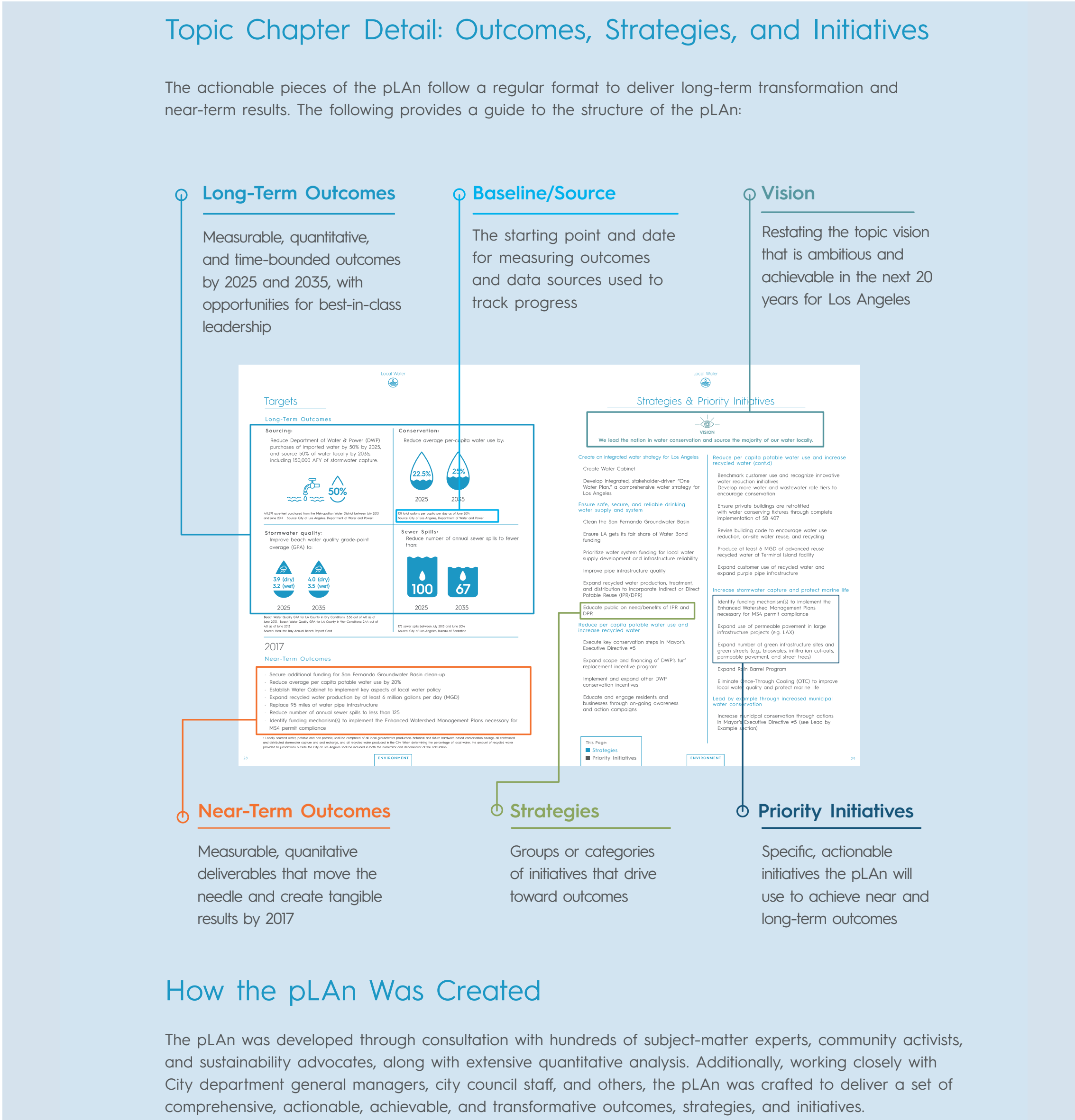
» Sensor networks and the Internet of Things (Chapter 11) can be used to improve maintenance efficiency by automatically programming various park features, such as irrigation, lighting, and trash collection.

The Planning Process

Participating in regionwide, county, city, and park-specific medium- and long-term planning processes can be a great opportunity for creating new or upgrading existing parks with new technology. This is typically when park management can engage in broader thinking about longer-term changes that might not be feasible with more immediate and near-term maintenance or operations. While not discussed in detail here, we recommend that managers identify and participate in these opportunities, including general plan updates, sustainability plans, and park master plans.

All cities and counties in California are required by law to periodically update their long-term general plans with their jurisdiction's vision, goals, and objectives for planning and development for land use, conservation, noise, safety, open space, environmental justice, and other factors.[3] Many of these topics are or can be impacted by SMART Park planning and development. For example, if a city's goal is to increase physical activity in disadvantaged communities, then park managers can propose using technology such as energy-generating exercise equipment (Chapter 8) or interactive playgrounds (Chapter 8).

Some cities have additional focused planning processes, such as when the City of Los Angeles developed its Sustainable City pLAn, which outlines goals to create a more healthy, sustainable, and economically prosperous city.[4] Such plans for environmen-



Credit: L.A. Mayor's Office

Figure 12.4: Example of the layout of the Sustainable pLAn for its water conservation goal. The City of Los Angeles focused on near- and long-term goals, priority initiatives, and strategies for sustainability visions for the environment, economy, and equity.

tal and sustainability initiatives provide an exciting opportunity for park managers and advocates to ensure that parks, and more specifically, technological upgrades, are included in the planning process.

Many city and county park departments create their own park master plan, sometimes even for individual parks, such as Golden Gate Park in San Francisco.[5,6] Similar to city master plans, these documents guide the development and use of a specific park or parks district for 20 to 30 years and make plans for the maintenance and expansion of parkland, recreational opportunities, and natural resource preservation.[7] City or county parks department staff create these plans, typically with public input.[7] If park managers and staff are working on master plan updates for their park(s), technology upgrades can be incorporated and built into park infrastructure. Technology implementation will be most successful if thoughtfully planned beyond its initial adoption.

Determining how and when park budgets are allocated, and how much funding is available for capital upgrades and long-term maintenance, is critical before making decisions about technology implementation. We recommend that managers identify which plans are already in place and when they can influence updates and new efforts.

A note on park programming

Park programming is an important consideration during the master planning process and at any time managers, designers and advocates are considering upgrades to parks or the creation of new parks. Park programming draws visitors and can multiply the benefits of technology investments, allowing parks to successfully meet the Value Criteria and improve community well-being.

Likewise, technology can be used to enhance park programming. In Los Angeles's Summer Night Lights program, park and community leaders extended nighttime hours in eight parks in troubled neighborhoods by keeping lights on until midnight and hosting nighttime movies and family-oriented activities four nights per week. The program reduced summertime gang clashes in park and recreation areas in poor neighborhoods, and provided safety for children and families who used the parks.[8] The Los Angeles County Department of Parks and Recreation has instituted its own program called Parks After Dark. The program provides classes, organized sports and exercise, concerts, and health care and social services in parks from Thursday to Saturday evenings during summer (June through August). UCLA's Center for Health Policy Research evaluated the program and found that it improved community relations with law enforcement, decreased crime, and saved millions of dollars in policing and health care costs.[iv,9] These types of programs could use technology to enhance their impact, such as by decreasing energy use through lighting efficiency (Chapter 10) or by increasing services to the public through apps and Wi-Fi (Chapter 11).

Credit: parks.lacounty.gov

Figure 12.5: The success of the Los Angeles County Parks after Dark program highlights the value in programming as a supplement to upgrades.

Programming can also multiply the benefits of technology upgrades in a park by creating new educational opportunities. For example, Chapter 6 mentions how parks can use drones to collect water-quality samples and monitor park conditions. By incorporating the use of drones into citizen science days, the public can collect samples and learn about water management and science. Vibrating pollinators, discussed in Chapter 4, can also be used in community gardens to help educate the public on the pollination process and gardening. It is important that, alongside planning for physical technology upgrades in parks, managers consider opportunities for new programming that can improve the visitor experience.

[iv] Ninety-five percent of Parks After Dark participants agreed that the program improved the relationship of the community with deputy sheriffs, who increased face-to-face interactions with kids and community members after the start of the program. From 2010 to 2016, the program prevented an estimated 81 violent crimes and 91 nonviolent crimes.[9] See http://healthpolicy.ucla.edu/publications/Documents/PDF/2017/PAD-report-may2017.pdf for more information.

Technologies ranked against Value Criteria

The following table shows all technologies featured in this toolkit and how they rank against each Value Criterion. Park managers should not be limited by the Value Criteria and, indeed, may find that other considerations (such as cost, site constraints, etc.) are also important. Managers should carefully consider their park's surrounding communities and existing budget constraints before making decisions.

Component	Technology	Access	Community Fit	Health	Safety	Resilience	Water	Energy	Operations & Maintenance
Landscape	Automatic Lawn Mowers	○	○	●	○	○	○	●	●
	Near-Infrared Photography	○	○	●	◒	●	●	○	○
	Green Roofs	○	●	●	○	●	◒	●	○
	Green Walls	○	●	●	○	○	○	●	◒
	Air-Pruning Plant Containers	○	○	○	○	●	○	○	●
	Vibrating Pollinators	◒	○	●	○	●	○	○	○
Irrigation	Smart Water Controllers	○	○	○	●	●	●	◒	●
	Low-Pressure and Rotating Sprinklers	○	○	○	●	○	●	◒	○
	Subsurface Drip Irrigation	●	○	●	●	●	●	◒	●
	Smart Water Metering	○	○	○	○	◒	●	◒	●
	Graywater Recycling	○	○	○	○	●	●	◒	●

Component	Technology	Access	Community Fit	Health	Safety	Resilience	Water	Energy	Operations & Maintenance
Stormwater	Engineered Soils	○	○	○	●	●	●	○	○
	Underground Storage Basins	○	○	○	○	●	●	○	◒
	Drones	○	◒	○	○	◒	◒	○	●
	Real Time Control and CMAC	○	○	◒	○	●	●	○	●
	Rainwater Harvesting	○	◒	○	○	●	●	◒	○
Hardscape	Cross-Laminated Timber	○	○	◒	○	○	○	●	◒
	Pervious Paving	○	○	○	●	●	●	●	◒
	Piezoelectric Energy-Harvesting Tiles	○	●	◒	◒	●	○	●	○
	Self-Healing Concrete	○	○	○	●	◒	○	◒	●
	Photocatalytic Titanium Dioxide Coating	●	○	●	○	○	●	○	●
	Transparent Concrete	○	●	◒	●	○	○	●	○
	Daylight Flourescent Aggregate	●	●	◒	●	●	○	●	○
	Carbon Upcycled Concrete	○	○	○	○	●	○	●	○

Component	Technology	Access	Community Fit	Health	Safety	Resilience	Water	Energy	Operations & Maintenance
Activity Spaces	Interactive Play Structures	●	●	●	○	○	○	○	●
	High-Performance Track Surfaces	●	○	●	○	●	○	○	◒
	Pool Ozonation	○	○	●	○	○	●	○	●
	Energy-Generating Exercise Equipment	●	●	●	○	●	○	●	○
	Outdoor DJ Booths	●	●	●	○	○	○	◒	○
	Hard-Surface Testing Equipment	○	○	●	●	○	○	○	●
Urban Furniture and Amenities	Smart Benches	●	○	◒	○	○	○	●	◒
	Solar Shade Structures	○	○	●	○	●	○	●	○
	Solar-Powered Trash Compactors	○	○	●	○	○	○	●	●
	Restroom Occupancy Sensors	●	○	○	○	○	○	○	●
	Smart Water Fountains	●	◒	●	○	○	●	◒	●
	Digital Signs	●	●	○	○	○	○	◒	●
	Automatic Bicycle and Pedestrian Counters	○	◒	◒	○	○	○	○	◒

Component	Technology	Access	Community Fit	Health	Safety	Resilience	Water	Energy	Operations & Maintenance
Lighting	Motion-Activated Sensors	○	○	○	●	○	○	●	●
	LEDs and Fiber Optics as Art	○	●	○	●	○	○	◐	◐
	Off-Grid Light Fixtures	○	○	○	◐	●	○	●	●
	Digital Additions to LED Fixtures	○	◐	○	●	○	◐	◐	●
	Lighting Shields	○	◐	●	●	○	○	●	●
Digiscapes	Wi-Fi	●	◐	○	◐	○	○	○	●
	Geographic Information Systems and Services	◐	◐	○	◐	◐	◐	◐	◐
	Application Software	●	●	◐	◐	◐	◐	◐	●
	Sensor Networks and the Internet of Things	◐	○	◐	◐	◐	◐	◐	●

● Indicates technologies that provide a positive benefit for a value criterion.

◐ Indicates technologies that represent a secondary effect on a value criterion or have a trade-off between their benefits and drawbacks.

○ Indicates technologies that have no effect, a negative impact, or are unrelated to the value criterion.

Funding opportunities

This section provides information on funding strategies, partnerships, and other resources to assist park managers in securing money for maintenance and capital improvements. It is important to consider that the cost of these technologies will likely decrease over time as the products become more readily available, competing products emerge, and manufacturing processes are streamlined. Additionally, several technologies help reduce operations and maintenance costs over time.

Funding to create, maintain, and improve parks is limited, especially in disadvantaged communities. Because SMART Parks is a new concept, there is no well-established process or list of resources for obtaining funding for such park upgrades. However, the fact that using technology to improve parks is a new idea may make it attractive to forward-thinking cities, foundations, and companies. While many traditional park financing mechanisms can be used to fund technological upgrades, proposals with an emphasis on technology could have a competitive advantage.

Garnering support and advocating for the benefits of SMART Parks is an essential part of implementing technology upgrades. To secure funds, park managers must make a strong case to city officials and/or voters on the multiple benefits associated with new SMART Parks or SMART Park improvements. Decisions can be largely driven by politics, and due to many competing interests, park managers must be excellent at communicating project benefits, such as long-term cost savings and broader neighborhood impacts like community development.[10] For example, city officials may overlook the energy savings and cost offsets from technologies that have upfront costs if park managers do not explicitly express those long-term benefits.[10] Using the Value Criteria presented in this toolkit may strengthen funding applications.

Park managers should consider research grant opportunities offered by technology companies or cities that specifically focus on increasing the use of technology. Established tech-focused companies like Cisco Systems Inc.[v] and IBM[vi] may be interested in SMART Parks because of their use of technology. Some cities also provide grant opportunities for technology use. For instance, the City of Los Angeles started the Innovation Fund, a $1 million tech-focused initiative to provide grants to city departments to improve the efficiency of operations and enhance residents' quality of life.[11] This type of initiative could provide an opportunity to fund local SMART Parks.

Utilizing Partnerships

Partnerships can be especially useful in leveraging resources, obtaining funding, and implementing SMART Park upgrades that might otherwise not be achieved independently. Developing SMART Parks may entice new partners such as startups, technology companies, and universities. Below we discuss three types of partnerships: public-private, public-public, and public-nonprofit.

Public-Private Partnerships

Public-private partnerships are an increasing trend in cities and can be replicated to benefit park upgrades. For example, private corporate sponsorships can fund events or facilities in public parks, produce revenue through advertising or naming rights, and/or generate funds through agreements for exclusive product placement.[12] Millennium Park in Chicago is a prime example of a public-private partnership in which some park features were funded through donations from banks. In return, their names were affixed to park sites (such as SBC Plaza and Bank One Promenade).[12] Banks often look for community projects to finance in order to comply with

[v] For more information, see http://csr.cisco.com/pages/global-impact-cash-grants.
[vi] For more information, see https://www.ibm.com/ibm/responsibility/grant_information.shtml.

Credit: Soofa

Figure 12.6: Startup tech company Soofa provided partnership and guidance to early adopters of its first Smart Bench.

the Community Reinvestment Act.[13]

Startups and technology companies could be excellent partners for SMART Park development, especially because they may be interested in evaluating their technology innovations in park settings. Google has partnered with several park departments in cities in California, as well as Philadelphia and Houston. These parks use Google's mapping tools and software to allow for "virtual park visits" via Google Maps tours of park areas. The virtual visits give people exposure to parks they might not otherwise be able to visit and thus increase interest and support for parks.[14,15,16] When technology startup Soofa first released its Soofa Benches and Signs, it also launched an early adopters program offering hands-on support and technical assistance to increase the effectiveness of the new products and improve the management of newly collected data.[17]

For all public-private partnerships, it is vital that park managers include community members, city officials, developers, and companies in the discussions to ensure that the agreements benefit all parties, especially the community that uses the park.[13]

Public-Public Partnerships

City, county, and state park departments should consider partnering with other departments or agencies, as this can help achieve the goals of all entities involved.[12] For example, some water providers, stormwater utilities, or public works departments could set aside funding for stormwater management that parks could use when planning projects like those identified in Chapter 6.[18] The Maryland Department of Transportation Port Administration, for example, agreed to remove an acre of pavement on public land in perpetuity for every acre it paves in the sensitive area around Chesapeake Bay.[19] The department created a fund for local park and school improvements that has been used to replace asphalt and parking lots with landscaped features that help improve stormwater management.[19]

Other departments in cities, such as mayors' offices or offices of innovation, could be ideal partners in providing funding for SMART Parks because their goals often align well with those of SMART Parks. For example, the City of Sacramento created the Mayor's Office for Innovation & Entrepreneurship to develop, test, deploy, and scale new technologies and services that will improve quality of life for residents.[20] The office offers various grants and pilot demonstrations to improve efficiency, meet community needs, and conserve resources.[20]

Public-Nonprofit Partnerships

Nonprofits, including large organizations, grassroots community groups, and research universities, are excellent resources of funding and support for park upgrades. Not only are these nonprofits eligible to apply to foundations and attract individual donors, but they also can be valuable resources in supplementing park annual operating budgets, establishing endowments, or implementing new projects.[21] They may also provide volunteers, programming design, outreach and marketing, or routine maintenance, which can free up funding for technology improvements.[21] Nonprofits can also advocate for increased funding and donations for parks.[21]

Credit: myphillypark.org

Figure 12.7: Numerous parks in Philadelphia have their own "Friends" nonprofit groups who volunteer for and support parks as part of the Fairmount Park Conservancy network.

For example, the City of Philadelphia Department of Parks and Recreation partners with 87 neighborhood nonprofits that advocate for and support specific parks in the city. The park department first partnered with the Fairmount Park Conservancy to create a Park Stewardship Program. The program provides financial, technical, and networking support to "Friends" of parks groups.[22] "Friends" groups are community-run nonprofit organizations that support parks or recreation areas through fundraising, volunteering, leading restoration projects and educational programs, or providing other assistance.[23] The Fairmount Park Conservancy also operates the Growing the Neighborhood Parks Grant Program, which provides funding to the "Friends" groups specifically for park physical improvements, programs, and events.[22] This innovative partnership structure allows the larger nonprofit, the Fairmount Park Conservancy, which has a strong resource base and can attract funding, to provide financial and technical support to smaller nonprofit partners (the Friends), who are then able to provide targeted assistance to their individual and unique community parks. The Park Stewardship Program encourages all parties to regularly connect and leverage their different skills and resources for park improvements and programs.

Park managers should consider which local nonprofit organizations have goals that align with the development of SMART Parks — goals, such as those focused on improving parks, community health, efficient resource use, increased opportunities to generate and use clean energy, increased access to technology, economic development, environmental protection, watershed improvement, and support of disadvantaged communities. For example, in the Los Angeles area, the nonprofit TreePeople[vii] is focused on urban forestry and environmental stewardship and has partnered with park departments to plant trees and organize volunteer days in specific parks.

In addition to partnering with local nonprofits, park departments should consider partnering with state and national nonprofit foundations such as the California State Parks Foundation and The City Parks Foundation.

Partnering with universities can provide multiple benefits for parks, including funding, evaluation, and volunteer or technical support. Many park projects require upfront research and/or planning that could be undertaken by universities. University researchers may be able to secure grants for work that could ultimately inform park management decisions. Parks can also be a testing ground for faculty and students who are interested in the goals of SMART Parks.

Universities often have access to research grants and other funding resources that park managers could not obtain on their own. Many universities undertake research in technology innovation and implementation, making them excellent partners for SMART Parks. For example, the UCLA Research in Engineering, Media and Performance (REMAP) Center partnered with California State Parks to develop and implement technology in the Los Angeles State Historic Park. The effort was part of a larger research initiative on cultural civic computing, a concept coined by REMAP, to consider computers in public spaces in the service of community (as opposed to personal computing).[24]

Students in particular could be assets to parks. Not only can those working with parks gain valuable educational experiences but they also can volunteer their time for maintaining parks, developing programming, or conducting research to inform management decisions. One model is the University of Utah's "Partners in the Park," which hosts summer programs and events to bring faculty, staff, students, community organizations, and West Salt Lake City (a disadvantaged community) residents together in parks.[25]

[vii] TreePeople works to inspire and support the people of Los Angeles to create a greener, shadier, and more water-secure city by planting and caring for trees, harvesting rainwater, and renewing depleted landscapes. In 2016, TreePeople partnered with the Los Angeles City Department of Recreation and Parks, City Plants, and volunteers to plant over 175 trees. Learn more at https://www.treepeople.org/.

These events, ranging from dance presentations to gardening, use the university's resources to provide programming and to connect with local youth to increase their awareness of and potential access to a college education.

Funding Resources

In addition to partnerships, various sources are available to park departments for funding improvements. Below are examples of grants; loan, bond, and rebate programs; and municipal government programs (such as the creation of park districts or special fees) that may benefit SMART Park development.

Grants

Numerous grant opportunities offering a wide range of benefits may be applicable to help develop SMART Parks:

- The Land and Water Conservation Fund, a federal program of the U.S. Department of the Interior, provides matching grants for parks, often helping to leverage additional public or private funding.[26] Of the total funds appropriated in the 30 years since the program's enactment, only 2% has been spent on projects in the 100 largest cities, but more recently the organization has expressed interest in providing more resources to urban parks.[26,27]
- The U.S. Environmental Protection Agency's Urban Waters Small Grants program offers money for water restoration and water-quality improvements.[28] Improving stormwater management in urban parks (by implementing the technologies in Chapter 6) may satisfy their criteria.
- Google provided $344,000 to Seattle's Digital Equity Initiative to install Wi-Fi in Seattle's 26 recreation centers,[29,30] and more funding opportunities may be available.
- The California State Parks Foundation offers Park Enrichment Grants that aim to support the use of technology in parks to enhance the visitor's experience.[31]
- The Mayor's Office of the City of Los Angeles operates a $1 million Innovation Fund that provides funding for innovative city projects that increase efficiency, improve quality of life, and/or enhance sustainability.[11]
- The City of Sacramento offers grants through its Mayor's Office for Innovation & Entrepreneurship.[20]

There are many other grants offered by governments, private corporations, and nonprofits that could be used to fund new and improved SMART Parks.

Loan, Rebate, and Bond Programs

The federal government, state governments, and local utilities often have special financing programs for municipalities to implement projects on renewable energy production, energy efficiency, and water conservation. For example, the California Energy Commission offers financing for energy-efficient public sector projects as loans to be repaid through energy cost savings over 20 years with only 1% interest.[32] The California Hub for Energy Efficiency Financing is another resource that provides loans, leases, and other assistance to residents, small businesses, and government or nonprofit entities.[33] The Drinking Water State Revolving Loan Fund program, a potential source for funding stormwater projects in disadvantaged communities, is a federal-state partnership. It provides financial support for water systems and state safe-water programs in all 50 states.[32,34]

California's investor-owned utilities (Pacific Gas & Electric, Southern California Edison, San Diego Gas & Electric, and Southern California Gas Company) provide on-bill financing, a program in which the utility or a third party pays for an upgrade upfront and charges customers over time via their utility bill.[35] These financing programs offer government entities 0%, no-fee loans of up to $250,000 (or $1 million under certain conditions), with terms of up to 10 years, for installation of qualified energy-efficiency measures.[36] Utility companies may also provide rebates for lighting upgrades, such as those featured in Chapter 10.

The Los Angeles Department of Water and Power (LADWP) offers rebates for solar panel installations, paying $1.15 per watt generated until 75% of project costs are covered.[32] LADWP also offers rebate programs for water-efficiency measures.[37] The Metropolitan Water District, which sells water to utilities and systems across Southern California, has SoCal Water$mart, a rebate program for its customers.[38] Rebates cover irrigation controllers, sprinklers, and turf replacement to residential, commercial, and public agency customers who upgrade to more water-efficient devices (See Chapter 5 for more information on irrigation efficiency upgrades that may qualify for rebates).[38]

States, cities, and counties can also finance renewable energy projects with Clean Renewable Energy Bonds from the U.S. Department of Energy.[32] Bonds are most useful to manage long-term debt for large capital projects that are well-planned and executed, such as the construction of greenways, trails, or recreation centers.[39] Voters can also agree to raise funds for parks through general obligation bonds, which do not use assets as collateral, are sold to investors, and repaid with property tax revenue over time.[12]

Municipal Government Tools

Local governments can create ordinances, park districts and business improvement districts, implement zoning changes, transfer public lands, or levy taxes to raise funds for parks. While most parks already obtain a large portion of their funds from city budgets, there may be opportunities for further support.

For example, the City of Houston passed an Open Space Ordinance that divided the city into "park sectors."[40] Within each sector, developers were required to either build private or public parkland as part of their plan or pay a fee to fund park improvements within the same sector as the development.[40]

Credit: Pexels

Figure 12.8: Loan and rebate programs from local, state, and federal government can provide financing opportunities, especially for energy or water efficiency upgrades such as solar panels or new sprinklers.

Depending on state legislation, cities can vote to create **metropolitan park districts**. For example, Chapter 35.61 of Washington State's Revised Code allows for creating these districts via ballot proposition. The districts are defined as separate, junior taxing districts within incorporated or unincorporated areas created for the "management, control, improvement, maintenance, and acquisition of parks, parkways, boulevards, and recreational facilities."[41] As of 2017, Washington State had 19 metropolitan park districts, including one in Seattle.[42] In 2014, Seattle voters approved Proposition 1 to fund and create the Seattle Park District. The district is funded through property taxes, thus ensuring a dedicated stream of money for parks separate from the city budget.[40] Illinois and Ohio similarly allow the creation of park districts.[43, 44] For states without such laws, advocacy can be focused on encouraging the legislature to pass bills that allow development of park districts.

Business improvement districts (BIDs) can also support park management and improvements. These "management corporations" collect additional property taxes from property owners within the district to improve the area by providing services such as maintenance, marketing, capital improve-

Credit: Wikimedia Commons

Figure 12.9: Denny Park in Seattle, Washington, is part of the Seattle Park District created by Proposition 1, a ballot measure in 2014.

ments, and landscaping.[45] BIDs require an agreement with all entities within the BID to pay additional taxes. Therefore, proposed BIDs must garner support of property owners and commercial tenants before formulation. Then, the BID is created through local government authorization or legislation.[46] For example, the 34th Street Partnership, a BID in New York City, manages and maintains Greeley Square Park and the surrounding 21-block area.[12]

Cities can also leverage their **zoning powers** to promote park improvements. Zoning incentive programs offer benefits to developers, such as relaxed zoning and increased floor area ratios, if they agree to incorporate parks in their plans or set aside funds for parks.[12] For example, when New York City was creating High Line Park, it allowed developers to exceed normal height and density limitations in West Chelsea if they contributed to the High Line Improvement Fund.[12]

Cities and counties can also **transfer development rights**[12] from land unsuitable for park development to public areas more suitable for this type of land use. These transfers can allow for the development of parks in areas where they were previously prohibited.[12] Such local opportunities to transfer development rights may be useful for SMART Park creation.

Municipalities can **levy special taxes and fees** for park improvements. Much like business improvement districts, tax increment financing districts can fund projects in specific areas. Municipalities that create these borrow future tax revenue to finance current development or improvement in designated areas.[47] The assumption is that the development will increase property values, and thus tax revenue, so the future increased tax revenue is used to pay back money borrowed to implement the upgrades.[47] The original amount of tax revenue is still used for its previously determined purposes, but the additional revenue goes into a fund to be used for particular projects.[47]

Another potential funding source is created when voters agree to **allocate a percentage of local or state sales tax for parks**, or pass special-purpose levees to increase property taxes for a limited period or one time only.[12] For example, 0.25% of sales tax in the City of Boulder, Colorado, funds open space and mountain parks.[12] The City of St. Louis, Missouri, uses 1/10 of one cent of its sales tax revenue for the Great Rivers Greenway.[12] Kansas City and the states of Minnesota and Arkansas also allocate dedicated portions of sales tax revenues for parks.[12]

Many cities have **impact development fees** that are paid by developers to cities to mitigate the impact of new development on public services and facilities.[48] Money from these fees can be set aside to build or improve parks in the area around the new development. This ensures that developers give back to the community and provide adequate green space in addition to their infrastructure development.[12] Park dedication fees are similar but require commercial or industrial developers to set aside a portion of land for public use or pay an equivalent fee to a parks fund.[12] Park managers may also generate revenue by charging fees for the use of facilities or services, such as parking or swimming pools. However, this can raise equity concerns; private donations or nonprofit fundraising may offset this by offering scholarships or fee coverage for low-income groups.[49]

Which funding options are applicable will depend on park context; the upgrades needed or desired; geographic location; as well as the local, regional, and state political structure and climate. Park managers should carefully research potential partnerships, funding options, and creative ways to leverage resources to best fit their needs.

Prioritizing SMART park technologies

This section presents suggestions on how to use the technology rating system and the eight Value Criteria described in Chapter 3. Each component chapter contains the ratings for the technologies it features. The table below displays the eight Value Criteria and which technologies might best yield the most appropriate benefits for a given park component. Park managers should first consider which type of component they are interested in (e.g., Hardscape, Activity Spaces, etc.) and which Value Criteria they prioritize, based on the needs of the community that the park serves. For example, managers interested in improving Access as it relates to Activity Spaces would consider interactive play structures, high-performance track surfaces, energy-generating exercise equipment, outdoor DJ booths — all of which received a full-circle rating. Although beyond the scope of this toolkit, it is critical to consider how technologies may be paired to multiply benefits.

Value Criterion	Park Components	Technologies (Chapter)
ACCESS	**Irrigation**	Subsurface Drip Irrigation (Chapter 5)
	Hardscape	Photocatalytic Titanium Dioxide Coating, Daylight Fluorescent Aggregate (Chapter 7)
	Activity Spaces	Interactive Play Structures, High-Performance Track Surfaces, Energy-Generating Exercise Equipment, Outdoor DJ Booths (Chapter 8)
	Urban Furniture and Amenities	Smart Benches, Restroom Occupancy Sensors, Smart Water Fountains, Digital Signs (Chapter 9)
	Digiscapes	Wi-Fi, Application Software (Chapter 11)

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Value Criterion	Park Components	Technologies (Chapter)
COMMUNITY FIT	Landscape	Green Roofs, Green Walls (Chapter 4)
	Hardscape	Piezoelectric Energy-Harvesting Tiles, Transparent Concrete, Daylight Fluorescent Aggregate (Chapter 7)
	Activity Spaces	Interactive Play Structures, Energy-Generating Exercise Equipment, Outdoor DJ Booths (Chapter 8)
	Urban Furniture and Amenities	Digital Signs (Chapter 9)
	Lighting	LEDs and Fiber Optics as Art (Chapter 10)
	Digiscapes	Application Software (Chapter 11)
HEALTH	Landscape	Automatic Lawn Mowers, Near-Infrared Photography, Green Roofs, Green Walls, VIbrating Pollinators (Chapter 4)
	Hardscape	Photocatalytic Titanium Dioxide Coating (Chapter 7)
	Activity Spaces	Interactive Play Structures, High-Performance Track Surfaces, Pool Ozonation, Energy-Generating Exercise Equipment , Outdoor DJ Booths, Hard-Surface Testing Equipment (Chapter 8)
	Urban Furniture and Amenities	Solar Shade Structures, Solar-Powered Trash Compactors, Smart Water Fountains (Chapter 9)
	Lighting	Lighting Shields (Chapter 10)

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Value Criterion	Park Components	Technologies (Chapter)
SAFETY	Irrigation	Smart Water Controllers, Low-Pressure and Rotating Sprinklers, Subsurface Drip Irrigation (Chapter 5)
	Stormwater	Engineered Soils (Chapter 6)
	Hardscape	Pervious Paving, Self-Healing Concrete, Transparent Concrete, Daylight Fluorescent Aggregate (Chapter 7)
	Activity Spaces	Hard-Surface Testing Equipment (Chapter 8)
	Lighting	Motion-Activated Sensors, LEDs and Fiber Optics as Art, Digital Additions to LED Fixtures, Lighting Shields (Chapter 10)
RESILIENCE	Landscape	Near-Infrared Photography, Green Roofs, Air-Pruning Plant Containers, Vibrating Pollinators (Chapter 4)
	Irrigation	Smart Water Controllers, Subsurface Drip Irrigation, Graywater Recycling (Chapter 5)
	Stormwater	Engineered Soils, Underground Storage Basins, Real-Time Control and Continuous Monitoring and Adaptive Control, Rainwater Harvesting (Chapter 6)
	Hardscape	Pervious Paving, Piezoelectric Energy-Harvesting Tiles, Daylight Fluorescent Aggregate, Carbon Upcycled Concrete (Chapter 7)
	Activity Spaces	High-Performance Track Surfaces, Energy-Generating Exercise Equipment (Chapter 8)
	Urban Furniture and Amenities	Solar Shade Structures (Chapter 9)
	Lighting	Off-Grid Light Fixtures (Chapter 10)

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Value Criterion	Park Components	Technologies (Chapter)
WATER	Landscape	Near-Infrared Photography (Chapter 4)
	Irrigation	Smart Water Controllers, Low-Pressure and Rotating Sprinklers, Subsurface Drip Irrigation, Smart Water Metering, Graywater Recycling (Chapter 5)
	Stormwater	Engineered Soils, Underground Storage Basins, Real-Time Control and Continuous Monitoring and Adaptive Control, Rainwater Harvesting (Chapter 6)
	Hardscape	Pervious Paving, Photocatalytic Titanium Dioxide Coating (Chapter 7)
	Activity Spaces	Pool Ozonation (Chapter 8)
	Urban Furniture and Amenities	Smart Water Fountains (Chapter 9)
ENERGY	Landscape	Automatic Lawn Mowers, Green Roofs, Green Walls (Chapter 4)
	Hardscape	Cross-Laminated Timber, Pervious Paving, Piezoelectric Energy-Harvesting Tiles, Transparent Concrete, Daylight Fluorescent Aggregate, Carbon Upcycled Concrete (Chapter 7)
	Activity Spaces	Energy-Generating Exercise Equipment (Chapter 8)
	Urban Furniture and Amenities	Smart Benches, Solar Shade Structures, Solar-Powered Trash Compactors (Chapter 9)
	Lighting	Motion-Activated Sensors, Off-Grid Light Fixtures, Lighting Shields (Chapter 10)

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Value Criterion	Park Components	Technologies (Chapter)
OPERATIONS AND MAINTENANCE	**Landscape**	Automatic Lawn Mowers, Air-Pruning Plant Containers (Chapter 4)
	Irrigation	Smart Water Controllers, Subsurface Drip Irrigation, Smart Water Metering, Graywater Recycling (Chapter 5)
	Stormwater	Drones, Real-Time Control and Continuous Monitoring and Adaptive Control (Chapter 6)
	Hardscape	Self-Healing Concrete, Photocatalytic Titanium Dioxide Coating (Chapter 7)
	Activity Spaces	Interactive Play Structures, Pool Ozonation, Hard-Surface Testing Equipment (Chapter 8)
	Urban Furniture and Amenities	Solar-Powered Trash Compactors, Restroom Occupancy Sensors, Smart Water Fountains, Digital Signs (Chapter 9)
	Lighting	Motion-Activated Sensors, Off-Grid Light Fixtures, Digital Additions to LED Fixtures, Lighting Shields (Chapter 10)
	Digiscapes	Wi-Fi, Application Software, Sensor Networks and The Internet of Things (Chapter 11)

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Appendices

Appendix A: Structured interviews

INTERVIEWEES

Mohammed Al Rawi, Chief Information Officer, Los Angeles County Department of Parks and Recreation and **Colin Martin**, Architect/ Systems Engineer, Cisco (June 5, 2017), phone Interview

Ryan Carpio, Director of Government Affairs, Los Angeles City Department of Recreation and Parks (February 22, 2017), phone Interview

Taylor Emerson, Policy Analyst, and **Janice Perez**, Planner, San Francisco Recreation and Parks (February 14, 2017), phone Interview

Jocelyn Estiandan, Policy Analyst, PLACE Program, Los Angeles County Department of Public Health (February 1, 2017), phone Interview

Alex Farassati, Environmental Services Supervisor, City of Calabasas (September 5, 2017), phone Interview

Mark Glassock, Director of Special Projects, Los Angeles Neighborhood Land Trust (February 15, 2017), phone Interview

Tom Jacobs, Stormwater Engineer, City of Lenexa, Kansas, (August 7, 2017), phone Interview

Edward Krafcik, Director of Strategic Partnerships, Soofa (July 28, 2017), phone Interview

Preceding page — Credit: Wikimedia Commons

When New York City was creating High Line Park, it allowed developers to exceed normal height and density limitations in West Chelsea if they contributed to the High Line Improvement Fund.

Clement Lau, Departmental Facilities Planner II, Los Angeles County Department of Parks and Recreation (February 16, 2017), phone Interview

Mia Lehrer, President; Claire Latané, Senior Associate; and Astrid Sykes, Senior Associate; Studio-MLA (March 8, 2017), phone Interview

Robin Mark and **Paolo Perrone**, Project Managers, Trust for Public Land (February 1, 2017), phone Interview

Yvonne Overmaat, Director (Netherlands), Yalp Interactive (August 17, 2017), phone Interview

Matthew Rudnick, Chief Sustainability Officer, Los Angeles City Department of Recreation and Parks (February 3, 2017), phone Interview

Melissa Spagnuolo, Senior Administrative Analyst, Santa Monica Recreation and Parks (February 21, 2017), phone Interview

Ana Straabe, Chief of Park Development, Mountains Recreation and Conservation Authority (February 14, 2017), phone Interview

Jason Thompson, License/Boat Registration Division Director, Mississippi Department of Wildlife, Fisheries, and Parks (August 28, 2017), Phone Interview

John Villasenor, Professor, UCLA Electrical and Computer Engineering (May 8, 2017), in-person Interview

Fabian Wagmister, Director, UCLA Center for Research in Engineering, Media and Performance (REMAP) (June 7, 2017), phone interview

GENERAL QUESTIONS ASKED IN INTERVIEWS

» Are there ways you believe technology could help you maintain and manage parks more efficiently and effectively?

» In your view, which park components would benefit from being SMART?

» Where do you spend most of your park management/maintenance funds?

» Which park elements or services are most expensive?

» Do you allocate funds for park management and maintenance according to specific categories of expenses (e.g., irrigation, lighting, building structures, etc.)? Can you let us know all these categories?

Appendix B: Questions to determine technology rankings

CRITERION 1: ACCESS

1. **Does this technology make the park easier for all types of people to access, either physically or psychologically (by removing barriers to use)?**
   » If Yes – Rate with filled-in circle.
   » If No – Proceed to next question.

2. **Does this technology make services available in the park that the community may otherwise have difficulty accessing?**
   » If Yes – Rate with filled-in circle.
   » If No – Proceed to next question.

3. **Does this technology have trade-offs so that access may be improved or made easier in some ways but reduced in other ways?**
   » If Yes – Rate with half filled-in circle.
   » If No – Proceed to next question.

4. **Does this technology have potential accessibility benefits only if used in a particular context, in tandem with other technologies, or as a secondary effect?**
   » If Yes- Rate with half filled-in circle
   » If No- Proceed to next question

5. **Does this technology have an effect that impairs accessibility to the park, making it harder for the community, whether physically or psychologically, to use or obtain services at the park?**
   » If Yes – Rate with empty circle.
   » If No – Proceed to next question.

6. **Is this technology unrelated to accessibility, or does it have no effect on this park component?**
   » If Yes – Rate with empty circle.

CRITERION 2: COMMUNITY FIT

1. **Does this technology have positive benefits on the park context; does it help the park creatively utilize and reflect its physical, ecological, social and cultural surroundings (especially with regard to programming or visitor engagement and education)?**
   » If Yes – Rate with filled-in circle.
   » If No – Proceed to next question.

2. **Is this technology adaptable to enable it to fit in a variety of park contexts? Can it be altered to meet community needs or existing park design?**
   » If Yes – Rate with filled-in circle.
   » If No – Proceed to next question.

3. **Does this technology have trade-offs so that the fit may be enhanced on one hand but diminished on another (such as by reducing some programing options)?**
   » If Yes – Rate with half filled-in circle.
   » If No – Proceed to next question.

4. **Does this technology have potential fit benefits only if used in a particular context, in tandem with other technologies, or as a secondary effect?**
   » If Yes – Rate with half filled-in circle.
   » If No – Proceed to next question.

5. **Does this technology have an effect that impairs the park context, such as reducing park programming options or not allowing alterations to fit the park?**
   » If Yes – Rate with empty circle.
   » If No – Proceed to next question.

6. Is this technology unrelated to community fit or does it have no effect on this park component?
   » If Yes- Rate with Empty Circle

CRITERION 3: HEALTH

1. Does this technology help facilitate healthy activities or promote community health in the park?
   » If Yes – Rate with filled-in circle.
   » If No – Proceed to next question.

2. Does this technology provide health benefits or health education for community members or improve the environmental health of the park (such as by reducing pollutants or monitoring air quality)?
   » If Yes – Rate with filled-in circle.
   » If No – Proceed to next question.

3. Does this technology have trade-offs so that it provides some health benefits, while impairing community or park health in other ways?
   » If Yes – Rate with half filled-in circle.
   » If No – Proceed to next question.

4. Does this technology have potential health benefits only if used in a particular context, in tandem with other technologies, or as a secondary effect?
   » If Yes – Rate with half filled-in circle.
   » If No – Proceed to next question.

5. Does this technology have an effect that impairs community health, such as by discouraging healthy activities or having a negative impact on environmental quality?
   » If Yes – Rate with empty circle.
   » If No – Proceed to next question.

6. Is this technology unrelated to health or does it have no effect on this park component?
   » If Yes – Rate with empty circle.

CRITERION 4: SAFETY

1. Does this technology improve safety, security, or comfort of the park or its visitors?
   » If Yes – Rate with filled-in circle.
   » If No – Proceed to next question.

2. Does this technology have trade-offs so that it may improve safety of the park on one hand but may increase vulnerability in another way?
   » If Yes – Rate with half filled-in circle.
   » If No – Proceed to next question.

3. Does this technology have potential safety/comfort/security benefits only if used in a particular context, in tandem with other technologies, or as a secondary effect?
   » If Yes – Rate with half filled-in circle.
   » If No – Proceed to next question.

4. Does this technology have an effect that impairs security or safety in the park?
   » If Yes – Rate with empty circle.
   » If No – Proceed to next question.

5. Is this technology unrelated to safety or does it have no effect on this park component?
   » If Yes – Rate with empty circle.

CRITERION 5: RESILIENCE

1. **Does this technology help the park prepare for, anticipate, or adapt to potential future changes in climate, population or land use?**
   » If Yes – Rate with filled-in circle.
   » If No – Proceed to next question.

2. **Does this technology have trade-offs so that resiliency may be improved for the park in one aspect but hampers adaption or preparation for change in another aspect?**
   » If Yes – Rate with half filled-in circle.
   » If No – Proceed to next question.

3. **Does this technology have potential resiliency benefits only if used in a particular context, in tandem with other technologies, or as a secondary effect?**
   » If Yes – Rate with half filled-in circle.
   » If No – Proceed to next question.

4. **Does this technology have an effect that impairs the ability of the park to prepare for, adapt to, or anticipate future changes?**
   » If Yes – Rate with empty circle.
   » If No – Proceed to next question.

5. **Is this technology unrelated to resiliency or does it have no effect on this park component?**
   » If Yes – Rate with empty circle.

CRITERION 6: WATER

1. **Does this technology conserve water resources or facilitate water reuse?**
   » If Yes – Rate with filled-in circle.
   » If No – Proceed to next question.

2. **Does this technology provide water benefits to the park or the community members, such as clean drinking water or water education?**
   » If Yes – Rate with filled-in circle.
   » If No – Proceed to next question.

3. **Does this technology have trade-offs so that water use is improved in some ways but impaired in others?**
   » If Yes – Rate with half filled-in circle.
   » If No – Proceed to next question.

4. **Does this technology have potential water benefits only if used in a particular context, in tandem with other technologies, or as a secondary effect?**
   » If Yes – Rate with half filled-in circle.
   » If No – Proceed to next question.

5. **Does this technology have an effect that impairs water use in the park, such as by requiring increased water use or costs?**
   » If Yes – Rate with empty circle.
   » If No – Proceed to next question.

6. **Is this technology unrelated to water or does it have no effect on park component?**
   » If Yes – Rate with empty circle.

CRITERION 7: ENERGY

1. **Does this technology conserve energy resources, facilitate clean energy generation, or provide energy education to the public?**
   » If Yes – Rate with filled-in circle.
   » If No – Proceed to next question.

2. **Does this technology have trade-offs so that it may provide positive energy benefits on one hand but could increase energy use or have other negative energy effects in other ways?**
   » If Yes – Rate with half filled-in circle.
   » If No – Proceed to next question.

3. **Does this technology have potential energy benefits only if used in a particular context, in tandem with other technologies, or as a secondary effect?**
   » If Yes – Rate with half filled-in circle.
   » If No – Proceed to next question.

4. **Does this technology have an effect that impairs energy benefits to the park, such as by requiring extra energy use?**
   » If Yes – Rate with empty circle.
   » If No – Proceed to next question.

5. **Is this technology unrelated to energy or does it have no effect on this park component?**
   » If Yes – Rate with empty circle.

CRITERION 8: OPERATIONS AND MAINTENANCE

1. **Does this technology streamline operations and maintenance, reduce costs, or otherwise make them more efficient?**
   » If Yes – Rate with filled-in circle.
   » If No – Proceed to next question.

2. **Does this technology have trade-offs between O&M benefits and drawbacks, such as by reducing long-term maintenance but requiring additional short-term maintenance upfront?**
   » If Yes – Rate with half filled-in circle.
   » If No – Proceed to next question.

3. **Does this technology have potential O&M benefits only if used in a particular context, in tandem with other technologies, or as a secondary effect?**
   » If Yes – Rate with half filled-in circle.
   » If No – Proceed to next question.

4. **Does this technology have an effect that impairs O&M in the park, such as by increasing requirements or costs?**
   » If Yes – Rate with empty circle.
   » If No – Proceed to next question.

5. **Is this technology unrelated to O&M or does it have no effect on this park component?**
   » If Yes – Rate with empty circle.

Appendix C: Answers to technology ranking questions

		Access						Community Fit						Health						Safety				
	Question ▸	#1	#2	#3	#4	#5	#6	#1	#2	#3	#4	#5	#6	#1	#2	#3	#4	#5	#6	#1	#2	#3	#4	#5
LANDSCAPE	Automatic Lawn Mowers	N	N	N	N	N	Y	N	N	N	N	N	Y	N	Y	N	N	N	N	N	N	N	N	Y
LANDSCAPE	Near-Infrared Photography	N	N	N	N	N	Y	N	N	N	N	N	Y	N	Y	N	N	N	N	N	N	Y	N	N
LANDSCAPE	Green Roofs	N	N	N	N	N	Y	N	Y	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	Y
LANDSCAPE	Green Walls	N	N	N	N	N	Y	N	Y	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	Y
LANDSCAPE	Air-Pruning Plant Containers	N	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y
LANDSCAPE	Vibrating Pollinators	N	N	N	Y	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	Y
IRRIGATION	Smart Water Controllers	N	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	N	Y	Y	N	N	N	N
IRRIGATION	Low-Pressure and Rotating Sprinklers	N	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	N	Y	Y	N	N	N	N
IRRIGATION	Subsurface Drip Irrigation	Y	N	N	N	N	N	N	N	N	N	N	Y	N	Y	N	N	N	N	Y	N	N	N	N
IRRIGATION	Smart Water Metering	N	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y
IRRIGATION	Graywater Recycling	N	N	N	N	Y	N	N	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y
STORMWATER	Engineered Soils	N	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	N	Y	Y	N	N	N	N
STORMWATER	Underground Storage Basins	N	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y
STORMWATER	Drones	N	N	N	N	N	Y	N	N	N	Y	N	N	N	N	N	N	N	Y	N	N	N	N	Y
STORMWATER	Real-Time Control/ Continuous Monitoring and Adaptive Control	N	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	Y	N	N	N	N	N	N	Y
STORMWATER	Rainwater Harvesting	N	N	N	N	N	Y	N	Y	N	Y	N	N	N	N	N	N	N	Y	N	N	N	N	Y

		Resilience					Water						Energy					O&M				
	Question ▶	#1	#2	#3	#4	#5	#1	#2	#3	#4	#5	#6	#1	#2	#3	#4	#5	#1	#2	#3	#4	#5
LANDSCAPE	Automatic Lawn Mowers	N	N	N	N	Y	N	N	N	N	N	Y	Y	N	N	N	N	Y	N	N	N	N
	Near-Infrared Photography	Y	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	Y
	Green Roofs	Y	N	N	N	N	N	N	N	Y	N	N	Y	N	N	N	N	N	N	N	N	Y
	Green Walls	N	N	N	N	Y	N	N	N	Y	N	N	Y	N	N	N	N	N	N	Y	N	N
	Air-Pruning Plant Containers	Y	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	Y	Y	N	N	N	N
	Vibrating Pollinators	Y	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	Y	N	N	N	Y	N
IRRIGATION	Smart Water Controllers	Y	N	N	N	N	Y	N	N	N	N	N	N	N	Y	N	N	Y	N	N	N	N
	Low-Pressure and Rotating Sprinklers	N	N	N	N	Y	Y	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	Y
	Subsurface Drip Irrigation	Y	N	N	N	N	Y	N	N	N	N	N	N	N	Y	N	N	Y	N	N	N	N
	Smart Water Metering	N	N	Y	N	N	Y	N	N	N	N	N	N	N	Y	N	N	Y	N	N	N	N
	Graywater Recycling	Y	N	N	N	N	Y	N	N	N	N	N	N	Y	Y	N	N	Y	N	N	N	N
STORMWATER	Engineered Soils	Y	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	Y
	Underground Storage Basins	Y	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	Y	N	N	Y	N	N
	Drones	N	N	Y	N	N	N	N	N	Y	N	N	N	N	N	N	Y	Y	N	N	N	N
	Real-Time Control/ Continuous Monitoring and Adaptive Control	Y	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N
	Rainwater Harvesting	Y	N	N	N	N	Y	Y	N	N	N	N	N	N	Y	N	N	N	N	N	N	Y

		Access						Community Fit						Health						Safety				
	Question ▸	#1	#2	#3	#4	#5	#6	#1	#2	#3	#4	#5	#6	#1	#2	#3	#4	#5	#6	#1	#2	#3	#4	#5
HARDSCAPE	Cross-Laminated Timber	N	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	Y	N	N	N	N	N	N	Y
HARDSCAPE	Pervious Paving	N	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	N	Y	Y	N	N	N	N
HARDSCAPE	Piezoelectric Energy-Harvesting Tiles	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	Y	N	N	N	N	Y	N	N
HARDSCAPE	Self-Healing Concrete	N	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	N	Y	Y	N	N	N	N
HARDSCAPE	Photocatalytic Titanium Dioxide Coating	Y	N	N	N	N	N	N	N	N	N	N	Y	N	Y	N	N	N	N	N	N	N	N	Y
HARDSCAPE	Transparent Concrete	N	N	N	N	N	Y	N	Y	N	N	N	N	N	N	N	Y	N	N	Y	N	N	N	N
HARDSCAPE	Daylight Flourescent Aggregate	Y	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	Y	N	N	Y	N	N	N	N
HARDSCAPE	Carbon Upcycled Concrete	N	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y
ACTIVITY SPACES	Interactive Play Structures	Y	N	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	Y
ACTIVITY SPACES	High-Performance Track Surfaces	Y	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	Y
ACTIVITY SPACES	Pool Ozonation	N	N	N	N	N	Y	N	N	N	N	N	Y	N	Y	N	N	N	N	N	N	N	N	Y
ACTIVITY SPACES	Energy-Generating Exercise Equipment	N	Y	N	N	N	N	N	Y	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	Y
ACTIVITY SPACES	Outdoor DJ Booths	Y	N	N	N	N	N	Y	Y	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	Y
ACTIVITY SPACES	Hard-Surface Testing Equipment	N	N	N	N	N	Y	N	N	N	N	N	Y	N	Y	N	N	N	N	Y	N	N	N	N

		Resilience					Water						Energy					O&M				
	Question ▸	#1	#2	#3	#4	#5	#1	#2	#3	#4	#5	#6	#1	#2	#3	#4	#5	#1	#2	#3	#4	#5
HARDSCAPE	Cross-Laminated Timber	N	N	N	N	Y	N	N	N	N	N	Y	Y	N	N	N	N	N	N	Y	N	N
	Pervious Paving	Y	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N
	Piezoelectric Energy-Harvesting Tiles	Y	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	Y
	Self-Healing Concrete	N	N	Y	N	N	N	N	N	N	N	Y	N	N	Y	N	N	Y	N	N	N	N
	Photocatalytic Titanium Dioxide Coating	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N
	Transparent Concrete	N	N	N	N	Y	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	Y
	Daylight Flourescent Aggregate	Y	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	Y
	Carbon Upcycled Concrete	Y	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	Y
ACTIVITY SPACES	Interactive Play Structures	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y	Y	N	N	N	N
	High-Performance Track Surfaces	Y	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	Y	N	Y	N	N	N
	Pool Ozonation	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N
	Energy-Generating Exercise Equipment	Y	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	Y
	Outdoor DJ Booths	N	N	N	N	Y	N	N	N	N	N	Y	N	N	Y	N	N	N	N	N	N	Y
	Hard-Surface Testing Equipment	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y	Y	N	N	N	N

		Access						Community Fit						Health						Safety				
	Question ▶	#1	#2	#3	#4	#5	#6	#1	#2	#3	#4	#5	#6	#1	#2	#3	#4	#5	#6	#1	#2	#3	#4	#5
URBAN FURNITURE AND AMENITIES	Smart Benches	N	Y	N	N	N	N	N	N	N	N	N	Y	N	N	N	Y	N	N	N	N	N	N	Y
	Solar Shade Structures	N	N	N	N	N	Y	N	N	N	N	N	Y	N	Y	N	N	N	N	N	N	N	N	Y
	Solar-Powered Trash Compactors	N	N	N	N	N	Y	N	N	N	N	N	Y	N	Y	N	N	N	N	N	N	N	N	Y
	Restroom Occupancy Sensors	Y	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y
	Smart Water Fountains	N	Y	N	N	N	N	N	N	N	Y	N	N	Y	Y	N	N	N	N	N	N	N	N	Y
	Digital Signs	Y	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	Y
	Automatic Bicycle and Pedestrian Counters	N	N	N	N	N	Y	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	N	N	Y
LIGHTING	Motion-Activated Sensors	N	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	N	Y	Y	N	N	N	N
	LEDs and Fiber Optics as Art	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N
	Off-Grid Light Fixtures	N	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	N	Y	N	N	Y	N	N
	Digital Additions to LED Fixtures	N	N	N	N	N	Y	N	N	N	Y	N	N	N	N	N	N	N	Y	Y	N	N	N	N
	Lighting Shields	N	N	N	N	N	Y	N	N	N	Y	N	N	N	Y	N	N	N	N	Y	N	N	N	N
DIGISCAPES	Wi-Fi	N	Y	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	Y	N	N	Y	N	N
	Geographic Information Systems and Services	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	N	N	N	Y	N	N	Y	N	N
	Application Software (Apps)	Y	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	Y	N	N	N	N	Y	N	N
	Sensor Networks and the Internet of Things	N	N	N	Y	N	N	N	N	N	N	N	Y	N	N	N	Y	N	N	N	N	Y	N	N

		Resilience					Water						Energy					O&M				
	Question ▸	#1	#2	#3	#4	#5	#1	#2	#3	#4	#5	#6	#1	#2	#3	#4	#5	#1	#2	#3	#4	#5
URBAN FURNITURE AND AMENITIES	Smart Benches	N	N	N	N	Y	N	N	N	N	N	Y	Y	N	N	N	N	N	N	Y	N	N
	Solar Shade Structures	Y	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	Y
	Solar-Powered Trash Compactors	N	N	N	N	Y	N	N	N	N	N	Y	Y	N	N	N	N	Y	N	N	N	N
	Restroom Occupancy Sensors	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y	Y	N	N	N	N
	Smart Water Fountains	N	N	N	N	Y	N	Y	N	N	N	N	N	N	Y	N	N	Y	N	N	N	N
	Digital Signs	N	N	N	N	Y	N	N	N	N	N	Y	N	N	Y	N	N	Y	N	N	N	N
	Automatic Bicycle and Pedestrian Counters	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y	N	N	Y	N	N
LIGHTING	Motion-Activated Sensors	N	N	N	N	Y	N	N	N	N	N	Y	Y	N	N	N	N	Y	N	N	N	N
	LEDs and Fiber Optics as Art	N	N	N	N	Y	N	N	N	N	N	Y	N	N	Y	N	N	N	N	Y	N	N
	Off-Grid Light Fixtures	Y	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	Y	N	N	N	N
	Digital Additions to LED Fixtures	N	N	N	N	Y	N	N	N	Y	N	N	N	N	Y	N	N	Y	N	N	N	N
	Lighting Shields	N	N	N	N	Y	N	N	N	N	N	Y	Y	N	N	N	N	Y	N	N	N	N
DIGISCAPES	Wi-Fi	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y	Y	N	N	N	N
	Geographic Information Systems and Services	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y	N	N	Y	N	N	N	N
	Application Software (Apps)	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y	N	N	Y	N	N	N	N
	Sensor Networks and the Internet of Things	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y	N	N	Y	N	N	N	N

Appendix D: Lighting materials and comparisons

LIGHTING MATERIALS

One factor that contributes to lighting's impact on safety and environmental and human health is the material and type of light bulb. This section will describe five common types of light bulbs: incandescent, fluorescent, ceramic metal halide (CMH), high-pressure sodium (HPS), and light-emitting diodes (LED). Each has its strengths and weaknesses, such as energy efficiency, cost of materials and installation, lifetime, color rendering, and toxicity. These properties arise largely from the materials used and method of operation.

Incandescent – Wire filament glows with visible light when heated.

Fluorescent – An electric arc passes through gaseous mercury, producing invisible ultraviolet light that then causes a coating on the inside of the lamp to glow. Fluorescent lights designed to replace incandescent ones in standard light bulb sockets or small lighting fixtures are also called compact fluorescent lights (CFLs).

Ceramic Metal Halide (CMH) – An electric current passes through a mixture of gaseous mercury and metal halides to make the gas conductive and produce light.

High-Pressure Sodium (HPS) – An electric current passes through a mixture of gaseous mercury and sodium to make the gas conductive and produce light.

Light-Emitting Diodes (LED) – A semiconductor releases light when influenced by an electric current or field (electroluminescence).

THE LIFE CYCLE

Understanding the life-cycle environmental impact of light bulb materials is essential to making smart lighting decisions. Waste can be hazardous if it exhibits ignitability, corrosivity, reactivity, or toxicity. Some end-of-life bulb components may be categorized as hazardous waste if they contain amounts of metallic elements exceeding federal and state regulations, such as the US Toxicity Characteristic Leaching Procedure (TCLP) and the California Total Threshold Limit Concentration (CA TTLC). Both regulations set an upper allowable limit on metal concentration in nonhazardous waste based on the potential for metal leached into landfills to pose noticeable environmental and human health concerns.[1,2] If a light bulb malfunctions or breaks, the cost of disposal may increase depending on whether those devices are locally considered hazardous waste. Such costs may include transport to a separate waste facility, arranging for special pickup, and/or the cost of replacement and cleanup. Table 1 lists metals that may be present in the above light sources at amounts exceeding US TCLP and CA TTLC toxicity thresholds.

Table 1: Potential toxic concentrations of metals in light sources[3,4]

	Incandescent	Fluorescent (CFL)	Ceramic Metal Halide (CMH)	High-Pressure Sodium (HPS)	LED
Exceeds these toxicity thresholds	—	Lead (TCLP) Copper (TTLC) Mercury* (TTLC) Zinc (TTLC)	Mercury* (TTLC)	Mercury* (TCLP)	Copper (TTLC)

Although solid mercury is not used to construct CFL, CMH, and HPS bulbs, the operation of these bulbs requires gaseous mercury, which can be released if the bulb breaks. However, the high-energy efficiency of these bulbs compared to incandescent bulbs may result in a net decrease in life-cycle mercury emissions by reducing those associated with electricity production.[5]

Effects of different light bulb materials on resource depletion, impacts to human health (human-toxicity) through air, water, and soil intake, and impacts to aquatic and soil ecosystems (eco-toxicity) have been approximated by the USEtox model.[6] USEtox is a scientific consensus model developed under the United Nations Environment Program (UNEP) and the Society for Environmental Toxicology and Chemistry (SETAC) Life Cycle Initiative.[7] A 2013 study published in Environmental Science & Technology used USEtox to find the following:

» CFLs may deplete energy and material resources 3–5 times faster than incandescent bulbs.

» LEDs may deplete energy and material resources 2–3 times faster than incandescent bulbs.

» When accounting for product life expectancies, CFLs pose 22–26 times higher human- and eco-toxicity potentials than incandescent bulbs, and LEDs pose 2-3 times higher human- and eco-toxicity potentials than incandescent bulbs.[3]

» While LEDs as recently as 2012 had a lead content higher than the US TCLP threshold,[3] more recent research and development has produced lead-free LEDs.[8]

In summary, CFL and LED bulbs require less energy and natural resources to produce a given amount of light than incandescent bulbs due to their high efficiency, but they may pose a greater health risk because they use various metals in potentially toxic concentrations.

COLOR RENDERING INDEX

Color rendering index (CRI) measures the ability of a light source to reveal the colors of objects faithfully compared to an ideal or natural light source. A light source with high CRI may provide better visibility, with a CRI value of 100 signifying an ideal light source. High CRI lights may also improve park aesthetic appeal due to enhanced color illumination. Finally, high CRI lights can provide high-quality lighting using less energy than other fixtures. As white light is produced from a combination of colors, it can generally render colors accurately and thus have a high CRI. Different white light sources may be classified as "warm" or "cool," indicating an increased presence of red or blue light, respectively. Blue light concentrations have been suggest-ed to create intense glare, potentially cause eye damage, and disrupt human sleep patterns.[8]

Incandescent, fluorescent, CMH, and LED bulbs produce more white light than sodium lights and thus generally have higher CRI values.[i] Some of these bulbs, especially LEDs, have been scrutinized for generating high amounts of blue light. Current innovations in LED technology seek to minimize blue light production, while maintaining a high CRI value.

Although CRI is traditionally accepted as the leading method for measuring light quality, it has been recently criticized for its inability to adequately judge LEDs.[9] CRI does not measure a light source's ability to render all colors; rather, only eight sample CRI colors are tested according to the source's warmness or coolness. In LEDs that mix red, blue, and green light to produce white light, the specific color wavelengths in the source light may not render the specific test colors used to evaluate CRI as a similar incandescent source would, thus earning a lower CRI score.[10] As a result, white-light LEDs have recorded a wide range of CRI values, as shown in Table 2. However, these lights may generate light that is pleasing to an observer by properly rendering the remaining range of colors that incandescent and fluorescent lights are not designed to specifically address.[ii,11,12]

LIGHTING MATERIALS COMPARISON

Table 2 (following page) compares relative cost, durability, energy efficiency, and toxicity of the different lighting materials. It should be noted that while the present (early 2018) materials cost of LED lighting is relatively high compared to other conventional sources, lighting demand for LEDs, driven by environmental guidelines and long-term savings, along with continued manufacturing research, continues to reduce production costs.

[i] Incandescent, fluorescent, and CMH light bulbs produce white light when dense gases or solids release heat. LEDs produce white light by mixing different colors of light, either from several colored LEDs or an external light source. Sodium lamps have lower CRI values, as they produce a distinct yellow light that casts a yellow hue over objects.

[ii] For more information about CRI measurements and white light in incandescent, LED, and other bulbs, additional resources include the U.S. Department of Energy's Building Technologies Program and Solid-State Lighting Technology Fact Sheet.

Table 2: Comparison of lighting materials[13,14]

Material	Materials Cost	Installation and Maintenance Cost	Energy Efficiency (lumens per watt)**	Lifetime (hours)	Materials Toxicity	Color Rendering Index
Incandescent	$	$$$	Low (16)	1000-3000	Low	95+
Compact Fluorescent	$	$$	Medium (80-85)	6000-20000	High	80-85
Ceramic Metal Halide	$$-$$$	$$	Medium-High (75-110)	10000-20000	Medium-High	80-94
High-Pressure Sodium	$$	$$	Medium-High (80-120)	15000-40000	Medium	22-70
LED	$$-$$$	$	Excellent (up to 145 for raw white LED)	Up to and exceeding 70000	Medium	42-97

** The lumen is a measure of the total quantity of visible light emitted from a source. The watt is a unit of power. Lumens per watt measures how much light can be produced with a given amount of energy.

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