THE Sustainability OF Parking
FIRST EDITION
ABOUT THE NATIONAL PARKING ASSOCIATION

The National Parking Association (NPA) is the industry’s leading authority on parking research, best practices and business process. It is the fastest growing parking association in North America, representing all sectors of the parking industry and its leaders.

In 2012, NPA established the parking industry Innovation Awards—recognizing excellence and innovation in parking practices including an award for Innovative Sustainability Project of the Year.

NPA serves the industry as a resource for thought leadership, networking, conferences, education and:

◆ Advocates for fair and equitable parking regulations;
◆ Develops ground breaking longitudinal research studies;
◆ Promotes best practices, business process models & industry standards; and
◆ Serves the private parking, private public parking, transportation, asset management & commercial real estate industries.

The National Parking Association is the nation’s leading parking trade group advancing the interests of the private and public sector in parking technology, sustainable mobility, certification, advocacy, research and education. Founded in 1951, NPA has 3,000 members and represents all segments of the parking industry.

ABOUT THE INTERNATIONAL PARKING INSTITUTE

The International Parking Institute (IPI) is the largest and leading association of parking professionals and the parking industry. IPI’s mission is advancing the parking profession.

Founded in 1962, IPI’s purpose is advancing the parking profession through:

◆ Leadership
◆ Education
◆ Professional development
◆ Conferences
◆ Connections
◆ Data collection
◆ Advocacy
◆ Outreach

Parking is integral to transportation flow, economic development, land use, law enforcement, architectural aesthetics and quality of life. For that reason, IPI members hale from a wide spectrum, including professionals from cities, port authorities, civic centers, academic institutions, hospitals and healthcare facilities, airports, corporate complexes, race tracks, transit and transportation agencies, retail, hospitality, and entertainment and sports centers, as well as architects, engineers, financial consultants, urban planners, and suppliers of equipment, products and services to the parking and transportation industries.
Publishers’ Note

Dear Readers,

Welcome to the first reference book for the parking industry on sustainability. The parking, transportation and commercial real estate industry all are looking at green trends and practices. At a time when our industry is increasingly going green, we are proud to have partnered to bring you case studies, parking practices and guidance on sustainable practices for on street and off street parking. We hope you find this publication interesting, valuable and relevant to your own work in the parking, transportation and asset management.

Both public and private parking are integrating sustainable practices into their surface lots, parking structures and on street environments. While parking hasn’t traditionally leapt to the forefront of people’s minds when they think about sustainable industries, that’s rapidly changing. We extend our thanks to the Certified PArking Professionals, Certified Administrators of Public Parking, consultants, industry suppliers for their contributions. We appreciate those who innovate, renovate and build parking that are going green.

This reference book is made possible by the contributions of some of our industry’s leading thinkers. We extend our thanks to the NPA’s Parking Consultants Council and Chuck Cullen, CPP, CAPP and to Rachel Yoka, LEED, AP BD+C at Timothy Haahs & Associates. Special thanks to Rachel for her tireless efforts to see this project through as its chair rallying contributors, authors and experts.

The parking industry has a tremendous role to play when it comes to sustainability. Each chapter in this book demonstrates positive, realistic steps that the parking industry is taking and can take to become more sustainable in our business practices. Some practices have a high ROI, others are simply good from a reduce, reuse and recycle perspective. All bring value to parkers, the community and the quality of the parking experience.

Again, many thanks to all our contributors for sharing your expertise. We hope you—our readers—find this a valuable reference resource.

Sincerely,

Shawn Conrad, CAE
International Parking Institute

Christine Banning, MA, CAE
National Parking Association
WE PLANNED THIS TO BE A GROUNDBREAKING PUBLICATION.

Groundbreaking by Topic:
We have addressed sustainability in the parking industry. This handbook generated a tremendous amount of new content on major topics, including electric vehicles, renewable energy, greening the surface and more. Yet, our authors have tackled far more than individual topics; they have sought to address the greater context of parking, transportation and the built environment.

How will the parking industry fit within and add value to the sustainability movement?
As an industry, we have a massive opportunity to shift from a reactionary stance to a more demanding, but effective, proactive one. A proactive stance to research, collaborate, advance, and indeed, to drive the parking industry to greater contributions to sustainability. This publication takes a meaningful step forward to frame the discussion of parking and sustainability. As an industry, it showcases our ability to lead, both in theory and in practice (not merely to follow and respond).

Groundbreaking by collaboration:
The International Parking Institute (IPI) and the National Parking Association (NPA) joined forces to publish a shared volume to advance the parking profession. Our authors and reviewers represent not only IPI and NPA, but also many sectors within the parking industry: architects, engineers and consultants; private and public and institutional owners; parking experts; and more. I would like to personally thank each author for his or her dedication and persistence as we moved this partnership forward.

Our peer reviewers played a critical role reviewing each chapter as subject matter experts. They shared guidance and direction as well as reinforcement and clarification. We took their generous feedback and integrated every comment. A number of our reviewers represent not only IPI and NPA, but also the board, staff, and volunteers of the Green Parking Council (GPC), and they offered an innovative perspective and depth and breadth of expertise that was invaluable during the development and refinement of this handbook.

Groundbreaking because we shifted focus:
We take readers on a journey from theory and expertise to real-world applications and on-the-ground reality. Organized into two primary sections, the handbook features chapters based on subject matter by experts in their field, along with case studies. We benchmarked success in this publication by our ability to move decisively from the theoretical to the concrete and applicable. We hosted an open call for case studies from all IPI and NPA members to submit their best and most sustainable projects and programs. These case studies showcase real applications that can serve as models for your next project or program. They detail the why and the how, and provide both objectives and results.

I hope you are educated, challenged, and inspired by what you find in this handbook. We welcome your feedback and responses to what you experience. Further, this book is a call to action, a call to increase both awareness and sustainability initiatives within your organization. We hope to feature your case study in the next edition.

RACHEL YOKA, LEED AP, CNU-A
Vice President, Strategic Business Planning and Sustainability
Timothy Haahs & Associates
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CHAPTER 1
The Concept of a Sustainable Garage

JERRY MARCUS

THIS BOOK WILL EXPLORE THE CONCEPT of adopting sustainable principles into one of the most ubiquitous building types of our time—the parking garage.

Every type of land use developed today—entertainment, retail, commercial real estate, aviation/transportation, medical complexes, convention centers, sports facilities, residential developments, or government offices—requires parking. In some cases, abundant, convenient parking is essential to the success of the development.

The International Parking Institute and the National Parking Association have engaged many of the industry’s preeminent professionals and designers to collaborate on this publication. Parking in all its forms, including stand-alone structures, integrated parking structures, concrete structures, and steel structures, will be reviewed. The publication examines existing parking facilities as well as new facilities and garages that will be designed in the future. In all its forms, the concept of sustainable parking is ready to be explored.

Green building is revolutionizing the business of architecture and engineering, encouraging design professionals to be accountable for their work in a way that promotes a better world for all of us. The green building revolution has spurred designers and builders to incorporate sustainable design into many types of buildings, but some have been garnered less attention than others.

Many of the leaders of the green design revolution take issue with the concept of a sustainable parking garage. Many feel it is absurd to call a structure built solely for cars anything close to sustainable. After all, the manufacture, distribution and operation of hydrocarbon-burning vehicles are as far from carbon neutral as it gets. Many also see the parking garage as a barrier to a more sustainable world. Many green design professionals feel strongly
about excluding parking from any green dialogue. Some feel that parking supply shortages will precipitate more transit infrastructure.

However, as an unintended consequence, such shortages also stifle development and produce long circuitous searches for parking spaces, increasing fuel consumption. Unfortunately, just a few metropolitan areas in the United States have sufficient transportation options available to significantly reduce parking demand.

Even in U.S. cities where mass transportation is widely used by the general public (such as New York, San Francisco, or Washington, D.C.) there are still vast numbers of vehicles that are on the highways and streets each day. (Those that drive the Washington, D.C. Beltway or the George Washington Bridge in New York can easily attest to the number of cars that stack up in these transit-friendly cities.)

Despite having established mass transportation options, these cities are nearly gridlocked on a regular basis. Worse yet, the majority of U.S. cities have poor public transportation options. For those cities, the automobile will be essential for many decades to come.

This publication will try to frame the argument a little differently: it will explore options from the point of view of the parking patron who has little choice but to drive and park, and from the parking design community whose members work on this under-appreciated building type.

Hypothetically, the user of the parking facility and the parking design professional have in common the desire to be as environmentally responsible as anyone. An important goal here is to create an overall understanding that parking can be executed as responsibility as any other building type.

Universal goals for sustainable parking:

◆ To help reduce the world’s dependence on fossil fuel.
◆ To reduce the energy required to locate a parking space.
◆ To “right size” parking structures and parking lots.
◆ To reduce the amount of land required to store vehicles.
◆ To encourage the purchase and use of alternative fuel vehicles and electric vehicles.
◆ To encourage change-of-mode commutes.
◆ To encourage carpooling.
◆ To reduce the energy needed to operate a parking facility.
◆ To use best sustainable practices in choosing lighting, structural materials, parking technology, and mechanical, electrical, and plumbing systems.
◆ To reclaim water from parking structures and surface lots.
◆ To incorporate renewable energy sources into our designs.

The above goals are similar to the overriding goals for LEED buildings, which are intended to use resources more efficiently. LEED-certified buildings often provide healthier work and living environments. The benefits of implementing a LEED strategy include improving air and water quality and reducing solid
waste, thereby benefiting owners, occupiers, and the larger community.

Issues

Many of those most passionate about sustainability seek to eliminate as many passenger vehicles as possible from our roads, for a number of reasons:

◆ If vehicles are present, so is the practice of searching for a good parking space.
◆ The U.S. has, by all accounts, a significant oversupply of parking. Some put the ratio at eight parking spaces for every car (250 million passenger vehicles and 2 billion spaces). Parking is always the single biggest land use in any urban environment.
◆ It takes a significant amount of energy to build a parking space, including the creation and transportation of concrete or precast elements.
◆ Parking spaces trap heat, creating an urban heat island that, in turn, raises the temperature of cities. This results in an additional energy load on buildings to maintain comfortable indoor temperatures.
◆ Parking garages may be as environmentally harmful as the cars housed in them. Vehicles
leak gas, oil, and transmission fluid. They also shed brake dust and bring in de-icing chemicals. Rain washes these caustic contaminants into drainage systems. Additionally, cars and trucks driving through them concentrate vehicle emissions.

◆ Many argue that empty parking spaces provide incentives for people to drive their own cars instead of taking more environmentally-efficient transit options.

◆ Paved surface lots are in many ways worse for the environment than garages. More paved area means fewer green areas, fewer carbon-absorbing trees, and less soil absorption to replenish aquifers.

**Opportunities**

The fact that parking facilities have many issues as they relate to the environment is precisely why we must improve their design. What better way to have a big effect on the environment than to provide parking designs that address the specific issue presented in the previous section?

If we must park vehicles, the industry can adopt sustainable principals in the design of the structures that will do that. Parking garages will never be as environmentally friendly as bicycles or rail, but they can serve as great places for rail stops or bicycle storage areas.

The authors will look at a host of opportunities to make the parking structure more sustainable, including the following major topics:

◆ Site planning considerations.

◆ Renewable energy options, including photovoltaic systems and wind generators.

◆ Lighting technology and controls.

◆ Green and cool roofs that reduce the heat island effect.

◆ Sustainable construction materials.

◆ Operational practices.

◆ Rating systems than can be applied to parking structures.

The concepts in this publication have been developed by some of the most talented professionals in the business. Our goal is to explore the opportunities of designing truly sustainable parking structures. People are going to keep building parking spaces. In the future, however, we suggest a more thoughtful approach to parking.

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**JERRY MARCUS**

is president and owner of

The Parking Advisory Group LLC.
Chapter 2
Sustainability Frameworks & Structured Parking
Context, Applicability, and Challenges

Rachel Yokas

Structured parking and sustainability are not by definition incompatible. When parking resources, both structured and surface, were planned, designed, built, renovated, and eventually demolished in the means and methods of the past 50 years, parking and sustainability were, for the most part, in conflict.

Our approach to parking has evolved, slowly but surely, over the past decade. Some of this evolution has happened as part and parcel of the sustainability movement, including the United States Green Building Council (USGBC) and the development of Leadership in Energy and Environmental Design (LEED) standards.

But much of the change from the parking industry has come from within as well; transformation in our industry has evolved with advancing technology, changing customer and owner needs, and the growing acknowledgment that no industry exists in a vacuum. As the parking industry becomes more integrated with urban planning, infrastructure development, mobility and transportation engineering, software and technology, and a host of other practices, parking professionals and those outside of our industry have begun to realize the complexity and inter-relationships that exist among all of these areas.

So it is the case with sustainability: the parking industry has been affected and changed by the sustainability movement, but sustainability practices are intimately linked with the planning, design, and operation of parking and mobility.\(^1\)
Rating Systems Overview

The Triple Bottom Line

The Triple Bottom Line (TBL), though not a ratings system, provides a framework for sustainability in any industry. This generalized approach, first coined by John Elkington in his 1997 book, Cannibals with Forks: the Triple Bottom Line of 21st Century Business, is often referred to as “People, Planet, Profit,” “3BL,” “TBL,” or the “three pillars.”

TBL addresses three critical components—economic, ecological, and social—that can be factored into decision-making processes.

Sustainability was first defined by the Brundtland Commission of the United Nations in March 1987:

“Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs.”

Within both the TBL and UN definitions, balance is critical to the success of the model. Although neither provides specific direction or priority for the parking industry, they do provide a foundation for our decision making, aiming to achieve balance among these three often-competing priorities.

The International Parking Institute’s Framework on Sustainability

In January 2012, The International Parking Institute (IPI) formally adopted its Framework on Sustainability. The IPI Board of Directors and Sustainability Committee believed that environmental sustainability goals and a well-designed and operated parking system can work together to meet customer needs, environmental responsibility, and financial goals.

Yet it was critical that IPI formally survey the organization’s membership prior to solidifying this approach, and drafting such a framework.

In early 2011, IPI launched a survey of members to solicit the feedback of parking professionals to ensure the organization was effectively representing our industry and, at the same time, moving the organization forward in response to the growing sustainability movement.

More than 80 percent of members responded that they were “concerned” or “very concerned” about sustainability in our industry.

Respondents identified a number of critical elements of sustainability in our industry, but felt the two most important elements were “green building and high performance building standards for parking structures” and “parking facility operations supporting alternative transportation modes,” ranking at more than 75 percent.

Based on this information as well as industry research and collaboration, IPI drafted its Framework on Sustainability and publicly solicited feedback from both members and those outside of the industry for comment. The resulting framework takes a generalized approach to sustainability and applies it specifically not only to the parking industry, but also to the organization’s strengths and capacity.

The Framework identifies strategic sustainability goals as well as accompanying action items to advance and strengthen the parking profession and the greater application of sustainability within it. These key priorities include but are not limited to:

- Expanding the use of multi-modal transportation options such as bike sharing, car sharing, pedestrian-friendly environments, and access to mass transit hubs.
- Focusing on transportation demand management (TDM) strategies.
IPI’s Framework on Sustainability is a continually evolving document that encourages these goals related to sustainability:

- Expand use of multi-modal transportation options such as bike sharing, car sharing, pedestrian-friendly environments, and access to mass transit hubs.
- Use waste reduction strategies.

**SUSTAINABILITY**

- Focus on transportation demand management (TDM) issues.
- Use alternative energy sources and energy savings technology, reduce reliance on fossil fuels, and accommodate alternative fuel vehicles.
- Make informed decisions based on long-term environmental impacts related to material and technology selection.
- Increase education and information sharing.
- Use effective natural resource management.

**GOALS**

**ACTION ITEMS**

1. Developing seminars, webinars, e-learning opportunities, and speakers on topics related to sustainability, including a sustainability track at the annual IPI Conference & Expo.
2. Writing articles, white papers, and publications on the latest solutions that reflect a balance between economics, public health and welfare, and reduced environmental impacts.
3. Encouraging and recognizing achievements and improvements in sustainable parking and transportation through awards programs and exhibitor visibility.
4. Adding courses related to sustainability as part of the required curriculum for the Certified Administrator of Public Parking (CAPP) certification program.
5. Creating forums for peer-to-peer sharing on sustainable parking design, management, and operations.
6. Developing tools and resources to facilitate sustainable design, management, and operations that result in long-term energy efficiency, informed material and technology selection, the availability of multi-modal transportation options, effective natural resource management, and the use of waste reduction strategies.
7. Forging partnerships with government agencies, vendors, and non-profit organizations to facilitate goal setting, information sharing, and funding incentives that encourage investing in sustainable parking solutions.
8. Supporting third-party certification solutions that recognize achievement in sustainable parking.
9. Initiating research that informs, justifies, and/or provides lessons learned on sustainable parking solutions.
10. Communicating with media, influencers, and the public to create awareness of the positive impact parking professionals can have on sustainability.
Using alternative energy sources and energy savings technology, reducing reliance on fossil fuels, and accommodating alternative fuel vehicles.

Ten identified action items leverage the strength of IPI as an organization, focusing on education, publishing, recognition and networking.

This approach is specific to the parking industry and relevant to its business practices and opportunities. Yet as a framework, it was not intended to serve as a ratings system such as LEED or to supplant any existing framework.

It complements and extends the TBL approach to the parking industry. It does not provide benchmarking and measurement tools by which to gauge success or failure, as rating systems are designed to do, but was designed to encourage and educate not only members of the parking profession but those outside it to the relevance and critical importance of parking to the sustainability movement.

**USGBC and LEED**

The USGBC currently leads the United States market in green building ratings systems, offering LEED rating systems for new construction, existing buildings, core-and-shell, and commercial interiors, as well as neighborhood development. LEED rating systems continue to grow and evolve, gaining in complexity as the sustainability movement changes.

Per the USGBC, LEED for New Construction & Major Renovations (LEED-NC) takes an integrative approach to producing buildings that are designed to be efficient and have a lower impact on their environment.”

At the time of this publication, LEED 2009 for New Construction was scheduled to be replaced by new version of LEED. Its predecessors include LEED v 1.0, 2.0, 2.1, and 2.2. A small number of parking structures were certified under LEED NC v 2.2, prior to the release of LEED 2009 and evolving Minimum Program Requirements.

Under v 2.2 and LEED 2009, the USGBC applies five main credit categories that contain multiple sustainable strategies under each heading. These include:

- Sustainable Sites (SS)
- Water Efficiency (WE)
- Energy and Atmosphere (EA)
- Materials and Resources (MR)
- Indoor Environmental Quality (IEQ)

An additional category exists termed Innovation and Design (ID). ID credits include exemplary performance as well as innovations not covered by the existing rating system.

The systems include both prerequisites and credits in each area. All prerequisites must be met for a building to achieve any level of certification. A building’s owner seeks to achieve a certain number of credits throughout the design and construction process, and points are allocated based on the relative importance of building-related impacts.

Prerequisites for LEED NC include the following, which may all be achieved by parking structures designed with the rating system in mind. Within each of these prerequisites, parking structures may present unique challenges and applications.

- SS Prerequisite 1: Construction Activity Pollution Prevention
- SS Prerequisite 2: Environmental Site Assessment
- WE Prerequisite 1: Water Use Reduction
- EA Prerequisite 1: Fundamental Commissioning of Building Energy Systems
- EA Prerequisite 2: Minimum Energy Performance
- EA Prerequisite 3: Fundamental Refrigerant Management
- MR Prerequisite 1: Storage and Collection of Recyclables
- IEQ Prerequisite 1: Minimum Indoor Air Quality Performance
IEQ Prerequisite 2: Environmental Tobacco Smoke Control

In addition, all buildings must integrate at least 1,000 square feet of conditioned space and provide space for a minimum of one full time equivalent (FTE) occupant.

Parking garages have been specifically addressed in the Minimum Program Requirements (MPR) for LEED and the associated Supplementary Guidance to the MPR.

These documents clarify the USGBC position on parking structures and their eligibility for certification, reflecting an evolving perspective on how the USGBC addresses parking structures and parking as a component of mixed-use buildings.

Pre-August 12, 2011, LEED Interpretation #10079 stated, “Parking garages may not pursue LEED certification. More specifically, buildings that dedicate more than 75% of floor area (regardless of whether or not they are covered, enclosed, and/or conditioned) to the parking and circulation of motor vehicles are ineligible for LEED.”

This interpretation was updated August 12, 2011 to state “Parking garages for cars and trucks may not pursue LEED certification. More specifically, buildings that dedicate more than 75% of floor area all square footage, to the storage and circulation of cars and/or trucks are ineligible for LEED. Square footage should be considered even if it is not covered, enclosed, or conditioned. This LEED Interpretation does NOT apply to vehicle maintenance shops of any kind, airport hangars, border facilities, car salesrooms, transit centers, or other buildings that deal with cars and trucks in a capacity other than parking, OR with vehicles other than cars and trucks.”

The most recent update to the interpretation as of October 1, 2012, which stands at the time of publication provides the following: “So as not to penalize projects for consolidating parking in garages, and to make this LEED Interpretation more consistently applicable across a broad spectrum of project types, please note that the specific limit on the amount of parking a project may include is hereby removed. Instead, the USGBC wishes to clarify that parking areas themselves are not now, nor have they ever been eligible for LEED-certification. It is the “gross floor area” of a project (which, by definition excludes parking areas) which is the basis for determining LEED certification fees and the focus of the certification analysis. Like other features of the site or location, parking, whether structured or at-grade, has an impact on certain credits, but it does not actually receive LEED certification. Applicable internationally.”

The final clarification essentially excludes parking garages (and areas) from pursuing certification.

For example, a mixed-use parking structure with interior conditioned space may pursue certification under multiple rating systems, but only the conditioned space will be in fact “certified.” The parking areas may contribute to certification (as relevant credits) but the entire structure will not be considered certified.

This interpretation may evolve as new projects pursue certification and create a body of experience and inquires that require further clarification.

Parking structures may add credits to a project if they lie within the LEED project boundary. In this fashion, a stand-alone garage with no mixed-use space that is adjacent to an office building may contribute credits to the project.

In many cases, garages will provide credits to the adjacent building (here, both buildings are considered a single project according to the LEED boundary and certification process.). In this scenario, a garage may offer significant credit value under the Sustainable Sites category, especially with regard to the alternative transportation credits.
Applicability of LEED Credits for Parking Structures

Some LEED rating system credits may be particularly relevant to parking structures. Some of the most relevant credits are detailed below; this should not be considered an exhaustive list, especially given the changing nature of parking and mixed-use structure design. As noted, all prerequisites for the system must be met for a building to achieve certification.

◆ **SS Credit 1: Site Selection.** The intent of this credit is to avoid development of inappropriate sites, including but not limited to environmentally sensitive greenfields and prime farmland. This credit is particularly relevant because “previously disturbed sites” are acceptable for development; these sites include surface parking lots, which often serve as landbanks for future development.

◆ **SS Credit 2: Development Density and Community Connectivity.** The intent of this credit is to encourage development to urban areas with existing infrastructure by selecting sites with higher levels of density and community connectivity (local resources). For structured parking to be required and desired as a building type in many cases, this level of density and connectivity also exists at the same location.

◆ **SS Credit 4.1: Alternative Transportation—Public Transportation Access.** The intent of this credit is to reduce pollution and other effects of automobile use. In a similar methodology to SS Credit 2, structured parking is often placed in close proximity to transit and alternative modes of transportation, not only to serve transit, but also because of the density factor. An urban area that requires additional structured parking probably also supports local transit options such as bus and rail.

◆ **SS Credit 4.2: Alternative Transportation—Bicycle Storage and Changing Rooms.** The intent of this credit is to reduce pollution and other impacts from automobile use by supporting bicycles as an alternative mode of transportation. The credits require the provision of secure bicycle racks and nearby shower and changing facilities for cyclists, which may be easily provided within a parking garage. The credit contains slightly different means for commercial/institutional and residential projects, but the intent remains the same. Garages may provide excellent bicycle storage as well as bike sharing or rental programs.

◆ **SS Credit 4.3: Alternative Transportation—Low-Emitting and Fuel Efficient Vehicles.** The intent of this credit is to reduce pollution and other impacts from automobile use by encouraging the use of low-emitting and alternative fuel vehicles. Options for this credit include providing preferred parking (or a discounted rate) for such vehicles, installing alternative fuel stations (such as EV charging stations), or providing low-emitting and fuel efficient vehicles for occupants. Preferred or discount parking for such vehicles is the most common and low-cost approach to achieve this credit in parking structures.

◆ **SS Credit 4.4: Alternative Transportation—Parking Capacity.** The intent of this credit is to reduce pollution and other impacts from automobile use by limiting the construction of new parking and providing preferred parking for carpools and vanpools. This threshold is commonly applied to meet but not exceed local zoning requirements. One challenge specific to this credit may be the application of shared parking strategies to obtain variances.
that provide less capacity than the zoning requirements. Shared parking strategies can maximize turnover and land use by minimizing the number of spaces to be constructed. This is one of the most sustainable strategies in the parking industry, and at this time is not accounted for in the LEED rating system.

- **SS Credit 7.1: Heat Island Effect—Non Roof.** The intent of this credit is to reduce the heat island effect, especially in urban areas. Under this credit, Option 2 states that 50 percent of parking spaces shall be under cover (as in a parking structure). In addition, the roof of the garage must also have a high Solar Reflectance Index (SRI), be vegetated, or shall be covered by solar panels.

- **SS Credit 7.2: Heat Island Effect—Roof.** The intent of this credit is to reduce the heat-island effect, especially in urban areas through the selection of roofing materials. Three options exist that may apply to parking structures under this credit: 75 percent of the roof must achieve a high SRI, 50 percent of the roof must be vegetated, or there must be a combination of those two requirements.

- **EA Credit 1: Optimize Energy Performance.** The intent of this credit is to achieve increasing levels of energy performance to reduce the effects of excessive energy use. For an office, residential, or retail building, this credit may equate to high point value (up to 19 points). Although this level of performance improvement may not be easily achieved for a parking structure, this credit may still add significant point value. By addressing the two primary energy demands of a structure (lighting and ventilation), significant gains in energy performance (as well as cost savings) may be achieved.

- **EA Credit 2: On-Site Renewable Energy.** The intent of this credit is to encourage the development of on-site renewable energy to reduce the impacts of fossil fuel use. Parking structures are well suited to provide rooftop photovoltaic arrays, providing on-site renewable energy. In this way, a structure may earn up to seven points by providing up to 13 percent of renewable energy to meet the energy demand of the garage.

- **MR Credit 4: Recycled Content.** The intent of this credit is to increase demand for materials with recycled content. Two materials in parking garage design feature prominently in many LEED projects. The steel used in parking structures may be as high as 90 percent recycled material, which can be verified by the supplier. In addition, concrete mixes may contain recycled materials in the form of aggregate and/or fly ash.

- **MR Credit 5: Regional Materials.** The intent of this credit is to reduce the transportation impact of materials selected for the building. In many cases, the precast concrete, cast-in-place concrete, and steel used in the construction of parking structures is produced within the regional radius of this credit.

This brief summary of a selection of credits demonstrates the value that parking structures can add to the LEED-pursuant project or the pursuit of LEED certification for a mixed-use parking structure. Additional credits may be available under the exemplary performance standards (for meeting even higher established thresholds than the credit itself).

LEED has also added the provision of Regional Priority credits, which allow for greater point values for selected zip codes because of regional geographic relevance of selected sustainability strategies. The certification process also employs the Carbon Overlay, which prioritizes credits based on relative value for greenhouse gas emissions based on the carbon footprint of a typical LEED building.

The LEED system relies heavily on energy performance, indoor environmental quality measures, and interior conditions, reducing applicability for our industry and building type. That said, the rigor and benchmarks provided by LEED form a solid foundation.
for improving the environmental performance of parking and mixed-use structures.

Green Globes

While LEED may be the current standard for the third party verification of sustainable design and construction, the Green Building Initiative’s (GBI) Green Globes rating system provides a viable alternative. The Green Globes process facilitates third-party verification of the sustainable construction of non-occupied projects such as parking structures.

Like other rating systems, Green Globes offers project teams and owners the ability to measure and certify the sustainable design and construction of new and existing structures; designated by the GBI as New Construction (NC) and Continual Improvement of Existing Buildings (CIEB).

The NC web application walks architects, engineers, construction professionals, building owners, and facilities managers through the process of evaluating, quantifying, and improving the environmental performance of new construction projects and major renovations. It provides building sustainability assessment, education, and feedback throughout the design-build-commission project lifecycle for new commercial buildings.

Projects that score high on the Green Globes rating scale and incorporate the sustainability enhancement suggestions given by the online tool are expected to consume fewer fossil fuels, reduce greenhouse emissions, conserve water, reduce other forms of pollution, minimize effects on land surrounding the building, and offer a better working environment for occupants. New commercial buildings that have implemented the improvement suggestions of Green Globes and have a higher rating may also offer subsequent advantages such as lower operating costs for energy and water.

CIEB is also web-based, and helps commercial building owners and property managers in the evaluation, documentation, and improvement of the environmental performance of their commercial buildings. The CIEB process provides sustainable options for capital improvements or implementation of best practices and allows teams to benchmark and rate the benefits of building attributes and procedures. As each entry is logged into the provided survey tool, Green Globes provides a report that can help the team evaluate opportunities to benefit from energy savings, reduced environmental impacts, integrated corporate goals and practices, and lower maintenance costs.

While still relatively unknown, the Green Globes rating system has been available in the U.S. since its origin overseas as a byproduct of the Building Research Establishment’s Environmental Assessment Method (BREEAM), which is largely regarded as the international green building rating standard.

Like other rating systems, Green Globes is based on the accrual of credits/points in each of seven recognized environmental assessment areas. The software tools and ratings/certification system assess impacts on a 1,000 point scale in multiple categories, including Energy, Indoor Environment, Site, Water, Resources, Emissions, and Project/Environmental Management. To achieve a Green Globes rating/certification of one to four Globes, a new or existing project must achieve a threshold of at least 35 percent of the total...
number of 1,000 points. Two Globes are awarded for achieving 55-69 percent, three Globes for 70-84 percent, and four Globes for 85-100 percent. Green Globes’ third-party assessors (with expertise in green building design, engineering, construction, and facility operations) interface with project teams and building owners during the third-party assessment process by reviewing building documentation and conducting on-site walkthroughs.

While the goals of Green Globes are similar to those of other rating systems, there are many differences in how the process is administered. In addition to sending an assessor to walk and review project seeking rating, Green Globes guides the integrated design process at each stage of project delivery, rewarding collaborative process and taking a holistic lifecycle approach to project assessment.

Many see the inclusion of lifecycle management as a more thorough measure of sustainability, which is literally defined as, “the ability to endure.” A project that requires more maintenance and cost over its lifecycle, such as a steel or pre-topped precast parking structure, may score lower than one that requires less maintenance over time, such as a cast-in-place structure. To facilitate the measurement of project lifecycle, Green Globes provides an online calculator.

The Green Globes rating system values energy optimization, a clean and environmentally-friendly construction process, and occupant/user comfort. Green Globes has been tested to be 90 percent harmonious with LEED; that is, 90 percent of the points/credits from one should translate easily into points/credits in the other.

While there are many credit and point similarities, there are many differences as well. For example, indoor environmental quality is weighted 5 percent more in Green Globes and energy optimization 8 percent more, while LEED places 13 percent more emphasis on aspects of the site. Green Globes generally makes sense for projects looking for third-party verification, especially those with an integrated team or design-build approach. Perhaps the area in which Green Globes provides the most benefit is the certification of structures without full time equivalent (FTE) occupancy, such as parking structures.

In Green Globes there are no prerequisites such as the 1 FTE requirement of LEED v3.0 that prevents non-occupied space from certification. Instead, the GBI requires that all major criteria topics be addressed in a significant manner for a non-fully occupied structure to be certified. The GBI also allows for the removal of non-applicable criteria. The project team has the ability to provide a compelling reason for certain criteria to be eliminated from measurement on their project. If agreed upon by the GBI assessor, these credit/point categories are deducted from the project’s possible point total so as not to count against the project’s rating.

While the limit for total point omission is 10 percent of the project total and the Energy Performance and Water Performance categories are ineligible for this deduction, this is very helpful to project teams seeking parking structure rating. Additionally, Green Globes assessors are given the authority to award partial points and have the freedom to award full points in categories that were not intended by the project team.

Green Globes includes provisions for acknowledging structures with integrated parking. Under this provision, structures with FTE occupancy and integrated parking will not suffer due to the non-FTE space. Energy Star takes integrated parking into account to normalize the energy use analysis, and this benefit applies to Green Globes (the GBI utilizes the Energy Star methodology to rate energy performance).

The Green Parking Council and the Development of the Certified Green Garage

The Green Parking Council (GPC) is a non-profit organization, offering certification and credentialing programs, open-source standards, professional lead-
ership and educational development and training for organizations and individuals in the parking industry. It is currently developing the Certified Green Garage rating system, which, at the time of publication, was in a public comment period. The GPC previously completed a Demonstrator Site program to foster the development of a more sustainable parking garage. The GPC recently formed a formal alliance with the International Parking Institute to advance the sustainability initiatives of both organizations.

The Green Garage Certification program will provide an industry and parking specific standard that can be applied to both new and existing parking garages. This tool will serve as another resource to take the best practices of the Department of Energy (DOE), Environmental Protection Agency (EPA), LEED, and other systems and apply them to make a direct impact on the long term sustainability of our industry.

The rating system will be organized into three primary areas: Management, Programs, and Structural Design and Technology. The GPC rating systems incorporates many of the same principles as other frameworks and rating systems, but also features specific and innovative measures when applied to parking. Sustainability measures include:

- Life Cycle Assessment
- Transportation Management Association
- Parking Pricing
- Shared Parking
- Placemaking
- Rideshare Program
- Alternative Fuel Vehicles
- Carshare Program
- Traffic Flow Plan
- Bicycle Parking
- Bike Sharing Program
- Energy Efficient Lighting
- Lighting Controls
- Mechanical Systems and Controls
- LEED or Green Globes Certification
- Parking Guidance Systems
- EV Charging Stations
- Net Zero Energy Building
- Roofing Systems
- Tire Inflation Station
- Automated Payment Systems

This rating system will continue to evolve and grow, and will build on past performance to push market innovations such as the LEED rating system.

![Commonalities Across Ratings Systems and Frameworks](image)

**INCREASE**
- Committed and educated leadership
- Transportation alternatives
- Energy efficiency
- Use of renewable energy
- Support for rating systems

**DECREASE**
- Carbon emissions and pollution
- Waste generation
- Harmful chemical use
- Potable water use
- Cost

**FIGURE 2: Commonalities Across Ratings Systems and Frameworks**
Additional Resources

Energy Star

Under the Energy Star program, the EPA offers a free interactive energy management tool for building owners to track and assess energy and water use. This program can be used for a single building or across an entire portfolio. At this time, there is no category for parking structures, but the tool monitors both commercial and industrial uses, and can be applied to benchmark and to offer best practices.

A variety of models, means and methods exists to integrate sustainability and parking structures. Each has its unique advantages and challenges, but each should be examined relative to the specific project in mind. Regardless of the system (or systems) selected to integrate sustainability and benchmark performance, certain best practices remain essential:

◆ Integrate sustainable design from project inception.
◆ Set clear, measurable goals from the start.
◆ Carefully align the program and budget.
◆ Document sustainability goals and include tracking mechanisms.
◆ Leverage your strengths, location, region, and organization.

Notes

1. We recognize that a multitude of rating systems exist and thrive beyond this context, including BREEAM (Building Research Establishment’s Environmental Assessment Method) in the United Kingdom and CASBEE (Comprehensive Assessment System for Building Environmental Efficiency) in Japan. It is our intent to limit this overview of rating systems to commonly applied systems in the United States, but we encourage our audience to expand their base of knowledge about these systems and their potential applicability to structured parking.

RACHEL YOKA, LEED AP, CNU-A
is vice president, strategic business planning and sustainability, with Timothy Haahs & Associates, Inc.
CHAPTER 3
The Garage in an Urban Context
ISAIAH MOUW AND BRIAN SHAW

THE FIRST INTERNATIONAL URBAN PLANNING CONFERENCE OCCURRED IN 1898. One topic of discussion that dominated the conference was a major transportation and environmental concern: horse manure.¹

As the world drew closer to the modern era, the populations of urban areas skyrocketed. In the U.S. alone, municipalities grew by more than 30 million residents in the 19th century, with 15 million new people there in just the final two decades.

This rapid population growth created transportation needs, and the horse was there to fill those needs. Horses were used to transfer people to and from work, haul materials, unload freight from trains and ships, transfer injured persons to hospitals, and rush firemen to put out fires.²

The growth of the horse population in urban environments was surpassing even the vast rise in urban residents when that meeting was held. With this rise of the horse population came major transportation problems: traffic accidents, congestion, flies, horse carcasses, and most devastating, the manure.

Professionals estimated that each horse produced between 15 and 30 pounds of manure per day. In 1880, New York City had an estimated horse population of between 150,000 and
175,000, which equates to between 3 and 4 million pounds of manure being discarded into the urban environment each day. Manure piled up faster than it could be discarded, leading to flies and filth.

Horse manure also releases methane, a greenhouse gas that is eight times more potent than CO₂. Just when this catastrophe seemed to reach its breaking point, one invention solved this environmental crisis and was widely hailed as an environmental savior: the automobile.

**The Present**

Since then, the automobile has unfortunately caused many environmental problems of its own. One of the biggest is the rise in greenhouse gases in the atmosphere that has led to air quality problems in several of the world’s largest metropolitan areas. The more dependent a region has become on the automobile, the worse its air quality tends to be.

Houston, Los Angeles, and Atlanta rank among the U.S. cities with the worst air quality, with a significant portion of that problem starting in the tailpipes of the millions of vehicles moving about. Ozone in the lower atmosphere is particularly harmful and is generated from tailpipe emissions that stagnate and hover over a region during hot, sunny days.

Cities across the U.S. now issue ozone alerts to warn their residents of days when conditions are right to generate harmful levels of ozone, which contributes to asthma and breathing problems. A seemingly beautiful summer day could actually be harmful or potentially deadly for young children and elderly people with diminished lung capacity in areas prone to ozone problems.

The automobile also affects water quality by necessitating the paving of more and more areas to accommodate the movement and parking of automobiles. Impervious surfaces such as concrete and asphalt do not allow water to be absorbed into the ground. The water runoff from parking lots and streets also contains heavy metals such as lead and mercury from vehicle fluids as well as dust from brakes and tires.

Contaminated water not captured and left to filter in cisterns or retention ponds may overwhelm sewer systems and ultimately end up in our rivers, streams, oceans, and lakes.

Automobiles have also contributed to the urban heat island effect and loss of open space. The urban heat island effect phenomenon is now blamed for localized severe weather, seen during the unusual tornado that hit downtown Atlanta in March 2008. The urban heat island is caused by the growing amount of hard surfaces in our urban areas, including streets, parking lots, and parking garages.

![](https://via.placeholder.com/150)

**LEED® defines the following as basic services:**

<table>
<thead>
<tr>
<th>Bank</th>
<th>Medical/Dental Office</th>
</tr>
</thead>
<tbody>
<tr>
<td>Church</td>
<td>Park</td>
</tr>
<tr>
<td>Supermarket/Conv. Store</td>
<td>Pharmacy</td>
</tr>
<tr>
<td>Day Care</td>
<td>Post Office</td>
</tr>
<tr>
<td>Dry Cleaner/Laundry Mat</td>
<td>Restaurant</td>
</tr>
<tr>
<td>Fire Station</td>
<td>School</td>
</tr>
<tr>
<td>Salon</td>
<td>Theatre/Museum</td>
</tr>
<tr>
<td>Hardware Store</td>
<td>Community Center</td>
</tr>
<tr>
<td>Library</td>
<td>Gym</td>
</tr>
</tbody>
</table>

Automobiles have also contributed to the loss of open space and habitat seen in the continuing urban sprawl type development of our urban areas. The automobile facilitates development that is more spread out and requires accommodations for the instrument used to traverse this landscape. Parking lots, single-family housing, and shopping centers require more land than more dense developments.

The Future Vehicles do not seem to be going away anytime in the near future, and the U.S. population is expected to increase significantly.

A recent study by the Urban Land Institute (ULI) found that by the year 2050, the City of Seattle is expected to add the current population of the City of Portland, which is currently more than 500,000, to its land, and the City of Charleston will triple in population.
More than 2 billion more people around the world are expected to live in urban areas, and more than 66 percent of the buildings needed in the U.S. for this increase have yet to be built. Even with an increase in transit ridership occurring each year, the parking facilities in urban environments will have to play a key role in this massive urban population increase.

With a common goal among many industries, organizations, and individuals to reduce CO₂ emissions and increase sustainability awareness, the parking garage in an urban environment will play a major role in achieving these sustainability objectives.

**Sustainability in Mind During Design**

Choosing where to construct a parking facility in an urban environment plays the most critical role in sustainability. Having a garage located near mass transit will decrease the dependence on the automobile for everyday use. Parking operators could then provide discounts for contract parkers who drive to work one day but take mass transit on another.

One way to design a garage to limit vehicle trips is having a garage located within walking distance of basic services. Having a parking garage within several blocks of basic services such as a bank or post office will limit vehicle trips by providing walking as an alternative to driving.

**Great Streets Issues**

Many people often consider parking garages in urban environments to be a deterrent in terms of street-level activity regardless of how important these parking garages are to urban planning and development. There have been many street movements or great street issues in recent years that have encouraged designers of garages to incorporate street life into their designs. Streets should be considered as more than public utilities simply used to get people from here to there. Streets moderate the form, structure, and comfort of urban communities, and have often been used rather than individual buildings as the primary focus of urban development.

Urban garages should relate to the street as any other building. When possible, a garage’s façade should emulate its setting, playing off the surrounding architecture. Making the workings of an urban garage, such as the elevators and stair towers, visible will bring life to the street and improve the safety of patrons in the garage.

Providing social interaction is a large reason why cities exist, and streets are a major public place for that sociability to develop. Parking facility designers can design the office of the garage at street level to encourage such sociability through customer interaction.

**Walkability**

Walkability is the measure of how friendly a particular area (or parking structure) is to walking. Factors that influence a parking garage’s walkability include sidewalks, pedestrian right-of-ways, traffic, and safety precautions, among others.

Walking is the most environmentally friendly mode of transportation possible, but many times people complain when having to walk any distance from the parking garage to their end destinations. Studies have shown that when customers can see their end destination from their parking spot, they are more willing to walk further than when they cannot see that destination.

Therefore, garages should use glass instead of solid facades along sidewalks when possible. LEED also encourages pedestrian access in green building. Pedestrian access is the ability of people to walk between a building to a basic service without being
blocked by walls, highways, or other barriers such as parking garages. Lobbies should be located with access from the sidewalk to avoid having to traverse the garage, which also helps the customer avoid crossing paths with moving vehicles.

**Ground Floor Retail**

Ground floor retail allows a parking garage to become a multi-use facility and contribute back to its community in more than one way. By providing space for retail establishments, services, or offices on the ground floor adjacent to the sidewalk, a parking garage can be a vibrant part of the urban fabric and street life of its community without consuming previously undeveloped land.

Most important to sustainability is that ground floor retail helps minimize trips by allowing patrons to accomplish multiple errands at one time. Many parking facilities reduce urban sprawl by having basic services such as convenience stores, restaurants, or post offices as their footprints.

There are other benefits to ground floor retail as well, including improving pedestrian safety by making the area around the garage livelier. Ground floor retail can also help generate revenue during times when the garage is not as busy, such as nights and weekends, and can also help with traffic flow out of the facility by giving patrons something else to do before returning to their vehicles during busy exit times.

Any parking garage owner can make use of ground floor retail. University, municipal, and private parking operators can and should continue to incorporate ground-level retail into their garages because it offers both environmental and economic benefits.

**Wayfinding**

Wayfinding is defined as the process of reaching a destination, whether it is located in a familiar or an unfamiliar environment. Parking patrons create cognitive maps while driving to and within a parking facility, and later summon these cognitive maps to reach their destinations. Visual cues and anchors are key components that drivers focus on when creating their cognitive maps, so having such visual cues and anchors such as signage, color-coded walls, and planters are easy ways to implement a wayfinding system.

Having an established wayfinding system will help prevent drivers from driving around unnecessarily searching for the parking facility or looking for a parking space, ultimately resulting in less fuel consumption, CO₂ emissions, and traffic congestion.

**Sustainability in Mind During Operation**

More than 1.7 billion tons of CO₂ is released into the earth’s atmosphere each year from vehicles. Currently, on average, each gallon of gasoline burned by a typical vehicle creates more than 20 pounds of CO₂, which equates to six to nine tons of CO₂ per vehicle each year.
Even with these staggering facts, more than 40 percent of urban trips in the U.S. are less than two miles, and yet 90 percent of these short trips are taken by car. Modern American history has shown that for the most part, as the population grows, so will vehicle registrations and the vehicle miles traveled (VMT) (see graph 1-1). The urban parking garage can help reduce VMT simply minimizing the need to take these short trips.

**Amenity Programs**

One way to minimize the need of vehicle trips is to implement amenity programs that provide additional customer service while reducing a car owner’s need to drive. Amenities that can be offered in a parking operation include:

- **Dry Cleaning Services.** By contacting a local dry cleaning service, a parking operator can use a section of their parking facility as a pick up and drop off area for dry cleaning services.
- **Auto Repair Services.** Many parking facilities offer auto repair services that bring the mechanic to the parking garage to perform simple vehicle maintenance and repair.
- **Auto Detailing Services.** Many parking facilities use in-garage auto detailing services.
- **Vending Machines.** In a parking facility with no ground floor retail, a simple vending machine may prevent a parker from making an additional trip to the nearest convenient store.
- **Concierge Services.** A parking facility can offer its clients services normally provided by concierges such as purchasing event tickets, running small errands, or shopping for gifts.

**Transportation Demand Management**

Transportation Demand Management (TDM) in an urban environment is just as relevant to sustainability as in university setting. There are several ways an urban garage can influence travel choice; for example, it can allow car-sharing vehicles to be parked in a convenient location near a transit station. An urban garage near transit can also leverage that proximity by incorporating walkways and signage to the station, selling transit fare media, and offering departure times information.

A garage can provide vanpool parking spaces on the first level where vertical clearances are usually highest. Better yet, make sure at least one area of the garage is accessible to taller vehicles such as commuter vans. Other ways to make it easier for patrons to use other modes of transportation include carpool parking, bicycle racks, and bicycle sharing.

**Incentive Programs**

People respond to incentives, so having incentive programs that reward parkers who make sustainable decisions is another way to keep sustainability a focus point of the parking operation in an urban environment. Incentive programs that can be implemented into a parking operation include:

- **Small Vehicle Parking Spaces**
  The 2006 model year featured the heaviest vehicles in the U.S. in more than 30 years. The decade between 1995 and 2005 marked the hottest 10 years on record; experts say this is largely due to the CO₂ emissions that the larger vehicle trend put into the atmosphere.
  However, vehicles are now getting smaller because the Corporate Average Fuel Economy (CAFE) standards of 35.5 mpg by 2016 are affecting automakers’ decisions. Many parking facilities have been redesigned to reward smaller vehicles, which, in turn, will provide greater space efficiency and help alter the larger vehicle trend of the previous decades. Redesigning parking stall sizes will also allow more vehicles to park than previously could, creating less need to use undeveloped land for parking structures. Offering discounted rates for small vehicle reserved parking will encourage the driving and
purchasing of small vehicles, which may lead to less pollution.

◆ **Tire Inflation Station**
Under-inflated tires cause a vehicle’s engine to work harder, making it consume more fuel. According to the Department of Energy, under-inflated tires waste more than 3.5 million gallons of gas every day.

On the other hand, properly inflated tires create less work for the engine, emitting fewer greenhouse gases into the atmosphere while improving gas mileage by 3.3 percent.23 Having tire inflation stations in a parking garage allows customers to keep their tires at the recommended pound per square inch (Psi), helping them save money on gas while emitting fewer greenhouse gases into the atmosphere.

◆ **Carpool Programs**
The average commute to work in America is 15 miles, which equates to more than 7,500 miles driven to and from work each year. Still, only 10 percent of Americans carpool to work.24 Urban garages can offer discounted parking rates, preferred parking spaces, or reserved parking spaces for those who carpool. Incentives such as these will limit vehicle trips. The LEED program also provides some guidelines on how to provide carpool programs that can earn buildings points toward their certification.

◆ **Alternative Fuel Vehicle Parking Spaces**
As fuel prices continue to climb, the market and availability of vehicles using alternative fuels and low emissions continues to grow. These vehicles do not rely on gasoline for power, which results in less air pollution. Designating spaces in an urban garage for use by these vehicles can provide a low-cost incentive that is highly visible to the garage’s patrons.

The LEED® program recognizes vehicles that have earned a Green Score of 40 or more from the American Council of an Energy Efficient Economy (ACEEE) or any of the Zero Emission Vehicles (ZEVs) designated by the California Air and Resource Board (CARB) as eligible low-emission or alternative fuel vehicles. The LEED® program provides guidelines on how to provide this parking for these eligible vehicles that can earn buildings points toward their LEED® certification.

**Enforcing Alternative Fuel Parking Spaces**
The LEED® Sustainable Sites guidelines do not provide guidance on how to manage and enforce preferred parking for alternative fuel vehicles. The class of vehicles LEED® approves for its preferred parking program is more than 850 models dating back to 1999. These vehicles are not easily identifiable and even those that are labeled “Hybrid” may not actually qualify on the LEED® vehicle list.

Needless to say, the enforcement of this program is a challenge. The University of Pennsylvania in Philadelphia is developing a database of qualified vehicles in their parking management and ticketing system. Penn’s ticketing system will then warn enforcement personnel that a vehicle is qualified and to not ticket it for using the alternative fuel parking spaces. Vehicles are initially warned before a regular ticket with a fine is issued.

While this program will help a building qualify for LEED® credits, it can be met with skepticism and frustration by patrons who do not qualify to use the spaces. As this type of preferred parking grows in use, it will become accepted and understood by the parking public.

**Pricing**
The price charged for parking can have a dramatic effect on parker behavior and should therefore be considered as a key strategy in achieving sustainability objectives.

Consider a pricing study done in Westwood Village, Los Angeles: The study found that vehicle cruising in one year for parking spaces in the town created more than 950,000 excess vehicle miles traveled, which is
equivalent to 38 trips around the earth or four trips to the moon.

The waste of fuel was even worse when considering the fuel efficiency of vehicles cruising at low speed in a start/stop fashion. The environmental bottom line is that 950,000 miles of cruising for underpriced parking wasted an estimated 47,000+ gallons of gasoline and produced 730 tons of CO₂ emissions in one small business district. On-street curbside parking should be more expensive than off-street garage parking to encourage higher turnover for curbside parking. This will, in turn, lead to fewer CO₂ emissions from vehicle cruising. Having less expensive garage parking rates will encourage the use of parking garages over on-street parking, which will ultimately lead to less VMT; drivers will be more apt to leave their vehicles parked for longer periods of time because of the lower rates and no fear of receiving parking violations.

Many cities still have on-street parking rates that are cheaper than their off-street garage rates. This fundamental error in pricing encourages people to park on the street and move their vehicles every couple of hours to prevent being ticketed, which in turn leads to more CO₂ emissions.

Parking studies should be conducted to determine the correct rate for the urban garage. Pricing should not be so expensive as to prevent people from shopping downtown, but should be expensive enough for visitors to consider taking alternative transportation such as mass transit.

Urban garages can play a critical role in minimizing trips, improving the quality of the city street, and facilitating travel choice. By embracing their role in the urban transportation system, owners and managers of urban garages can help to reduce traffic, lower vehicular emissions, and foster economic development.

When retail offerings, services and amenities are provided in a parking garage, these facilities can help reduce trips, generate additional revenue, and encourage loyalty and return customers. The urban garage can and should be more than a place to park cars. They can be, have been, and should continue to be developed to serve their cities as multi-faceted facilities that provide economic and environmental benefits to their communities.

**NOTES**

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ISAIAH MOUW, CAPP, CPP, LEED GA
is general manager, south sector, with Republic Parking System.

BRIAN SHAW, CAPP
oversees Penn Transit, Penn Parking Services, Penn Mail Services and the Penn Ice Rink.
SUCCESSFUL SUSTAINABLE DESIGN PRACTICES FOLLOW AN INTEGRATED PROCESS THAT INVOLVES MANY STEPS AND A TEAM APPROACH. An early and important step is the selection of the right team. Project success depends on the experience of this team and the right balance of leadership, organization, creativity, decisiveness, and efficiency.

The team needs to include stakeholders from all aspects of the project who are committed to the sustainable vision of the project, are willing to explore new ideas, and can constructively work with a group whose members will likely offer differences of opinion and priorities.

The sustainable design process focuses on a multidisciplinary integrated approach where team members explore the interrelated effects of design, materials, function, and cost.

The team can include a wide range of members who are involved with or affected by the project, including but not limited to:

1. Owner
2. Architects
3. Engineers
4. Landscape architects
5. Sustainability consultant
6. Energy modeling consultant
7. Site or municipal planners
8. Construction manager
9. Cost consultant
10. Contractor
11. Tenant or building users
12. Facility operator
13. Maintenance staff
14. Local government agencies
15. Local utilities
16. Interested public
Choosing members to invite to the team depends on several criteria:

- **Project stakeholders.** In addition to the owner and key design team members, these are people who hold a stake in the project and can provide effective and constructive input to the process.

- **Availability of project members at the beginning of the project design process.** In a design-bid-build project delivery scenario, a construction manager or contractor may not be available to be part of the team during the design phases, but having a construction element involved during design can be invaluable.

It is possible to engage a contractor during the process for the express purpose of providing input on feasibility and cost. Involving a construction manager or contractor at the early stages of the project leads to the reliable evaluation of the effects design considerations have on project costs.

- **External Project Considerations.** Many times, projects involve or affect more parties than the building owner or users. There may be a mix of private and public goals or expectations that are critical during the project decision-making process.

The project may be part of a larger development or long-range land use plan. The project may be considered the cornerstone of a more extensive plan and will set the bar for the rest.

In these cases, representatives from various government agencies or committees, local utilities, property management entities, or specialized consultants may be considered.

It is critical that each stakeholder take responsibility and has the authority to make decisions for their respective role/party.
Team Roles

The team guides the sustainable design process from the original project vision commissioned by the owner to a completed project that achieves project goals and meets budget and schedule expectations.

Team members have specific roles and responsibilities. The following expectations are placed on each member:

1. Commit to developing and implementing an integrated building design process.
2. Review the owner’s project requirements that outline the sustainable vision and goals of the project.
3. Actively participate in design meetings/charrettes.
4. Be willing to educate and be educated on the benefits of various sustainable design considerations, materials, and systems being proposed for the project.
5. Be willing to think beyond one’s own specialty or responsibility and understand the building will be a system of interrelated systems, materials, and products.

The sustainable building design process is framed by roles and expectations of three general groups of team members: owner, design team, and contractor. Additional or specialized roles may be included on some projects.

Roles and Expectations of Owner, Design Team, and Contractor

Owner

◆ Develop a clear program that includes the sustainable vision of the project. These are commonly called the owner’s project requirements (OPR). This can be as simple as, “I want the building to be as sustainable as possible while staying within the budget,” or can include specific goals: renewable energy sources such as solar or wind power, LED lighting systems, recycled materials, stormwater quantity and quality control, incorporation of green spaces within the project site, or a completely underground structure that reduces the heat island effect of the project.

◆ Determine who is responsible for leading the sustainable design process on behalf of the owner. This could be the architect or another member of the team. Consider engaging a sustainability champion who’s independent of the design team. Having an unbiased person leading the process can be very effective, as they lead discussions toward the goals of the project without being directly affected by how these goals may influence design responsibilities and/or efforts.

◆ Establish and maintain a design environment that encourages and stimulates integrated discussion among the team members.

Design Team (Architects/Engineers/Sustainability Champion)

◆ Participate in design charrettes with the following goals:
  – Define the sustainable priorities of the project, typically focusing on key local issues such as water, energy, or traffic.
  – Present and explore design options, considerations, and concepts.
  – Refine the list of design concepts that have consensus from the team for further consideration.
  – Evaluate the concepts and begin to develop design feasibility and project impact responses, including costs.
  – Use energy analysis processes including holistic energy modeling software to evaluate the impact on energy consumption and operating costs.
– Obtain consensus on the sustainable considerations to be included in the project design.

◆ Design: At the end of each design phase (schematic design, design development, construction documents), review for confirmation that project goals identified in the OPR are being achieved and that project cost projections are accurate.

◆ Construction: Periodically review for confirmation that project goals identified in the OPR are being achieved.

Contractor
◆ Participate in design charrettes (if engaged during the design phase).
◆ Review the design documents and offer comments/suggestions regarding the sustainable goals of the project (if not engaged during the design phase).
◆ During construction, provide documentation required in the design documents and as requested by the owner to confirm the project OPR are being achieved.

Sustainability Champion
The role of the sustainability champion is critical to the success of the project. The sustainability champion is the leader of the team and is responsible for ensuring the goals of the project are achieved by:
◆ Setting the expectations of the integrated design process.
◆ Controlling the pace and direction of the process.
◆ Moderating design discussions to maintain constructive progress.

The Traditional Design Process
The traditional design process is characterized by a linear flow of information and responsibility (Fig.1)

Although there are many variations on this project delivery method, it generally begins with the owner developing the project program goals and expectations. These are passed on to the architect, who uses them to develop conceptual designs, frequently with minimal input from other project stakeholders. The conceptual designs are then presented and ultimately approved by the owner. At this point, many of the driving forces behind the project have been decided.

The approved conceptual design is presented to the remainder of the design team, which is then tasked with developing construction documents that, in many cases, incorporate predetermined concepts and strategies.

Finally, the completed design documents are presented to the contractor for pricing and construction.

This delivery method has proven to be effective and efficient. Unfortunately, in many cases, the end result is a project that does not incorporate new ideas and concepts and leaves many options and their inter-relationships unexplored.
Integrated design can be characterized by the common statement, “The whole is stronger than the sum of its parts.” Similar to the traditional design process, the project starts with a vision from the owner and ends with a completed project. However, in an integrated approach, the path the project design takes between these two points is significantly different.

As shown in the diagram above (Fig.2), the sustainable design concepts are the center of the process developed with input from key project stakeholders.

**Keys to Success**

The keys to success for any sustainable design process include:

- Selection of the right team.
- Establishing project vision and stated sustainable goals at the beginning.
- Commitment by the owner to the process.
- Commitment by the team to the project vision.

- Organization and leadership by the sustainability champion.
- Willingness and ability of each team member to think beyond his or her own specialty in the interest of the project.

The most important step in the sustainable design process is the selection of the right team members. These partners need to be committed to the project vision and should be willing to educate and to be educated on the benefits of various sustainable design considerations, materials, systems being proposed for the project, and what effects these concepts have on other building aspects.

Establishing a clear vision and setting the sustainable goals at the beginning of the project is the foundation of the sustainable design process.

Commitment to the process by the owner is critical. In most projects, the driving force behind the schedule is completing the project as quickly as possible. The sustainable process is an additional step in an already complicated and time-consuming process and can, if not planned and moderated, place added pressure on the project team affect the project outcome.

To owners and all new-to-the-process participants, this added step may be viewed as unnecessary. It is true that more time is spent at the beginning in the sustainable project design process when it’s compared to the traditional process, but performed effectively, it will usually reduce time spent on the later phases; decisions are made earlier and are final, resulting in fewer changes and construction issues.

Once the team is assembled, it is important that the sustainability champion develop and present to the team a game plan for the process that includes:

- Summary of the project vision and OPR.
- Expectations for the roles of the team and the process.
- Schedule including design charrettes and benchmarks.
The expectations outlined by the sustainability champion need to be understood and accepted by all members of the team to make the process effective and efficient. The team needs to be committed to the project vision.

The sustainable design schedule needs to allow sufficient time for exploration and discussion, but be rigid enough to keep the process going without compromising the overall project schedule. Each design charrette shall have an agenda of items to be discussed, decisions to be made, and a timeline. The sustainability champion needs to keep the discussions free-flowing but structured to meet the expectations and benchmarks.

Meeting the expectations and benchmarks of the process will be challenging, but as members become more comfortable, the creative juices will begin to flow.

The sustainable design process is different from the traditional process in that it requires an integrated team approach. The project team works in a multi-disciplinary environment exploring the interrelated impacts of design, materials, function, and costs on the project.

This process of exploring and refining design concepts occurs early in the project and begins with the initial vision from the owner. Establishing a clear program and vision for the project at the beginning lays the foundation for the sustainable design process.

Commitment to the process by the owner and project team ensures that the project goals are met in the most creative and practical manner. Organization and leadership are essential to avoid the “too many cooks in the kitchen” phenomenon, and are keys to the success of this process.
This chapter identifies the many areas that can be addressed in a sustainable parking operations program. Ideas are presented for the parking operator or owner to consider, whether the parking system includes one or multiple facilities, and whether it is an established system or a new one.

Section 1 presents a structured approach to developing a parking operations and management program that is designed to meet specific sustainability goals.

It should be noted that, while this chapter references programs geared toward reducing greenhouse gasses and other climate change related issues, we are not saying that carbon emission reductions is necessarily the ultimate goal, but that it is one example of “measurable outcomes” if your program has adopted a climate change based philosophy. Many other ways to quantify sustainable parking and transportation program impacts exist and more are being developed as these programs evolve.

Sustainable Parking Operations and Management: A Structured Program Approach

Introduction

This section outlines a recommended approach to developing and operating an environmentally sensitive parking management program. Several areas are explored that offer opportunities for “green approaches” to parking operations that can be implemented by an institution, owner or parking operator in the day-to-day management of a parking facility or program.
Before embarking on the development of a sustainable parking management initiative, it is important to answer the following questions:

◆ What is the motivation for the initiative?
◆ What are the stated goals?
◆ What level of support exists for implementing programs that may result in increased expenses or reduced revenues?
◆ How important is the initiative relative to the organization’s core vision and mission?

There are many possible answers to these questions, and the answers will have a direct impact on the approach to a sustainability initiative. For example, if an institution has adopted significant carbon emission reduction goals and integrated sustainability into its vision statement, then its approach will differ significantly from that of an organization that views sustainability as “important as long as it doesn’t impact the bottom line.”

Other important goals such as reducing overall traffic and single occupant vehicle usage reflect the multiple levels that a sustainable parking and transportation program might incorporate.

If an institution is fully committed to sustainability and considers the environment in every aspect of its operations, that institution may employ strategies that go so far as changing the parking department’s name or at least how it “brands” its parking program.

One example of this is University of Colorado’s Parking and Transportation Services (PTS) department. Upon adopting its greener approach to parking operations, the traditional PTS was rebranded/redefined to reinforce the new program mission — PTS became “Promoting Transportation Sustainability.”

**Defining the Approach: Sustainable Parking Operations and Management Principles**

The first step in implementing a sustainable parking operations and management program is to develop a set of principles that will frame the scope and goals of the program. These principles could cover a wide range of objectives depending on the organization’s environment, motivation, priorities, and resources. To illustrate, the following is a basic set of principles that could serve as a starting point:

**Sustainable Parking Operations and Management Principles**

The _____________ parking program has adopted the following guiding principles for developing a more environmentally sensitive and sustainable parking program:

**Principle # 1: Support for Institutional Goals.** The _____________ parking program will be a leader in promoting sustainable parking and transportation best practices as a means of supporting our institution’s commitment to the global climate compact (or other specific institutional commitments).

**Principle # 2: Recognition of Industry Impacts.** We recognize that on a national basis, transportation-related activities account for approximately 30% of all carbon emissions.

**Principle # 3: Core Strategy Areas.** We will adopt a variety of strategies to help reduce our operation’s carbon footprint. These strategies are divided into four primary areas.

*Sustainable Parking and Transportation Core Strategy Areas*

- Planning, Design, and New Construction
- Policy and Program Development
- Facility Operations and Maintenance
- Support for Alternative Transportation Solutions

**Principle # 4: Developing Program Metrics.** We will develop tools to identify specific measurable metrics to track and document the progress and impact of our sustainable parking operations program.

**Principle # 5: Reporting and Community Education.** The _____________ parking program will report our progress on sustainability goals and new management initiatives and celebrate program accomplishments annually.
There are many potential advantages of adopting a greener approach to facilities planning and new construction. Some of these potential benefits include:

- Contributions to community or institutional environmental goals
- Decreased environmental impacts
- Long-term reduction of operating costs
- Increased building values
- Improvement in return on investment (ROI)
- Increased tenant, customer, and staff satisfaction

However, operations and management sustainability initiatives can create increases in operating costs and even decreases in operating revenues in the short term. Therefore, it is important to understand all of the potential impacts, track the specific costs, and ensure the institution is supportive of these initiatives.

The key to success in sustainability initiatives is being able to quantify outcomes that are directly related to larger community or institutional sustainability goals. This is accomplished by developing a set of success metrics at the beginning, and obtaining buy-in from the larger institutional administration on both the goals and the measurement metrics. Defining the right metrics is discussed later in this section.

Charting the Course: Effective Goal-Setting Strategies

By December 2007, over 450 American colleges and universities had signed American College & University Presidents Climate Commitment (ACUPCC) pledges to “eliminate their campuses’ greenhouse emissions over time.” Since then, similar initiatives have been enacted by mayors, governors, and other governmental agencies as well as many private corporations across the country.

These pledges require the various agencies and institutions to implement carbon mitigation activities, develop robust plans, and forecast dates by which to attain “climate neutrality.” Climate neutrality is defined by the ACUPCC as “no net emissions of greenhouse gas emissions.”

One aspect of aligning a parking program’s sustainability initiatives with larger institutional goals is understanding the level of commitment required by the program or operation as a component of the overall institutional goal. The size of the specific goal for the parking operation could have significant staffing and budgetary impacts.

Establishing a Baseline

Establishing a baseline is essential for measuring success and documenting progress. Generally, this process begins by conducting a current conditions and program assessment to determine what metrics are available for measurement.

The follow are examples of program metrics that parking and transportation programs might track:

**Transportation Mode Split (Reducing Single-Occupant Vehicle Usage)**

Measurement of this metric involves developing a methodology for estimating total campus trips and
defining the breakdown (%) of various transportation mode split categories:

- Drive Alone
- Motorcycle
- Carpool
- Vanpool
- Bus/Transit
- Walk
- Telecommute
- Other

Within each category, there are numerous potential metrics that could be tracked. Take the vanpool category for the University of California, Los Angeles (UCLA) as an example. In LA, the long commute distances make vanpooling an effective alternative.

LA has been promoting vanpooling for over 20 years. There are more than 150 vanpools in LA metropolitan area serving more than 80 southern California communities. The vanpool program at UCLA has over 1,500 full-time and 700 part-time riders. These numbers can be broken down into the following categories: 80% staff/faculty, 10% students, 10% non-UCLA.

The following is a summary of the 20-year vanpool program contributions measured by the UCLA program¹:

- Elimination of 8.1 million passenger vehicle trips
- Elimination of 324 million passenger miles
- Savings of 15.3 million gallons of gasoline
- Elimination of 107,000 tons of carbon dioxide
- Elimination of 3,200 tons of carbon monoxide
- Elimination of 343 tons of nitrogen oxides
- Elimination of 212 tons of hydrocarbons

This example provides important lessons in defining benchmarks and metrics for sustainability program results. The first lesson is to identify base unit measurements that can be combined to create relational metrics. For example, the base elements measured above include vehicle trips and vehicle trip miles.

Those numbers then can be related to relatively “hard numbers” for acceptable industry standards such as: average miles per gallon of gas, estimated tons of CO2 per 100 miles driven, or estimated tons of hydrocarbons per 1000 vehicle miles.

**Annual Trips Saved Due to Transportation Demand Management (TDM) Programs (by TDM program type)**

Using UCLA again as an example, the University documented 1.7 million trips saved due to TDM program usage. They broke down their results in Table 1.

In this example, the base elements measured include participants by program type, and annual trips saved by program type.

### Developing the Data Baseline: What to Measure

As previously discussed, to quantify progress there must be a baseline to measure against. Therefore, it is important to identify what will be measured and why.

For example, consider a relatively small hospital with four parking garages and 20 surface parking lots totaling approximately 5,000 parking spaces. The hospital’s CEO has pledged to reduce the campus’ carbon emissions by 20% in 5 years. Every department head must define strategies to contribute to this goal. The

<table>
<thead>
<tr>
<th>Program</th>
<th>Participants</th>
<th>Annual Trips Saved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employee Carpool</td>
<td>934</td>
<td>132,000</td>
</tr>
<tr>
<td>Student Carpool</td>
<td>1,754</td>
<td>68,000</td>
</tr>
<tr>
<td>Vanpool</td>
<td>1,510</td>
<td>558,000</td>
</tr>
<tr>
<td>Campus Shuttle</td>
<td>1,000,000</td>
<td>193,000</td>
</tr>
<tr>
<td>Transit Subsidy</td>
<td>23,000</td>
<td>200,000</td>
</tr>
<tr>
<td>Bicycling</td>
<td>1,039</td>
<td>114,000</td>
</tr>
<tr>
<td>On-Campus Housing</td>
<td>9,289</td>
<td>441,000</td>
</tr>
</tbody>
</table>
parking department head could develop a baseline for measuring the effectiveness of his/her strategy using following data sources:

- Based on the parking access and revenue control system, the number of vehicles entering and exiting the hospital facilities each day is documented. Each entry and exit is characterized as one trip.
- By working with the local transit agency, the hospital learns the number of boardings and deboardings that occur at bus stops on its campus on a daily, weekly, and monthly basis.
- A survey of bicycle trips reveals the average bicycle trips per day.
- Several consultants have models that can estimate vehicle emissions by the amount of time vehicles remain queued in hospital parking garage exit lanes. By measuring vehicle queuing at campus parking facility exit lanes a baseline of parking queuing related emissions can be established.

Strategies for Quantifying Impacts

To meet carbon emission reduction goals, parking program changes may include:

- Offering more commuting options
- Providing alternative commute incentives
  - Preferred parking spaces for carpool vehicles
  - Reduced parking prices for alternative fuel vehicles
- Offering “guaranteed ride home” programs
- Creating a campus bike share program
- Adding shower/changing facilities for bike riders
- Implementing disincentives to driving alone
  - Increased parking prices
  - Decreased parking supplies

Tracking the participation levels in each new program, as well as the impacts on overall campus trips will enable program managers to quantify the results of their green initiatives. Campus trips can be measured in the same way they were for establishing the data baseline. It also is important to document the timing of the rollout of the program changes as well as any changes to the baseline elements (loss of a surface lot, addition of new demand generators such as a new campus building, etc.). Success with these metrics may be measured by a reduction in annual campus vehicle trips and growth in alternative mode choice categories.

One of the more complicated elements to measure is vehicle emissions (and emission reductions resulting from green initiatives). Research may be necessary to relate baseline operational metrics to environmental elements such as assumed emission rates for Carbon Monoxide (CO), Volatile Organic Compounds (VOC), and Nitrogen Oxide (NOx).

To achieve and maintain credibility, it is important that methodologies and calculations be unassailable. Therefore, methodologies and assumptions should be tested and supported by the organization’s management before they are set in place.

Example

One green initiative commonly undertaken by parking operations is reducing vehicle emissions from idling vehicles at the exit plaza of a parking facility. Quantifying the results of this initiative can get somewhat complicated due to the variety of operational factors such as the specific conditions created by different exit lane processing/payment methods. There are measurable differences, for example, among the idling vehicle emissions from an exit lane configured for free flow, versus an “express” exit for motorists using access or pre-paid cards (stop-and-go), versus an exit designed to handle cash and/or credit transactions (stop-and-idle).

Generally these emissions calculations are made using an air quality monitoring spreadsheet model. A sample from such a model is shown in Figure 1.
The model shows key factors and related variables that are derived from specific research. For example, the key factor in the sample model shown, emission rate for an idling vehicle (75 grams/hour), is related to the variables associated with the conditions at the exit plaza: number of lanes, service rate (seconds/vehicle), number of vehicles per hour per lane, hours of operation per day, and days of operation per year. All of these factors and variables are combined to calculate kilograms of CO emissions per year. Using other key metrics, the model also provides the annual CO, VOC, and NOx emissions.

**Getting Started: Current Operations Assessment from a Sustainability Perspective**

Once the motivating factors and approach are determined, guiding principles are drafted, preliminary goals are established, and baseline data requirements are considered, specific action items can be developed for the sustainable parking operations and management program.

**Assembling a Team**

It is important to assemble a team of parking department staff who are energized about the program. They need to understand the overall goals and direction, but more importantly, they also must understand the importance of their involvement.

Developing realistic and achievable goals supported by measurable tasks that give each staff member a role to play is one key to developing an effective program.

**Identifying “Green Opportunity Areas”**

Defining focus areas within the context of the overall operation is a good way to get started and engage staff in the program development. They may not be highly knowledgeable about LEED® certification or climate compacts, but they do know their own campus, their own facilities, and their daily routines. They will be able to provide details that can lead to action items for effective and sustainable operations.

Specific teams should be created within the overall program. For example, teams for a typical university or hospital might include:

- parking team
- transportation demand management team
- fleet management team

Opportunity categories then can be developed for each team. Below are several opportunity categories and related action items organized by the three teams noted above.

---

**FIGURE 1: Processing Lane Type III—Cash/Credit (stop-n-idle)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of lanes</td>
<td>7</td>
</tr>
<tr>
<td>Emission rate for idle</td>
<td>75 gm/hr</td>
</tr>
<tr>
<td>Delay per vehicle (sec/veh)</td>
<td>60 sec/veh</td>
</tr>
<tr>
<td>Number of vehicles per hour per lane</td>
<td>18</td>
</tr>
<tr>
<td>Hours per day of operation</td>
<td>8</td>
</tr>
<tr>
<td>Days per year of operation</td>
<td>250</td>
</tr>
<tr>
<td>Total Yearly CO Emissions</td>
<td>965 kg/yr</td>
</tr>
<tr>
<td>Total Yearly VOC Emissions</td>
<td>95 kg/yr</td>
</tr>
<tr>
<td>Total Yearly NOx Emissions</td>
<td>74 kg/yr</td>
</tr>
<tr>
<td>Total idle CO Emission for all Type III (Cash/Credit) Processing Lanes</td>
<td>315 kg/yr</td>
</tr>
</tbody>
</table>
Parking Team: Opportunity Categories and Potential Action Items

**Facility lighting**
- Reevaluate lighting types (consider replacement with LED or fluorescent lights to reduce power usage)
- Develop a fluorescent lamp recycling program
- Stain or paint interior parking garage surfaces to maximize reflectivity and enhance facility lighting without increasing energy costs
- Consider the use of sensors/timers to reduce light levels in certain zones when not in use, or during daylight hours
- Evaluate individually powered solar parking lot lights

**Use of recyclables**
- Replace all light bulbs in the parking department with compact fluorescent bulbs
- Replace concrete parking and traffic products with those made from 100% recycled rubber (e.g., wheel stops, speed humps, sign bases, etc.)

**Water management**
- Replace plumbing fixtures with water-saving fixtures
- Use water-efficient landscaping (e.g., xeriscaping/native plants to reduce irrigation needs)

**Facility cleaning**
- Implement on-site wastewater treatment
- Use sustainable cleaning supplies
- Make interior spaces tobacco free
- Add recycling containers for all facilities where they are convenient to patrons and staff

**Alternative transportation support programs**
- Increase the amount and types of bike parking
- Be a funding partner for campus or community bike rental programs
- Invest in changing rooms/showers
- Partner with bike concierge services

**Reserved parking areas**
- Implement or expand reserved areas for car/vanpools
- Implement or expand reserved areas for hybrid/low emission vehicles

**Discounted parking rates and special offers**
- Offer “Clean Air Car Discounts” or “Green Parking Permits” (i.e., reduced parking rates) for car/vanpools
- Offer “Clean Air Car Discounts” or “Green Parking Permits” (i.e., reduced parking rates) for hybrid/low emission vehicles

**Electric vehicle charging stations**
- Provide charging station(s) for electric vehicles

**Parking guidance**
- Evaluate or implement parking guidance systems to improve parking efficiency
- Develop a parking availability/location mobile device application to reduce the circling of vehicles

**Shared parking**
- Promote shared parking whenever possible to promote the “rightsizing” of parking development, (taking advantage of complementary peak parking accumulation patterns by certain combinations of land-uses when the parking resources can be effectively shared.)
**Demand reduction**
- Evaluate changes to parking pricing that could reduce parking demand
- Consider restricting parking availability
- Provide easy access to alternatives
  - Offer discounted transit passes and sell them along with parking permits
  - Develop a “commute options” program to make patrons more aware of the alternatives to driving alone
  - Commute bonus for alternative commute—up to $65/month (pre-tax deduction)
  - Company bike or a free bike for an employee who commits to bike to work at least 2 days/week
- On-line commute management system that allows employees to claim commute bonus, track parking charges and plan alternative commute trips and find carpool/vanpool partners.

**Parking allocation**
- Develop a parking allocation program based on “essential need”. The way we allocate our resources gets to heart of a parking program’s philosophy and core principles. If sustainability is considered a core value, then decisions related to parking resource allocation should reflect sustainability principles. For example, at the Seattle Children’s Hospital, all parking is provided only on a daily fee basis (monthly parking charges were eliminated. With no sunk costs related to monthly parking passes, other commute options are encouraged.)
Layout

- Assess current parking space layouts, and consider options to maximize use of existing spaces

Gross square foot (GSF) ratio

- Develop a parking space-to-GSF ratio goal that reflects “essential need”
- Use the target ratio in campus planning

Green garages

- Adopt a standard that all parking construction will seek a LEED®-based equivalency rating of “Silver” or better when feasible and/or Green Parking Council standards.
- Adopt a standard for new garage development that solar arrays that generate up to 50% of the facility’s power needs must be integrated

Transportation Demand Management (TDM) Team: Opportunity Categories and Potential Action Items

- Promote zero-impact modes of travel
- “Unbundle” monthly parking by offering a punch card option instead of a traditional access card
  - Drivers only pay for days they drive
  - Creates an incentive to consider alternatives to driving
- Add or expand secured parking facilities for bikes
- Implement a program of providing temporary bike racks to handle seasonal demand peaks for bike parking. The temporary bike rack pictured to the right takes up only one on-street parking spaces
- Implement a bike-share program
- Improve marketing of transportation alternatives
- Improve TDM marketing outreach to include direct participation in all new student and employee orientations
- Solicit and convey vanpool and bus club customer testimonials about their positive experiences as members
- Solicit/Expand transportation department’s participation in the larger campus’ Sustainability Committee
- Promote an increase in funding for pretax transit and campus shuttle
- Generate/Expand car-sharing program participation through user-based promotional efforts
- Fleet Management Team: Opportunity Categories and Potential Action Items
- Reduce campus fleet vehicles’ reliance on fossil fuels
- Increase percentage of “alternative fuel” vehicles in fleet
- Expand car-share fleet to meet daily vehicle trip demand of departments, employees, and students
- Integrate campus fleet management with car-sharing programs providing faculty, staff, and students instant access to a fleet of vehicles within walking distance from campus offices
- Develop a “transit first” campus policy

Developing teams, exploring opportunity categories, and developing a list of primary action items are important steps to creating well a defined sustainable parking and transportation operation and management program. As described previously, a fully sustainable program spans across the organization’s entire transportation system, not solely the parking facilities. The potential action items listed, while comprehensive, should not be considered all-inclusive as new
ideas are identified every day as system owners and operators discover new ways to be more sustainable.

Summary

The following are key steps to developing a successful sustainable parking operations and management program:

◆ Promote and uphold the program’s guiding principles
◆ Develop baseline data for each activity and focus area
◆ Create metrics for tracking progress related to each major program initiative
◆ Develop benchmarks that relate program metrics to carbon emission reduction and other environmental targets

Notes

The following is a list of resources that offer additional information on strategies and approaches to developing environmentally conscious programs:

2. Fostering Sustainable Behavior, Doug McKenzie-Mohr, 1999
5. CU-Boulder Blueprint for a Green Campus, 2006
7. Oberlin College Carbon Neutrality Plan, RMI, 2002
8. University of Florida Carbon Neutral Assessment Project, 2004
9. CU-Boulder GHG Emissions Inventory, 2007
15. “American Research Universities During The Long Twilight Of The Stone Age,” Michael Crow, President, Arizona State University, February 21, 2007, CU-Boulder
17. Tackling Climate Change in the U.S., ASES, 2007

L. DENNIS BURNS, CAPP
is senior practice builder and regional vice president for Kimley-Horn and Associates, Inc.

H. DEAN PENNY, P.E.
is principal and senior vice president with Kimley-Horn and Associates, Inc.
According to the U.S. Census Bureau, an additional 110 million people will be added to the country’s population over the next 40 years. This increased population will require convenient, affordable housing with access to jobs that will not likely be provided by the sprawling greenfield development that dominated recent decades. That kind of development will be significantly more challenging given restrictive stormwater limitations, the need for extended infrastructure, long commutes, and the near build-out of many suburban areas.

In addition, it appears that many in our nation, awakened by the Great Recession, increasing oil prices, longer commutes, and the tedium of the suburbs, recognize the benefit of more sustainable, denser, vibrant, transit-oriented, and economically viable development and communities. Baby boomers (born 1946-1964), one of our nation’s largest population cohorts (76.2 million people), are fast becoming empty nesters and no longer need or want big homes on large lots. Their children—Generation Y (born 1976-1995) with 83.5 million members—express a strong desire to live in more urban environments close to transit, jobs, amenities, entertainment, and communities.1

This generation, according to John McIlwain and J. Ronald Terwillinger of the Urban Land Institute, could become the first smart growth generation.

Smart growth and transit oriented development (TOD) are generally defined as higher density, mixed-use residential or commercial areas located within a radius of one-quarter to one-half mile of a transit stop. Communities or projects typically incorporate residential, commercial, retail, and entertainment uses that tend to create street level vibrancy and a prolonged period of activity in the community.
TOD incorporates features to encourage walking and biking, provide access to transit, and accommodate other transportation options to reduce the reliance on the automobile. The overall intent of smart growth and TOD is to create more sustainable communities in which to live, work, and play; boost transit ridership; reduce traffic; use existing infrastructure; and provide a living and working environment with a mix of housing and jobs.

In recent decades, smart growth advocates have championed TOD, and significant strides and vibrant communities have been made. Most real estate professionals and public leaders understand that the sprawling, suburban-focused, auto-dependent development that has defined suburban land use since WWII is no longer sustainable, fashionable, convenient, or desirable. According to Katherine Perez, ULI LA executive director, “The next generation of projects will orient to infill, urbanizing suburbs, and transit-oriented development. ... People will continue to seek greater convenience and want to reduce energy expenses.”

The Need for Parking
A primary strategy, focus, and benefit of smart growth and TOD is planning for and creating places and lifestyles that are much less dependent on the single-occupancy vehicle than we have been the past few decades. Providing abundant space for the car—often more for the car than the people—has been a key convenience and planning objective of sprawl development, and the substantial space for parking, typically in vast surface lots, has helped define the segregated, monotonous suburban form.

However, as we revitalize, plan and develop new smart, transit-oriented communities, we must be mindful of the enduring love affair with the automobile. The car has been an American fixture for almost a century and has influenced—perhaps even dominated—the lifestyle of the average U.S. citizen. This dependence will not subside anytime soon.

In 2009, there were 246 million registered vehicles and 210 million licensed drivers in the U.S. The upward trend of both numbers over the past 50 years will likely not change drastically over the next decade.

In addition, due to limited mass transit options outside of urban areas, many of the places we need to access for work, dining, shopping and recreating are not conveniently accessible by anything but the automobile. Accordingly, accommodating the car is a critical planning component to the success of smart and transit-oriented communities.

In *TOD and Carsharing: A Natural Marriage*, author Robert Cervero found that TOD housing developments produce 44 percent fewer vehicle trips on a typical weekday than what is called by the Institute of Transportation Engineers (ITE) the average number of trips per dwelling unit.

Researcher John Renne compared 103 TODs around the United States to 12 metropolitan statistical areas (MSAs) in terms of transit share of work trips and found that on average, more than twice the number of work trips, (16.7 percent) from a TOD will be made using transit, as compared to 7.1 percent from the surrounding MSA.

However, he says, more than 80 percent of work trips are made in TODs by another means of transportation, which is most likely the automobile. This reliance on the automobile is not necessarily because people want to drive, but because after more than 50 years of post-WWII sprawl-oriented development, there is limited mass transit access to jobs, shopping, and attractions.

So while one of the overriding goals of smart growth and transit-oriented development is creating vibrant places that are less reliant on the automobile, the reality is that the automobile must be accommodated—just in a more sustainable, intelligent, and efficient manner.
The Challenge of Structured Parking

While smart growth through TOD certainly represents a robust segment of our nation’s real estate economy, developers, mass transit agencies, and municipalities that promote, plan, and implement TOD understand that many significant challenges confront these projects.

The challenges include difficult and expensive property acquisitions and assemblage, local opposition to higher density projects, increased traffic, and the cost, size, and effective integration of structured parking for TOD projects. In many projects, structured parking, rather than surface parking, is the required solution to achieve higher density. Surface parking wastes space where land is limited, interrupts the urban form and street activity, and creates huge swathes of impervious surfaces that exacerbate stormwater runoff. Structured parking is more efficient in terms of land use and provides significantly more parking in less land area.

Structured parking can also serve as more than just a warehouse for cars by becoming integrated with ground floor retail, commercial, and residential development. The concentrated pedestrian access and egress to and from the facility can help create continuous foot traffic to enliven public spaces or retail areas. The structure can mask cars from the urban landscape and with thoughtful design, the façade can complement the surrounding urban form. As Thomas J. Murphy, former mayor of Pittsburgh, recognized, “Parking is a part of the mosaic of a city.”

Given the constrained development sites, the required higher densities, and the mix of uses, structured parking is often the necessary parking solution and the most arduous economic challenge for TOD projects. The cost of structured parking challenges a project on the financial side, and the mass of a structure, which can approach 50 percent of the built square footage of the development program, can overwhelm the scale of a community and arouse local opposition, especially in an area whose residents aren’t familiar with parking structures.

The challenge is further magnified when transit agency or municipality-owned surface commuter parking is redeveloped as a TOD project. These properties are prime opportunities for TOD, but the commuter parking often needs to be replaced and incorporated into the project.

Where surface parking costs range from $3,000 to $6,000 per space to construct, above-ground structured parking can cost $15,000 to $20,000 per space, depending on the region and a host of other design and site considerations. Underground parking, which is often the preferred parking solution for many TOD planners, costs 50 to 100 percent more than above ground structure parking.

As an example, if a developer is required to provide two structured parking spaces for every residential rental unit in a project, structured parking will add
$30,000 to $40,000 to the cost of each residential unit, and an additional $160 to $250 per month to cover parking costs. Factor in the added expense of building in dense and limited land areas, the increased operating costs of structured parking, and the fact that market parking fees are often not adequate to support new structured parking, and it’s easy to understand the economic challenge.

**The Right Amount**

It is critical that smart, cost effective, and best practice parking planning and design strategies are incorporated into TOD projects to both mitigate the amount of parking to be constructed and ensure adequate parking to support the project.

The first step to meeting the parking challenge is to ensure that the parking facilities are sized correctly and in accordance with TOD parking principles. TOD and parking planners employ various strategies to measure and moderate the required amount of parking, both to provide adequate parking to ensure the marketability of the project and avoid costly parking overbuilds.

**Parking Ratios**

A key and challenging factor in right sizing parking for a TOD project is the application of appropriate parking ratios, or the number of parking spaces provided per unit of land use. There are many factors of a TOD project that affect the right parking ratio, and these factors can vary significantly from project to project and location to location.

The project density and the characteristics of both its residents and employees, including age, income, auto ownership, and the availability of alternative modes of transit (including pedestrian and bicycle accommodations) can change the numbers. Also, whether a project offers for-sale or rental units will affect the necessary parking ratio, as for-sale units typically require higher parking ratios than rental units.

Census data provides valuable information about existing car ownership per household in an area, and parking occupancy data from nearby projects or communities with similar characteristics and transit services is an excellent source to guide and support the establishment of an appropriate parking ratio. These factors can establish more accurate parking ratios that will help right size the parking demand for a project in a way that may be more appropriate than the typical parking ratios recommended by the Institute of Transportation Engineers (ITE) Parking Generation guidebook.

Many TOD analysts and parking professionals believe there is a suburban bias in the current ITE source book, as much of the book’s data is drawn from suburban areas with singular land uses. It is believed that this bias generally results in more parking spaces being built for a project than are necessary.

While many suburban communities and project financiers find the reduction of parking ratios in TOD projects a bit suspect, it is important to recognize that many people choose to live and work in a TOD because they seek an environment that is walkable, provides convenient amenities, and offers mass transit. It is logical that households with convenient access to mass transit will likely avoid the significant cost of owning and maintaining (at least) a second car, savings several thousand dollars per year. Indeed, research indicates that TOD households are twice as likely to not own cars.

In its *Planning for Transit-Friendly Land Use: A Handbook for New Jersey Communities*, N.J. Transit recommends the reduction of parking ratios for different land uses depending on their distance from a transit station or hub. For example, an office or residential building within a one-quarter mile radius of a bus or light rail route should have its parking ratio reduced by 10 percent from the national standards. If a project is near a multi-modal transit hub, it should consider reducing its parking requirements by up to 60 percent for office and residential uses and 25 percent for non-residential uses.
Shared Parking

The mix of land uses that is typical in TOD projects provides meaningful opportunities for shared parking, defined as “the use of a parking space to serve multiple land uses without conflict and the utilization of the same parking space by multiple user groups (i.e., parking for commuters during the day, and residents or retail patrons in the evening and weekends).”

Shared parking is highly dependent on a complementary mix of land uses with different peak parking demand periods that provide opportunities for different groups to use the same spaces. Shared parking maximizes the use of the parking structure, reduces the amount of parking to be built, and if parking fees are charged, enhances the financial performance of the facility to support debt service, and operating and capital repair expenses.

For example: commuter parking, which is often a component of TOD, offers a good opportunity for shared parking. Commuter parking typically peaks in the early afternoons on weekdays and then steadily vacates by 6 p.m. or an hour later in the evening. Available parking in the late afternoons, evenings, overnights, and weekends provides a valuable opportunity to share commuter parking with residential, entertainment, theater, retail, and restaurant parking during off-peak period, reducing the overall amount of needed parking.

Shared parking was used in the Bay Street Station TOD in Montclair, N.J., where the parking garage built adjacent to the station for commuters also provides parking for an adjacent residential project during evenings and weekends. The ability to share the parking asset allowed the residential developer to reduce the parking built to one space per unit, significantly enhancing the economic viability of the project.

The Tri-County Metropolitan Transportation District in the Portland, Ore. area, has implemented similar strategies to support TOD. The strategies here include sharing commuter parking with other types of land uses, including apartments, churches, movie theaters, and office buildings near transit stations, using lower minimum parking requirements around transit stations, and allowing commuter parking to be reduced if the land is used for TOD, encouraging walk/bike trips to replace car trips.

Shared parking is a commonly accepted strategy in many urban communities, but can still be met with skepticism in small downtowns and suburban areas where higher density, mixed use projects are still unfamiliar. In addition, some of the same developers who hope to reduce their parking requirements and development costs often insist on segregating or “nesting” their primary users, such as residents or office tenants, from other parkers.

Nesting or providing reserved parking for residents, employees, or different parking groups significantly reduces or eliminates the opportunity to both share parking and oversell the parking facility to maximize its use. Many developers still cling to the notion that residents must have reserved or nested parking. Hopefully this sentiment will subside as people realize that structured parking is too valuable and expensive to sit empty for a large portion of the day. Even major corporations such as Google, Sony, and Netflix recognize that reserved parking is a waste of their parking resources and have eliminated reserved parking at their campuses and buildings.

Parking Maximums Versus Minimums

To reduce the amount of required off-street parking and its effects, some jurisdictions set parking maximums that take into account the availability of mass transit, car sharing, and other modes of transportation instead of dictating the minimum amount of parking for a property. Allowing the development of a limited amount of off-street parking promotes more efficient use of land, encourages alternative modes of transportation, and provides for better pedestrian movement.
In Cambridge, Mass., parking maximums were used in 2006 to create adequate parking facilities to meet the reasonable needs of all building and land users, without regulations that unnecessarily encourage automobile usage. Most cities link parking maximums to the availability of alternative transportation modes. Cities such as Portland, San Diego, Bellevue, N.Y., Boston, Toronto, and San Francisco have established maximum parking requirements for new development as part of transit first or auto trip reduction policies and goals.

Many cities have established parking maximums based upon parking use studies rather than relying on typical parking ratios based on national standards. In Oregon, the cities of Portland, Bend, and Hood River have taken this approach. Seattle has set parking maximums in its downtown of one space per 1,000 square feet for non-residential uses.

Another example of a designated area using maximums is Tyson’s Corner, Va. One of the original edge cities, Tyson’s Corner was planned in the 1950s as an auto dependent city. As part of an overall effort to make the area more walkable and transit friendly, Fairfax County amended its comprehensive plan for the area. Minimum parking requirements will not apply for new buildings within a quarter mile of the four new Metrorail stations.

Provide Credit for On-Street Parking
To right size parking, TOD planners need to maximize the use of on-street parking, thereby reducing the amount of structured parking to be built. On-street parking adds vibrancy, convenience, and a buffer of parked vehicles between the traffic lane and sidewalk that contributes to the sense of place of TOD project.
On-street parking can also be designed and integrated with a transit station so that it serves as short-term, drop-off parking during the commuter rush period, and is available for downtown merchant parking during off-peak hours. On-street parking areas adjacent to a transit plaza, civic area, or open space (often a planned component of a TOD) can be used during public events to effectively expand the size of public space without having to permanently dedicate extra land to that.

On-street parking, priced and regulated to promote turnover, is an outstanding parking resource for the retail component of a TOD, reduces the amount of structured parking to be developed, and provides an excellent source of revenue that can be reinvested to maintain, market, and improve the district.

Oklahoma City is currently in the process of converting many of its one-way streets into two-way streets with parallel parking. By replacing travel lanes with parallel parking, Oklahoma City is not only making its streets more pedestrian friendly and vibrant, but adding 800 parking spaces. Other cities throughout the country have also reconfigured streets to provide on-street parking.

**Car Sharing**

According to an Arizona State University study, the average car is parked 23 hours per day. It’s no wonder that more and more people, especially those in areas served by mass transit, use car sharing programs to meet their mobility needs. According to one car-share company, 2010 saw a 15 percent increase in car sharing memberships in the U.S. Car sharing allows commuters, residents, and employees to access vehicles when needed. These programs are also beneficial because one shared car can take 15 cars off the street.

Integrating car sharing into TOD projects is an effective strategy to reduce parking requirements and provide residents, commuters, and employees with access to vehicles. The San Francisco planning department granted a variance to construct the 141-unit Symphony Towers apartments with only 51 parking spaces (rather than the required 141) in part because of the commitment for two-car-sharing parking spaces and the unbundling of parking costs from apartment rents.

The City of Hoboken, N.J. provides another example of a city with significant transit resources reducing auto dependence through car sharing. On-street parking there is in high demand and extremely limited, making car sharing viable. The program provides on-street spaces around the city that are devoted to shared cars. Any resident can join the program and receive shared car service credits for giving up their on-street residential parking permit.

**Bicycle Sharing**

Another approach to reducing reliance on cars that has been gaining momentum is bicycle sharing. This allows individuals access to bicycles without the worries and responsibilities associated with ownership. Shared bicycle stations can be incorporated into parking structures and provide a safe and secure location.

The Capital Bikeshare program in Washington D.C. and Arlington, Va., is a great example of a metropolitan area expanding access to bicycle ridership. For a membership fee of $75 per year, a bike can be used for 30 minutes for free or $1.50 for up to 1 hour. There are also day passes that allow tourist and visitors to use the bicycles. Currently there are more than 110 stations and 1,100 bicycles to choose from. Washington, D.C., has made bicycling more convenient when driving may not be the most desirable form of travel, given traffic congestion and the high cost of gasoline.

**Unbundling Parking**

It is not uncommon for parking development costs to be passed along to office tenants or housing renters for a given development regardless of whether the tenant or renter actually uses the parking. Bundling occurs when the cost of the office or housing is combined with the cost of parking, reducing the
affordability of housing and office space and having a negative effect on the economic viability of the development by requiring more parking to be developed. This is especially true in developments in close proximity to mass transit.

Parking fees in TOD projects should be unbundled, allowing opportunities for renters who do not use parking to pay a lower rate than those who do. By unbundling the cost of parking, the developer is not providing an incentive to have a car (I’m paying for the parking so I might as well drive) and the tenant has the option of foregoing a vehicle and increasing the affordability of their rental unit.

In 2008, San Francisco required that parking be unbundled for all housing developments of 10 units or more. According to the U.S. Department of Labor, Bureau of Labor Statistics, car ownership costs are the second largest household expense in the U.S. and the average household spends almost as much on cars as on food and health care combined. A 2002 study on housing markets and their relationships to railway proximity estimates that households within a half-mile of transit stations are significantly less likely to own cars, and even more likely to own only one.

**TOD Parking Planning and Design**

The planning, integration, design, and user convenience of structured parking serving TOD projects is critical to the overall success of the project and requires the application of sound planning principles.

TOD parking facilities are the front door of dynamic projects serving several user groups and providing meaningful impressions to their users including residents, visitors, restaurant patrons, shoppers, and commuters. As such, parking facilities should be planned and designed to contribute to the overall project as people places” not just a storage facility for cars.

To the extent possible, retail and mixed-use development should be integrated at the ground level of the garage to enliven the streetscape and maintain the connectivity between the land uses adjacent to the garage.

Pedestrian and vehicular access points and sections of the facade should be adorned with architectural elements that contribute to the aesthetic character of the community. Given the number of pedestrians who come and go from a parking structure, the access and egress areas should be designed as public spaces with adjacent retail and quality hardscape, water, and landscaping elements.

Stair and elevator towers serve as desirable architectural features and should be designed using glass with maximum visual access and exposure to vibrant streets to enhance user comfort and security. Lighting levels should be increased beyond the typical to provide a higher level of user comfort, and components of the structure should be painted or stained to promote brightness and improve the aesthetic appeal.

The interior elevator and stair vestibules can be enhanced to reflect the quality and design of the TOD project. Paint, graphics, and wall and floor treatments should be used to project the design sense of the entire community.

Often in large-scale TODs, planners include individual parking structures for each building or land use component, wrapping them with that component as camouflage. While these plans and designs are aesthetically pleasing, developing multiple structures to serve individual buildings or project components is often economically infeasible. To reduce structured parking costs, parking facilities should be
consolidated and shared to the greatest extent possible. For-sale condominiums often require dedicated parking adjacent to the building, but other uses such as residential rentals, office, and retail do not. A short walk from the parking structure will enliven the streetscape and support area retailers.

In situations where a centralized parking facility can serve multiple nearby projects, payment in-lieu of parking is a funding strategy that helps developers and municipalities. This is a system whereby a developer can bypass minimum parking requirements by paying the municipality for each required space he does not build. This means that the developer can use more of a site for developable area, and the municipality can use the money contributed by the developer to create public parking that will serve multiple projects or areas.

One example of a city using the payment in-lieu of parking strategy is Palo Alto, Calif. The city charges a developer almost $18,000 for every required space that is not built. In-lieu payments are not just for urban communities; suburban Oak Bluffs, Mass., has also successfully used this approach. The town uses the money to fund the maintenance and enforcement of the downtown on-street parking. Other cities that have taken this approach include Beverly Hills, Calif., Lake Forest, Ill., Jackson, Wyo., Bend, Ore., and the Coconut Grove neighborhood in Miami, Fla.

### Sustainable Design

Given the sustainable and efficient nature of TOD communities, it is important that parking structures serving them maximize sustainable parking design features to the greatest extent possible. These features include renewable on-site energy, energy efficient lighting, stormwater capture and reuse for washdowns, maintenance, landscaping irrigation, and bicycle storage facilities, to name a few.

Solar arrays can provide the predominant amount of electricity for lighting and other electrical equipment, and preferred parking and charging facilities for alternative fuel and energy efficient vehicles can be implemented to represent and emulate smart growth development.

### Parking Management

A parking structure in a TOD community will often be used and shared by multiple users and serve as a gate-

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58 SUSTAINABILITY OF PARKING
way to the community. As a result, it must be managed and maintained to a high standard. The facility should be clean, safe, and convenient to use. Given the regular flow of new visitors, signage and graphics should be well designed and easy to understand.

The parking access and revenue control system (PARCS) should be able to accommodate the various users conveniently and efficiently. It should accept various convenient payment options, allow for quick entry and exit to avoid long queues, and use intelligent signage systems to provide parkers quick access to available parking. Security cameras and personnel should be deployed appropriately to dissuade criminal activity and increase the level of comfort for residents, commuters, and visitors. Ultimately, the parking facility must reflect the ambiance, image, comfort, and security of the entire TOD community.

The facility should also be managed to generate adequate revenue to cover debt service, operating costs, and replacement and reserve funds. Parking structures require ongoing maintenance to ensure that they remain in a state of good repair, and having adequate funded reserves is critical to extend the effective use of the structure to the greatest extent possible.

Smart Growth and Parking Infrastructure

Mitigating the parking requirements of smart growth and TOD projects and increasing their financial viability will require the application of the recognized best practice strategies outlined here. However, even with the application of best practices for the planning and sizing of parking facilities, TOD projects, especially in the present economic period, will require creative solutions, partnerships, and financing strategies to meet the financial challenge of structured parking.

The increased desire and focus on developing vibrant, sustainable mixed-use communities with convenient access to mass transit will provide the opportunity for both the public and private sectors to reconsider the usual thinking regarding parking requirements and adopt the many proven practices to appropriately plan, size, design, and implement intelligent parking strategies to support smart growth.

Notes
1. 2010 American Community Survey, US Census Bureau
2. 2010 ULI Emerging Trends in Real Estate
3. Title 23, U.S. Code
4. Robert Cervero. “TOD and Carsharing: A Natural Marriage.” ACCESS, no. 35 (Fall 2009), 27
8. ULI Shared Parking Handbook

James M. Zullo, CAPP, LEED AP

is vice president with Timothy Haahs & Associates, Inc.
CHAPTER 7
Sustainable Parking Facility Operation:
Accommodating Multiple Modes of Travel

CASEY JONES

PARKING FACILITIES ARE NO LONGER JUST FOR PARKING CARS. Based on user demands, financial considerations, and environmental goals, many owners and managers of parking facilities now see their parking garages and lots as multi-modal centers that are capable of addressing not only drivers’ needs, but also those of people who bike, ride the bus, use carpool and vanpools, and make use of increasingly popular car share programs.

The multi-modal parking facility includes consideration for bicycle parking, car share, carpool/vanpool, and other sustainable transportation choices in parking garages and lots. These are distinguished from other operational considerations such as building lighting, ventilation and air handling, vegetation systems, water retention, revenue control equipment, and electric vehicle charging stations covered elsewhere in this publication.

The 2009 national household Travel survey\(^1\) revealed that 87 percent of all daily trips and 91 percent of commuting takes place in personal vehicles. Americans make 1.1 billion trips that cover 11 billion miles per day. Forty-seven percent of our trips are for shopping and errands, 27 percent are socially and recreation related, and 15 percent of daily trips are for commuting.

The same survey found that biking and walking make up a large portion of the total mode share. At the time of the survey, these made up 11.9 percent of all trips in the U.S., which was up from 9.5 percent in 2001. From a sustainability standpoint, the increase in biking and walking for all trips is encouraging. Current trends are not as encouraging for commute trips.

According to the 2007 U.S. Census\(^2\), more than 75 percent of workers drive alone to work—nearly an all-time high—while carpoolers dropped from 20 percent of workers in 1980 to 10 percent in 2007 (see Table 1). Of the alternatives to driving alone to work, only telecommuting increased since 2000.
Table 1: Means of Transportation to Work

<table>
<thead>
<tr>
<th>Mode of Transportation</th>
<th>1980 (%)</th>
<th>1990 (%)</th>
<th>2000 (%)</th>
<th>2007 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drove Alone</td>
<td>64</td>
<td>73</td>
<td>76</td>
<td>76</td>
</tr>
<tr>
<td>Carpoled</td>
<td>20</td>
<td>13</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Public Transit</td>
<td>6</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Walked</td>
<td>6</td>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Telecommute</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Civil engineers at the University of California, Berkeley, recently published the first comprehensive estimate of parking spaces in America and put the figure at somewhere close to 800 million; these parking spaces accommodate an estimated 250 million cars on the road in the U.S. But the industry and the driving it supports have a high cost. If an average car produces 5.5 metric tons of carbon dioxide (CO₂) each year, the 250 million cars in this country produce almost 1.4 billion tons of CO₂. That amount requires 6.87 billion trees to offset. (This is only a portion of the greenhouse gases (GHGs) associated with the industry. Building parking garages and lots also adds to the total GHG load.)

The enormity of this environmental challenge is so great because of current driving habits and patterns and our shared and continued heavy reliance on fossil fuel-based transportation modes. A concerted effort by parking professionals is called for to build more sustainable parking facilities and help people drive less. Parking facilities are an ideal place to support other modes of transportation.

Accommodating Bicycles

Bicycles can be safely accommodated in existing parking garages and lots, or parking facility projects can design for them from the beginning. To provide safe, attractive, and desirable bike parking, one must first identify how much is needed.

There are several good sources for determining bicycle parking demand, including the International Green Construction Code Version 2.0, the Association for Pedestrian and Bicycle Professionals 2010 Bicycle Parking Guidelines, and those standards developed independently by municipalities, universities, and others dedicated to promoting bicycle use.

The University of Colorado at Boulder currently uses assignable square footage and the number of resident hall beds to calculate bike parking demand, making no distinction between long- and short-term parking. (Table 2)

San Francisco uses a gross square footage method and, unlike the other examples listed here, specifically requires bicycle parking in parking garages. When a commercial building is built or undergoes a major renovation of $1 million or more, the owner must provide at least three bicycle parking spaces or more depending on gross square footage (GSF) (Table 3). San Francisco further distinguishes parking by class of facility, either Class 1 or Class 2.

Class 1 is defined as a facility that protects the entire bicycle and its components and accessories against theft and inclement weather, including wind-driven rain. Examples of this type of facility include lockers, check-in facilities, monitored parking, restricted access parking, and personal storage. Class 2 is a standard bike rack users can lock to.

Bicycle Parking and LEED

Credit can be earned for buildings whose owners are interested in earning Leadership in Energy and Environmental Design (LEED) certification under the LEED Sustainable Sites category. For new construction, credit
Table 3: San Francisco Bicycle Parking Requirements

<table>
<thead>
<tr>
<th>Commercial Property based on Gross Square Footage (GSF)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional Service: 10,000 -20,000 GSF or Retail: 25,000-50,000 GSF</td>
<td>3 bicycle spaces (Class 1, 2 or both)</td>
</tr>
<tr>
<td>Professional Service: 20,000 -50,000 GSF or Retail: 50,000-100,000 GSF</td>
<td>6 bicycle spaces (Class 1, 2 or both)</td>
</tr>
<tr>
<td>Professional Service: 50,000 -100,000 GSF or Retail: 100,000+ GSF</td>
<td>12 bicycle spaces (Class 1, 2 or both)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>All Parking Garages with 10 or More Spaces</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>General Standard</td>
<td>Minimum of 6 spaces (Class 1, 2 or both)</td>
</tr>
<tr>
<td>Garage with 120-500 auto spaces</td>
<td>1 bike space for every 20 automobiles (Class 1, 2 or both)</td>
</tr>
<tr>
<td>Garage with 500+ auto spaces</td>
<td>25 bike spaces +1 for every 40 auto spaces over 500, up to a max of 50 bicycle spaces (Class 1, 2 or both)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>City Buildings: Class 1 (Lockers, Bike Room, Security) Parking Requirements</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Bldgs with 1-20 employees</td>
<td>2 bicycle spaces (Class 1)</td>
</tr>
<tr>
<td>Bldgs with 21-50 employees</td>
<td>4 bicycle spaces (Class 1)</td>
</tr>
<tr>
<td>Bldgs with 51-300 employees</td>
<td>equal to 5% of the number of employees in the Bldg, but not less than 5 spaces (Class 1)</td>
</tr>
<tr>
<td>Bldgs with 300+ employees</td>
<td>equal to 3% of the number of employees in the bldg, but not less than 16 spaces (Class 1)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>City Buildings: Class 2 (Basic Bike Racks) Parking Requirements</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Bldg with 1-40 employees</td>
<td>2 bicycle spaces (Class 2)</td>
</tr>
<tr>
<td>Bldg with 41-50 employees</td>
<td>4 bicycle spaces (Class 2)</td>
</tr>
<tr>
<td>Bldg with 51-100 employees</td>
<td>6 bicycle spaces (Class 2)</td>
</tr>
<tr>
<td>Bldg with 100+ employees</td>
<td>8 bicycle spaces with at least 50% shall be covered (Class 2)</td>
</tr>
</tbody>
</table>

is currently provided when bicycle parking spaces are provided within 200 yards for at least 5 percent of a building’s full time equivalent (FTE) occupant load at the peak, and when a shower and changing facilities are provided within the building or within 200 yards of the building for 0.5 percent of FTE occupants.10

Rack Types

There are many bicycle manufacturers and many rack types from which to choose. Generally, racks should be anchored securely to the ground, allow locking to the frame and one or both wheels with a U-type lock, support the bike in a way that it doesn’t tip over, and prevent the wheel from being bent if the bicycle is pushed from the side. Additionally, the rack should be constructed to resist being cut.
Design Considerations

Properly placed and installed bicycle parking racks will promote use. Poor access and visibility or placing racks too far from building entrances or paths will result in poor use and bicycles being parked in places not intended for their use. Parking lots and garages can successfully accommodate long- and short-term bicycle parking when these guidelines are followed:

- Short-term bicycle parking should be within 50 to 75 feet of a building entrance.
- Long-term bicycle parking should be within 300 feet of a building entrance.
- Not less than 50 percent of long term bicycle parking should be within a building or provided with a permanent cover including, but not limited to, roof overhangs, awnings, or bicycle storage lockers.
- Bicycle parking should be in a highly visible location supported by wayfinding signage.
- Bicycle parking facilities should be secure and placed to take advantage of natural surveillance, which means designing the placement of physical features, activities, and people to maximize visibility and foster positive social interaction among legitimate users of private and public space. (The International CPTED Association, www.cpted.net offers additional information about crime prevention through environmental design.)
- Bicycle parking should be located in in flat areas that are well lit (not less than one foot-candle at the parking surface) and at the same grade as the sidewalk or in a location reachable by ramp or accessible route.
- Bicycle parking facilities should be located in close proximity to changing facilities, showers, and lockers.
- High conflict areas should be carefully managed so bicyclists feel safe when parking and retrieving their bicycles.

Bicycle racks that are not recommended include “wheelbender” racks and comb racks. Wheelbender racks only support the wheel of the bicycle and can cause serious damage if the bike is twisted while secured in the rack. This rack also does not work with some types of locks. Comb racks have similar disadvantages because only the front or rear wheel of the bicycle is supported. Many users of this rack type lift their bicycles over the top and rest the frames on the racks to allow use of bicycle locks.

In addition to site selection considerations, the way bicycle parking racks are installed affects how the racks are used. Inverted-U, post/ring, and hanger/modified hanger racks should be placed no less than 36 inches apart when measured on center (Figure 2).

For single-sided installations where bicycles enter from one side, a minimum of two feet should be maintained on the sides and front of the installed racks, four feet should be allowed for the parking area, and at least four-and-a-half feet should be left behind the parking area for access (Figure 3).

Similar dimensions hold true for double-sided bicycle parking areas (Figure 4).

More space is needed around bicycle lockers (Figure 5).

Other End Trip Facilities

Depending on the climate, bicyclists often arrive at their destinations muddy, wet, or sweaty. This can be a deterrent to riding a bicycle, especially when commuting to work. Providing riders with a place to shower and store and change clothes can help en-
FIGURE 2: On-Center Dimension

FIGURE 3: Single-Sided Bicycle Parking Area Minimum Dimensions

FIGURE 4: Double-Sided Bicycle Parking Area Minimum Dimensions

FIGURE 5: Bicycle Locker Parking Minimum Dimensions
courage bicycle commuting. There are several ways to provide these services:

◆ They can be required in new buildings or retrofitted in old buildings. A shower and clothes lockers can sometimes be added to existing restrooms. A single shower stall and space to change clothes typically requires a six-by-four-foot space.
◆ Employers can partner with places that already have these facilities, such as a local gym.
◆ Several employers or a transportation management association (TMA) can establish facilities that are shared by several companies or clients.

Everett, Wash., uses the following guidelines for establishing shower facilities requirements as modified from similar requirements from Santa Cruz, Calif.12:

1. Employee shower facilities in compliance with ADA standards shall be provided for any new commercial building constructed or for any addition to or enlargement of any existing building in compliance with Table 4.

2. Shower facilities shall include at least one personal locker for every 20 employees. If only one shower is provided, it must be designed as a unisex facility that is accessible to the handicapped.

3. As an alternative to including shower facilities within a building, a new business may submit a written agreement for employees to utilize existing shower facilities of a business within three hundred feet of the project’s property lines. This agreement must be signed by both parties involved, allow use of the facilities in perpetuity, establish allowable hours of use, include provisions for maintenance, and involve shared liability agreements.

In addition to showers, there must be decent access to and from the bicycle parking area. The International Green Construction Code requires that not less than one independent, paved walkway or bicycle path suitable for bicycles, strollers, pedestrians, and other forms of non-motorized conveyance connecting a street or other path to a building entrance be provided.13 Further, any such paths are to connect to existing paths or sidewalks and are to support stormwater management. This is a benefit for bicyclists and pedestrians alike.

Well-designed end trip facilities promote bicycle use. But other programs are needed to further assist bicyclists. Parking facilities can house some of these services in tenant space, unused space previously assigned to auto parking, or in underused or unassigned space. Services to consider include bicycle repair services or businesses, rider safety education courses, bicycle safety assessments, minor repairs, and retail accessories sales. Parking facilities can also offer compressed air and be used to house air compressors and tools needed for quick repairs.

### Accommodating Carpool, Vanpool, Car Share and Low Emission Vehicles

Carpooling, vanpooling, and car sharing can reduce vehicle miles traveled and save money for individual commuters. Parking garages and lots are natural places to accommodate such alternatives to driving alone.

#### Table 4: Everett, Washington Shower Requirements

<table>
<thead>
<tr>
<th>USE</th>
<th>Gross Floor Area of New Construction (Square Feet)</th>
<th>Number of Showers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial, manufacturing, and medical, general business office or financial service</td>
<td>0–12,499</td>
<td>No requirement</td>
</tr>
<tr>
<td></td>
<td>12,500–29,999</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>30,000–49,999</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>50,000 and up</td>
<td>4</td>
</tr>
<tr>
<td>Retail, eating and drinking and personal service</td>
<td>0–24,999</td>
<td>No requirement</td>
</tr>
<tr>
<td></td>
<td>25,000–99,999</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>100,000 and up</td>
<td>2</td>
</tr>
</tbody>
</table>
A carpool is established when more than one person rides in a vehicle to a destination. Carpooling choices include:

◆ Sharing a ride to work with someone who lives close by.

◆ Carpooling with other parents taking children to school or activities.

◆ Carpooling to meetings and to lunch with co-workers instead of taking separate vehicles.

A vanpool is like a carpool, only bigger. Here, groups of seven to 15 people who share a similar commute agree to ride together in a van on a regular basis. Vanpools are typically organized by businesses or governmental entities seeking to help their employees reduce travel costs and reduce parking demand requirements.

Many such businesses and large organizations are compelled to reduce driving, such as is the case with Washington’s Commute Trip Reduction Law. Enacted in 1991, the law “require[s] local governments in those counties experiencing the greatest automobile-related air pollution and traffic congestion to develop and implement plans to reduce single-occupant vehicle commute trips. Such plans shall require major employers and employers at major worksites to implement programs to reduce single-occupant vehicle commuting by employees at major worksites.”

Popular in Europe, car sharing is increasingly used in many markets in the U.S., from early adopters in Portland, Ore. and Washington D.C., to recent additions in secondary markets such as Boise, Id., and Austin, Tex. Car sharing refers to automobile rental services that can substitute for private vehicle ownership. This can be less expensive per mile than owning a car, depending on the number of miles driven and the fee structure of the service. Successful car share programs rely on the following features:

◆ Accessible. They should be located in or near residential neighborhoods.

◆ Affordable. They should offer reasonable rates that are suitable for short trips.

◆ Convenient. Vehicles should be easy to check in and out at any time.

◆ Reliability. Vehicles should usually be available and have minimal mechanical failures.

Car sharing organizations can be cooperatives or private businesses. Cooperatives sometimes receive grants to cover startup and administrative expenses. Some car sharing services have been established at multi-family residential cooperatives as a service for residents. Station cars are often implemented by public transit agencies. Governments can provide various types of support and incentives to help develop car sharing services, including promotion, funding, favorable parking policies, incorporating car sharing into public organizations and development projects, and establishing favorable tax policies.

Carpool, vanpool, and car share programs require dedicated parking spaces that are clearly signed for intended use, and offer strict enforcement. Spaces should be highly visible and proximate. To earn LEED credit, a parking facility must contain carpool spaces equal to or greater than 5 percent of the total parking supply. LEED also provides alternative credits for car share programs that are included in residential projects, and for parking reserved for low-emission vehicles when there are at least 0.03 times the number of FTE at the peak spaces for those vehicles (see Figure 1– LEED FTE Calculation) or 5 percent of total parking spaces. LEED credit can be earned when electric charging stations or refueling stations are provided for at least 3 percent of the total parking supply. Preferred parking means parking closest to a building entrance (though this does not take precedence over parking spaces that are required to be accessible in accordance with the Americans with Disabilities Act or International Building Code). For the purposes of this credit, low-emitting and fuel-efficient vehicles are defined as vehicles that are either classified as zero emission vehicles (ZEV) by the California Air Resources Board or have achieved a minimum green score of 40 on the American Council for an Energy Efficient Economy (ACEEE) annual vehicle rating guide.
IGCC offers a slightly different method. When employee parking is provided for a building that has a total floor area of more than 10,000 square feet and a building occupant load of more than 100, at least 5 percent, but not fewer than 2 percent, of the employee parking spaces are to be designated as preferred parking for carpools and vanpools. The same amount must be reserved for low emission, hybrid, or electric vehicles.\textsuperscript{19}

In addition to locating carpool and vanpool parking spaces in preferential locations, parking managers must also decide how these spaces are to be managed. While some locations reserve the carpool spaces for a majority of the day up to 24 hours, others only reserve spaces through the morning rush hour (with the thought that carpooling is for commuting to and from work and that normal work hours have workers arriving between 7 and 10 a.m.). This method allows the spaces to be used for other parking needs throughout the day if a carpool or vanpool vehicle is not present.

Accommodating Transit Riders

Many communities fund rubber-wheeled (bus) mass transit systems; increasing numbers are funding light rail and streetcar infrastructure. Parking facilities are located in good proximity to bus and train stations, and such proximity might create a need to accommodate passenger drop-offs or longer-term stays as in the case of park-and-rides. Parking facilities can receive credit for being sited near mass transit stations.

LEED provides credits for projects located within one-half mile of an existing or future planned (and funded) train or subway station, or within one-quarter mile of two public or campus bus lines.\textsuperscript{20}

Proper signage and wayfinding is necessary when providing drop-off facilities (kiss-and-rides) and long-term parking.

There are also revenue control equipment ramifications for facilities located near bus and train stations. It may be beneficial to offer pay-by-phone options for parkers using park-and-ride locations. Rather than require patrons to pay at a meter, for example, pay-by-phone options allow drivers to forgo standing in line to make payment and risk missing a train or bus.

Viewing parking lots and garages as multi-modal facilities places these facilities in the context of a meaningful effort to reduce the deleterious effects of fossil-fuel based transportation. What's more, many Americans make use of multiple travel modes. There is reason to believe that helping a commuter with bicycle parking will result in their continued patronage when a trip requires an automobile.

It's very likely that providing bicycle parking, carpool/vanpool spaces, and kiss-and-ride drop-off locations can be done without adversely affecting the performance or profitability of a parking garage or lot.

As noted in the beginning of this chapter, national surveys suggest that the share of people driving alone for work-related trips has remained unchanged for the
better part of the last decade. At the same time, the share of total modal split for bicycling and walking is increasing. While there are many variables that affect travel patterns and behaviors, it’s safe to assume that without the proper facilities, design, and service, no mode will be attractive. If the parking profession is committed to improving our industry’s effect on the environment, we’ll need to play a role in supporting all modes.

NOTES
2. U.S. Census Bureau, decennial census and American Community Survey as presented by the Population Reference Bureau, Mather, Mark (2011).
8. University of Colorado at Boulder, Parking & Transportation Services.

CASEY JONES, CAPP, MPA is vice president, institutional services for SP Plus.
CHAPTER 8

Alternative Energy Sources for Parking Facilities
Definition, Implementation Issues, and Financial Aspects

MICHELLE WENDLER

There are multiple reasons to consider alternative energy sources to power your parking facility. One is to provide a commitment to a sustainable environment, including the reduction of greenhouse gas emissions; another is to reduce ongoing maintenance costs by using energy with less costly sources.

Alternative energy sources are renewable and have lower carbon emissions than traditional fossil fuels; they include solar, wind, fuel cells, and geothermal. Each of these systems has a different application for a parking facility.

Solar
Solar systems are the most common alternative energy sources used in parking facilities. A solar system converts the sun’s light into energy. In an application such as parking, the system that captures the solar energy is known as a photovoltaic (PV) system (photo=light; volt=energy). Today’s photovoltaic systems are composed of cells made of silicon, which is the second most abundant element in the earth’s crust. Power is produced when sunlight strikes this semiconductor material and creates an electric current. Cells wired together form a module, and modules wired together form a panel. A group of panels is called an array, and several arrays form an array field.

There are generally two types of photovoltaic systems that are installed over parking. The first is a fixed system where the solar panels are fixed at a consistent angle and orientation to the sun. The second is a tracking system, which has panels mounted to units that move to track the sun. Fixed tilt sys-
tems can either be full canopy, covering the stalls and the drive aisle, or specific locational and cantilevered, covering only the stalls or portions of stalls.

These cantilevered structures can be structures, L structures, or solar trees/single post. Single axis trackers are generally full canopy, covering the stalls and drive aisles; for maximum efficiency, the rows should be exactly north south and tracking east to west with the sun. Fixed systems generally cost less per square foot than tracking systems, but are not as efficient. Tracking systems cost more but are more efficient in producing energy per square foot, so may be less expensive per kilowatt hour to install. Tracking systems have moving parts so are more costly to operate over time. Each project requires its own analysis to determine the best approach.

One of the biggest misconceptions about PV solar energy is that solar structures need to be in a warm climate to be efficient. PV panels derive electrical energy from light energy (photons), not heat energy, so cooler climates don’t prevent electric power generation.

However, solar panels produce proportionately less power during the shorter daylight hours of winter. If the modules are covered with enough snow to prevent light penetration, they stop producing power. Fortunately, snow generally melts quickly when the sun warms the modules, and they resume operation immediately once the snow is brushed off. The amount of power generated is partially dependent on geographic location, parking lot/facility orientation, and size of the canopy, but the biggest factor that determines the amount of power generated is the panel efficiency.

**Incentives and Payback for Solar Systems**

The payback for solar systems varies based on available incentives. Incentives are a combined sum of federal tax incentives, state tax incentives, utility incentives, and local incentives, as well as the cost of energy that is being offset or replaced by the PV energy that’s generated. The main variables of the system component costs that affect payback are the solar PV modules, usually based on efficiency; the cost of the solar PV structure itself; and associated required structural engineering and or modifications that may be required.

Payback varies dramatically across U.S. markets, depending on the above combination of scenarios. Some utilities have solar-friendly rate tariffs that allow for switching when installing solar PV projects. This allows for a faster payback due to the restructuring of an electric bill, which will generally raise the peak kWh energy costs into the same time period that solar is performing at its peak, resulting in an offsetting of the most expensive energy. Rate tariff switches also generally lower the mid peak and off peak time-of-use (TOU) rates and reduce and/or diminish the kWh demand charges.

The investment tax credits and depreciation incentives continue to change and should be researched at the time of the project. There could be state depreciation as well as property tax exemptions. Utility incentives are usually disbursed as performance-based incentives (PBI) and paid per kWh of energy generated by solar PV systems for an agreed term, or are lump sum or are structured as a Solar Renewable Energy Credit (SREC) and can be monetized as such.

One of the key factors of being able to receive tax incentives is that the supporting structure only be designed to support the solar PV system and not a structure that is designed as a waterproof system with roofing or a waterproofing component. If a solar project and owner qualifies for incentives, then these all have the net effect of lowering the cost of a project and, therefore, reducing payback times.

Often, larger projects and those that cannot qualify for tax incentives due to nonprofit status or lack of capital will monetize all the incentives into a finance vehicle called a power purchase agreement (PPA). PPAs are companies that build, own, and maintain the entire system and sell energy back to the designated client, resulting in an energy sale only and off-balance sheet financing. This reduces the capital expenditures and budget approval processes that are generally
required for same. It is to be noted that for a PPA to be feasible, the client must have good credit and the project would need to be cash flow positive from either day one or within a reasonable time that is better than a cash purchase.

Operations and maintenance must be considered as real costs as well and budgeted for accordingly. Generally, a minimum of twice a year cycle is recommended. There has been a significant drop in cost of solar PV modules in recent months along with more professional firms entering into the markets, improving the economies of scale and driving costs down to help improve paybacks. Simply stated, full turnkey systems continue to decrease in price.

It is of significant importance and value to have financial and energy modeling and analytics done by a qualified firm to validate the entire project’s economics and effects, and to verify paybacks, per region, per utility, per client.

Design Issues for PV Systems

The following issues should be considered before embarking on a solar installation project:

◆ **Loading criteria:** Determining the load the PV system will apply to the base structure is important to the design of the structure. A structural engineer who specializes in parking structure design and has PV experience can provide criteria that allow for a range of systems. However, the more a system can be quantified, the more savings can be achieved by designing the structure for more specific loading. For example, if a fixed panel system is selected over a tracker system, overdesign of the base structure is not required.

◆ **Seismic and wind design:** It is important not to oversimplify the loading potential. Depending on the PV geometry and seismicity of the area, wind or seismic design may govern. The loads are larger when systems are placed on top of a parking structure than they would be if placed on the ground.

◆ **Parking layout:** Some PV systems assume a carport-style framing with columns near the back of the parking stall. A common stall layout on a parking roof uses all available space by placing stalls side-by-side with no space between. Adding a steel column to support PV systems between stalls reduces stall width and makes parking much more difficult. It also reduces future flexibility to restripe the facility when needed. This is also a potential violation of municipal parking regulations. A cantilevered system or a full span system should be evaluated to preserve parking efficiency and level of service.

◆ **Sprinklers:** In parking structure applications, the designer should review codes and meet with appropriate officials to determine whether sprinklering of the PV level is required. As a general rule, if the parking structure is sprinklered, the PV will have to be sprinklered as well.
◆ **Fireproofing**: As with sprinklers, a determination of fireproofing requirements by the building designer is crucial, as the cost implications can be very large and there are aesthetic and other issues.

◆ **Height limit**: A prominent solar installation may be desirable to express a commitment to sustainability. However, city codes should be reviewed to determine whether or not the added PV system will be counted as building height. In some cases, the PV system can be treated in a manner similar to light poles, elevator penthouses, and other items that are permitted to exceed height limit. In other cases, the PV system must be included.

◆ **Aesthetics**: Including a PV system on the roof of a parking structure can significantly alter the look of the building’s architectural character. This effect can be eliminated or significantly reduced by installing the system on the interior of the project only. 3D modeling can be used to illustrate a PV system's visual effect for owner and officials.

◆ **Lighting**: An alternate lighting system with fixtures attached to the PV system instead of to light poles will need to be used in both parking lot and structure applications.

◆ **Connection to main structure (couplers, future bollards, embeds)**: The interface between the main parking structure and PV system is critical. This is often the most difficult and expensive design issue. In many cases, the PV system is installed at a later date or in a separate bid package from the parking structure. Special detailing is required to provide couplers or embed plates, bollards, column extensions, wall extensions, and many other connections to allow a smooth installation.

◆ **Mechanical and Electrical Systems**: In addition to structural connections, it is important to provide mechanical and electrical infrastructure for the PV system. Electrical rooms need to provide room for inverters, which generally require additional cooling. In many cases, this is the only air conditioning in the parking structure. Conduit should be provided for easy installation of electrical wiring.

PV systems can be installed in new construction or as retrofits of existing installations. All of the above issues apply in either case. If you are designing a new parking lot or structure, it would be prudent to address many of these issues at the time of the design even if you aren’t going to install the system in the first phase. It will save time and money later.

**Wind**

The U.S. wind industry had 40,181 megawatts (MW) of wind power capacity installed at the end of 2010, with 5,116 MW installed that year alone. The U.S. wind industry has added more than 35 percent of all new generating capacity over the past four years, which is second only to natural gas and more than nuclear and coal combined. Today, U.S. wind power capacity represents more than 20 percent of the world’s installed wind power.

There are different scales of wind installations that generate this power; parking facilities use small wind turbines. A wind turbine converts the kinetic energy of the wind into mechanical energy, which is used to produce electricity. Building-mounted small wind turbines are a new breed in the development of small-scale wind power. In this case, the wind turbine is directly installed onto a building, usually on the rooftop.

Designs of such systems vary from manufacturer to manufacturer and include both vertical and horizontal axis machines. Horizontal axis wind turbines (HWAT) need to be located facing directly into the wind with the rotor shaft and generator located at the top of the tower. Vertical axis wind turbines (VWAT) do not need to point directly into the wind to be effective, and their generators and gear boxes can be placed near the ground.
Small-scale wind turbines vary in size, with a range of models available from fewer than 100 watts (W) up to 50 kilowatts (kW). Turbines ranging from 0.6kW to 50kW can be used to provide electricity for individual houses and businesses, with rooftop models varying from 0.5kW to 2.5kW in size.

According to Renewable UK, “Many potential users of small wind turbines think how nice it would be to put up a wind turbine and use the free power of the wind. Unfortunately, whilst the wind is free, the means to extract the power from it is not. Buying and installing a turbine costs money, and there are also operation and maintenance costs. Consequently serious consideration much be given to siting the turbine to get the best performance and reliability from it.”

In December 2009, the American Wind Energy Association (AWEA) finalized a technical standard that can be used voluntarily to test small wind systems for performance and safety criteria. Third-party organizations such as the Small Wind Certification Council (SWCC) can certify systems tested to this standard. An average of six to 12 months of field testing is required to meet the standard’s requirements.

Technical Factors that Affect the Installation of Small Wind Turbines Excerpted in part from Renewable UK

- Getting a reliable estimate of the wind speed at the proposed site. Turbine manufacturers should be prepared to help. The generator must get acceptance for connection to the electricity distribution network (if applicable).
- Mounting the turbine as high as possible and well clear of obstructions without going to extremes. Easy access will be required for erection, and foundations may be needed depending on the size and tower type. It is also important to ensure that the wind turbine can be easily lowered for inspection and maintenance.
- Having a clear, smooth fetch to the prevailing wind (e.g. over open water, smooth ground or on a smooth hill).
- Using cable of adequate current carrying capacity (check with the turbine supplier). Cable costs can be substantial.

Design Issues for Small Wind Turbine Systems

Many of the same issues exist with the installation of turbine systems as with PV systems.
◆ Loading criteria: The type of turbine to be installed needs to be determined so the building structure can be designed to support the weight and loads that will be transferred to the building. It is important that these loads be evaluated at the beginning of the design process. If the turbine is to be installed on a surface lot, the type of foundation needs to be evaluated.

◆ Parking layout: The location of the support system for the turbine needs to be coordinated with the parking layout in order to not impact the overall project.

◆ Connection to main structure (couplers, future bollards, embeds): The interface between the main parking structure and turbine system is critical. The design of the attachment is the most difficult part of the process and can have a large effect on the overall cost and implementation of the system.

◆ Height limit: A prominent wind installation may be desired to express a commitment to sustainability. However, city codes should be reviewed to determine whether or not the added system will be counted as building height.

◆ Aesthetics: Including a small wind turbine system on the roof of a parking structure can significantly alter the look of the building’s architectural character. 3D modeling can be used to illustrate a system’s visual impact for owner and officials.

**Geothermal**

A geothermal system circulates a water-based solution through a buried loop system to take advantage of constant ground temperatures that remain the same all year. Ten feet underground, the earth’s temperature is pretty constant, and the planet absorbs 47 percent of all the heat energy that reaches its surface from the sun.

During the heating season, the fluid circulates through the loop to extract heat from the ground; that heat energy is then transferred to the geothermal unit. The unit compresses the extracted heat to a high temperature and delivers it to a radiant heat system. For cooling, the process is simply reversed.

In parking, geothermal systems are usually used to heat or cool mixed use spaces. The ground conditions must be tested to be sure that the system can be installed at each specific location. The loops can be installed in the ground in either vertical or horizontal configurations.

If adequate land area without hard rock is available, a horizontal loop installation is usually the most economic: the trenches are normally four feet deep or more, and vary in length depending on the number of pipes to be buried. One of the advantages of a horizontal loop system is being able to lay the trenches according to the size of the lot. One college campus used the area underneath a large parking lot to install a loop system that serves neighboring buildings.

If land is limited, a vertical loop can be installed for the geothermal piping. Vertical installations might also be used where the land is too rocky for trenching, for existing buildings, and for large commercial or educational facilities. To install a vertical loop, a contractor bores holes into the ground. Long, hairpin-shaped loops of pipe are then inserted. The hole is backfilled, plugged, or grouted, and the pipes are connected to headers in a trench that leads back to the building. The drilling depth is determined by the lowest total cost based on the conditions at the job site, but a typical borehole depth is 150 to 250 feet.

The objective of a vertical borehole is to install a specific amount of pipe, not to reach a certain depth. If 1,200 feet of pipe are required, three 200-foot boreholes are acceptable and may be more cost-effective than one deeper hole. Drilling boreholes for geothermal loops is much simpler than drilling to find well water. The borehole is generally smaller, which reduces drilling time, and no casing is required because the hairpin-shaped loop is its own casing. (alliantenergy-geothermal.com)
Design Issues for Geothermal Closed Loop Systems

- Adequate information on soil condition is critical to determine if the system will be feasible and economical. The depth of the borings affects the cost of the system and the presence of rock adds to the cost of borings as well. Deeper borings are necessary when the available footprint is smaller.

- When used under a building, the system needs to be coordinated with the building’s foundation system.

- If used under a parking lot to supply heat to a building, future buildings will not be able to be built in that location without removing or disabling the loop system.

Fuel Cells

A fuel cell operates like a battery but does not run down or require recharging. It produces electricity and heat as long as fuel is supplied. A fuel cell consists of two electrodes sandwiched around an electrolyte. An oxidant passes over one electrode and a fuel passes over the other, generating electricity, water, and heat, and converting chemical energy from a fuel into electric energy. Hydrogen is one of the more common fuels, and oxygen is the more common oxidant. While fuel cells are being used in many applications, the focus for the parking industry is in supplying power for fleet vehicles, including buses.

More than 2,500 stationary fuel cell systems have been installed around the world, either connected to the electric grid to provide supplemental power and backup assurance for critical areas, or installed as grid-independent generators for on-site service in areas that are inaccessible by power lines.

Fuel cell power generation systems currently achieve 40 percent fuel-to-electricity efficiency using hydrocarbon fuels. Because fuel cells operate silently, they reduce noise pollution as well as air pollution, and when the fuel cell is sited near the point of use, its waste heat can be captured for beneficial purposes (cogeneration). In large-scale building systems, these fuel cell cogeneration systems can reduce facility energy service costs by 20 to 40 percent over conventional energy service, and increase efficiency to 85 percent.

Design issues for Stationary Fuel Cell Systems

There are not many design issues associated with the use of stationary fuel cell systems. The most critical issue is determining the location of the system relative to what it is servicing. The location will generally need ventilation and may need to be located outside a building.

More than 50 fuel cell buses have been demonstrated in North and South America, Europe, Asia, and Australia in recent years. Fuel cells are highly efficient, so even if the hydrogen is produced from fossil fuels, fuel cell buses can reduce transit agencies’ CO2 emissions. And emissions are truly zero if the hydrogen is produced from renewable electricity, which greatly improves local air quality. Because the fuel cell system is much quieter than a diesel engine, fuel cell buses significantly reduce noise pollution as well.

Financial Aspects of Alternative Energy

Why would someone consider using alternative energy? Generally, they would because they want to do
the right thing regarding the environment. This may be because the organization has made a commitment to climate change or because there are legislative mandates to reduce greenhouse gas emissions or other similar reasons. However, there are financial considerations to keep in mind: will these alternative energy systems have a better life cycle cost than traditional systems? At this point in time, it’s unclear. However, over time the cost of the use of traditional energy will rise, and as these systems become more available, their cost will go down. This will help the life cycle cost of these systems.

The cost for society of not moving to alternative energy sources is problematic. As the earth runs short of traditional fossil fuels, we are depleting areas that cannot be re-created. The emissions created by fossil fuels and their effect on the environment are very costly to mitigate. That is why there is strong legislative initiative to provide incentives for using alternative energy.

The Renewable Energy Investment Tax Credit (ITC) provided under Section 48 of the Internal Revenue Code allows project owners or third-party investors to receive credits against federal income taxes for installing designated renewable energy generation equipment. The ITC is an investment-based credit, and the amount of the credit depends on the type of renewable energy equipment. The ITC totals 30 percent of the cost of solar energy systems, fuel cells, and small wind turbines. The ITC totals 10 percent of expenditures for geothermal heat pumps, microturbines, and combined heat and power systems.

Pursuant to the Energy Improvement and Extension Act of 2008, the ITC is generally available for systems that are placed in service on or before December 31, 2016. The ITC may be claimed in the year in which the eligible system is placed into service. There is no tax credit cap per project. The ITC may be carried back one year or carried forward for five years. The ITC may be used against alternative minimum tax.

In addition to these federal tax credits, there are many local rebate programs in place to help fund the initial cost of these systems and help to make their life cycle costs more palatable. However, many of these rebate programs have limits on total availability so it is critical to investigate the current status of the rebate funding before investing in a system.

Once initial installation is funded, alternative energy sources can reduce ongoing operations and maintenance costs. Most solar and wind systems are installed to take advantage of net metering, which is a method of metering the energy consumed and produced at a home or business that has its own renewable energy generator, such as a small wind turbine or PV system. Excess electricity produced by the generator will spin the electricity meter backwards, effectively banking the electricity until it is needed by the customer. This provides the customer with full retail value for all the electricity produced and allows the customer to use any excess energy to offset that used at other times during the billing period. In other words, the customer is billed only for the net energy consumed during the billing period. Each local utility company has its own net metering rules, so it is important to check on these before getting started.

A Power Purchase Agreement (PPA) allows systems to be purchased, installed, and maintained by a third party through a contract between a consumer and the company that owns and operates an energy generator. The PPA establishes a price and time period for the generator owner/operator to sell electricity to the consumer. This arrangement provides the consumer a predictable, insured electricity price over an extended period of time, freedom from risks and responsibilities associated with equipment ownership, and the ability to use renewable energy without a large upfront capital investment. The PPA provides the generator owner/operator predictable cash flow on their investment and offers certain tax advantages.

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MICHÉLLE WENDLER, AIA
is principal with Watry Design, Inc.
A LIGHTING SYSTEM IS A SIGNIFICANT CAPITAL AND OPERATIONAL INVESTMENT FOR EVERY PARKING FACILITY. It represents both a considerable purchase and installation investment and likely the second most expensive monthly feature of a parking facility, behind cashier labor costs. It is, however, one of a facility’s most critical safety and security components, and helps the perception of the facility’s users and with attracting customers.

Many published articles have detailed the importance of parking lighting systems, with many focused on the quality and quantity of light needed to provide adequate visibility and security. This chapter will address the role of lighting from a sustainability perspective.

Technology Increases Lighting Options

The rapid development of new lighting technologies has increased the number of options available to parking facility owners. A few of these technologies offer higher quality light sources that require less energy to operate than their traditional counterparts. We will focus on the increasing number of sustainable technologies for parking garage lighting systems that are available, ways to improve lighting quality while lowering the operating costs, and their impact on the environment.

In 2009, the International Parking Institute (IPI) conducted a survey of its membership for the U.S. Department of Energy (DOE) to characterize the types of lights used and typical operating hours of parking lots and structures in the U.S. The results were published in “Energy Savings Estimates of Light Emitting Diodes in Niche Lighting Applications,” Navigant Consulting, Inc. (2008). The number of light fixtures was based on an approximation of three parking garage spaces per fixture and 20 surface lot parking spaces per fixture. Results showed that the number of lights in use in a garage is directly associated with the total number of parking spaces the structure contains.
There is no commonly accepted number of total parking spaces in the U.S.; estimates range from 105 million to 2 billion. For the purposes of the DOE lighting analysis, a middle ground of 505 million non-single family, residential parking spaces (395 million surface lot spaces and 110 million garage spaces) was selected. This calculation results in an estimated 36.4 million parking garage light fixtures and 15.8 million surface lot light fixtures.

According to this survey, approximately 23 percent of parking garage fixtures are high-pressure sodium (HPS) fixtures, while approximately 38 percent of surface lot fixtures are either HPS or Mercury Vapor (MV). Metal halide (MH) fixtures compose 54 percent of surface lot fixtures and 15 percent of garage fixtures. Approximately 55 percent of all parking lighting comes from high-intensity discharge fixtures (HPS, MV, or MH).

Based on the IPI survey, the average operating hours for parking lots was defined as 13 hours per day or 4,754 hours per year; garage lights were estimated to be used for 18 hours per day or 6,570 hours per year. All of the HID fixtures combined are estimated to use 51 trillion watt-hours (TWhr) of electricity annually to provide light for these parking spaces.

If 100 percent of HID fixtures were converted to a more energy efficient lighting system, a conservatively low estimate of the savings is 16 TWH/year. Understanding that in many applications fluorescent and LED installations often result in up to 50 percent savings over HID, it may be possible to realize as much as 25 TWH/year in savings, which is enough electricity to power 1.3 million residential households every year. Improved parking facility lighting can make an important contribution to our industry and help improve our industry’s environmental impact.

Traditionally, the lighting system in a parking garage represents a significant percentage of a facility’s total energy consumption. Improving the efficiency of this lighting system can lead to significant cost savings and reduced environmental impact. The data presented in Table 1 and Table 2 provide insights into the current installed base of parking lighting and the potential for energy savings through more efficient lighting technologies.

### Table 1—Parking Light Installed Base (Source 2008 DOE Report)

<table>
<thead>
<tr>
<th>Niche Application</th>
<th>Annual Electricity Consumption in 2009 (TWh/yr)</th>
<th>Electricity Savings in 2009 (TWh/yr)</th>
<th>Additional Potential Electricity Savings (TWh/yr)</th>
<th>Total Potential Electricity Savings (TWh/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Garage Lighting</td>
<td>28.1</td>
<td>0.6</td>
<td>6.5</td>
<td>7.1</td>
</tr>
<tr>
<td>Lot Lighting</td>
<td>23</td>
<td>0.8</td>
<td>8.1</td>
<td>8.9</td>
</tr>
</tbody>
</table>

### Table 2—Energy Consumption and Savings Potential of Parking Lights (Source 2008 DOE Report)

<table>
<thead>
<tr>
<th>Application</th>
<th>Lamp Type</th>
<th>Percentage</th>
<th>Number of Lights</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lot Lighting</td>
<td>Incandescent</td>
<td>1.6%</td>
<td>581,500</td>
</tr>
<tr>
<td></td>
<td>Halogen</td>
<td>2.2%</td>
<td>808,000</td>
</tr>
<tr>
<td></td>
<td>Fluorescent</td>
<td>45.9%</td>
<td>16,595,000</td>
</tr>
<tr>
<td></td>
<td>Induction</td>
<td>7.4%</td>
<td>2,701,000</td>
</tr>
<tr>
<td></td>
<td>Mercury Vapor</td>
<td>0.1%</td>
<td>46,500</td>
</tr>
<tr>
<td></td>
<td>High Pressure Sodium</td>
<td>23.2%</td>
<td>8,517,000</td>
</tr>
<tr>
<td></td>
<td>Metal Halide</td>
<td>15.3%</td>
<td>5,622,500</td>
</tr>
<tr>
<td></td>
<td>LED</td>
<td>4.1%</td>
<td>1,502,500</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>100%</td>
<td>36,370,500</td>
</tr>
</tbody>
</table>

| Lot Lighting | Incandescent | 2.6% | 411,000 |
|             | Halogen      | 0.1% | 16,000  |
|             | Mercury Vapor| 2.4% | 385,000 |
|             | High Pressure Sodium | 36% | 5,688,000 |
|             | Metal Halide | 54.2%| 8,568,500 |
|             | LED          | 4.6% | 728,500 |
|             | Total        | 100% | 15,797,000 |
overall operating budget. With an MH or HPS lighting system, this can often be as high as 20 percent of an owner’s operational costs. Based on improvements in lighting fixture technologies and implementation of lighting controls, it is possible to reduce these operational costs by as much as 75 percent. Studies have shown that payback periods to convert conventional MH or HPS lighting systems to more energy efficient lighting technologies typically vary between two and four years, at an average electric utility cost of $0.08 per kWh. At a higher utility cost, the payback period is less; it is somewhat longer at lower utility cost.

Lighting technology for parking garages and surface lots has evolved rapidly. Due to these advancements and improvements to existing technologies, there are improved alternatives for owners to consider.

**Lighting Technology Overview**

For many years, light was provided in parking facilities with high-intensity discharge fixtures, both high pressure sodium (HPS) and, more recently, metal halide (MH) fixtures. MH fixtures became prominent because they provided a white light that greatly enhanced brightness perception for users; HPS fixtures offered a yellow glow. This system came at a cost, however, as the MH fixtures required 10 percent more energy to operate at equivalent lighting levels.

In many markets, linear fluorescent fixtures (LF) became a preferred solution to provide light quality similar to the MH solutions, but at a 40 percent more economical energy consumption level. Recent advances in the design and construction of LF fixtures have improved this technology application for many parking garage facilities. Fluorescent induction lighting has also entered a few markets; it offers benefits similar to LF fixtures with somewhat lower light output, but with an extended life span.

Most recently, light-emitting diodes (LED), a solid-state solution, has entered the parking garage lighting market. LED technology has existed for many years but was never considered a viable alternative for general lighting applications due to cost and technology development.

The first generation LED parking garage fixtures were significantly more expensive (six to 10 times more) in initial costs than other systems, but they were able to achieve similar energy savings as LF fixtures. More manufacturers have entered the LED market, resulting in competitive fixture costs between the LED options and a more reasonable life cycle cost. Due to the lower utility and maintenance costs associated with LED and LF fixtures and the improved life cycle costs, many parking garages are developed to use these energy-efficient lighting systems, resulting in significant electricity use reductions.

It is anticipated that lighting system alternatives will continue to advance, with additional improvements in efficiencies and costs. Start-of-project evaluations are recommended to assess what options are most advantageous for each particular facility at that particular time. It also is recommended that owners consult lighting specialists who are familiar with the intricacies of parking applications their technological advances.

**Sustainability**

A parking facility’s lighting system offers an opportunity to incorporate sustainable elements in the design and construction and in operations. There are several aspects of parking facility lighting that directly relate to sustainability:

- Energy consumption
- Recycled material content
- Diversion of chemicals
- Industry growth and job creation

**Energy Consumption**

The energy efficiency of any lighting system is relative to its energy consumption at a particular light level. The typical layout of basic lighting systems has fixtures spaced at approximate 30-foot centers.
Assuming that grid, the following typical total fixture wattages, including the drivers and ballasts, are usually required:

- **HPS**: 190 watts (typical 150 watt lamp plus 40 watt power source)
- **MH**: 190 to 210 watts (typical 150W to 175 watt lamp plus 35 watt power source)
- **LF**: 100 to 120 watts (typical 4 – 32 watt T8 lamps or two, T5HO lamps plus normal power electronic ballast)
- **LED**: 50 to 80 watts (dependent on quantity of LEDs in each fixture)
- **Induction**: 85 to 100 watts (typical 85 watt lamp plus 15 watt power source)
- **CFL**: 170 to 190 watts (typical 4 42 watt lamps plus power source)

The typical parking garage lighting system operates 24 hours a day, seven days a week, using a significant amount of energy when the garage may not be highly utilized. Adding controls to the lighting system can reduce energy use without compromising patrons’ experiences. These options include:

- **Perimeter lighting controls**. Turn off the perimeter lights within the facility during daylight hours and take advantage of natural light that spills inside.
- **Motion sensor technology**. During periods of low use, motion sensors allow lighting in zero-activity zones to be turned off or dimmed to lower levels. When motion is sensed, (i.e. when someone enters the zone) the lighting returns to normal levels.
- **On-site renewal energy**. Photovoltaic (PV) panels are popular on garage and stair/elevator tower roofs. The cost of the electrical power generated by these systems is still relatively high, meaning that a partnership with a third party, such as a government agency or a local power company, is required to make these systems financially feasible. In some cases, the panels are used to generate power for the garage lighting itself. In other cases, the power is sold back to the power grid.

**Recycled Material Content**

Many lighting systems feature a high percentage of recycled content in fixture components and housing. As various manufacturers strive for different marketing opportunities, the amount and type of reused materials varies greatly. Some manufacturers offer products that are constructed with 90 percent recycled material content that includes aluminum housing and fixture reflective components. This sustainable trend is expected to continue.

**Diversion of Chemicals to Landfills**

Traditional HID lamps and fluorescent lamps must be replaced every 18 to 36 months. Disposing of those lamps results in a substantial amount of waste. Furthermore, LF and induction fixture lamps contain small amounts of mercury, which is hazardous and requires special disposal. It is believed that many fluorescent fixtures end up in landfills improperly.

LED fixtures are comprised of silicon chips, not traditional lamp bulbs. In the future, they may be recycled for different uses. Newer versions of some LED fixtures are being designed with LED replacement modules that can be replaced in the field, which eliminates the need to remove and ship the fixture housing to the manufacturer. Because no lamps are replaced, the impact on landfills is greatly reduced.

**Creation of New Industry and Jobs**

LED technology has generated an opportunity for the creation of jobs in an expanding market. The advances in this green energy technology have received substantial political, national, and international attention. LED lighting technology has advanced so quickly that the DOE has developed the Solid-State Lighting (SSL) Research and Design Program to protect the future and quality of SSL technology. The program is
mainly focused on preventing over-commercialization of SSL, reducing U.S. building energy use and costs, and formulating codes to help protect U.S. energy security interests.

**Economics**

Determining a preferred system for a particular parking facility involves developing a comprehensive approach to compare the various available lighting systems. The key elements included in such an analysis should be evaluated by a lighting system specialist, as the variables are constantly changing. A comprehensive life cycle cost analysis is recommended, and should include initial construction/installation, energy, and maintenance costs.

A sample life cycle cost analysis is shown on the following pages. In this example, MH and LED fixtures are compared for a specific opportunity, demonstrating the components that should be included in such an analysis. This example was completed in 2010 by Kimley-Horn and Associates, Inc. The results of this example should not be considered typical of all analyses.

**Recommended Lighting Levels**

Providing adequate lighting without over-lighting a parking facility is a delicate balance. Minimum lighting level standards were developed and documented by the Illuminating Engineering Society of North America (IESNA) for parking garages and surface lots. These standards have been in use for parking facilities since 1985, were based on minimum illuminance levels for adequate visibility of hazards in a parking garage, and were developed using measurements of HID light sources.

Minimum lighting criteria are defined in Table 3 (based on IESNA).

Beyond the minimum required lighting levels, high quality, uniform lighting throughout a facility contributes to an enhanced atmosphere for patrons. The effect of a well-lit facility has become paramount in attracting customers, and in some cases, reducing liability from potential claims. Following recommended lighting parameters helps provide a safe and secure atmosphere for patrons.

**Types of Lighting Systems**

**High Intensity Discharge Lighting Systems**

Until recently, parking garages traditionally used high intensity discharge (HID) lighting systems consisting of HPS, MV, and MH lamps. HPS and MH systems currently make up more than 90 percent of all surface parking lot installations. According to IPPI’s survey, approximately 38 percent of all parking garage lighting in 2009 was either HPS or MH.

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**Table 3—Recommended Maintained Illuminance Values for Parking Garages**

(Source IESNA RP-20-98)

<table>
<thead>
<tr>
<th></th>
<th>*Minimum Horizontal fc</th>
<th>*Max/Min Horizontal Uniformity Ratio</th>
<th>*Minimum Vertical fc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic</td>
<td>1.0</td>
<td>10:1</td>
<td>0.5</td>
</tr>
<tr>
<td>Ramps:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day</td>
<td>2.0</td>
<td>10:1</td>
<td>1.0</td>
</tr>
<tr>
<td>Night</td>
<td>1.0</td>
<td>10:1</td>
<td>0.5</td>
</tr>
<tr>
<td>Entrance Areas:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day</td>
<td>50</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Night</td>
<td>1.0</td>
<td>10:1</td>
<td>0.5</td>
</tr>
<tr>
<td>Stairways</td>
<td>2.0</td>
<td>10:1</td>
<td>1.0</td>
</tr>
</tbody>
</table>

*Definitions:*

**Minimum Horizontal Illuminance (fc):** the measure of brightness from a light source (measured in footcandles), taken through a light meter’s sensor at a horizontal position on a horizontal surface.

**Uniformity Ratio:** Ratio of light illumination consistency across an area expressed as the maximum measured lighting value over the minimum measured value.

**Minimum Vertical Illuminance (fc):** the measure of brightness from a light source (measured in footcandles) taken through a light meter’s sensor at a vertical position on a vertical surface.
HPS was often chosen due to relatively low installation and operating costs. This lamp produces light with a distinct yellow glow that offers a uniform lighting level throughout a facility with fixtures spaced at typical 25- to 30-foot centers. HPS also provided an efficient lighting source when compared to other technologies available at that time. Most HPS systems feature 150-watt lamps that must be replaced every two to three years. While these provide lighting levels above the minimums required, their yellow light does not facilitate facial recognition, and distorts colors somewhat; white light has better brightness. HPS systems also appear dark to the human eye, resulting in a perception of poorly lit facilities.

The development of pulse-start metal halide (PSMH) lighting systems resulted in 50 percent longer life and 20 percent higher lumen output than previous MH lamps. Although the lamp life was still 40 percent shorter than HPS and the lamps offered 12 percent less light output, the life cycle cost was only five to 10 percent less than HPS. So PSMH fixtures provided an economic alternative to HPS and steadily increased in popularity within the parking garage market. In fact, in 2009, MH and PSMH fixtures were estimated to have captured approximately 15 percent of the U.S. garage lighting market, primarily due to improved perceived light quality.

MH provided a better lighting environment in parking facilities because the white light improved detail and color rendering. The perception of dark spots could also be eliminated by the proper placement of fixtures. In most MH systems, the main lamps in a garage are 150 to 175 watts and must be replaced every 18 months.

**Fluorescent Lighting Systems**

As designers and owners continued to search for better lighting options, fluorescent lamp systems began to capture a significant portion of the industry. The 2010 DOE report estimated that approximately 46 percent of all parking garage lighting was linear fluorescent.
(LF). LFs were initially used in parking garages with varied results: they provided a white light alternative to MH at a much lower installation and operating cost, but did not perform well in extreme cold temperatures. Exposure to insects and dirt proved to be a problem as well. Despite these initial challenges, LF lighting technology has improved with electronic ballasts, vapor-tight fixtures, UV resistant acrylic lenses, and better resistance to cooler temperatures.

LF bulb disposal is a significant challenge as the lighting industry strives for increased environmental awareness and sensitivity. A typical LF fixture contains two to four lamps, resulting in more waste material than HIDs. In addition, LF bulbs contain mercury and argon gas, which are hazardous materials and require special disposal procedures. Continued improvements in LF bulb technology have reduced mercury content since their introduction.

Newer types of LFs, including compact fluorescents (CFs) and induction fluorescents (INDs), have entered the general lighting application market in recent years.

There are two main components in a CF fixture: the gas-filled tube (also called bulb or burner), and the magnetic or electronic ballast. An electrical current from the ballast flows through the gas (mercury vapor), causing it to emit ultraviolet light. The ultraviolet light then excites a phosphor coating on the inside of the tube, which emits visible light.

A single CF fixture typically contains multiple CF lamps or bulbs. Typical CF fixtures may contain as many as four lamps, meaning additional maintenance expense and larger power sources are a common hurdle. CF lamps also have a much reduced lamp life compared to LF lamps.

The induction fluorescent lamp (IND) does not use electrodes or a filament like conventional discharges or incandescent sources. IND light is generated by means of induction—the transmission of energy via a magnetic field—and gas discharge. This produces an efficient, long-life source that starts up quickly with little deterioration throughout its rated life. This system greatly increases the longevity of the power source, maximizing the lifespan of the lamps. It is not uncommon for an IND light fixture to last up to 100,000 hours.

Historically, this technology has struggled to gain traction in the parking industry; this may be due to a combination of inadequate marketing exposure and higher costs relative to comparable systems, as well as lower light output per wattage than other more efficient light sources.

**Light Emitting Diodes (LED) Lighting Systems**

LED technology has been in existence for many years. Many people recognize LED technology as specialty lighting used in watches, cell phones, computer screens, and other applications. The defense industry has relied on it for many years. Manufacturers have
discovered ways to improve mass production and efficiency of the diode light output itself, and have found a variety of ways to disperse light output to produce a viable general lighting source. Advancements in LED technology are made every day; with 20 percent gains in efficiencies annually, LED systems have become a viable alternative for garage lighting.

The 2011 DOE report estimated that approximately 4 percent of garage lighting was LED. Since then, manufacturers have estimated that as much as 30 percent of new sales has been LED. Based on current market conditions, this percentage should increase steadily.

In 2010, the initial installation cost for an LED system was still somewhat high as compared to other systems. The estimated cost of a LED fixture is five to 10 times more than other types of fixtures, depending on wattage. Even so, operational costs, along with other sustainable features, have led many owners to select LED lighting for their facilities. It’s a solid-state technology, so unlike other systems, there are no filaments to burn out and no gas-filled tubes that require proper disposal.

Additional differences between LEDs and other lighting sources include the power variances throughout the life of a traditional HID. Traditional HID fixture lamps become less efficient as they require more power to produce less light. Eventually, they burn out. Most HID lamps have to be replaced every 18 to 36 months, and fluorescent lamps last approximately three to five years between replacements.

The diodes in a LED fixture remain efficient throughout their life, only gradually losing light output (30 percent light loss over the rated life of the light fixture). While the life expectancy of LED fixtures is not yet defined, most manufacturers guarantee an effective life for five years or 60,000 hours, and many expect the fixture and diodes to last much longer. Currently, the power source in the LED fixture is considered the weak link, with a five-year warranty.

LEDs are expected to continue to produce light at the end of their designed life. Standards define the end of the LED’s design life as the point in time when the diode is producing 70 percent of its original light output. This is usually called the L70 lifetime curve.

LED lighting technology does not come without challenges. Those in extremely humid and/or hot areas of the country should closely examine the applicability of LED performance. The performance of an LED
can diminish greatly if it does not have proper heat sinking technology and is surrounded by hot air. LEDs have been observed and tested to perform at their best in cool to cold climates. Once the technology has been in existence and in use for 10 to 15 years, real data will allow life cycle cost comparisons.

**Lighting Effects**

For many years, parking garages were viewed as necessary evils, and minimal attention was given to their internal design. As a result, many people have negative connotations of parking garages as dark, dangerous, and risky places.

Parking garage owners and designers have realized that a patron’s experience will dictate whether they want to return. Lighting may be the single most important factor in this.

**Visibility**

Internal visibility is critical. A driver must be able to see to navigate and park his vehicle. Driving inside a garage is different than driving on a street or freeway because of obstructions such as columns, walls, and the close proximity of other elements. Ambient light levels need to be such that a driver can detect and read signs without being blinded by the glare of light sources. Just as important is the ability of pedestrians to see and be seen.

Pedestrians should be able to detect details such as curbs, wheel stops, and other objects as they make their way to and from their cars. Many claims result from tripping and falling by walking guests. The ability to detect facial features and distinguish color differences may deter potential crimes from occurring. Uniform, high-quality lighting throughout a facility can significantly reduce the chance of such events and may minimize the potential for claims against an owner.

There are four major aspects of lighting:

- Lighting intensity measures the average illuminance or lighting output in footcandles. Typical minimum and average lighting intensity standards measure the lighting intensity on the floor (horizontal illuminance) as well as five feet above (vertical illuminance).
- Uniformity measures illuminance variations across an area, generally by comparing the maximum intensity to the minimum intensity and establishing a max to min ratio. A lower ratio is indicative of uniform lighting and a better perceived quality to the human eye.
- Lower variance light levels minimize adjustments the human eye must make between bright and dark spots, allowing people to see better. Having bright or “hot” spots next to dark areas requires adjustment by the eye, which results in a period of time when sight is impaired. If many such adjustments are required while moving through the facility, visibility can be significantly hindered.
- Color temperature is a measure of the temperature of the light source expressed in degrees Kelvin. The higher the temperature,

**Table 4—Lighting color characteristics based on lighting technologies.**

<table>
<thead>
<tr>
<th>Lighting System:</th>
<th>HPS</th>
<th>MH</th>
<th>T8FL</th>
<th>CF</th>
<th>IND</th>
<th>LED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color Temperature (K)</td>
<td>2100</td>
<td>4000</td>
<td>3,500–4,500</td>
<td>3,000–6,500</td>
<td>4,000–4,500</td>
<td>4,000–6,500</td>
</tr>
<tr>
<td>Color Rendering Index (CRI)</td>
<td>21</td>
<td>60</td>
<td>50–90</td>
<td>50–90</td>
<td>60–80</td>
<td>70–80</td>
</tr>
</tbody>
</table>
the whiter the light source is perceived as being. Traditional lighting sources, such as HPS or interior incandescent lighting, usually appear more yellow or orange in color. Energy-efficient lighting systems such as fluorescent and LED usually appear whiter in color. As a frame of reference, sunlight at noon has a color temperature in the 6,500 K range. Refer to Table 4 for a comparison of the typical color temperature range values between different lighting technologies.

- Color rendition affects the ability of the eye to detect details and colors. A color rendition index (CRI) is a quantifiable measure of a light source’s ability to reproduce colors as they are seen under a natural light source. A CRI of 100 is equivalent to broad daylight on a sunny day at noon while a CRI of 0 is equivalent to complete darkness. Higher CRI values demonstrate an improved perception of quality light and an accurate representation of true natural colors.

**Maintenance**

The maintenance costs associated with a lighting system are important. Exposure to environmental conditions such as moisture, insects, and dust make easy cleaning another vital aspect to consider during the selection process. Fixture design and construction need to facilitate the cleaning process while minimizing the need for constant attention.

Because of the high number of fixtures generally required for a parking facility, the mounting heights, and sometimes difficult access, replacing lamps can become a significant maintenance cost.

**Notes**

- Beta Lighting Incorporated: LED Education Center: http://www.betaled.com
- Solid-State Lighting: Comparing LEDs to Traditional Light Sources: http://www.netl.doe.gov/ssl/usingLeds/general_illumination_efficiency_comparison.htm

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DEAN PENNY, P.E.

is principal and senior vice president with Kimley-Horn and Associates, Inc.

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DENNIS BURNS, CAPP

is senior practice builder and regional vice president for Kimley-Horn and Associates, Inc.
PUBLIC AND PRIVATE PARKING SYSTEM OWNERS WHO WISH TO SUPPORT SUSTAINABILITY INITIATIVES SHOULD HAVE AN INTEREST IN ELECTRIC VEHICLES (EVs) AND EV CHARGING STATIONS. Provisions should be made to accommodate these vehicles as they grow in popularity and availability. Providing the infrastructure to charge EVs in a parking system and promoting their use can help achieve this goal.

History

EVs are not new, as they were widely used in the 19th century. In fact, electric vehicles were preferred over the gas-powered vehicles that we drive today because they did not emit odors and noise. The construction of new roadways connecting towns and cities altered consumer needs and shifted the market demand to longer-range gasoline-powered vehicles.

Recent years have seen another push for electric vehicles that is rooted in the desire for cleaner air; this started with the U.S. 1990 Clean Air Act. The Zero Emission Vehicle (ZEV) Mandate, which required 2 percent of California’s vehicles to be zero-emission by 1998, also helped renew the research and development for the mass production of personal electric vehicles. While the ZEV Mandate was eventually repealed, it played an important role in bringing the EV to the 21st century by mandating that automobile manufacturers produce a minimum percentage of electric vehicles.

The first hybrid vehicles, such as the Toyota Prius, are actually parallel hybrid vehicles and were introduced as a compromise between traditional gasoline-powered and electric vehicles. Using a power split device, the internal combustion engine can power the vehicle by itself, the battery-powered electric motor can power the vehicle by itself, or they can power the vehicle together. Traditional hybrid vehicles do not obtain any power from
Plug-in hybrid electric vehicles (PHEVs), such as the Chevrolet Volt, combine the benefits of operating a pure electric vehicle with the convenience of being able to operate with readily-available gasoline or diesel fuel. PHEVs initially use the battery power with an internal combustion engine that turns an alternator to recharge the battery, or engages a motor to propel the vehicle. PHEV batteries are meant to be charged from an external power source, such as an outlet or charging station.

“Pure” electric vehicles, or battery electric vehicles (BEVs) have only one power source and must be recharged from an external power source such as an outlet or charging station. The Nissan LEAF is a pure electric vehicle; once the battery is completely discharged, the vehicle cannot operate until it is recharged.

The battery in a BEV must be able to meet all of the range and power requirements for the vehicle, with the exception of some additional power that is recaptured through regenerative breaking or solar photovoltaic (PV) panels.

**Geometrics**

While a typical compact vehicle has a footprint size of approximately 86.8 square feet, some common electric vehicle models range from 62 square feet for the Mitsubishi iMiEV, to 86.6 square feet for the Chevrolet Volt. Because EVs tend to occupy a smaller footprint than other vehicles, it may be possible to use smaller dimensions in a parking facility if needed. Similarly, a standard parking stall may be large enough to accommodate the EV and charging equipment without extending the length of the stall.

While most EVs today are smaller to allow for a lighter vehicle and longer range, once battery technology is further improved, larger EVs may become more popular (Figure 1).

**How They Work and Their Safety**

There have been some concerns about the safety of storing and charging electric vehicles in parking

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**FIGURE 1: Comparison of Electric Vehicles**

<table>
<thead>
<tr>
<th>Year</th>
<th>Make</th>
<th>Model</th>
<th>Length</th>
<th>Width</th>
<th>Area (sq.ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>Mitsubishi</td>
<td>iMiEV</td>
<td>144</td>
<td>62</td>
<td>62</td>
</tr>
<tr>
<td>2011</td>
<td>Tesla</td>
<td>Roadster</td>
<td>155.1</td>
<td>72.9</td>
<td>78.5</td>
</tr>
<tr>
<td>2011</td>
<td>Ford</td>
<td>Focus EV</td>
<td>175</td>
<td>67.8</td>
<td>82.4</td>
</tr>
<tr>
<td>2011</td>
<td>Nissan</td>
<td>LEAF EV</td>
<td>175</td>
<td>69.7</td>
<td>84.7</td>
</tr>
<tr>
<td>2011</td>
<td>Chevrolet</td>
<td>Volt</td>
<td>177.1</td>
<td>70.4</td>
<td>86.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type</th>
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facilities. In particular, consumers are concerned about the need to provide ventilation while EVs charge. Some previous electric vehicles required ventilation, but most newer electric vehicles today do not. In addition, ventilation requirements are determined through the electric vehicle supply equipment (EVSE). If the EVSE detects that a vehicle requires ventilation, a ventilation system can be activated. If a ventilation system is not available, the vehicle will not be able to use the EVSE to charge.

Other desired safety measures for locations with EVSE include at least two emergency shut-off switches, one of which is not located next to the equipment or vehicle; a fire extinguisher immediately adjacent to the EVSE; signage with emergency telephone numbers; and a defibrillator. In addition, EVSEs should be examined at least daily for damage or tampering and, if possible, should be placed in a location that is visible to cashiers or other parking staff.

**EVSE Charging Standards**

Charging systems currently come in three levels to denote their power specifications. AC Level 1 chargers operate off of a standard North American 120 volt AC 15-20 amp circuit. These are the lowest voltage circuits found in most residential and commercial buildings. Level 1 chargers have the lowest power output and take the most amount of time to fully recharge an EV battery.

Fully charging a 24kWh battery using a Level 1 charger would take approximately 13 hours and 20 minutes.

Level 1 charger hourly power output = 120 volts x 15 amps = 1.8kW/hour

Charging time = 24kWh battery / 1.8 kW per hour = 13 hour 20 minutes

AC Level 2 chargers operate off more powerful 240 volt AC, 30 amp circuits and are considered the preferred method. Most North American homes contain 240V sockets in the laundry rooms and kitchens, where they are commonly used for clothes dryers and ovens. Level 2 chargers allow users to significantly reduce the time needed to fully recharge an EV battery.

Level 2 hourly power output = 220 volts x 30 amps = 6.6kW/hour

Charging time: 24kWh battery / 6.6 kW per hour = 3 hours 40 minutes

In the U.S., Level 1 and Level 2 chargers both operate using the North American industry standard SAE J1772 EV connector, which transfers AC power from an electric supply to the EV on-board charger. The five pin J1772 connector was designed with several safety components, including a grounding conductor, two current-carrying conductors (AC Line 1 and AC Line 2), and two communication conductors (Control Pilot and Proximity Detection).

AC Line 1: Transfers 120 volts AC and up to 16 amps.

AC Line 2: Transfers 240 volts AC and up to 80 amps.

Control Pilot: Verifies an EV is present, establishes vehicle ventilation requirements, monitors the presence of the equipment ground, transmits the power supply equipment rating to the vehicle, and allows charging (or de-charging) of the supply.

Proximity Detection: Prevents starting or moving the vehicle while connected to the charger.

Ground Conductor: Safety measure to direct faulty current away from the vehicle.

Quick charge or Level 3 chargers operate off of high-voltage DC current—up to 500 volts DC and 125 amps, which is typically only found in commercial applications. A formal standard connector has not been adopted at this time, however some automobile manufacturers have already began using the Tokyo Electric Power Company’s (TEPCO) CHAdeMO connector. This connector is capable of charging a 24kWh battery in as little as 40 minutes.

In addition, a new J1772 Combo connector also allows for Level 3 fast DC charging as well as AC
charging. The new “combo connector” will allow EV owners and manufacturers to have one charging standard regardless of the power source.

Wireless technology is being developed and improved to allow for the proximity charging of electric vehicles using electrical induction. These systems allow users to charge their EVs by simply parking in a specific location where a charging pad or block has been installed. An adapter must be installed inside the vehicle to communicate with the charging station and perform the wireless charging of the battery.

The last proposed method for charging EVs is use of a battery swap or exchange. Instead of recharging the battery by connecting it to a power source or wireless charging system, the motorist would stop at a battery swap location that removes the depleted battery from the vehicle and replaces it with a fully-charged battery. This can be done in about the same amount of time it takes a traditional gasoline-powered vehicle driver to stop and purchase fuel.

**Infrastructure**

EVSE is best incorporated during design and construction, as electrical conduit can be integrated with the other MEP systems. However, depending on where stations will be located, the cost to retrofit may not be much higher.

The general requirements for EVSE is that charging cords should be no longer than 25 feet and should be installed in an area with minimal pedestrian traffic, as the cord may be a tripping hazard. EVSE requires an electrical panel up to 80 amps, at least one breaker for each charging station within the electrical panel, and preparation for mounting the stations. Wall- and ceiling-mounted EVSE may require additional brackets and hardware as specified by the manufacturer. It may be necessary to consult with an engineer prior to installation. Floor-mounted stations may require cement slabs with J bolts and bollards or some other form of physical barrier to prevent damage and injury.

For on-street applications, electrical conduit will be needed at the location of each EVSE. Cost will depend on the actual location of each charging station, the availability of power, conduit size, and labor rates.

Lighting is required to read signage and directions. Shelter is preferred for customer convenience, although there is EVSE rated for safe outdoor use, even in the rain.

The Manual on Uniform Traffic Control (MUTCD) defined a standard sign for electric vehicle charging

<table>
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stations. The symbol uses traditional signage for gas stations with the addition of “EV” marked on the gas pump. In addition, several municipalities and parking facility owners have created their own signage to communicate the presence of an EV charging station. There is also a proposed standard for European signage.

Accessible Parking
The 2010 ADA Standards for Accessible Design do not specify requirements for EVSE. However, a minimum ratio of one accessible stall to every 50 EVSE stalls is recommended until an official requirement is established. In cases where fewer than 50 EVSE stalls exist, it is advised to install the EVSE between an accessible and standard stall so it can be used by vehicles located in either.

Opportunities
The cost to install the necessary infrastructure to charge electric vehicles in a parking facility is minimal when compared to the benefits. Parking facility owners can enhance a destination by providing EV charging stations. Customers are becoming more environmentally conscious and making a point to buy products from like-minded companies.

Likewise, the owner of an electric vehicle may choose to shop at locations that provide EV charging stations. Aside from the potential parking revenue from these customers, the nearby businesses benefit from additional sales. Providing free charging as an amenity is also a means of promoting a parking facility to those who drive electric vehicles.

Shopping centers or downtowns that provide EV charging stations can benefit from higher rates of parking facility use, higher property lease or rent prices, and, depending on location, revenue from customers who charge their vehicles.

A parking facility owner may wish to combine EV charging stations with a rooftop solar panel canopy to provide two environmentally friendly services along with covered rooftop parking.

Because electric vehicles are, on average, smaller than most gasoline or diesel-powered vehicles, a parking facility owner may wish to use a slightly smaller stall size for a portion of the EV charging stations, to gain additional parking stalls and minimize inefficiencies.

Those who install EV charging stations will benefit from free marketing and publicity as pioneers in their community, higher federal and state rebates and grants, and more opportunities to negotiate agreements with vendors who may wish to eventually charge customers for use. For a full list of all federal rebates and grants, refer to the U.S. Department of Energy’s official website (www.energy.gov).

VICKY GAGLIANO, LEED AP
is parking specialist/senior parking consultant with Timothy Haahs & Associates.
BUILDING ROOF SYSTEMS HAVE PLAYED AN EXPANDING ROLE IN ENERGY CONSERVATION AND SUSTAINABILITY. The consideration and incorporation of green roofs and cool roofs on buildings have grown in recent years due to a number of economic, environmental, and public benefits. Likewise, sustainable roofs on parking structures have received a lot of attention.

The term “green roof” has a number of definitions. In the context of sustainability, it refers to a variety of sustainable practices that can be implemented on the roof, including installation of plants, use of a reflective waterproofing membrane, or installation of solar panels. The growing green roof industry is striving to differentiate and quantify the sustainability of these approaches.

Here, a green roof refers to one that is partially or completely covered with vegetation, such as plants, grasses, and flowers, in a layer of growing medium. These systems typically also include layers of filter fabric, drainage mat, root repellant, and a waterproof roofing membrane. Further, green roofs are classified as either intensive, semi-intensive, or extensive, depending on the type of plants that are used, the depth (and weight) of the growing medium, and the amount of maintenance they require.

“Cool roofs” include roofing systems that reflect higher levels of sunlight than traditional roofing materials, and are also referred to as having high solar reflectance or albedo. They also radiate non-reflected solar energy, which is referred to as having high thermal emittance. The combination of reflectance and emittance results in a much cooler roof surface than traditional materials, reduced cooling costs, and reduced urban heat island effects. Most cool roofs are white or another light color, however, a large variety of colors is available.
Solar power systems convert sunlight into electricity using photovoltaic solar panels. This rapidly expanding renewable energy technology is being retrofitted into existing buildings and incorporated into new buildings, including parking structures. Photovoltaic arrays are typically either mounted on top of the building roof or on the walls. Alternatively, an array can be located on the ground adjacent to the building.

On parking structures and parking lots, solar arrays are being integrated into canopies that cover parking spaces, providing the benefits of shading, weather protection, and renewable energy. Solar power is covered in more detail in Chapter 5.

Green Roofs History and Background

Green roofs have been used for centuries, especially in northern European and Scandinavian countries, as a means of weather protection and insulation. Sod roofs were used by some early Canadian and American settlers as well. The modern green roof technology was first developed in Germany in the 1960s, with rapid 15 to 20 percent annual expansion occurring in the 1980s. Germany has led the research and development effort, including publication of green roof standards developed by the German Research Society for Landscape Development and Landscape Design that are referred to as the FLL Guidelines.

Because of the lack of green roof design guidelines and standards in other countries, the FLL Guidelines have become an international reference. Today, about 10 percent of roofs in Germany are estimated to be green roofs.

Green roofs expanded into other European countries and have seen rapid growth in part due to government regulations and incentives at local and national levels. Local regulations related to stormwater runoff management spurred the use of green roofs, which retain rain water instead of discharging it into the storm sewer system.

More recently, the benefits of green roofs in limiting the urban heat island effect have further increased interest and incentives. Many countries and cities provide financial incentives to building owners who install green roofs.

Green roofs have been slower to take off in North America due to a lack of awareness and knowledge, negative perceptions, lack of national design standards, high upfront cost, and insufficient regulatory pressure or incentives to promote change. That said, the demand for green roofs has grown.

Green roof initiatives and principles have been advanced by the cities of Chicago, Portland, Ore., Denver, and Atlanta, as well as the state of California. These initiatives have been further promoted by associations such as the Green Roofs for Healthy Cities, and LEED® standards available through the U.S. Green Building Council (USGBC).

At this time, the Green Parking Council is also developing standards and incorporating initiatives for their Certified Green Garage program, which will reward parking facilities that use green roofs. Also, ASTM International, (formerly the American Society for Testing and Materials) has published six recent standards related to green roofs, with more in the works. The growing industry has resulted in more firms specializing in the design, materials production, and construction of green roofs, which has helped lower the cost of installation. Further, as the public benefits of green roofs are becoming known, more cities and states are updating regulations and incentives to promote their use.

Green Roof Types

Green roofs are commonly classified as either intensive, semi-intensive, or extensive.

Intensive green roofs are generally park-like with grass lawns, large and diverse plants, trees, and growing media that is at least a foot deep and deeper yet at large plants and trees. Often, intensive green roofs are accessible to be used as recreation, park, or open
space. The weight of intensive green roofs can range from about 60-200 pounds per square foot, so they are most common on new construction projects. They are labor intensive for both installation and maintenance, and generally require irrigation and fertilization.

Extensive green roofs are intended to be much more self-sustaining than intensive roofs and tend to be simpler in both construction and maintenance. The lightweight growing media for extensive green roofs is quite thin—typically between one and five inches—so the weight is typically about 10 to 50 pounds per square foot.

Because of their lighter weight, extensive green roofs are usually more feasible on existing structures than intensive systems, and less costly to construct. Extensive green roofs are often only accessible for maintenance and not for other public uses, but walking paths can be incorporated to make them more accessible. They typically have specialized planting that can take harsh rooftop exposure to sun and wind, such as Sedum or other alpine, dryland plants.

Typically, these plants only require watering and slow release fertilization until they are established, and then irrigation should not be required except during times of excessive dry weather. Maintenance usually consists of twice-annual inspections of drainage, membrane, and safety features along with weed control. The primary differences between intensive and extensive green roofs are related to depth of growing media and the types of plants supported. Secondary differences include accessibility and usability, extent of irrigation and maintenance, weight, and cost.

Semi-intensive green roofs are a hybrid between intensive and extensive, with portions of the roof allocated to one type or another, depending on structural support capacity, access goals, and budget.

Although green roof systems may incorporate pavers or other hardscape features, rooftop systems constructed primarily with walkway pavers and isolated planter boxes generally are not referred to as green roofs, but as roof gardens or plazas.

Green Roof Applications in Parking Structures
Parking structures are excellent candidates for green roofs in a number of possible configurations. It seems that new parking structure development is often met with opposition for land use planning and environmental reasons. Installing a green roof along with other sustainable design strategies can help promote a project during the feasibility and public approval process.

Parking structure green roof applications include:

◆ Intensive green roofs that can be used as ground-level parks on top of underground parking structures. There are a multitude of such projects in North America, but the largest and perhaps the most intense is Chicago’s Millennium Park.

◆ Ground-level pedestrian plazas above underground parking structures that are intended more for aesthetics and access to above-ground buildings than for recreation. One such location is the Allegan Plaza at the Michigan governmental office complex in Lansing, Mich.

◆ Green roofs on above-ground parking structures that put the green space up in the air. This type of green roof can be either intensive or extensive. One example is the Blue Cross Blue Shield Parking Structure in Detroit, Mich., that has an exercise track for employee use in an extensive green roof area that is not meant for public access.

◆ Soccer or football fields can top a parking structure, such as on the Drollinger Parking Garage at Loyola Marymount University in Los Angeles.
Green roofs on top of parking structures need not have access, but instead can be used for aesthetic, vehicle visual screening, shade and weather protection, stormwater management, and other environmental reasons. The Red Deer Parkade in Red Deer, Alberta, Canada, has an arching extensive green roof over the center ramp.

**Benefits of Green Roofs**

There are many benefits of green roofs on parking structures for the owner and the public that help offset the added construction and maintenance costs. For the owner, benefits include aesthetic, environmental, regulatory, public relations, and land use. The public at large also benefits thanks to the aesthetics, environmental, education, recreation, and health improvement opportunities.

**Owner Benefits of Green Roofs**

Parking structures covered by green roofs are more attractive in an urban or campus environment, as vegetated green space can be viewed instead of vehicles and plain gray concrete. When a parking structure is built underground with an intensive green roof, open space for park and recreational uses can be provided, maximizing the value of limited site area for cities and campuses.

A primary benefit is that a green roof can serve as part of the stormwater management program needed to comply with local regulations. Because the growing media is designed to absorb water for a slow release to plants, there is less stormwater discharge. Additionally, the discharge rate is slowed as the water takes time to pass through the growing media, resulting in even further reductions in flow during peak rain events.

Where the green roof is used over finished space such as retail/commercial areas projecting from the parking structure and on canopies or stair/elevator towers, the system protects the roof membrane and its life span can be more than doubled. In these cases, the green roof also provides an insulating effect, reducing the energy cost for air conditioning by 20 percent or more.

**Green Roofs in Branding**

Green roofs are a public relations advantage and can help brand the parking structure and make it a more desired parking destination, increasing its financial value. A green roof, along with other sustainability features, can help reduce the resistance to new parking structure development. It can also help satisfy green space requirements of some local zoning ordinances so a larger structure can be built than would otherwise be allowed.

If the owner desires that the parking structure be LEED® certified or contribute LEED® points towards the certification of a mixed-use facility, a green roof can earn credits towards the following categories of the USGBC’s rating system:

- **Sustainable Sites:** Restore open space, development footprint credit, and landscape design that reduces urban heat islands.
- **Water Efficiency:** Stormwater management, water efficient landscaping, water use reduction, and innovative wastewater technologies.
- **Energy and Atmosphere:** Optimize energy performance if used above occupied space, and ozone depleting substance reduction.
- **Material and Resources:** Recycled content materials for use in the growing media and other layers.
Innovation in Design

Public Benefits of Green Roofs

While the cost of green roof construction and maintenance is borne by the owner, the surrounding community also receives a multitude of benefits. Because of this, many European cities offer financial and regulatory incentives to building owners who install green roofs.

Progressive American cities such as Portland, Ore., also recognize the public benefits and contribute up to $5 per square foot to help offset the added cost of green roofs, and provide discounted stormwater utility rates.

The enhanced appearance of parking structures with green roofs is a public benefit, especially in dense downtown areas. There is likely improvement in mental attitude, stress reduction, and productivity enhancement associated with viewing green space rather than brick walls or drab roofs. The open space provided by green roofs atop underground parking structures may not only benefit the facility owner and its visitors and employees, but also benefits the public beyond its enhanced aesthetic appeal if it is open for public access and use.

Many cities are challenged by aging and over-capacity stormwater sewer systems as the amount of impermeable surface for buildings, roads, and parking lots has grown. Often in heavy rains, the storm system is overtaxed, causing erosion and waterway pollution on a more frequent and extensive basis. Green roofs can be designed to retain much of the rainfall. City of Portland monitoring indicates that green roofs “typically capture and evaporate an average of 60 percent of the rain that falls on them. This reduces stormwater runoff volume and speed, helps prevent combined sewer overflows, and protects rivers and streams.”

Another public benefit of green roofs that has received a lot of attention is their ability to reduce the urban heat island effect. The temperature of many large urban areas is 5 to 7 degrees Fahrenheit warmer than the surrounding rural areas due to both reflected solar radiation that produces heat from roofs and pavements, and the reduction of green spaces.

Green roofs can create an excellent habitat for a very diverse group of birds, butterflies, and other insects. They can also be designed to replicate endangered local or regional ecosystems or habitats. This creates the opportunity for green roofs to become a forum for education for schools and the public in general. Further, green roofs can be used as locations for urban gardens where residents grow vegetables, herbs, and fruit.

Disadvantages of Green Roofs

The biggest disadvantage of green roofs is the increased first and maintenance costs as described later in this chapter. While green roofs cost more than conventional roofs, there has been much study and research to quantify the cost benefit over the roof life cycle.

The Cost Benefit Evaluation of Ecoroofs—2008 report prepared for the City of Portland, Ore., Bureau of Environmental Services concludes, “The costs and benefits identified in this evaluation clearly show that investment in ecoroof construction generates, in the long run (40-year), significant benefits both to developers and building owners as well as to the public stormwater system and the environment. However, from a short term (five-year) perspective—one typically associated with developers—benefits accrued by a developer for ecoroof construction would only account for approximately half the cost of the ecoroof. Benefits do not appear to exceed costs until year 20 when an avoided cost of conventional roof replacement would be accrued.”

Because of this, increased financial incentives by governmental entities, as is common in Europe, may be necessary for green roof use to expand in North America. It should be noted that most parking structures do not have roofs (unless they are below grade), and in those instances, the incremental cost of adding a green roof must include the cost of the roof structure itself in addition to the added cost of the green
Because of the additional weight of green roof systems, there are increased structural requirements for not only the roof supporting elements, but for columns, lateral load-resisting elements, and foundations. The ASTM standards mentioned later provide design criteria for estimating the roof dead loads and live loads associated with green roofs. Because of their heavier weight, green roofs may not be feasible when retrofitting existing roof structures with conventional roofing materials. However, an assessment by a qualified structural engineer can determine the available capacity or needed upgrades to accommodate a green roof. On new parking structures, roofs can be designed by qualified parking structure engineers to carry the load of intensive or extensive green roofs.

Green roofs take more expertise and attention to maintain, including at least annual inspections of drainage systems, waterproofing, and safety items. Extensive roofs need to be watered and fertilized until they are established, and even then, periodic fertilization is still beneficial.

Weeding of extensive roofs should occur once or twice a year, as birds and wind will deposit a variety of seeds of undesirable plants, such as trees whose roots could damage the membrane, weeds, invasive ivy, or plants that grow prolifically and could dry out and become fire hazards. Intensive green roofs that have lawns, bushes, flower gardens, trees, and irrigation systems will require maintenance like any other park or yard.

**Maintenance Concerns**

One potential concern with green roof maintenance is locating leaks in the waterproof membrane that is hidden under the layered system. It is advisable to flood test the membrane when it is installed to check for leaks and to segment the roof area into sections to facilitate partial removal of the layers for membrane maintenance.

However, with proper design, construction, and maintenance, the membrane should perform very well and even have an extended life due to being protected from sun, wind, rain, and people. Also, there are electronic leak detection techniques available where a stainless steel or aluminum wire mesh that can pinpoint leak locations is placed above the waterproof membrane, but these can be cost-prohibitive.

Because green roofs are not yet common practice in many parts of North America, there is increased risk of improper design, construction, and maintenance leading to less-than-desired performance. Expertise should be sought to help assure a successful green roof installation.

Further, there are numerous references available to educate owners, designers, governmental approval authorities, and maintenance staff on proper materials and techniques. It is recommended that the construction warranty for the green roof be given special consideration, including obtaining an extended warranty period (i.e. 15 years) and requiring a single-source responsibility or joint and several responsibilities for the roof construction. Some roof membrane manufacturers will not enter into joint and several warranties with the installer. It may also be advisable to receive bids for annual maintenance contracts for specified duties from the green roof contractors for the early years when the roof is being established if there is not qualified maintenance staff for the task on-site.

Other criticisms of green roofs are that they can be a fire hazard and can cause insurability issues. When properly design and constructed, specialized green roof growing media should provide a natural resistance to fire. Inclusion of vegetation-free zones around the perimeter of the roof and between roof segments can also help mitigate the risk of fire.

Inclusion of a water source on the roof, even if no irrigation system is provided for the roof itself, is highly advisable to water during particularly dry periods when the risk of fire might increase. Additionally,
insurance issues should not pose roadblocks if proper steps are taken to assure the roof can support the loads and the system is properly designed and constructed. It is advisable to investigate if the building insurance carrier has specific requirements related to green roofs.

**Green Roof Materials and Design Considerations**

Green roofs are layered systems comprised of vegetation, growing media, filter fabric, drainage layer, root barrier, and waterproof membrane. Some systems also include insulation, but that isn’t typically needed above an unheated parking structure. It is important to note that the insulation below a green roof system provides other benefits beyond just preventing heat loss. In cooler climates, insulation prevents plants roots from feeling the warmth of interior spaces. This ensures the plants enter dormancy during the cold winter months. Insulation also provides an additional layer of protection from overzealous landscaping activities and equipment that might pierce the membrane waterproofing below. The need for an irrigation system depends on the type of roof and location. Each of these layers is made of specialized materials and must be properly selected.

Intensive green roofs can have various types of plants, including grass lawns, trees, flower beds, shrubs, etc. The growing media will need to be much thicker than for an extensive green roof. It is common for the depth to vary, with built-up berms or pits to provide deeper soil where trees and large plants are located. As with extensive systems, specialty engineered growing media that are lighter weight, drain well, and retain moisture for plant viability are recommended.

Due to the specialty nature of green roof design, parking consultants, architects, and landscape architects experienced in their design should be retained. The design team should work with the owner in considering parameters such as:

- Owner’s objectives.
- Local requirements for obtaining financial incentives, if any.
- Permitting requirements.
- Insurance company requirements, if any.
- Budget.
- Appearance goals.
- Accessibility for use by people, whether for public or private use.
- Structural load capacity of the roof and saturated weight of the green roof system.
- Project location and climate, including exposure to wind, sun, precipitation, and temperature ranges.
- Local or regional experience of green roof installers.
- Planting options and preferences.
- Specialty growing media options.
- Products to specify for the filter fabric, drainage layer, root barrier, and waterproof membrane.
- Stormwater retention.
- Drainage and erosion control.
- Sloped roof effects.
- Maintenance requirements.
◆ Irrigation provisions.
◆ Vegetation-free zones for curbs, borders, walkways, fire breaks, railings, or hardscape features.
◆ Lighting.

As noted above, there is a lack of accepted design standards for green roofs in the U.S. ASTM International prepared green roof standards first published in 2005 and is currently in the process of updating all of the existing green roof standards and writing additional standards. These standards are not yet incorporated into the International Building Code (IBC-2009), but are still a good resource for those designing and constructing green roofs. ASTM’s green roof standards include:

◆ ASTM E2397 - 05 Standard Practice for Determination of Dead Loads and Live Loads associated with Green Roof Systems (which has proposed revisions pending in committee).
◆ ASTM E2399 - 05 Standard Test Method for Maximum Media Density for Dead Load Analysis of Green Roof Systems (which has proposed revisions pending in committee).

Other proposed green roof standards currently being developed by this committee include:


Costs of Green Roofs

As with most building components or features, the question of how much a green roof costs is answered with, “It depends.” The cost of green roofs can vary widely depending on whether one is considering a new or existing roof, type of green roof (intensive, semi-intensive, or extensive), depth of growing medium, type of plants and other features, inclusion of irrigation, accessibility for use, and location.

Due to the number of variables, it is important to retain specialists in the design of parking structures and green roofs to provide options for the green roof design along with associated estimated costs, advantages, and disadvantages.

The following information might serve as a starting point when considering costs:
The Design Guidelines and Maintenance Manual for Green Roofs in Semi-Arid and Arid West states that, “In the past, the cost related to the installation of a green roof has been high. As the industry develops, the initial cost of implementation may be reduced with standardized practices and programs that allow consistent availability of products, suppliers, and installers. Additionally, incentives at the public and municipal level, technology advances, and integrated building designs may decrease the project cost and make green roofs more cost effective and attractive to a wider range of clients.” This publication provides detailed cost ranges for various components, including membrane, root barrier, protection board, insulation, drainage and water retention, growing medium, vegetation, irrigation, walkways, and railing. A number of green roof case studies are presented with costs that range from $12.75 to $58 per square foot. Some include the roof membrane and others do not.

Chicago’s Green Rooftops, a Guide to Rooftop Gardening reports, “Green roof systems, as a general rule of thumb, cost about 50 percent more than a conventional roof. An extensive green roof system is generally less costly than an intensive garden.”

The Design Guidelines for Green Roofs includes a section on detailed cost estimates and variables. For extensive green roofs that are not accessible for use by people and have sufficient loading capacity, the summation of costs range from $19 to $36 per square foot, including the root repelling membrane, green roof system, plants, and installation. For accessible intensive green roofs with sufficient loading capacity and code required stairs and elevator access, the summation of cost range from $40 to $250 per square foot, with the cost “completely dependent on the type and size of plant chosen, since virtually any type of plant suitable to the local climate can be accommodated (one tree may cost between $200 and $500).” This cost includes the root repelling membrane, green roof system, plants, irrigation, and installation, but not freestanding planter boxes, guardrails, or fencing.

Ecoroof Handbook—2009 states that, “Ecoroof costs vary and depend on several factors. Installation of an ecoroof costs from $10 to $40 per square foot. This includes materials, labor, and structural upgrades” for an extensive type roof suitable to the Portland, Ore., environment.

Cost Benefit Evaluation of Ecoroofs—2008 provides more cost information than Portland’s Ecoroof Handbook in the bullet item above. It states, “Ecoroofs vary greatly in cost. Costs are dependent on a number of factors such as the height from street level that roof materials must be transported, the type and thickness of the growth medium, the number and type of plants, if the plantings require an irrigation system, and if the roof is new construction or retrofitting an existing roof. For the purposes of this evaluation, a simple ecoroof (author notes this means a thin extensive system) that represents the bare minimum components that will function effectively in Portland’s climate and yield the range of benefits was assumed.” It goes on to state “Assuming a conventional roof construction cost of $10 per square foot (i.e. $400,000 for a 40,000 square foot roof), total ecoroof cost would be approximately $15.75 per square foot (i.e. $630,000 for a 40,000 square foot roof). This additional cost appears on the low side of the cost estimates from the literature reviewed where costs were found from $10 to $25 or more per square foot.”

On top of the installation costs noted above, there may be other costs related to design, administration, permitting, structural evaluation (for existing roofs), structural upgrades (if needed on existing roofs without sufficient capacity to support
a green roof), fencing, railing, and regular and annual maintenance.

**Cities May Subsidize Costs to Owner**

Because of the many public benefits of green roofs, some cities are subsidizing the installation cost of the building owner. Portland, Ore., reimburses building owners who install green roofs up to $5 per square foot. Portland has set a goal of 43 acres of planted rooftops by 2013.

New York City is reported to provide tax abatements to owners who build green roofs covering at least 50 percent of the roof area. Other cities provide reduced stormwater utility fees because green roofs hold stormwater. Grants toward the cost of green roofs may also be available. Specialists in the design of parking structures and green roofs can provide information related to the project location on public financial incentives for green roof construction.

**Cool Roofs**

Despite the many benefits of green roofs, they are not always practical or warranted. In locations with little exposure to sunlight or limited accessibility for maintenance, green roof installation may be ill-conceived despite good intentions. In other cases, the existing structure may not have adequate capacity, or the installation may be cost-prohibitive. In many cases, cool roofing is a more feasible approach to designing for sustainability. In parking structures, cool roofs are well-suited to elevator and stair tower roofs, retail area roofs, or pedestrian walkways whose roofs are neither accessible nor visible.

Standard dark-colored roofing can experience dramatic temperature fluctuations, particularly in full sun where roof surface temperatures can exceed 160 degrees Fahrenheit during summer months. Such high temperatures can add considerably to the urban heat island effect as well, resulting in increased
cooling costs and energy consumption (particularly during peak hours), and reduced indoor comfort. Cool roofing, by contrast, experiences fewer temperature fluctuations, with peak summer temperatures as much as 50 degrees Fahrenheit lower than comparable standard roofing.

**Properties of Cool Roofs**

The coolness of a roofing system is dependent on two primary properties: solar reflectance and thermal emittance. Solar reflectance (SR), or albedo, is the property of roofing that represents its ability to reflect solar energy in the form of visible, infrared, and ultraviolet wavelengths of sunlight. Thermal emittance (TE) is the ability to radiate absorbed, non-reflected energy.

Each of these properties is measured on a scale of zero to one, with one representing the “coolest” value. These properties can also be measured by the Solar Reflective Index (SRI), which is calculated based on the combined measurements of SR and TE with a maximum value of 100. (SRI calculators are available online.) It is important to note that the cool roof definition does not include insulation R values. Conversely, the required R values for a roof are not affected by the coolness of the roofing material. As a thermal break, insulation helps maintain cooler temperatures in summer and warm temperatures in winter; cool roofing’s benefits are realized only during the warmer months.

**Cool Roofs Defined (or not)**

There are no universally accepted criteria for what constitutes a cool roof; it is a general term applied to roofing systems and products that exhibit higher levels of both SR and TE. Cool roofing requirements set forth in California’s Title 24, for example, have different requirements depending on the roof slope, material thickness, and climate zone.

The U.S. Department of Energy defines a low-slope cool roof as one that has a three-year aged SR of .55 and TE of .75, or an SRI of 64. Interestingly, Energy Star, a voluntary labeling program designed to identify and promote energy-efficient products, has no cool roof definition. To be Energy Star qualified for low-slope roof applications, a product must have initial and three-year values of SR not less than .65 and .50 respectively, with no consideration of thermal emittance. Because of the varying requirements, it is conceivable that a product could be Energy Star rated but not meet the cool roof requirements of California’s Title 24.

In addition to governmental requirements for cool roofing, the USGBC offers one LEED point for roofing materials that meet their criteria for reflectance, emittance, and coverage. To qualify for LEED, a roofing system in a new application must have minimum values of 78 and .9 for SRI and TE respectively and must cover at least 75 percent of the roof surface. As with Title 24, it is possible for roofing material to meet Energy Star requirements without qualifying for LEED points. It is important to understand all governing codes and regulations as well as LEED goals prior to selecting the final roofing material.

**Savings Potential**

Cool roof applications can offer substantial reductions in cooling costs, particularly in warmer climates. A cost-benefits analysis presented by the EPA as part of its publication, “Reducing Urban Heat Islands: Compendium of Strategies,” found annual savings to be in the range of $0.16 to $0.66 per square foot with an average savings of $0.47 for California climate zones. That said, cool roofing does not always translate into net energy savings. The very things that make a cool roof beneficial in summer months can result in increased heating costs during winter months.

In northern climates, where energy consumption for heating far outweighs cooling costs, the overall energy consumption of a building can be increased. Exactly where the increase in energy consumption for heating will outweigh the savings in cooling is not entirely clear. The U.S Department of Energy’s Oak Ridge

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National Laboratory has developed an online savings calculator that estimates energy and peak demand savings for flat roofs with non-black surfaces.

There is general agreement that the life cycle cost of cool roofing material will be decreased in all climates due to the reduction in extreme temperature swings. Maintenance costs for over-taxed cooling equipment will also be reduced. Additionally, cool roofs can provide other benefits such as LEED point contribution and reduced installation costs through available incentive and rebate programs.

Cool Roofs in Darker Colors
Generally speaking, roofing materials that are lighter in color will exhibit higher levels of solar reflectance than darker colors. For this reason, the vast majority of cool roof products come in varying shades of white. There are, however, more roofing products available in darker pigments that are highly reflective in the non-visible infrared and ultraviolet spectrums.

Applications and Costs
Cool roofing is interchangeable with standard roofing in virtually any application. In a parking structure, these could include stair and elevator towers, mechanical rooms, occupied spaces, and/or pedestrian bridges. The installation cost of cool roofing is comparable to standard roofing materials, with a material upcharge in the range of $0.10 to $0.20 per square foot, which is generally offset by energy savings achieved.

Nearly all standard roofing materials today offer a cool roofing option, so the same design principles that apply to standard roofing also apply to cool roofing. The difference is that to qualify as a cool roof, certain physical properties need to be met; the requirements for each depend on local governing codes, LEED goals, and the roof slope.

Unlike green roofs, which require careful consideration of existing conditions in retrofit applications, cool roofing can be readily incorporated into retrofit projects because of its similarities with standard roofing. Additionally, there are coatings available that can be applied to convert existing roofing into cool roofing by lightening the surface color, consequently increasing the solar reflectance of the roof surface. These coatings are most effective in treating low-slope roofs and can be applied to many different surfaces.
including single-ply, metal, as well as gravel. Coatings typically cost in the range of $0.75 to $1.50 per square foot depending on the local market.

**Maintenance and Service Life**

As previously mentioned, maintenance needs associated with cool roofs are generally less than standard roofing because of the reduced thermal stresses on the roofing materials. As such, 20-year or longer warranties are available. Over time, cool roofs will require similar repairs and maintenance as conventional materials to assure good performance. Cool roofing does require periodic cleaning to maintain the physical property of solar reflectance.

Over time, solar reflectance will reduce due to aging, the collection of dirt or other particulates, and biological growth. Keeping the roof surface clean will help maintain the solar reflectance, with decreases of only about 20 percent in the first year. To account for this reduction, products today are rated based on their initial and three-year values of solar reflectance. Actual values are, however, dependent on the maintenance performed.

**Solar Canopies**

Green and cool roofs can add to the sustainability and eco-friendliness of a parking structure in many ways. The use of photovoltaic (PV) panels can further reduce the carbon footprint by generating electricity to satisfy much, or all, of the electrical demands of a parking facility. Refer to Chapter 5 for more information.
MATERIALS ARE GENERALLY NOT THE PRIMARY FOCUS OF MOST SUSTAINABLE BUILDING DISCUSSIONS. Parking garages are unique, however, as they use relatively little energy when compared to other buildings. Even a large reduction in energy use of a parking garage will be small in the bigger picture.

To make a significant impact, other areas of focus become more important. Structural materials comprise a much higher percentage of overall materials in parking garages than in other building types, so careful selection of structural materials should be a major focus when considering sustainability.

Choosing sustainable materials mitigates the environmental effects of a new garage and leverages the materials’ advantages. Sustainable materials reduce waste, have reduced energy costs or toxicity, and/or last longer than typical materials.

Common Structural Materials

Structural materials are traditionally chosen based on their economic benefit and appropriateness for a given structure. Parking garages require materials that can span longer distances to maximize parking spaces and withstand exposure to the elements. They are primarily constructed of concrete with steel rebar, or steel with a concrete slab. By focusing on the efficiency, availability, and effects materials have on the environment, a greater contribution to the overall environmental impact can be made.

Concrete and Cement

Concrete, the most common structural material for parking garages, can either be cast-in-place or precast. Cast-in-place concrete is mixed and poured into forms onsite, while precast concrete is formed offsite and trucked to the
job location. The environmental effects of using concrete as a construction material can best be evaluated by focusing on the individual ingredients of concrete: Portland cement, water, and aggregate.

The most energy- and carbon dioxide (CO2)-intensive material in concrete is Portland cement. Production of this material is a very energy-intensive process that converts virgin raw materials such as limestone, sand, and clay into the cement. Cement production is responsible for approximately 1.5 percent of annual U.S. carbon dioxide emissions, [The Portland Cement Association (PCA)] and as much as 7 percent of worldwide annual emissions [Mehta, 1998]. Manufacturers can use a dry process instead of wet and use a horizontal (or rotary) kiln instead of a vertical (or shaft) kiln. However, on average, for every ton of cement produced, 0.9 tons of CO2 are emitted. Therefore, reducing the amount of Portland cement in concrete mixes will reduce the overall carbon footprint of the structure.

Because the amount of cement needed in a concrete mix relates to the amount of water, size of aggregate, and specified strength of the final material, this reduction can be achieved by:

- Reducing water content by adding fly ash or superplastizers.
- Replacing a percentage of the Portland cement with a complementary cementitious material such as fly ash, slag, or silica fume.
- Using the largest aggregate appropriate to reduce the paste volume.
- Specifying the proper strengths of the concrete.

Complementary cementitious materials (CCMs) can replace a certain amount of Portland cement in concrete mixes. They do not contribute to the embodied energy or carbon footprint of concrete. They have certain advantages such as improved workability, finishability, pumpability, and alkalinity resistance. Some of their disadvantages may be increased curing time and potential color fluctuation.

Determining the proper replacement values for these materials depends on the goals of the mix design, but replacement values of 15 to 25 percent for fly ash, 30 to 40 percent for slag, and 5 to 7 percent for silica fume are common in most construction projects. (concretethinker.com/solutions/Recycled-Content.aspx)

One way to leverage concrete’s strengths and reduce overall construction material waste is to use it both as a construction material and as an exterior finish. Exposed concrete surfaces can be made to fit a variety of architectural tastes through the use of stains,
stamps, or inlaid materials. Using concrete as the final finish reduces the need for installation, maintenance, repair, and replacement of finish materials, fulfilling the adage that less is more.

**Steel**

Steel can be a cost-effective building material for parking garages. Steel is strong and flexible, and can help buildings take many shapes. Primary environmental issues associated with steel construction involve the manufacturing process, how far the steel needs to travel to the job site, and how construction waste is managed.

Steel is typically produced using one of two manufacturing processes: basic oxygen furnaces (BOF), and electric arc furnaces (EAF). The two processes vary in the amount of raw materials needed, energy consumed, and environmental impacts. The BOF process is an older process than EAF that uses more raw materials and is more energy-intensive. The BOF process generally produces steel with a recycled content of up to 25 percent while the EAF process produces steel with approximately 95 percent recycled content. Therefore, steel for parking garage construction should be chosen from an EAF manufacturing plant.

There are some inherent materials savings that can be incorporated by using steel efficiently. Because steel is a stronger material than concrete, less is required for the same application and the overall tonnage of the structure can be reduced, thereby reducing the amount of foundation needed by up to 25 percent (AISC).

**Evaluating Material Sustainability: Attribute-Based Evaluation**

Most current green building rating systems use attribute-based assessment to quantify the sustainability of different types of construction materials. Attribute-based assessment focuses on individual sustainable attributes of the project’s overall construction materials, including how much total waste will be diverted, what percentage of recycled materials is used, or how much energy is used transporting the materials from their sources to the project site.

**Recycled Content**

A common attribute of a green material is recycled content; a higher recycled content indicates that the material potentially both used less raw material and reused materials that would have otherwise been diverted to a landfill. Recycled construction materials can be made of either pre-consumer waste (byproducts of the manufacturing process) or post-consumer waste (materials that have been used and discarded by the consumer). Typically, post-consumer waste is considered to have a higher sustainable value than pre-consumer waste, although both are considered when determining a material’s total recycled content. For LEED calculations, pre-consumer waste is considered to have half the sustainable value of post-consumer waste.

The main contributing factor to a concrete system’s recycled content is the rebar, although aggregate and replacement of Portland cement with CCMs such as fly ash or silica fume can also contribute. Typically, steel rebar produced with the EAF process have 98 to 100 percent recycled content. Steel reinforcement, however, only accounts for 2 to 4 percent of the total weight of the concrete system. CCMs only count for half the recycled content of post-consumer recycled material as
they are industrial by-products and therefore post-industrial. Recycled aggregate (typically generated from demolition of old concrete) can be used for pavement reconstruction, but not usually for structural elements as it has lesser properties than new aggregate.

One of steel’s most touted sustainable features is its recycled content. Presently, the primary method for producing structural shapes and bars is the EAF process. This steel’s recycled content is typically made up of both post-consumer and post-industrial waste. Because there is such a large market for recycled steel, steel from a demolished parking structure can be recycled for a new construction project.

**Regional Materials**

Obviously, energy is used to transport a material from its place of origin or manufacture to the building site. Limiting the distance a material has to be transported will also limit its detrimental effect on the environment. Although the actual carbon footprint will vary based on project conditions, on average, transportation energy accounts for 20 to 25 percent of total construction energy (Malin 1996).

By using construction materials from local sources, the transportation energy—and therefore the overall construction energy—can be reduced. Ideally, the materials would be both harvested and manufactured in the local area.

For steel parking garages, the location of the manufacturing plant in relationship to the job site should be considered. Most grades of steel used in parking garages are made in the U.S., although there are also producers in other countries. Wide flange steel beams are only produced in a few U.S. locations. Specifying domestic steel when available will minimize the use of fossil fuels and decrease the overall environmental impact.

Transportation costs for concrete should also be evaluated. Due to the high expense of shipping heavy building materials, most concrete is sourced and batched locally. Most ready-mix plants are within 50 miles of any building site and most precast plants are typically located within 200 to 500 miles. (Van-Geem, 2006) However, in 2006 the United States imported 24 percent of all cement used, so it is important that local concrete is specified to reduce transportation emissions.

**Durability**

Durability is another sustainable attribute that can be used to evaluate a material’s “greenness”. Durable materials are more highly valued from a sustainable perspective if they will cost less energy over the lifespan of the building to maintain, and not require replacement before the building’s use is over. Parking garages do not typically have enclosed building envelopes, leaving them exposed to the elements and daily abuse from road salt, acid rain, chemicals, petroleum products, water drainage, and the weight of hundreds of vehicles. Durability becomes a major sustainable focus as maintenance versus replacement costs over the structure’s lifespan are considered.

Maintenance of concrete parking garages and concrete decks of steel parking garages can be a major concern if not properly addressed in the design and construction phases. The number-one cause of concrete deterioration over the life cycle of a garage is the corrosion of the reinforcement. This will cause concrete spalling and more serious concerns over time. One way to address this is for the structural engineer to provide a thicker concrete cover to the rebar than required by code; this method requires more concrete, which may not be worth the gain in durability. Another preferred way to address the issue is to specify a lower permeable concrete mix so water and other substances have a more difficult time penetrating into the rebar.

For steel parking garages, it is important the structural steel framing is protected with a coating system that’s designed to prevent water infiltration. Without a proper coating system, water will react with the steel properties and start to corrode the system, creating a maintenance issue.
Other Sustainable Attributes

Two other sustainable material attributes evaluated in green building ratings are biobased or rapidly renewable, but they are typically not used much in parking garages. An example of a rapidly renewable resource is bamboo. The amount of time it takes to grow and harvest bamboo is much shorter than the time it takes to cultivate and extract limestone for concrete. Therefore, bamboo can be produced and reproduced on a much faster scale using the same resources. Unfortunately, bamboo’s use in parking garages is limited.

Designing for the deconstruction of parking garages can be an additional sustainable avenue to pursue. Typically, buildings designed for deconstruction rather than demolition are made of pre-constructed materials such as precast concrete or steel framing with connections that are designed to make them come apart easier at the end of the life of the building.

Attribute-Based vs. Life Cycle Assessment (LCA)

In addition to attribute-based assessment, a newer type of material sustainability assessment is becoming popular: life cycle assessment (LCA). LCA considers the sustainability of materials over the course of their life cycles and takes into account a full range of environmental impact indicators per material, including embodied energy, solid waste, air and water pollution, and global warming potential.

Evaluating the aggregate sustainability of construction materials based on their individual attributes has its strengths and weaknesses. One of the main strengths is that it is easier to quantify and calculate. Most manufactures will be able to provide information on the recycled content of their product, for example, or provide the location where the product was manufactured or sourced, allowing the transportation effect to be determined. If information is gathered on all or most of the construction materials, a collective total can be determined and used to determine the overall sustainability of the material.

One of the major downsides to attribute-based assessment is that materials can be declared green based on a single sustainable attribute, which may not be the case when considering the whole aggregate.

For example, if you look at the recycled content of the structural steel framing of a parking garage, it can be more than 90 percent in many cases. However, if the steel was manufactured overseas using less sustainable manufacturing processing and then shipped thousands of miles on a freighter and transported thousands of miles on a truck, the overall environmental impact will be much higher than that of steel with only 75 percent recycled content that only traveled 500 miles.

LCA is an internationally recognized method that has been constantly updated and improved since its introduction in the 1960s. It is relatively new to the green building rating systems and requires a comprehensive analysis into the various aspects of a material’s lifecycle. Large databases of different types of materials and their effects on the environment are needed to be able to compare their various aspects (USBGC 2008).

Common environmental effects that are evaluated through a LCA are:

- Extraction of materials and fuel used for energy.
- Manufacture of building components.
- Assembly and construction.
- Operation, including maintenance repair and renovations.
- Demolition, disposal, recycling, and reuse of the building materials at the end of their useful life.

Not all these things are weighted equally. A comparison between two materials might find that one of them used fewer raw materials during its construction but was then shipped from farther away, creating more transportation energy waste. A weighting system must be put in place to evaluate which of the criteria is more important to the user and to the overall sustainability of the material. This weighting
system should provide a level playing field based on consistent methodology.

Future Green Building Rating Systems Trends

Both LEED and Green Globes are moving towards LCA for sustainable material assessment in their rating systems, but there are still materials systems that cannot be evaluated using it. Therefore, attribute-based assessment will be an option in the next versions of green building rating systems until the databases used for calculating LCA are more fully populated.

Although LEED 2009 uses attribute-based assessment to evaluate material sustainability, there is a pilot credit that uses LCA as an alternate system to test viability. Users will get an innovation point for completing the procedure for LCA and filling out a survey to give feedback.

USGBC anticipates that the LCA portion of the credit will require less effort to document than the previous methods used to obtain these credits. The LCA approach uses an LCA software tool (currently the Athena EcoCalculator) to generate LCA scores for major building assemblies in each of a set of impact categories (measures). Other software tools may be incorporated as they become available.

The current LCA is based on a 60-year lifecycle and generates a score between 0 and 100 percent, where 0 is average impact to the environment and 100 is the best possible impact to the environment. The percentage is then multiplied by the full number of LEED credit points and rounded to the nearest integer (see Figure 1).

The Green Building Initiative (GBI) is planning to incorporate LCA into the next version of the Green Globes rating system, and the current version has an education credit that encourages the design team to use LCA in their materials decision-making process. GBI has a new LCA tool that is also based on the Athena EcoCalculator to compare building material systems. According to the GBI website, the next version of the Green Globes tools will fully incorporate the Green Globes LCA Credit Calculator.

This trend means that for future parking garage projects, it will not be enough for construction materials to meet only regional or recyclable guidelines. The material system as a whole will need to meet sustainability guidelines and be more sustainable overall than the sum of construction materials used in parking garages.

Material Evaluation in Ratings Systems

LEED

In the LEED-NC (new construction) 2009 rating system, there are six categories: Sustainable Sites, Water Efficiency, Energy & Atmosphere, Materials and Resources, Indoor Environmental Quality, and Innovation & Design Process. Thirteen of the total available 69 points are in the Materials and Resources category, broken down into seven credits as listed in Table 1.

Of these seven credits, three are fairly attainable for parking garages with proper support from the construction team. These credits are Construction Waste Management, recycled Content, and regional Materials. Parking garages that are undergoing major renovation or another building type that is being converted to a parking garage can try to achieve the building reuse or material reuse credits; these are not typically attainable for brand new structures. The Rapidly
Renewable Materials and Certified Wood credits are difficult to obtain in typical buildings, let alone parking garages with fewer non-structural building materials.

There are ways for the construction team to achieve additional innovation in Design credits through their choice of construction materials. LEED has a standing innovation point for using 40 percent cement replacement with supplementary cementitious materials (see previous concrete section). This point is intended to show the reduction in carbon dioxide (CO2) emissions by reducing the amount of cement used in a project. This is a credit that a cast-in-place parking garage could strive for. Using a lifecycle analysis approach (see previous section) to optimize the building design and demonstrate quantified benefits can also be attempted as an innovation credit.

**Green Globes**

In the Green Globes rating system, the material contribution to the overall sustainability is evaluated in the resources area of assessment. A total of 100 points is achievable in the following categories:

- Low-impact systems and materials (LCA).
- Minimal use of non-renewables.
- Reuse of existing buildings.
- Durability, adaptability and disassembly.

Table 1: LEED Materials and Resources Credits

<table>
<thead>
<tr>
<th>MR Credit</th>
<th>Credit Name</th>
<th>Points Available</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Building Reuse</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Construction Waste Management</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Materials Reuse</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Recycled Content</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Regional Materials</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>Rapidly Renewable Materials</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Certified Wood</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>13</strong></td>
</tr>
</tbody>
</table>

The LCA category can be achieved by choosing the overall most sustainable material system for the parking garage system while allowing for garage efficiency and practicality. Because parking garages typically minimize non-structural materials, minimal use of non-renewables can be difficult to achieve. Reuse of an existing building really depends on the project.

**Notes**

- http://www.bcorpation.net/resources/bcorp/documents/B percent20Resources percent20percent20Conducting percent20Life percent20Cycle percent20Assessment percent20( LCA).pdf
- United State Green Building Council (USGBC) “LEED Pilot Credit Library.”
- Portland Cement Association (PCA), http://www.cement.org/concretethinking

ERIN KUEHT, P.E., LEED AP BD+C

is an associate with WALTER P MOORE.
CHAPTER 13

Automated Vehicle Storage and Retrieval Systems
in Sustainable Parking

RYAN ASTRUP AND SHANNON SAUNDERS MCDONALD

Historical Contributions

Vehicle stacking-type technologies have been a part of the parking industry since its origin in the early 20th century. As long as the motor vehicle has been around, so has the need to park it, and the first type of garages put to use used mechanical devices such as turntables and elevators to efficiently store vehicles on multiple levels. The ramp-access garage gained popularity in the 1920s, but several multi-story automated parking structures were constructed in the United States during that time as well, using systems that fully integrated vertical and horizontal movement with a center open space for the transfer of vehicles.

One of the first automated garages that went beyond elevators and turntables was developed in Paris, by Augustus Perret; the Garage Rue de Ponthieu made its debut in 1905 (The Parking Garage: Design and Evolution of a Modern Urban Form; 2007).

Automated technology was further developed in the U.S. around the 1920s, when innovation in architecture and engineering was taken to exceptional levels. Some facilities were 25 stories high and due to the nature of their design, some were adaptively reused and have been converted into apartments and condominiums. A Kent Automatic Parking Garage, New York, is an Art Deco landmark that was converted into the luxury Sofia Apartments in 1983 (McDonald; 2010). This adaptability shows how automated parking garage structures, now known as Automated Vehicle Storage and Retrieval System (AVSRS) parking structures, contributed to the urban landscape as sustainable facilities, both in the initial design and their ability to change for adaptive reuse.
The early use of turntables and elevators in AVSRS parking structures allowed for a maximized use of floor plates, which gave flexibility to use several locations without having to adhere to any particular pattern for parking. Because cars were not necessarily stored in rows, elevators could be placed in every possible position [McDonald, 2007 p. 28]. The use of flat floor plates provided a suitable structure for possible adaptive reuse at a later stage By the late 1920s, garages that relied on the use of elevators for vertical movement existed only in dense urban environments, such as New York, Los Angeles, Chicago, and Cincinnati, where land was limited and valuable, and public transportation systems meant the newer, more efficient ramp garages were less essential to the viability of the area (McDonald; 2007).

Advanced systems of mechanized parking garages continued to develop well into the 1950s, especially in Japan, as the demand in urban areas caused by a growing suburban lifestyle increased; many small towns across the United States constructed fully automated facilities in the 1950s. McDonald (2007) shows that the most popular systems were the Bowser and the Pigeon Hole, with more than 74 constructed by 1957; some of those are still in use today.

In the last nine years, at least 17 AVSRS parking structures have been completed in the U.S. and eight more were under construction at this printing. (Mohan; 2010).

Fundamentals To Sustainable Parking

What are AVSRS—Automated Vehicle Storage and Retrieval Systems?

The concept of AVSRS is not new and many facilities are operating around the world. Since 2000, the demand for these types of structures in the U.S. has increased at a gradual pace as alternative solutions in construction and technology have been implemented towards a more sustainably-built environment.
more interactive communities, which fit with the major architectural and planning goals of sustainability.

The AVSRS method provides a holistic approach to efficient parking design and contributes significantly to sustainable architecture as currently promoted by LEED and other rating systems around the world. The parking facility can become sustainable through multiple approaches that are both conventional to the parking industry and support new urban patterns. Most importantly, AVSRS reduces the amount of land required for parking. It can also reduce the amount of dirt removed for underground parking, as these facilities use considerably less space to park the same number of cars as more traditional garages. They reduce carbon emissions (because cars do not run in the facilities), provide greater security for people and vehicles (as transfer stations are localized), and can be quite cost-effective in the urban landscape where space is limited. They can also allow projects to be built in restrictive site conditions. Additionally, principles of sustainability can also be applied to their preparation, construction, and longevity, just as in a conventional ramp-style parking facility.

Types of Automated Vehicle Storage and Retrieval Systems

Vehicle stacking equipment is generally classified into three distinct categories: mechanical parking systems, semi-automated parking structures, and AVSRS.

Mechanical parking systems (also known as car stackers or valet/attended parking units) are typically designed for attended parking applications and consist of simple devices that stack two, three, or four vehicles in an area normally occupied by a single vehicle. A trained operator raises a vehicle on a platform from a push-button or lever control device, which creates an additional space for another vehicle to be stored below. This process is repeated until the system reaches capacity. To retrieve a vehicle, the operator removes the vehicle in the lower position (at grade) to lower the platform and return the stacked vehicle to grade position. Units running in series may share common vertical structural supports (legs/posts) to increase stability and reduce materials and costs. Typical systems store two to four vehicles per unit.

Semi-automated parking structures (also commonly referred to as Puzzle Park or lift/slide parking) are hybrid vehicle stackersthat include a matrix of stacked platforms that can be maneuvered in horizontal and vertical directions] to provide direct access to all vehicles from grade level. Configurations vary from simple two-high systems to 15-high and three-below grade (using an in-ground pit), providing a stacking capability of up to 18 spaces in one traditional stall. Each matrix consists of all adjoining vertical stacks, including one partially empty stack that allows for required voids when a particular platform is requested. The system can be customized for indoor and outdoor applications and may include external siding and remote controlled garage doors, and comply with roof-per-client requirements. A limitation to this stacking type is the ability to only perform one cycle per matrix at any given moment, meaning that critical breaks or separations in the system are necessary to provide required system throughput.

Automated parking structures use robotic storage/retrieval devices that are controlled by integrated software technology to park and return vehicles from a centralized transfer station. Vehicles are stored on racks or on trays in compact areas where public access is not permitted. Multiple devices can operate simultaneously to store and retrieve vehicles in multiple rack structures vertically and horizontally, and often, no direct human intervention is required. These systems use considerably less space and building materials than conventional parking structures while eliminating the need for ramps, drive aisles, lighting, HVAC systems, and excavations. They have a reduced environmental effect thanks to their efficiencies of space.

Many equipment variations exist between manufacturers of these systems, but the general principles remain the same. The most common differences between them occur in their handling systems, being either pallet systems (where vehicles are placed on
pallets/trays and exchanged in storage areas), and comb systems (that effectively rely on horizontal traveling devices such as shuttles and dollies to handle vehicles by their wheels). Vertical lifting devices are fixed at some point along the transfer aisles, or traveling cranes (combinations of vertical lifting devices and horizontal traveling devices) are used, leaving the transfer aisle as an open void (similar to mobile racking). Turntables are also used to present the vehicles face-out on retrieval, but may also be required to re-orientate vehicles according to equipment location and positioning.

The future generation of AVSRS has been developed through the use of automated guided vehicle (AGV) technology, which incorporates the use of battery driven robotic devices that are guided by markers or embedded wires in the floor. This technology has been in use since the 1950s, particularly in industrial applications to move materials around a manufacturing facility or warehouse, but has recently broadened to other environments such as parking. AGVs are self-guided devices that are mainly laser navigated and programmed to communicate (via onboard servers) with other devices to ensure continual processing, path decisions, and traffic control. AGVs collect vehicles parked on trays for transfer to storage areas; multiple AGV devices can operate simultaneously to manage trays, storage/retrieval processes, and meet throughput requirements. Should any one particular AGV component fail, the remaining devices are able to effectively continue normal operation of the facility. The shift toward AGV technology is primarily driven by the advantages of greater capacities, the ability to retrofit existing structures, and the strong potential for adaptive reuse.

Unique Contributions to Sustainability in Parking

AVSRS parking structures contribute to sustainability, allow for urban density, and community connectivity thanks to their ability to reduce the volume of space required for parked vehicles (thereby promoting urban green space,) their ability to ensure significantly improved air quality with reduced emissions exposure (due to cars not operating within the facility), their ability to require less energy to operate and maintain, the improved sense of security for people and vehicles with localized collection/drop-off areas, and an economic benefit that qualifies the facility for accelerated depreciation as a system as opposed to a building (See section 5.5: Cost Incentives).

Because cars are parked in dense vehicle storage vaults where drivers do not enter, much smaller spaces are required, with lower ceiling clearances, less space between vehicles (since doors are not accessible), and reduced drive-aisles, ramps, walkways, elevators, lobbies, and stairs that help reduce the overall volume. This provides the ability to maximize space for other buildings and alternative functions such as additional retail, commercial, residential uses, or open space.

The primary LEED sustainability goals are to limit suburban sprawl with retail and housing encouraged to be close to transit. Protecting and restoring local habitat is also a key priority that requires more untouched land area, and these goals create challenges for integrating parking of automobiles. AVSRS, due to its ability to condense parking is one way to address these key sustainability goals.

Sites suited to build AVSRS are those that are limited in size, can benefit from little or no excavation, where drop off and delivery of vehicles is desired, and/or where higher capacities are required. Great applications include residential buildings, hotels, multi-modal transit facilities, transient parking facilities, auto dealerships, car rental facilities, and mixed-use developments. Small urban infill lots in existing downtowns are also prime locations, making redevelopment of these sites beneficial to stakeholders and the community as existing infrastructure can be used.

AVSRS means that small areas can be utilized for compact vehicle storage, often integrating the facility within a smaller building footprint, which can translate to an enhanced pedestrian environment. This approach has the added ability of maximizing opportunities to locate these facilities in dense urban areas that
are rich in history, parks, and people. AVSRS can help preserve existing urban areas and encourage lifestyles where patrons park closer to where they live and work while limiting vehicle use. This can also lead to the consideration of shared vehicle programs that, along with the sustainable goals mentioned above, can reduce the number of cars requiring multiple parking spaces during the day. All together, these strategies contribute to a reduction in road congestion, vehicle miles traveled, and adverse environmental effects.

Although walkable urban communities are being embraced, personal vehicles are still in demand. They’re being offered in many new ways (such as car share programs) that also require parking. Even the bicycle, requires dedicated land use for parking. Consider Tokyo, where the bicycle is part of an average business person’s commute; parking lots, parking areas with elevated bicycle racks, and many multi-story AVSRS bicycle parking facilities exist.

Parking lots tend to spread buildings apart and are counterproductive to creating walkable communities; underground parking and AVSRS facilities are the most direct way to minimize this sprawl. This form of technological advancement is fundamental to sustainability.

2.4 Other Rating Systems and Their Goals
LEED is the most common rating system in the United States, but other systems have gained ground around the world. BRE Environmental Assessment Method (BREEAM) in the United Kingdom and Green Star in Australia are just two among many. Safety, security, robustness and cost efficiencies are part of the point systems for these systems. AVSRS meets many of these systems goals.

Environmental Contributions

Land Use Efficiency
Parking is one of the single largest land uses in urban areas in the U.S., and this greatly affects the industry’s efforts to become sustainable. Statistics show that parking spaces outnumber vehicles at a minimum of three to one (Chua; 2007), which currently equates to more than 500 million empty parking spaces at any one time.

Prevailing U.S. zoning codes often require a minimum number of parking spaces based on a building’s intended use. This by itself often leads to an oversupply of parking. Yet, at the same time, shifting consumer preferences towards mixed-use communities provides an opportunity to redefine how parking facilities are constructed while maximizing accessibility and mobility and providing shared parking. Parking facilities need to become smaller and more space-efficient buildings that are safer, more convenient, sustainable, and capable of efficient vehicle retrieval.
AVSRS parking structures address these issues with their compact design, localized collection points that are easily monitored, and ability to adapt and integrate within technological platforms to meet required throughputs.

Smaller facilities further take advantage of small pockets of land in urban areas left when surrounding development constrict a site: these are often referred to as infill or notch lots, and are often economically challenging from a development standpoint. The adaptability and modular form of AVSRS parking facilities is often a great economical solution and best suited to develop infill lots, making use of otherwise wasted urban space (McDonald; 2007).

Reducing the amount of land used for parking will create more urban open spaces that contribute to recreation, ecology, and aesthetic value. For the same amount of parking, AVSRS parking structures can be built smaller as the unoccupied storage areas are limited to mechanical equipment and vehicle dimensions. The reduced spatial requirements equate to smaller building footprints and reduced volume, and in many cases up to 61 percent in spatial savings (Astrup, 2010). Due to a significant reduction in emissions, they can be safely placed in the core of buildings or the center of a block where the least amount of natural light occurs, allowing more desirable spaces in buildings to be left for other uses (McDonald, 2007). This provides for a more efficient land use without reducing mobility and accessibility, for a modern urban environment.

**Air Quality**

One of the most significant advantages of AVSRS is its ability to reduce air pollution: AVSRS parking structures save up to 83 percent in vehicle fuel emissions when compared with conventional parking facilities. (Schwartz: 2009) Drivers leave their vehicles in transfer stations with the ignition off, and the robotic equipment transports and stores the vehicle in the unoccupied storage vault until the vehicle is retrieved at a later time. The amount of volatile gases saved by a 200 vehicle system is equal to removing 92 cars from the road each year or planting 67,000 trees. In facilities designed and constructed as net-zero energy projects that have been energy neutral for more than one year, these numbers increase to 115 cars off the road each year, or planting 85,000 trees (Arup Engineering, 2009).

A recent pollution and energy characteristic study comparing a 350-space conventional parking garage to an AVSRS parking structure of the same capacity found that volatile organic compounds were reduced by 68 percent, carbon monoxide by 77 percent, nitrogen oxides by 81 percent and carbon dioxide by 83 percent (Schwartz: 2009) in the AVSRS structure. These are impressive results that support a reduced carbon footprint provided by AVSRS parking structures. (Schwartz: 2009) A recent AVSRS system built for the Ibn Battuta Gate Complex in Dubai reduces CO2 emissions by more than 100 tons per year with comparable reductions in other pollutants and greenhouse gases. It additionally saves 9,000 gallons of gasoline per year thus contributing significantly to carbon footprint reductions. The estimated emission reductions and energy saved are based on the following assumptions:

- Average total distance driven in a conventional garage entering and leaving: 1 mile
- Average days the garage is used per year: 275 per year
- Hydrocarbons per mile: 3.3 gram per mile
- Carbon Monoxide per mile: 0.026 grams per mile
- Nitrogen Oxides: 1.7 grams per mile
- Carbon Dioxide: 1 pound per mile
- Gasoline: 0.05 gallons per mile (source: http://www.roboticparking.com/robotic_parking_green_parking.htm)

**Energy Consumption**

In general, energy consumption for typical buildings is significant; 72 percent of all electrical use and 38 percent of carbon dioxide emissions produced. Parking garages are no different and must become more
efficient facilities to help reduce these numbers.

Because the storage area of an AVSRS parking structure is unoccupied and vehicles do not run inside, there is little or no need for typical high energy consumption systems such as lighting, heating, ventilation, and cooling. Lighting—one of the largest users of energy—is greatly reduced in an AVSRS facility, where it is only required for maintenance and can be activated in key areas when necessary. The storage vault can effectively be non-illuminated most of the time. Reduced lighting also plays an important role in limiting light pollution while reducing the energy demand, another LEED credit area (Light Pollution).

Heating and cooling are also not mandatory, but may be necessary in extreme conditions to keep surfaces from freezing. Reduced ventilation is required for enclosed AVSRS parking structures, but only two air changes per hour are required instead of 12 in conventional underground or closed parking facilities. These are significant areas of energy conservation from systems that would normally be in a permanent state of high-energy use.

Although AVSRS parking structure equipment
is electro-mechanical and consumes energy for the operation of the robotic storage and retrieval devices; these are only active for the time of storage and/or retrieval processing, allowing the system to hibernate or become dormant when not in use. Typically, an AVSRS parking system uses between 0.3 and 0.5 kWh per combined park and retrieve cycle. The cost of a unit of electricity in New York City in 2008 and 2009 was between $0.15 and $0.29 per unit; this equates to a cost of between $0.10 to $0.15 per park/retrieve cycle using the highest electricity cost/kWh. In general terms, this equates to burning a 100 watt light bulb for three to five hours or using a hair dryer for 20 min. (Electricity Cost Calculator http://www.handymath.com/cgi-bin/electric.cgi) Some systems make use of rechargeable batteries as alternative energy sources, which can be energy efficient and recyclable.

Having the potential to link to alternative sources of energy, an AVSRS facility can easily function with alternative energy sources such as solar, wind, bio-mass, and fuel cell along with green grid solutions.

Resources

As fewer building materials are required to construct AVSRS facilities for an equal number of cars parked, fewer resources are used. This has direct and indirect effect on the immediate environment: as fewer materials are sourced and used in the construction, the need to transport additional materials to and from the site is greatly minimized while the actual AVSRS systems themselves can be constructed and shipped within the United States. Further, in many cases excavation and removal of materials from site is significantly reduced or eliminated altogether, preventing transportation, relocation, additional energy and fuel consumption, as well as landfill issues.

Structural steel-framed racking systems for AVSRS parking structures allow for the use of up to 90 percent post-consumer recycled, regional, and renewable resources. In many instances, the racking can be disassembled and re-erected for reuse. The modular characteristics of AVSRS parking structures mean that retrofitting in the future or reuse of structure and materials contributes to sustainable practices in the built environment. Reassembly of critical components is also possible if the need arises to replace faulty components or install replacement devices. Much of the structural steel, concrete, and mechanical equipment can be recycled and is likely to contain recycled content.

Dual performing equipment and/or backup power should be designed and integrated into the system to ensure constant functionality. Backup systems include natural gas-powered generators or battery pack units, and are adapted to the system similarly to backup power for passenger elevator equipment. These ensure that vehicle storage and retrieval can continue even when main power supply is down. Battery recycling aims to reduce the number of batteries being disposed as solid waste. Batteries contain a number of heavy metals and toxic chemicals; their dumping has raised concern over soil contamination and water pollution risks. Most types of batteries can be recycled, but some batteries are recycled more readily than others such as lead-acid automotive batteries and button cells due to the value and toxicity of their chemicals.

The benefits of battery recycling include environmental safety, compliance with applicable environmental laws, adherence that hazardous materials are
recycled correctly, re-use of materials, saved landfill costs and effects, and conserved natural resources. Suppliers, owners, and consumers should be aware of recycling programs available in their area, and can inquire for services offered by private and/or state managed facilities such as those found at http://www.recycle.net

Industrial rechargeable batteries are undergoing technological advancements and have presented opportunities for mechanical equipment to store required energy for expected use applications, with the ability to recharge when not in use. Some batteries use a power charge technique that quickly recharges a battery, while others require a secondary device to serve as a backup unit in the event that a device is being recharged or as a replacement. This also ensures system redundancy. Disposal of the heavy metals and toxic chemicals used in rechargeable batteries must be addressed by local programs.

Water Efficiency
The reduced size of the parking facility also plays an important role in controlling excessive stormwater run-off and minimizing the urban heat island effect (another LEED credit) created by large impervious surfaces as these surfaces are dramatically reduced in an AVSRS facility. Bernard Engel, professor at Purdue University, points out that parking lots are a major source of water pollution and present a host of other environmental and economic problems. “The problem with parking lots is that they accumulate a lot of pollutants—oil, grease, heavy metals and sediment—that cannot be absorbed by the impervious surface. Rain then flushes these contaminants into rivers and lakes. Parking lots turn out about 1,000 pounds of heavy-metal run-off per year,” he says (Malik:2007). Consolidating parking into compact facilities contributes considerably to stormwater control and discharging, reduces run-off, reduces the need for additional pervious surface materials, and further reduces the heat island effect.

Integrating with Electrical Vehicles
Inductive Power Technology (IPT) wireless charging for electric vehicles (EVs) is a suitable method to integrate EVs into AVSRS facilities. IPT systems allow drivers to park their electric/hybrid vehicles over a pad that transfers power wirelessly to a receiver on the automobile. In an AVSRS facility, this allows recharging to occur wherever the vehicle is placed in the storage area. All stalls can be fitted with IPT technology and patrons are charged according to usage. Interestingly, this technology is also being developed for road systems and highway lanes, meaning that vehicles may be able to charge constantly even when being driven!

Electro-mechanical devices vs pneumatic devices
Electrical energy supply can be a clean energy source compared to pneumatic (hydraulically) operated equipment. Devices within the AVSRS parking structure, such as lifting devices for vehicle handling or vertical transfer from level to level, have been designed for electro-mechanical operation and/or hydraulic operation. Hydraulic cylinders can be problematic when seals burst or break, contaminating the immediate area and sending chemicals into local drainage systems. Containing or eliminating this potential hazard at the source prevents pollution. Environmentally safe hydraulic fluids are available, but these are considered not as effective, and the use of pneumatic devices has shifted to electro-mechanical in preference.

Social Contributions
Sense of Community
AVSRS structures create more urban open space, which can contribute to a greater sense of community and include parks, recreation activities, and public plazas. Public spaces are used to link activities, provide gathering spaces, and allow for enhanced social interaction, so their importance is great when considering the urban fabric and how we use limited space.
rated into existing and historic streetscapes, as their area and façades are compact. Bohl Architects added 18 underground AVSRS spaces into an office/retail project in historic downtown Annapolis, Md. (2009) while allowing the design of the new building to fit in the minimal space of its predecessor. This design maintained the historic fabric of the city while achieving additional parking (McDonald; 2010).

Site selection and location in urban areas are vital for the revitalization of communities; improvements near transportation nodes (a LEED credit) increase the viability of an area, and the ability to park vehicles nearby is essential to providing new living choices for people. AVSRS parking structures can easily be integrated into or near multi-modal facilities, allowing simple and direct access to other forms of existing transportation. A high-density parking structure can be effectively integrated with minimal effects on the existing urban fabric, creating greater vibrancy and an improved standard of living.

**User Experience**

The interaction between humans and machines has provided a longstanding fascination for people, and new technological experiences continue to inspire and intrigue. AVSRS parking structures present new opportunities between humans and machines. Improved user experiences include concierge-type handling of vehicles for customer convenience, shortening the time typically spent in a parking facility. Cell phone technology can be used to notify the system when a vehicle is required, allowing the vehicle to be moved to a storage area closer to the exit station for quicker retrieval. Visual experiences can be enhanced through glass walls and openings into the vault or machine areas as vehicles are delivered and presented to patrons.

Because transfer stations are typically localized into a single area, they can be well designed, well lit, and easily monitored, and can act as community gathering spaces. In larger mixed-use projects, these areas can be extensions of lobbies, link other common areas of buildings, or present leasing prospects for other building uses such as additional retail, commercial, or residential occupancy within or connected to the transfer stations.

Lobbies of AVSRS parking facilities can be designed as active community gathering spaces. These areas are designed to be accessible to all users and can include amenities such as coffee shops, dry cleaners, retail spaces, daycare facilities, beauty salons, or post-offices. Even a carwash can be integrated into the design, providing a great additional service. These amenities would enable people to experience the time otherwise used in self-parking facilities (as opposed to hunting for parked cars and circulating through the building toward the exit) to enjoy a cup of coffee, read some news, or interact with fellow patrons. An example of this is a residential project in Copenhagen that incorporated two 700-car towers with a public garden and skate park between them, along with interior community waiting areas (McDonald; 2010).

The ability to allow a machine to perform functions usually done by humans, such as parking, allows users to dedicate time to more important activities and less time to the mundane, thereby allowing patrons to become more efficient in more important aspects of a daily lifestyle. Software integration with third-party devices allows AVSRS parking structures to be dynamic in their performance: integrating real-time messaging technologies and presenting user-friendly methods of

![Ibn Battuta Gate robotic parking facility. Dubai, UAE.](image-url)
notifying the driver of availability of parking spaces.

Safety and Security

Localized collection/drop off areas created by the use of transfer stations eliminates the need to hunt for parking spaces. The time and car emissions spent on this activity has been thoroughly documented in Donald Shoup's book, *The High Cost of Free Parking*. Multiple transfer stations allow for multiple ingress and egress cycles from a single location. A patron simply returns to the transfer station to collect vehicle where it was initially delivered; this area is normally easily accessible and can be conveniently positioned close to elevators and lobbies, providing for increased personal safety.

Life safety is a priority in terms of sustainable design and counts toward points for other world programs such as BREEM and ISI. A study conducted by the U.S. Department of Justice found that one out of 12 rapes occurs in a parking garage and more than 40 percent of assaults by strangers occurs in parking garages (Schwarz; 2009). With often limited cellphone reception and inadequate tracking ability in below-grade garages, these are places criminals are able to lurk and hide before and after crimes. Efficient design that minimizes this potential should be considered. Surveillance of limited areas of consideration, such as common transfer stations and their immediate locations, allow for quicker and more accurate response times than accounting for large floor areas.

Because AVSRS facilities store vehicles in unoccupied vaults, reduced accidental damage, vandalism, and theft occurs.

Economic Contributions

Construction and Operation Costs

If a site is limited by size or soils, AVSRS parking structures can avoid costly excavation and site work to achieve required parking capacities. AVSRS has the greatest efficiency in square feet per stall (approximately 225 square feet compared to 320 square feet in conventional parking structures). This translates into a total cost per stall that’s less than a ramp garage under a building and above grade as well as a ramp garage under a building and below grade per data compiled by Walker Parking Consultants (Monahan; 2011). An AVSRS below grade under a building costs less than a ramp garage under a building and

<p>| FIGURE 3: Construction cost comparisions (conventional ramp garages vs. automated garages) |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>Unit Cost, $ per sf</th>
<th>Efficiency, SF/Stall</th>
<th>Cost per Stall</th>
<th>Automated Machinery Cost, $/Stall</th>
<th>Total Cost, $/Stall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ramp Garage, Above Grade</td>
<td>$45</td>
<td>320</td>
<td>$14,400</td>
<td>0</td>
</tr>
<tr>
<td>Ramp Garage, Under Building, Above Grade</td>
<td>$75</td>
<td>450</td>
<td>$33,750</td>
<td>0</td>
</tr>
<tr>
<td>Ramp Garage, Under Building, Below Grade</td>
<td>$105</td>
<td>450</td>
<td>$47,250</td>
<td>0</td>
</tr>
<tr>
<td>Automated Garage, Under Building, Above Grade</td>
<td>$65</td>
<td>225</td>
<td>$14,625</td>
<td>$16,000</td>
</tr>
<tr>
<td>Automated Garage, Under Building, Below Grade</td>
<td>$85</td>
<td>225</td>
<td>$19,125</td>
<td>$16,000</td>
</tr>
</tbody>
</table>

Monahan: 2011
below grade.

Unnecessary site work, material removal, and transport costs are minimized or eliminated altogether thanks to the compact nature of design in meeting parking requirements. Operation costs for lighting, heating, ventilation and cooling are also greatly minimized since the storage vault area is unoccupied and vehicles are not running; only occupied areas such as the Transfer Stations and associated lobby areas require adequate lighting, heating, ventilation and cooling, which are considerably smaller and more compact spaces to provide for. Furthermore, since the mechanical equipment is only active when in use, energy cost saving occurs during non-operation periods where the system lies dormant.

As AVSRS structures are reduced in size, construction periods are typically reduced. The mechanical equipment is manufactured separately from the structure, allowing parallel processing to occur. The equipment is pre-assembled off-site and installed in phases as and when the structure reaches stages of completion, providing staged integration of structure and equipment. This minimizes the overall completion period of the project and has a direct sustainable cost-saving effect.

According to a comparison of expenses and capital costs for a parking alternatives case study in upper Manhattan, New York City in 2008 by Sam Schwartz Engineering, PLLC (Schwarz; 2009) the cost of operating an AVSRS parking structure is less than half (55 percent) that of a conventional garage. In this particular case, it was established that an operator could save more than $1.1 million per year by using an AVSRS parking structure, which is currently equivalent to a capital cost savings of more than $15 million (Schwarz;2009). Annual operating costs per space are estimated to be approximately 50 percent more with AVSRS parking structures compared to conventional ramp access parking structures due to higher maintenance costs associated with mechanical equipment. However, security costs, lower insurance, and lower utilities are key areas where costs are minimized.

Life Cycle Periods

Generally, useful life cycle periods for AVSRS equipment are in the range of 20 years before it is necessary to replace the hardware and critical components. Maintenance costs include regular services for preventative maintenance procedures to ensure reliability, in a similar fashion to passenger elevators. Regular lubrication of parts, cable, cable extensions, and replacement rollers and sensor cleaning are normal procedures during inspection. System diagnostics and early warning detection will assist in setting up inspection times and expected replacement of parts, and the ability of the system to communicate these issues is simple through computerized notifications.
Managers are able to monitor AVSRS parking structures in real-time through computer-aided software, which provides for efficient working procedures in system controllability. This efficiency allows for energy use control throughout the systems; graphic interfaces allow control from macro to micro levels, recording data for quick review. This allows commissioning and systems management to monitor building performance and user satisfaction, assessing and meeting standards for accountability and long-term maintenance. Patron assistance can occur remotely: system override, troubleshooting and software upgrades are easily resolved through computer controls and ethernet connections. AVSRS parking facilities allow for modern upgrades while minimizing cleaning that adds pollutants to the local environment.

Increased Revenue Potential

The efficiency of a garage is reflective of its ability to generate revenue; increased capacities provide for increased revenue potential. Combining ramp facilities with mechanical car stackers is a basic cost-effective approach to optimizing space and meeting immediate short and long-term parking needs.

The ability to double, triple, or quadruple the parking capacity of any area can provide for an increase in revenue.

Cost Incentives

As AVSRS parking structures consist of mechanical devices, an economic benefit exists in the form of accelerated depreciation: this is an annual tax deduction that allows recovery of costs over the expected useful life of the equipment.

Under both financial accounting and tax accounting, companies are not allowed to claim the entire cost of a capital asset (any asset which can be used for many years) as an expense immediately. They must amortize the cost of the asset over some period, which is usually an approximation of the useful life of the asset. The depreciation basis is the cost incurred by the company in acquiring the asset. The useful life of the asset is determined by looking at Section 168(e)(3) of the United States Tax Code, and is known as the class life of the property.

AVSRS parking structure equipment would qualify for accelerated depreciation reinforcing its ability to be economically viable as described in section 4.3 Safety and Security.

Tax incentives are also offered for projects that meet sustainability goals; many projects are seeking areas of design that contribute towards achieving sustainability standards, and AVSRS parking structures help to provide innovations in design for reduced spatial requirements, reduced carbon emissions, and providing local limited parking capacities with managed storage areas for no additional parking.

Conclusion

Thinking of parking as a machine is in the United States a new process, but by examining how many sustainable aspects can be contributed by using these new technologies, this parking solution can be appropriate and the best choice in many situations. While it cannot compete in cost to a stand-alone conventional garage where land is not a major concern the
AVSRS parking structure has many applications and contributions to sustainability that can encourage walkable design and sustainability while still allowing for personal automobile use. Even in underground applications, the AVSRS can most frequently be the best choice for long term sustainability.

Notes


RYAN ASTRUP, M ARCH (PROF) ASSOC., AIA
is the principal architectural designer in automated robotic vehicle storage/retrieval systems for Park Plus, Inc.

SHANNON SAUNDERS MCDONALD
is an assistant professor at Southern Illinois University, Carbondale.
CHAPTER 14
Greening the Surface

STEVE ROLOFF AND GERARD A. REWOLINSKI

SURFACE PARKING LOT DESIGN IS TYPICALLY DRIVEN BY LOCAL MUNICIPAL ZONING CODES. Many local zoning codes include design guidelines that require a minimum percentage of the site be dedicated to green space, which can further be defined as landscape areas or stormwater facilities.

In many cases, minimum landscape standards may require parking lot screening using evergreen and deciduous shrubs. Some landscape ordinances dictate a minimum quantity of deciduous canopy trees, ornamental scale trees, evergreen trees, and ground covers that must be incorporated into the design.

Today, there is a green movement to use low-maintenance native plant materials that are indigenous to the area. They are well adapted to the soils and natural precipitation volumes, eliminating the need for permanent irrigation systems and regular fertilization/pesticide applications.

Natural landscape design works well when using various green methods of stormwater management tools such as bio-swales, rain gardens, bio-retention/infiltration basins, bio-filters and wet detention ponds. In our crowded urban environments, native landscaping also provides a natural wildlife habitat.

Appropriate pervious green strategies can help you achieve LEED® points. Depending on the application and what materials are selected, LEED® points are available in the categories of sustainable sites, water efficiency, materials and resources, and innovation in design. Specific LEED® credits include:

◆ LEED® Credit SS-c6.1 Stormwater Design—Quantity Control.
◆ LEED® Credit SS-c6.2 Stormwater Design—Quality Control.
LEED® Credit SS-c7.1 Heat Island Effect — Non-Roof.
LEED® Credit WE-c1.1 Water Efficient Landscaping.
LEED® Credit MR-c4.1 Recycled Content.
LEED® Credit MR-c4.2 Recycled Content.
LEED® Credit MR-c5.1 Regional Materials.
LEED® Credit MR-c5.2 Regional Materials.

**Stormwater Management Practices**

Stormwater runoff is generated when rain and snow-melt flow over land or impervious surfaces without infiltrating the ground. As the runoff flows over land or impervious surfaces (paved streets, parking lots, and building roofs), it carries with it debris, chemicals, sediment, and other pollutants that could adversely affect water quality if left untreated.

Traditional stormwater conveyance methods have included underground piping and storm sewers that quickly discharge runoff to wastewater treatment facilities or directly into nearby waterways. Today, the primary method to control stormwater discharges is the use of best management practices (BMPs), including various designs of vegetated swales. Properly designed and maintained vegetated swales can last indefinitely.

All local, state, and federal permit requirements should be established prior to final stormwater drainage system design.

**Bio-swale**

Bio-swale is the term generally given to any vegetated swale or roadside ditch that conveys stormwater. These are usually part of a larger storm drainage system and provide beneficial treatment of stormwater runoff through the removal or breakdown of pollutants and total suspended solids (TSS) without a high degree of maintenance.

The most polluted runoff occurs during the first few minutes of a storm event, or “first flush” period of a storm. The bio-swale or “treatment train” initially removes the pollutants before the runoff reaches its final destination. In addition to removing pollutants from stormwater, bio-swales provide runoff detention and through soil infiltration, can reduce peak flow velocity that can contribute to flooding downstream.

Vegetation in the bio-swale should be trimmed annually to prevent woody plant species or other invasives from taking over. As sediments collect and create pooling, it may become necessary to regrade the bio-swale to restore the original cross-section. Regular maintenance activities for bio-swales include inspection for debris build-up and removal, repair of any eroded surface areas, and removal/replacement of plant materials.
Bio-retention/Infiltration Basins

Bio-retention basins are vegetated depressions or basins used to slow and treat on-site stormwater runoff. Stormwater is conveyed via bio-swales to the basin, where it is treated and allowed to collect and slowly percolate through native or engineered soils. Basins are generally constructed with specialized soils, an aggregate base, an under drain, and site-appropriate native plant materials that tolerate both wet and dry conditions. Any overflow is then directed to nearby stormwater drains or receiving waters. Generally, bio-retention basins are designed to hold water for approximately three days while it slowly filters through the soil.

When considering the incorporation of a bio-retention basin, the limiting factors are appropriate soil infiltration conditions and the protection of groundwater. When incorporated into a site's overall landscape, bio-retention involves little to no additional cost other than the importation of engineered soils, grading modifications, and plantings.

Routine maintenance is required and can be part of a regular landscape program. A biannual evaluation of the health of the plant materials is necessary. The use of native plant materials reduces the need for pesticides, fertilizers, and irrigation.

Wet Detention Basins

Wet detention basins are permanent pools of water that effectively treat stormwater runoff. By capturing and retaining runoff during storm events, wet ponds effectively control water quantity and quality.

Generally, wet ponds are more effective in controlling water quality and quantity than are other BMPs such as dry ponds or infiltration basins.

General maintenance requirements include inspections after each storm event and looking for debris buildup at the outlet structure, erosion problems, and burrowing animal damage. Sediment accumulation in the pond can reduce its storage capacity and decrease its ability to enhance water quality. Sediment removal should be scheduled for every two to five years.

Paving Materials

Traditionally, impervious concrete or asphalt has been the norm for pavement materials. But with sustainability added to the mix, there are a number of viable materials to choose from. There is a large array of materials/products available, and engineers can offer aesthetically functional and durable sustainable paving surfaces.

Pervious pavements work well in parking lots. Typically, the heavier traffic roadway surface is poured with traditional concrete or asphalt while the lighter traffic parking aisles are poured with pervious pavement. Pervious pavements serve as a wonderful BMP for stormwater management: they reduce impervious areas, recharge groundwater, improve water quality, and, in some cases, eliminate the need for detention basins.

It has been demonstrated that pervious pavement does not cost more than conventional pavement materials; the underlying stone bed can be more expensive.
than a conventional compacted sub-base. This cost can be offset with the reduction and/or elimination of underground pipes and detention basins.

Some of the available options for pervious pavement include pervious asphalt, pervious concrete, permeable pavers, belgium block pavers, turf block pavers, plastic grids, cobbles and gravel.

**Pervious Asphalt**

Pervious asphalt pavement is made from standard bituminous asphalt with the fine aggregates (passing through no. 30 sieve) removed to allow water to pass through. Under the asphalt pavement is a uniformly graded 1.5 – 2.5-inch clean-washed stone bed with 40 percent voids. Depending on stormwater requirements, the stone bed is generally 18 to 36 inches deep. A layer of geotextile filter fabric should be placed between the stone bed and soil sub-base to prevent migration of fines into the stone bed. A choker course of stone should be placed under the surface layer, with an optional layer of geotextile filter fabric over the stone bed to provide stabilization for paving equipment. Very often, the stone bed layer can provide stormwater management for adjacent impervious areas such as roads and roofs. The water reaches the stone bed through underground piping and is distributed evenly through perforated pipes.

The key issue associated with maintenance of pervious concrete pavements is clogging of the void structure. Do not allow surrounding landscape zones to drain onto and over the pervious asphalt. Mulch, sand, topsoil, and debris can quickly infiltrate the voids, rendering the pervious functionality of the pavement useless.

It may be necessary to annually vacuum the surface to remove any accumulated debris. Power blowing and pressure washing has also proven successful for this. It has been shown, in some cases, that pressure washing can restore 80 to 90 percent of the permeability to clogged pavement. In cold climates, do not use sand or gravel for de-icing; it is alright to use salt or calcium chloride. Light plowing may eliminate the need for de-icing materials because the snow melts and quickly drains through the pervious asphalt.

**Pervious Concrete**

Pervious concrete functions nearly identically to pervious asphalt. It is made with controlled amounts of aggregates, water, and cementitious materials, creating a mass of aggregate particles covered with a thin coating of paste to bind them together. A substantial void content in the concrete mixture is due to there being little or no sand used in the mixture. Pervious concrete mixes generally allow a 15 to 25 percent void content that provides flow rates near 480 inches per hour (0.34 cm/s).

Similar to pervious asphalt, pervious concrete is supported on a stone base of uniformly-sized stone. Maintenance practices, too, are the same.

**Permeable Pavers**

Permeable pavers are manufactured modular units of clay or concrete that come in varying shapes, sizes and colors, allowing for maximum design freedom. The degree of permeability depends on the size of the gaps or joints between units. ADA-compliant surfaces restrict joints to a maximum half-inch when onsite retention/infiltration is mandated. The maximum gradient of the pavement surface should be about 5 percent (one in 20), to prevent water flowing over the surface instead of into the paving joints.

Generally there are three principal design situations that are suitable for permeable pavers, depending on site conditions and soils. The design can allow for total infiltration, partial infiltration, or no infiltration.

**Total Infiltration**

This design is suitable where existing sub-grade soils are very permeable. It allows all water to infiltrate down through the joints between pavers, into the stone storage zone, and eventually into the
sub-grade. It is sometimes referred to as a “zero discharge,” as no additional water from the new development is discharged into traditional drainage systems of pipes, structures, or swales. This situation can be very economical, eliminating the need for additional systems. Overflows may be needed in some situations when the design capacity is exceeded.

**Partial Infiltration**

This design is suitable where existing sub-grade soils may not be capable of allowing all the water to pass through to ground below. A fixed amount of water is allowed to infiltrate. Outlet perforated drainage pipes are installed near the bottom of the stone storage zone and connected to other drainage devices such as ponds, swales, or sewers, allowing excess water to be removed.

**No Infiltration**

This design is suitable where existing sub-grade soils have poor permeability or are contaminated, and allows for complete capturing of the water. This design is similar to partial infiltration with the use of outlet drainage pipes, but an impermeable, flexible membrane is placed below the stone storage zone and up the sides to form a bathtub. Outlet pipes are constructed through the membrane to other drainage devices; they are sized to restrict flow so water is temporarily held in the storage zone and slowly discharged.

Sustainable surface parking lots incorporate landscaping with trees, shrubs, and ground covers, managing stormwater on-site, reducing the urban heat island effect and using sustainable materials and technologies. Opportunities for newer green technologies in site design are less dependent on high maintenance and costly inlets, pipes, and ponds.

Integrating BMPs in surface parking lot design achieves the goals of:
- peak flow control
- volume reduction
- water quality
- water conservation
- community aesthetics

When compared to conventional parking lot construction, alternate pervious pavement approaches provide excellent parking lots and roads. Properly designed and maintained vegetated swales offer an economic, aesthetically pleasing alternative to an otherwise expensive storm sewers drainage system, with many water quality benefits.

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STEVEN J. ROLOFF, PE, LEED AP
is director of structural engineering at Arnold & O’Sheridan Consulting Engineers.

GERARD A. Rewolinski, RL, ASLA
is senior landscape architect at Stantec.
Parking and the Environment

Author and essayist E. B. White wrote, “Everything in life is somewhere else, and you get there in a car.” Indeed, getting around in a car is a common occurrence in our mobile society. Unfortunately, while the car gets us to “somewhere else,” it consumes natural resources and leaves behind emissions that sometimes adversely affect the environment.

Until recently, all automobiles had internal combustion engines that required fossil fuel to function. Obtaining those fuels necessitates the removal of a nonrenewable natural resource—crude oil—from the earth. The crude oil must be distilled to produce gasoline, a process that itself requires energy, and the gasoline must then be delivered to local sites, usually by trucks that are powered by other internal combustion engines.

Once placed in a car, the conversion of the fuel into energy produces gases that can have a negative impact on air quality. The more a vehicle operates, the more fuel it uses and the more harmful gases it emits.

A parked vehicle requires no fuel and emits no harmful gases. To enhance the sustainability of parking, it is important to enable vehicles to be parked with minimal delay.

Properly managed on-street parking can usually provide a driver with the least delay locating a convenient parking space when compared with most off-street alternatives.

On-street parking is highly efficient from a land use perspective. According to expert Todd Litman:

“On-street (curb) parking tends to be shared efficiently since it is convenient to use and serves multiple destinations. An on-street parking space can usually substitute for two or three off-street parking spaces. On-street parking uses less land per space..."
than off-street parking since it does not require access lanes. As a result, on-street spaces typically use a quarter of the land that would be needed to provide the same amount of service with off-street parking serving a single destination.”

Many off-street parking structures have adapted elements of LEED® certification in their design and construction. The U.S. Green Building Council (USGBC) has developed guidelines that award points for incorporating sustainable elements in the construction of offices, hospitals, schools, and other habitable buildings. Points are awarded for site selection, water conservation, energy use, indoor air quality, and the use of natural resources. If a building earns a minimum number of points, the building becomes LEED® certified. The more points that are accumulated, the greater level of certification (silver, gold, or platinum) the building receives.

The USGBC does not certify on-street parking programs because there is no physical structure involved. Though omitted from USGBC consideration, on-street parking can incorporate sustainable features that enhance both the environment and the customer experience. By implementing what we refer to as PARC (Practices Aiding Recycling & Conservation), the parking industry can contribute to a more eco-friendly environment through on-street operations.

**PARC and On-Street Parking**

Of all the parking options, on-street represents the most convenient location for the temporary storage of an automobile. A parking space directly in front of one’s destination allows the driver to limit his or her search for a parking location.

Carts, horses, carriages, and bicycles all traversed and parked on public roadways before the car. The existence of roads is likely the result of the invention of the vehicle. Author Mark Childs says:

“The wheel and axle came into use at least 5000 years ago. Existing archaeological evidence places the origin of wheeled vehicles in the region of the Caucasus Mountains. The vehicle is perhaps responsible for the road, as the concentration of weight on the wheels demands a ‘made’ surface in a manner that foot and animal traffic does not.”
The way an entity manages its on-street spaces determines its level of sustainability. PARC is the practice of implementing sustainable policies and procedures that support local Transportation Demand Management (TDM) programs and/or encourage the use of renewable products in the delivery of on-street parking services. On-street parking provides many opportunities for an agency to support PARC.

### PARC and TDM

TDM programs are established to decrease the use of single-occupancy vehicles, or at least reduce the number of miles driven by single-occupancy automobiles. Properly managed, on-street parking programs encourage alternative modes of transportation by reducing or eliminating the hidden subsidy often incorporated into parking rates. In addition, a sustainable on-street program will decrease the number of miles driven. According to Donald Shoup:

“Consider a congested downtown area where it takes three minutes to find a curb space. If the parking turnover is 10 cars per space per day, each curb space generates 30 minutes of cruising driving around looking for an on-street parking space per day, and if the average cruising speed is 10 miles per hour, each curb space generates five VMT (vehicle miles traveled) per day.”

Drivers who are able to locate on-street parking spaces in the least amount of time reduce or eliminate the need to drive around searching for spaces.

By decreasing or even eliminating this search, fuel use is decreased and fewer vehicle emission gases are emitted into the atmosphere. The vehicle miles traveled per day cruising for that one on-street space is reduced or even eliminated.

On-street parking is administered by imposing appropriate restrictions on the use of available spaces. All on-street parking programs must consider several attributes, such as the location of the spaces, parking duration, hours of enforcement, rates, and enforcement activity, and establish them in a coordinated approach to contribute to the TDM policies of the community:

- On-street parking spaces should have appropriate time restrictions.
- Rates must be established to encourage the posted time restrictions.
- Fines for infractions must encourage the payment of the rates.

If one attribute is not in alignment with the others, the ability of the on-street program to reduce vehicle miles traveled will be reduced. Together, these attributes can support a viable TDM plan.

**Location**

The primary purpose of public streets has traditionally been to facilitate the movement of vehicular traffic. Creating on-street parking will usually restrict traffic flow and discourage the use of automobiles.
and calming traffic so the pedestrian environment is enhanced; TDM is naturally supported. Moreover, on-street parking will promote nearby businesses. Robert Weant and Herbert Levinson write:

“Where to provide and where to prohibit (or restrict) on-street parking are major issues in small and large cities alike. Resolving those concerns depends on the type of street, character of abutting land use, traffic flow characteristics, and the availability of off-street parking and loading space.”

A traffic engineer is usually required to study the roadway conditions and traffic volume to determine if on-street parking is feasible. It may also be necessary to reserve curb space for bus stops and/or truck loading. If on-street parking is possible, even for part of the day, the exact location of the spaces must be determined.

For TDM purposes, on-street spaces within business districts are most useful in front of or adjacent to businesses that depend upon a large volume of customers who spend a short period of time (two hours or less) conducting transactions; these include banks, dry cleaners, bakeries, fast food restaurants, and smaller retail establishments. The availability of these spaces for multiple customers will reduce vehicle miles for those seeking parking.

Locations near sporting venues, entertainment sites, medical centers, and large retail complexes do not generate as much turnover because customers often need to park for longer periods of time. With limited turnover of spaces, the support for a TDM program is less effective but still useful in reducing the number of miles driven.
On-street parking may also be appropriate for areas outside of a central business district (CBD), where the demand for parking is greater than the existing off-street supply. Such parking is an efficient user of a public asset and aids in reducing vehicle miles.

**Duration**

Once parking space locations are determined, the maximum length of time one may remain parked must be established. Generally, on-street spaces in retail districts are dedicated to accommodate short-term parking. One- or two-hour durations are common in CBDs, but other time limits may be more appropriate to promote a TDM program. The key is to establish a duration that supports local businesses while reducing the number of miles driven by automobiles. Before establishing an effective duration for on-street spaces, it is important to not only consider the type of businesses that the on-street spaces serve but also local TDM goals. In some locations, using 90 minutes instead of two hours or 30 minutes instead of one hour may be a more appropriate duration to promote space availability. Over time, the mix of businesses in an area will likely change, so an occasional review of parking durations is prudent.

**Hours**

For a TDM program, the time of day a person may park in an on-street space should reflect the period(s) of higher demand for those spaces. The hours of parking regulation often reflect normal business hours, but they can vary. If a district has entertainment venues, extended hours of enforcement beyond the normal business period should be established. If a residential area is nearby and the local businesses are not active until later in the day, then hours of enforcement need not commence until late morning.

**Rates**

Rates for on-street parking spaces are perhaps the most important attribute in promoting a TDM program. If rates are too low, too many spaces will be occupied and the temptation to “feed” an expiring meter will be greater. Drivers will not be able to find spaces and will commence cruising.

If rates are too high, few people will park at the locations to patronize local businesses. In general, on-street rates in CBDs should be greater than nearby off-street facilities for short-term parking. The cost of parking at an on-street space should also be greater than the cost of riding the local bus, trolley, or light rail.

Ideally, agencies will conduct regular studies of the hourly occupancy rates of their on-street spaces. These studies can provide valuable data that can be used to revise rates. Several cities are currently experimenting with in-ground sensors that can provide this data on an ongoing, real-time basis, enabling even greater management of the on-street parking assets. In general, when the occupancy rate for an on-street space is regularly greater than 90 percent, it is time to increase rates. If the occupancy rate is regularly less than 70 percent, maintaining the same rate or implementing a slight reduction of rates may be appropriate.

**Violation Fines**

Enforcement must be adequate to ensure on-street parking customers comply with posted regulations, pay parking fees, and do not remain parked in excess of the established duration. Effective enforcement is a necessary element of an on-street TDM program. The fine should be much more expensive than the parking fee. For example, if parking is $1.00 per hour, a fine of at least $20 is appropriate.

**Towing and Booting**

Ideally, fines associated with citations are sufficient to encourage compliance with on-street parking regulations. When the threat of a citation is not effective to prevent parking violations, removing or immobilizing vehicles are sometimes necessary. Unfortunately, from a sustainability viewpoint, both enforcement methods have adverse environmental consequences. Towing requires dispatching a heavy-duty vehicle that is usually not very fuel efficient. That tow truck must travel to the
site of the infraction, secure the vehicle, and move it to an impound lot. Once removed, however, the parking space becomes available to support TDM goals.

Immobilization, often called booting, can be a more energy-efficient operation, but the offending vehicle remains parked and prevents others from using the parking space. Booting usually uses a more fuel-efficient vehicle such as a car or van. The enforcement vehicle arrives at the location and the staff places a boot on the offending vehicle.

There are several booting methods, but the one that’s most sustainable involves placing a notice on the vehicle that informs the owner to call a number. Payment is made over the phone and the owner is given a release code. The owner uses the release code to unlock the boot and must then deliver the boot to a specified location or face additional charges.

Fewer vehicle miles are usually required with this booting method when compared to the method that requires a return trip by enforcement personnel. When it is necessary to take enforcement action greater than citation issuance, the organization should consider the both options and choose the one that is most eco-friendly under the circumstances.

**PARC in the Delivery of On-Street Parking Services**

To provide on-street parking, an agency must purchase and/or use a number of products. This gives the agency opportunities to select those that are sustainable in nature or that encourage recycling. The following are some examples of PARC during product selection.

**Parking Meters**

Occasional enforcement along with posted signs informing drivers of the maximum allowable time duration for parking might be adequate to ensure on-street parking turnover. In many cities, however, a more precise means of monitoring on-street spaces is necessary. Parking meters provide that means. They are usually installed in business districts to provide a method to enforce the maximum allowable parking duration.

In addition, the revenue generated from the meters can be used to pay for their maintenance and parking enforcement. If approved, revenue can be shared with local business or civic associations to support eco-friendly programs. There are several options to choose from.

**PARC: Policies Assisting Recycling & Conservation Considerations for Managing On-Street Spaces**

- **Meters**: consider rates, installation, maintenance, and collection to determine most sustainable meter for a particular area
- **Enforcement Routes**: establish routes to provide maximum coverage in areas of high usage
- **Vehicles**: consider walking, carpooling, public transportation, and fuel-efficient vehicles
- **Payment**: allow phone and on-line payment of fines
- **Appeals**: conduct online
- **Uniforms**: look for eco-friendly material
- **Products**: made from recycled material
- **Supplies**: purchase items that are earth-friendly
The mechanical meter is perhaps the most sustainable regulator of on-street parking time limits. It relies on only an internal spring to power the timing device. No electricity or batteries are required. If regularly maintained, mechanical meters can last for decades. While the mechanical meter has many sustainable features, it is not without operational trade-offs and limitations. The timing mechanism is susceptible to inaccuracy, and the units do not provide any audit data. Moreover, changing rates is usually a labor-intensive process that requires new parts. These concerns have been significantly reduced with the advent of the electronic parking meter.

Electronic single-space meters provide accuracy, precise coin differentiation, and audit data. Rate changing is accomplished via a handheld device that modifies the unit’s programming. Power comes from a battery that must be replaced at least on an annual basis.

Single-space electronic meters that accept credit cards are now available, with rechargeable battery packs connected to small solar panels. Credit card meters also have another sustainable advantage when it comes to collections: Using credit cards instead of coins means the number of collections is decreased. Fewer collections diminish the number of vehicle miles driven for performing meter collection.

From a PARC perspective, one must examine the installation, maintenance, and collection of single-space meters to determine the most sustainable product for use in a particular location. They are usually mounted on poles that are anchored into the ground. Each installation requires equipment to dig a hole and pour concrete to place around the pole in the ground. Sometimes, two meters can be mounted on a single pole thus reducing the fuel usage and material resources, and at some locations, meters can be installed on existing utility poles.

All meters require periodic maintenance, but the electronic models generally need less since there are fewer moving parts. Electronic meters, however, do require regular battery replacement. Batteries can contain heavy metals such as lead, mercury, and cadmium. These metals can contaminate the ground, water, and air if the batteries are not properly disposed of. It is suggested that the entity responsible for meter maintenance find a battery dealer that will recycle or properly dispose of old batteries as part of a sales contract.

Many municipalities and universities are incorporating multi-space meters for their on-street meter programs. In most applications, multi-space meters are usually powered by internal rechargeable batteries that are connected to solar panels; no external power is required.

One multi-space meter replaces eight to 10 single-space parallel parking meters. In locations with angled parking, the ratio can be up to 16 spaces to each multi-space meter. An entity conserves fuel and vehicle miles by installing one multi-space meter instead of eight or more single-space meters. Fewer meters will also result in fewer maintenance trips, conserving vehicle miles for years. Most multi-space meters have a self-diagnostic feature that will notify the owning entity of a problem, so maintenance personnel can be dispatched.

Multi-space meters offer payment by coins, credit cards, and paper currency. Most units can be equipped to accept stored-value cards, also known as smart cards, that contain embedded microchips storing monetary value. Upon each use in a meter, the value is re-


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duced. Cards can usually be reloaded with additional value. Stored-value cards are ideal for micro-payments because their use is not associated with the traditional credit card fees. By increasing the payment options, fewer collection trips are usually necessary.

There are two categories of multi-space meters—pay and display, and pay-by-space. Pay and display requires a receipt made from thermal paper. There is usually an option to set the length of the paper receipt. To better promote sustainability, the entity should select the smallest size possible to reduce the use of paper. Recycled thermal paper is now available from several providers, further reducing the destruction of trees. Pay-by-space does not require a paper receipt for each transaction, eliminating paper consumption. Pay and display can sometimes provide additional on-street parking spaces as individual parking spaces need not be designated at a minimum length. Thus, a block face that would normally be striped for eight spaces could accommodate nine vehicles. Pay-by-space does not provide that opportunity, because each space must be physically defined, signed, or numbered.

Rates for multi-space meters can often be set by programming from a local computer, which transmits the rates to each meter. This remote programmability is a significant sustainable feature when compared to programming individual meters.

The poles once used to mount single-space meters can be retained to designate space numbers when using pay-by-space multi-space meters. The poles can also be used to secure bicycles.

Cell phone parking payments are now being implemented in locations around the world. A customer parked at an on-street space are instructed to call a posted number, provide the location (space number), and indicate the desired duration of parking time. Cell phone payments can be used in conjunction with a pay-by-space system or without any meters. Some providers require the customer to be pre-registered and have a credit card or bank account linked to their account. All phone payments reduce the amount of cash in meters and thus reduce maintenance and collection requirements. Payment by cell phone also makes it possible to extend the original parking duration without returning to a parking space. From a TDM perspective, however, this option should not be activated since as reduces turnover of the on-street parking spaces.

In-car meters are another method to regulate parking duration at on-street spaces. These devices are purchased with a stored amount of time—say 20 hours. When parked, the customer activates the device and places it on the dashboard or hangs it from the rearview mirror. As long as time is visible on the in-car meter display, parking is valid. In-car meters, when used in lieu of single-space or multi-space meters, eliminate all maintenance and collections because there are no meters to maintain. With no meters to maintain or collect, significant vehicle miles are eliminated.

It is also possible to designate on-street spaces solely for more fuel-efficient vehicles such as motorcycles. At least four motorcycles can park in a 20-foot section of a street normally assigned to park one automobile.

Meters can regulate time and provide revenue data but they can’t provide all the information needed to effectively manage the spaces they regulate. Effective parking rates must be based upon the actual use of the on-street spaces.

Until recently, periodic surveys of the use of on-street spaces were necessary to calculate hourly occupancy, turnover, and violation capture rate. Now, in-ground space monitoring devices can provide that information. These devices detect the arrival and departure of vehicles and can be linked with adjacent meters. Thus, they can determine the number of vehicles that park within a defined period of time, the time each vehicle stays, and the fact that a vehicle is parked after time has expired.

Knowing the number of spaces occupied within a defined area and the number of different vehicles that use the same space during a day allows the managing agency to establish effective policies and rates.
Table 1 summarizes the sustainability features of exiting methods to monitor on-street parking.

**Enforcement**

Enforcement of on-street parking regulations provides opportunities to employ sustainable strategies. Usually, enforcement routes are established based on the location of the on-street spaces and when those spaces are usually occupied.

Enforcement routes should be reviewed whenever there are substantial changes to the location, duration, or hours of enforcement. Businesses change over time. When changes are made to the meters in an area, enforcement routes also need to be reviewed and modified if necessary.

In addition, enforcement routes should be reviewed at least every three years to ensure the maximum efficiency of enforcement personnel. The bakery on Main Street might become a shoe store, and its 10-minute parking duration may no longer be appropriate.

With on-street spaces integrating in-ground detectors, it is possible to deploy targeted enforcement. Instead of patrolling established routes seeking violations along the way, enforcement action can be directed toward areas where actual violations exist. Targeted enforcement can reduce vehicle miles when it is done in such a way as to limit the miles driven.

Parking entities that use handwritten citations generate at least two pieces of paper for every cita-

<table>
<thead>
<tr>
<th>Space Monitoring Method</th>
<th>Sustainability Features</th>
<th>Sustainability Issues</th>
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<td>Mechanical meters Electronic meters</td>
<td>Self-powered</td>
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<td>Electronic meters with credit card</td>
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<td>Multi-space meters (pay and \display)</td>
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<td>Multi-space meters (pay-by-space)</td>
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<td>In-car meters</td>
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Computerized handheld ticketwriters reduce the use of paper by at least 50 percent, because only one document is produced. Additional ecological savings can be achieved by not providing a payment envelope with a citation.

The mode of transportation used to manage on-street parking can support PARC. Of course, walking is the preferred form of eco-friendly enforcement transportation. Using human legs to get around is very healthy and ecologically friendly. When walking is not practical, there are fuel-efficient vehicle options, including bicycles, motorcycles, mopeds, Segways, and electric and hybrid vehicles.

It is important to maintain the tire pressure of any passenger vehicle or truck used as part of an on-street parking program. This can increase fuel efficiency by up to 3 percent.

Internal carpooling can be used for enforcement personnel who serve areas farther away from the office. A single vehicle can drop off officers at the starting point of their route and then pick them up later towards the end of their shift to return them to the office.

Another possible option is public transportation. A pre-paid pass or permit that is valid on a local public transportation system (bus or light rail) can be used as an alternative to a vehicle.

License Plate Recognition (LPR) can be a useful and eco-friendly enforcement tool. A vehicle-mounted camera can digitalize license plates and forward the data to an on-board computer. The computer can then check the license plate against a database and determine if a violation exists. This method allows large parking areas to be enforced with minimal resources. If the vehicle is energy efficient, even more sustainability is realized.

**Payments and Appeals**

Online and phone processing of citation payments can help develop a more sustainable on-street parking program. These payment options reduce vehicle miles driven for both the entity and errant driver. Payment kiosks, located in areas with high pedestrian activity, can also reduce the use of automobiles.

Likewise, online appeals of citations also support PARC.

**Uniforms**

The National Basketball Association (NBA) now uses uniforms that are made from fiber that is comprised of 60 percent recycled material. Eco-friendly uniforms are available for meter enforcement, collection, and maintenance staff. Several PARC-friendly clothing options are available.

One innovative product uses recycled two-liter plastic bottles to create a polyester material that can be spun into clothing. A two-piece uniform can be made from about 25 bottles.
Hemp is another option for clothing material: it improves soil conditions as it grows and requires no herbicides or pesticides because it is naturally resistant to mold, fungus, and insects. Hemp is ideal for enforcement personnel because it provides a natural ultraviolet protection from the sun’s rays.

A third option—cotton—has been available for many years. In recent years, cotton production has become more sustainable when it is grown without chemicals.

Office Equipment and Supplies
Purchasing common office supplies (pens, file folders, paper, etc.) made from recycled material is another important initiative of PARC. Other sustainable products used to maintain on-street parking can also be purchased. Signs, barricades, and traffic cones are examples of products that can be manufactured from recycled materials.

Over time, meters and meter housings require thorough cleaning. In the past, petroleum-based products were often used for that purpose. Now, environmentally friendly cleaners can be used. These products are usually safer to use, as they are not flammable and have very low levels of volatile organic compounds (VOCs). Bio-based lubricants are also available for use in meter locks.

NOTES
• Mark Childs, Parking Spaces (Boston: McGraw-Hill, 1999), p.2-3
• Robert Weant and Herbert Levinson, Parking (Washington, DC; Eno Transportation Foundation, 1990) p. 241

CHUCK CULLEN, CAPP, CPP
is senior associate with The Integrity Group.
CHAPTER 16
Transforming Strategy into Reality
Case Studies in Parking Design and Operations

PARKING GARAGE DESIGNS

GREENWAY SELF PARK
Owner: River North Self Park LLC
Location: Chicago, Ill.
Submitting Firm: Standard Parking

About the Project:
Greenway Self Park is a fully automated, freestanding parking garage located in Chicago’s popular River North neighborhood. It was built to accommodate booming development in the surrounding area by providing 715 much-needed parking spaces in an aesthetically pleasing and sustainable presentation.

Greenway Self Park was designed to integrate seamlessly with an adjacent hotel and future condominium building.

Notable operational aspects of the facility include gray water cisterns for capturing and recycling rainwater, vertical urban wind turbines mounted on the southwest corner of the building, electric car charging stations, a themed floor reminder system, and the future installation of a green roof, which will double as a recreational space and poolside lounge for residents of the pending condo development. Each level is identified by a green-living-related theme; the walls of each lobby display a tip for greener living that coincides with the floor’s theme.

All pedestrian areas of the facility provide mixed-use recycling receptacles to minimize trash output. The facility employs a full-time maintenance person, and all maintenance supplies and equipment are the most eco-friendly options available, including a propane-powered sweeper.

During construction, the project team implemented a waste management plan in an effort to divert more than 80 percent of construction waste from the landfill. To reduce resource use during construction, the team turned off all non-essential lighting during nights and weekends.
The flooring in the elevator lobbies consists of sustainable unglazed porcelain Ecotech tile on precast floor. Ecotech tile also covers the walls on the ground floor lobbies. Lobbies are finished with a painted gypsum board drop ceiling.

Each parking level features a green-living-related theme and green living tip reflected in the murals. The centerpiece of each lobby is the flatscreen television mounted above the elevators, which displays a music video coinciding with the floor’s theme. This Music Video Floor Reminder System is the next generation of co-developer Myron Warshauer’s patented system.

DUKE UNIVERSITY RESEARCH DRIVE PARKING GARAGE

Owner: Duke University
Location: Durham, N.C.
Submitting Firm: Walker Parking Consultants

About the Project:

The Duke University Research Drive Parking Garage was the first (and one of few) LEED certified standalone parking facility. The university faced the challenge of achieving enough LEED points without a physical link to a traditional occupied building and without incorporating mixed-use. The University, with the help of the project team, approached this issue by seeking ways to increase efficiency through cutting-edge infrastructure systems that benefit the facility’s performance once the garage is operational.

In addition to this approach, the university worked with the project team to implement a number of sustainable design and construction strategies throughout the course of the project. For instance, an LED lighting system allowed for daylight harvesting, while minimizing or eliminating light pollution/waste from the garage. This system provided substantial energy savings.

During site selection, the university considered a number of locations to most effectively accommodate the growing parking demand. As a result, the garage sits on what was an existing surface parking lot, allowing the university to maximize available parking spaces while maintaining green space on campus.

During construction, the project used recycled materials directly from local suppliers, which mitigated energy impacts from long-distance transportation while supporting area businesses. The project also included a comprehensive recycling management process targeting the reuse or local disposal of materials generated during the construction project.

The Research Drive Parking Facility includes a number of green infrastructure systems that contributed toward its LEED certification. These systems include:

◆ Two 10,000-gallon cisterns to collect rainwater for landscaping.
◆ Green trellises and walls to reduce heat island effect.
◆ Rain gardens to slowly filter excess stormwater into the city’s stormwater system.
◆ Preferred parking for low-emission, fuel-efficient, and carpool vehicles.
◆ Efficient payment system that reduces idling.

Ultimately the Duke University Research Drive Parking Garage earned 31 LEED points, while serving as a groundbreaking example of the many sustainable design strategies that can be incorporated into standalone parking facilities.
SANTA MONICA CIVIC CENTER
PARKING STRUCTURE

Owner: City of Santa Monica
Location: Santa Monica, Calif.
Submitting Firm: International Parking Design (IPD)

About the Project:

The Santa Monica Civic Center parking facility is widely recognized as the first LEED certified parking facility in the United States. In preparation for pursuing LEED certification, the city considered a number of important issues including site selection, community connectivity, alternate transportation, stormwater management, and reduction of thermal differences with the surrounding areas.

As the gateway to the Santa Monica Civic Center, special consideration was taken to make the façade of the parking structure unique with playful and colorful design. At street level, there is future tenant use space and restaurant space available that overlooks the City Hall, County Court House and the Public Safety Facility.

The City of Santa Monica’s goal was to make this parking structure LEED Certified. In preparation for the certification, site consideration including community connectivity, alternate transportation, stormwater management and reduction of thermal differences with the surrounding areas was incorporated into the design. The Santa Monica Civic Center parking facility succeeded in implementing a number of sustainable design and construction strategies. Some of these include:

◆ Use of reclaimed city water for landscaping and tenant space toilets.
◆ 213 kW DC rooftop photovoltaic panels which provide electricity to support the facility, while providing shade for vehicles parked on the roof.
◆ Natural light and efficient fluorescent lighting reflects off white ceilings to enable lower lamp wattage and to minimize light spill to unwanted places.
◆ Stormwater Management Runoff water treated using on-site filtration to reduce total suspended solids and phosphorus before entering municipal waste water collection system.
◆ Concrete includes locally mined aggregate, and recycled flyash.
◆ Structural steel contains up to 68 percent post-industrial recycled content.
◆ Recycled glass material.
◆ Bicycle storage lockers provided free to the public to encourage alternate transportation modes.
◆ Significant portion of construction waste diverted from disposal sites.
◆ LEED signage throughout the facility educates the community and increases awareness about the green building elements of the facility.

Source: http://www.smgov.net/Departments/OSE/categories/content.aspx?id=4419
“The Wave” Mixed-Use Facility

Owner: Casino Reinvestment Development Authority
Location: Atlantic City, N.J.
Submitting Firm: Timothy Haahs & Associates, Inc. (TimHaahs)

About the Project:

The Casino Reinvestment Development Authority (CRDA) and the city of Atlantic City have embarked on a major redevelopment effort to revitalize the city’s core and establish a more active and vibrant environment in this heavily traveled entertainment district. Located adjacent to Atlantic City’s The Walk retail district, the structure supports the parking needs of nearby restaurants, residential housing, a Sheraton Hotel, the Atlantic City Convention Center and the Boardwalk Hall entertainment center. Combining a variety of parking uses takes advantage of shared-use parking strategies, maximizing the use of the facility.

Planners of “The Wave” have incorporated a number of smart growth and sustainable design principles throughout the project. The facility is located on a previously disturbed site which included a parking lot, community center and fish market. The location of this facility was very important for the success of the project—transit-accessible, urban infill, located near existing retail—the structure builds on these foundations to increase density and provide efficient parking resources.

By maximizing parking resources through shared parking and intentionally designing the structure to increase walkability, the parking facility will help to reduce the number of automobile trips throughout the area, and as a result reduce traffic congestion and resulting vehicle emissions as well. Visitors can park at the garage and visit a variety of retail and restaurant destinations, as well as the boardwalk and the beach. Visitors arriving immediately off of the Atlantic City Expressway can park their vehicles at the facility and walk to all of these destinations via a convenient, pedestrian-friendly sidewalk route.

The Wave includes approximately 16,000 square feet of ground floor retail, as well as space for a parking office. The facility is a destination in itself, serving as an attractive complement to the existing mix of destinations in the surrounding area, while helping to contribute to the overall liveliness of the community. The inclusion of retail at grade helps to reduce the scale of the building, and create a pedestrian-friendly environment.

The garage integrates a number of unique features including edge lighting, colored elevator core lighting, metal screening and an LED digital billboard. The unique lighting components portray visual waves around the top of the parking facility, with changing colors and a video screen. These features contribute to a livelier atmosphere along the streetscape.

The Wave also includes energy efficient lighting throughout, electric vehicle charging stations, and a 54,000 square foot solar array to provide renewable energy. Each of these components will contribute to a considerable reduction in energy use within the garage and retail areas, as well as significant savings in associated energy costs throughout its useful life.

The transformation of this high-profile site will provide an inviting gateway or “front door” experience to arriving visitors. The Wave will enhance the ambiance of this important section of the city and improve

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the neighborhood fabric. However, in addition to creating an exciting destination for tourists, the project has also generated a greater sense of pride within the community. Residents of Atlantic City have come together to show their support for the project, and believe that it will prove vital in improving the overall perception of the city.

The project also included the addition of two floors of Class-A office space above the parking structure, and the conversion of retail space along Pacific Avenue.

The renovated Pacific Plaza complex is a model of sustainable design. The USGBC awarded the project with a LEED Platinum Core and Shell certification. This was the first core and shell construction project in Washington State to achieve this designation.

The renovated Pacific Plaza complex virtually eliminated rainwater runoff. A 28,500 square foot green roof, the first of its size in Tacoma, captures and filters stormwater runoff, which is collected as gray water for non-potable use and irrigation of rooftop vegetation.

New energy-sipping garage lighting with daylight harvesting sensors ensure that the garage is well-lit, yet energy efficient during peak usage hours. Select lighting fixtures turn off at night to conserve energy.

The garage includes a number of features which encourage energy conservation and sustainable practices by users, including twenty-six preferred parking stalls reserved for alternate fuel and low emission vehicles. Also, to encourage alternative commuting methods, a secure storage area accommodates twenty-one bicycles. In addition, each floor of office space features complimentary storage lockers, showers and a private changing area to those who walk, jog or bike to work.

The sustainable theme throughout the garage is complemented by environmental graphics and wayfinding signage. Parking levels are named in accordance with Pacific Northwest natural themes including Ocean Wave, Coastal Sand and Pacific Sun.

Pacific Plaza reused 78.3 percent of the original building, and diverted 97.9 percent of all construction waste from the city landfill to be recycled into other byproducts. Over all, the new building design specified 35.6 percent in recycled products and nearly 12 percent of all products used were obtained regionally. Throughout, 72.6 percent of all wood products used were harvested from Forest Stewardship Council accredited forests.

**PACIFIC PLAZA COMPLEX GARAGE RENOVATION**

Owner: City of Tacoma
Location: Tacoma, Wash.
Submitting Firm: BLRB Architects

**About the Project:**

The City of Tacoma, Washington faced a dilemma in determining the most appropriate steps forward concerning its downtown parking facilities. One of the facilities in question was the Pacific Plaza Complex parking garage which, while nearly fully leased and quite profitable, had become an eyesore in the downtown core. The parking facility featured outdated design features and a serrated concrete finish that had rapidly aged the building long before its time.

However, rather than demolish the garage, the city implemented a complete seismic overhaul and added three floors to the building. The addition included 102 new parking spaces, a new stair and elevator core in the center of the garage and the modernization of existing stairwells to improve safety and visibility.
About the Project:

The University of Florida’s Southwest Parking Garage Complex was the first parking garage in the United States to achieve LEED Gold certification. The facility provides 927 parking spaces, as well as a two-story integrated Transportation and Parking Services liner building.

The complex is part of University of Florida’s pioneering “green” Master Plan. The University implemented a number of sustainable planning, design and construction strategies, which were critical to the successful achievement of LEED Gold certification. For instance, the complex occupies the footprint of a previous 300-space surface parking lot, providing more than three times more parking spaces, as well as significant office space.

The parking facility includes features which encourage alternative transportation access such as secured bike/moped storage, changing rooms and showers for commuters, convenient access to local bus transit systems and parking spaces for carpool vehicles and plug-in facilities for fuel-efficient vehicles. In addition, walkways are fully integrated with existing pedestrian circulation networks and bicycle parking areas.

The garage includes materials and treatments used to minimize the “heat island effect” generated from sunlight on surfaces. These include pervious concrete pavers, maximum use of grass as ground cover, reflective pigments in roof surfaces and extensive use of high-shade trees.

Surrounding the parking garage, drought-tolerant native grasses and plant materials help to reduce the use of water for landscaping. There is no long-term mechanical irrigation, which helps to reduce water consumption by approximately 70 percent. Non-potable water is used for landscaping irrigation. Nearby, a dedicated landscape buffer protects adjacent wetland area, providing natural filtration of runoff from the complex.

The facility includes a number of strategies to reduce energy use. An energy-efficient lighting system, utilizing solar photo cells with back-up timers, as well as motion sensors, reduces light use inside and outside the garage. In addition, lighting shields prevent light spillage from the garage onto adjacent areas. An insulated window glazing system also helps to reduce the amount of energy used for heating and cooling within the occupied spaces. The storefront systems provide an open feel within the liner building, which are controlled by motorized roller shades, thus allowing for energy savings.

Another unique aspect of this project is the university’s concern for the health of construction workers during construction, and of building occupants post-construction. By using low-emitting materials and taking precautions against the entrance of particulates into the air, the overall health quality of construction workers increased significantly. These precautions further affected the health quality of the permanent building occupants by reducing the long term effects of particulates and debris on permanent building systems.
The University of Florida sought to promote the significant achievements through the LEED Gold certification of this mixed-use parking facility. Throughout the garage, monitors positioned in customer service areas broadcast videos which explain strategies utilized in the complex to meet LEED standards. In addition, the university conducts site tours for students to educate them on the various planning, design and construction strategies incorporated in this sustainable parking facility.

North Carolina Department of Administration Parking Garage

Owner: North Carolina Department of Administration
Location: Raleigh, N.C.

About the Project:

The North Carolina Department of Administration parking facility is part of the Green Square Complex. The Green Square Complex is hailed as the most sustainable state-owned project ever developed in the state of North Carolina. This complex includes the DOA parking deck, an adjacent Nature Research Center and a Department of Environmental and Natural Resources Office building. The Nature Research Center is an addition to the adjacent Natural Science Museum, and includes 2 levels of below-grade parking that extends under and ties to the DOA parking deck. The NRC parking adds approximately 400 spaces to the 900 spaces in the DOA deck resulting in a total of 1,300 parking spaces in the complex.

For this project, the design team successfully implemented sustainable design approaches that promote energy efficiency, reduce operating costs, increase long-term durability, and minimize impacts on the environment and the health of the deck patrons. This deck design incorporates numerous sustainable design elements, including the following:

- Rooftop photovoltaic array constructed over the entire parking decks’ roof level. The total PV system capacity is 250kw and can generate 330,000kw hours per year. The energy savings is equivalent to a reduction of 235 tons of carbon dioxide, or planning 700 trees, or removing 60 cars from the roadways. In addition to the clean energy generated, the PV arrays provide shade for rooftop parking reducing the heat island effect on the roof.

- Rooftop rainwater is collected and filtered through an oil-water separator and stored in a cistern to provide irrigation for landscaping within the Downtown Government Complex.

- Energy efficient LED lighting reduced power requirements, as well as the long-term maintenance costs required for re-lamping the deck over the life of the structure.

- Façade elements provide shade to the interior of the garage, while maintaining classification as an open parking structure, eliminating need for mechanical ventilation, as well as allowing natural lighting to help visibility during daylight hours within the garage.

- Car-charging stations (23 total) promote use of cleaner, more efficient electric vehicles for employees and visitors. Provisions have been made for an additional 20 car chargers to be installed at a future date.

- A reduced building footprint maximizes the efficiency of the parking layout, while maintaining an acceptable level of service for patrons.
Consideration of building orientation, incorporation of long-span construction to minimize columns, and openness of the parking deck perimeter maximized the amount of daylight at each level to reduce artificial lighting required during daytime hours of operation. In addition, the use of up-turned beams along the perimeter of the deck allows daylight further into the parking deck than traditional below-slab beams.

Lighting controls eliminate spillover of perimeter fixtures onto adjacent properties.

Fly-ash (a waste by-product) and air-entrainment in the concrete mix-design increased durability. This provides a productive use for a waste product and reduces the amount of cement required.

Structural members incorporated into the façade elements as finished products reduced the number of materials needed in the overall project.

Specified low volatile organic compound (VOC) limits for adhesives, sealants, primers, paints, and traffic coatings reduced negative impacts to air quality.

Upgraded revenue control technology with automatic vehicular identification provide more efficient transaction processing, resulting in shorter queues and less wait time for vehicles to idle.

Energy efficient passage elevators reduced power consumption by 50 percent.

Recycling canisters are located at every stair / elevator lobby on each parking floor.

COLORADO STATE UNIVERSITY LAKE STREET PARKING GARAGE

Owner: Colorado State University
Location: Fort Collins, Colo.
Submitting Firms: Carl Walker, Inc. / H+L Architecture

About the Project:

The Lake Street parking facility is located on the Fort Collins campus of Colorado State University. The facility serves as a gateway into the campus, and is a first step toward concentrating parking on the perimeter of campus to free up the core for pedestrians and public transit.

The Lake Street mixed-use facility is pursuing LEED Platinum certification. The garage includes reserved parking for low-emitting vehicles, on-site stormwater management and treatment, and an energy efficient induction lighting system.
A 9,000 square foot photovoltaic array provides on-site power for the structure. The array is located on the top level of the building. The steel tube structure supporting the PV panels spans across parking bays, while the power generated from the PV panels goes directly into the campus electrical grid. At least 35 percent of energy supplied to the building comes from green sources, including solar power and wind.

The landscaping around the facility includes plants that were selected to meet the campus landscape guidelines and improve the quality of stormwater. The landscaping treats 100 percent of the pollutants associated with stormwater runoff. Two long bioswales aid in the treatment of stormwater quality. The landscaping plan has resulted in a confirmed 40 percent savings due to reduced water use for water efficient landscaping.

The project earned LEED points for a number of features, including:

* Utilizing recycled materials including steel, aluminum and fly ash; regional material suppliers.
* Public bike storage.
* Enhanced ventilation and indoor air quality monitoring.
* On-site renewable energy generation.
* On-site water treatment and detention.
* Use of water-efficient landscaping.

As a result of the Lake Street parking garage's numerous sustainable design features, the university pursued LEED Platinum certification for the facility, and anticipates a LEED Gold rating.

**UNIVERSITY OF CALIFORNIA, SAN DIEGO**

**HOPKINS PARKING STRUCTURE**

Owner: University of California, San Diego  
Location: San Diego, Calif.  

**About the Project:**

The University of California at San Diego needed a new parking structure and planned the Hopkins Structure in conjunction with expansion of the San Diego Supercomputer Center, to more effectively accommodate growing parking needs.

The university initiated a sustainability movement on campus and the parking facility incorporates a number of sustainable design elements. One example of this commitment is the on-site photovoltaic system. The structure incorporates solar trees in the form of canopies of photovoltaic panels on the seventh level. The modules supply clean energy for the structure including power for vehicle charging stations.

The landscaping accomplishes sustainable best practices by incorporating native and drought tolerant trees and shrubs watered with drip irrigation. Plants are composed in like-water use zones with higher water plants located in stormwater collection zones. The entire parking structure is wrapped with newly-planted trees to enhance the transition between the building and the surrounding walkways, making paths more aesthetic and beautiful.

The garage incorporates numerous sustainable materials, including local concrete and aggregate as well as low VOC paints and coatings. In addition, the university was able to recycle 90 percent of the construction debris and encourages the use of alternative transportation by providing preferred parking for carpools, hybrids, and electric vehicles.
SONY ELECTRONICS HEADQUARTERS PARKING STRUCTURE

Owner: Sony Electronics
Location: San Diego, Calif.
Submitting Firm: International Parking Design (IPD)

About the Project:

The Sony Electronics Parking Structure located at the company’s headquarters in San Diego, Calif., is a dynamic addition to the complex, and accommodates the adjacent Sony Office Building, which achieved a LEED Gold certification.

The mixed-use parking facility includes a 12,200 square-foot fitness center and a 16,600 square-foot activity deck that features a basketball court. This element adds a unique and fun component to the structure’s uses. A convenient concrete bridge connects the office building to the fitness center and activity deck on the fourth level of the garage.

With environmental and energy awareness in mind, the structure utilizes green building practices by incorporating photovoltaic panels on the roof level. The parking facility also includes 48 bicycle racks and 12 double-sided bicycle lockers.

SAN JOSE MINETA SAN JOSE INTERNATIONAL AIRPORT CONRAC

Owner: City of San Jose
Location: San Jose, Calif.

About the Project:

As part of a comprehensive airport improvement program and a strong desire to make Silicon Valley’s airport more attractive and convenient for business travelers, the airport chose to relocate its rental car center and public parking directly in front of the new Terminal B. The parking facility accommodates 3,000 rental cars, with 350 public parking spaces and a 25,000 square-foot Customer Service Building (CSB).

Supporting the city’s environmentally conscious policies, the structure includes a 1.12 megawatt solar array on its four-acre roof. This array—one of the largest airport installations in the United States—consists of 4,660 panels and offsets approximately 20 percent of the structure’s overall energy use.

The structure is first of its kind to open with a stacked quick turnaround facility (QTA) for the area used by the rental car companies. The QTA allows the structure’s 10 rental car companies to wash and fuel all cars immediately and onsite, and return them to service very efficiently. In addition to reducing rental
companies’ operating costs, the QTA eliminates rental car trips between facilities, which relieves traffic on airport roads and reduces congestion and vehicle emissions.

The parking facility contributed numerous points to the overall LEED Silver certification of the airport improvement program.

The rooftop design of the Ronald McDonald House fulfilled the mixed use potential for the site and was instrumental in the House attaining LEED Silver certification with 33 points.

The parking facility contributed a number of sustainable design strategies toward the LEED Silver certification of the Ronald McDonald House. Notable strategies include using fly ash in the concrete, energy-efficient lighting throughout the structure, preferred parking for low-emitting and fuel efficient vehicles, and charging stations for electric vehicles.

In addition, the garage also provides support for a number of attractive destinations to enhance the experience of House guests and create a greater sense of community. A podium built on top of the garage includes a playground, significant green space, and fountains. This area creates an attractive plaza area to serve the residential units that surround it. In addition, the roof of the Ronald McDonald house features a solar array which helps offset the energy used there.

RADY CHILDREN’S HOSPITAL PARKING FACILITY
Owner: Rady Children’s Hospital
Location: San Diego, Calif.
Submitting Firm: Walker Parking Consultants

About the Project:

The Rady Children’s Hospital Parking Structure in San Diego, Calif., was a project born out of necessity. The addition of the new Acute Care Tower project, which added 104 patient beds to the existing 500,000 square-foot hospital, spotlighted an already critical lack of available parking.

The hospital has a close relationship with Ronald McDonald Charities and has had a Ronald McDonald House on-site since 1980. To accommodate this and effectively use space, the hospital built a state-of-the-art 47-bedroom Ronald McDonald House on top of the parking structure. The House includes a computer lab, teen center, laundry facilities, play room, dining services, and even a beauty salon for families.

MOUNTLAKE TERRACE TRANSIT CENTER
Owners: Community Transit and Washington State Department of Transportation
Location: Seattle, Wash.

About the Project:

Community Transit (CT) is the main public transit authority in Snohomish County, Washington, providing bus and vanpool services for about 40,000 passengers per day. Environmental stewardship is one of the agency’s core values, so it was only natural to create a green park-and-ride structure for commuters.

One of Community Transit’s goals is to help reduce single occupant vehicles on the roads. CT understood that one way to do this is to provide easy-to-use public transportation that is accessible to the local population. As a result, CT developed the Mountlake Terrace Transit Center, which includes a parking garage and surface lots with space for up to 880 vehicles.
Community Transit sought to ensure that the park-and-ride structure incorporated green design and construction principles. They started with an integrated team approach during design development, including collaboration among the owner, architects, engineers, consultants, the public, and stakeholders.

The Transit Center was developed on an existing site, which minimized ecological effects. Minimal trees were removed for construction of the five-level structure, and the project reduced stormwater runoff with increased pervious surface area.

The Transit Center uses energy-efficient lighting fixtures, lamps, ballasts, HVAC equipment, controls, and elevators. The ceiling is painted white for maximum reflectivity, and motion sensors allow lighting to be reduced during non-operational times. In addition, the lighting is designed to minimize light trespass to adjacent properties.

The south side of the building features a solar array that is rated to output 5440 watts under peak sun conditions. The panels are estimated to generate 5500 kWh per year. This will offset more than 3.5 tons of CO2 per year and is enough to run two energy efficient homes.

CT is in the process of seeking a green building rating for the Mountlake Terrace Transit Center structure. Using the Green Globes system, it could become one of the few uninhabited structures in the world to be rated as a commercial green building.

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**EAST 54 MIXED-USE DEVELOPMENT**

**Owner:** East West Partners Management Company  
**Location:** Chapel Hill, N.C.  
**Submitting Firm:** Kimley-Horn and Associates, Inc.

**About the Project:**

Located in Chapel Hill, N.C., East 54 features 500,000 square feet of hotel, office, retail, and residential development spread through six buildings, along with 350,000 square feet of structured parking.

Building 400 is a six-story structure featuring two levels (43,000 square feet) of residential condominiums over a four-level parking deck. The 370-space parking facility was designed to serve condominium residents, office workers, hotel visitors, and retail patrons who live, work, and/or visit the East 54 complex. The deck’s first level is below grade, enabling it to connect to the other buildings on-site via the basement level parking under each building. Building 400 also includes a clubhouse and three-lane swimming pool on the first residential floor, on top of the deck.

In addition, an elevated plaza is located between each of the buildings on the site, connecting each building at the ground floor level. The plaza serves as a connector for the buildings as well as a roof for the basement parking below.

The East 54 Development achieved Gold certification in the LEED® Neighborhood Development (ND)
pilot program. As part of the ND pilot program, this development is leading the way for future mixed-use projects in defining sustainable design in new developments. Sustainable design elements incorporated into this project include:

◆ Parking deck integrated into a residential building to minimize site impacts and incorporate required number of spaces close to destinations. This results in several impacts to reducing the project’s overall carbon footprint, including:
  – Reduction in heat island effect of the parking, as the parking footprint is smaller, and 50 percent of parking is under cover/ below grade. Heat island was also reduced by incorporating a highly reflective paver system on the plaza space above the parking structure.
  – The parking proximity to the residential, office, and retail components reduces overall vehicle trips, reducing gas emissions and consumption.
  – Stormwater effects are reduced as a result of smaller areas of impervious pavements that are created through the development of a parking structure integrated into the building.
◆ Connection to local and regional transit, providing convenient alternative transportation modes to the site.
◆ Parking deck includes bike storage facilities to promote low-impact modes of transportation. Showers and locker facilities were also provided to serve office and residential tenants.
◆ The parking deck roof serves as a community space with a pool and terrace space.
◆ The parking deck concrete incorporated fly ash (a waste byproduct) and air-entrainment into the concrete mix to increase durability. This technique provides a productive use for a waste product and reduces the amount of cement required.
◆ The design team specified low-volatile organic compound (VOC) limits for adhesives, sealants, primers, paints, and traffic coatings to reduce negative effects on air quality in the facility.
◆ The design of the parking deck allows it to meet open parking garage requirements, allowing natural ventilation and eliminating the need for mechanical ventilation systems.
◆ Incorporation of structured parking left open area on site for a playground facility and a community park which is dedicated for use by the citizens of Chapel Hill.
◆ The numerous openings and access points throughout the development contributed to a pedestrian-friendly environment featuring walkable streets.
◆ Connectivity is provided through multi-use pedestrian paths between the East 54 community and surrounding larger neighborhood.
◆ The development features a comprehensive waste management program and infrastructure.
OLD TOWN PARKING GARAGE

Owner: City of Traverse City
Location: Traverse City, Mich.

About the Project:

The Old Town Parking Deck is green right down to its core. Having received LEED Silver certification, the facility offers an array of creative sustainable elements providing financial and customer service advantages, in addition to environmental benefits.

Its location on a brownfield redevelopment site in the heart of the city’s Old Town section allowed the city to reclaim and remediate a piece of land that was contaminated through earlier industrial use. In addition, the facility’s central location encourages people to walk throughout the area after parking their vehicles, helping to reduce traffic and congestion on area roadways.

The facility includes many sustainable design external and internal elements, including a rooftop network of 180 solar panels that produce approximately 31 kilowatts of power on a sunny day; that’s more than enough to power the entire facility. On days when a surplus of electricity is produced, that surplus is returned to the city’s power grid. Further, the garage’s two stair/elevator towers are topped with green sedum roofs that not only reduce the heat island effect, but also filter stormwater.

Five car charging stations located inside the facility can recharge up to 20 electric vehicles throughout the day. The state-of-the-art stations can provide a full charge in just two hours. The structure’s lighting system also promotes sustainability. High efficiency fluorescent and LED controlled lighting is strategically located throughout the structure. The high efficiency of these lights is expected to provide energy and cost savings of nearly 60 percent over their lifespans.

Even the deck’s customer service amenities include impressive sustainable elements. The facility’s public restrooms feature dual flush toilets and low-flow faucets. The city expects to reduce the facility’s water use by approximately one-third through these plumbing features. Three recycling bins spaced throughout the garage provide places for patrons to dispose of cans, glass, and paper, as well as non-recyclables.

The Old Town Parking Deck also fosters sustainability by promoting downtown bicycle use. The structure provides a special area for bicycle enthusiasts and bike commuters. This section offers five bike racks where commuters can safely store their bicycles, as well as eight bike storage lockers for valuables.

Finally, the development team promoted sustainability through materials management. Most of the materials used in the structure’s construction were harvested and manufactured within 500 miles of the project site, dramatically reducing the amount of fossil fuels required to transport these materials. Additionally, more than 90 percent of the resultant construction waste was set aside for recycling rather than being disposed of in landfills.

Most of the sustainable design elements incorporated in the Old Town Parking Deck were implemented without adding significantly to the project cost. Many of the environmentally-friendly gains resulted from the creative use of more efficient plumbing, lighting, and other elements that can be found in any typical parking structure.
NATIONAL RENEWABLE ENERGY LABORATORY (NREL) PARKING FACILITY

Owner: National Renewable Energy Laboratory
Location: Golden, Colo.
Submitting Firm: Desman Associates

About the Project:

The new parking structure on the National Renewable Energy Laboratory (NREL) campus in Golden, Colo., proves that a parking structure can be designed and built sustainably with no or minimal additional cost. The facility is a showcase for energy efficiency, renewable energy technologies and water conservation that can be replicated by others.

The 1800-space garage is divided into two symmetrical halves separated by a dedicated pedestrian circulation area and monumental stair connecting all levels. The stairway is encourages pedestrian safety and activity while reducing the energy used by two elevators. Most of the employees parking in the garage use the stairs instead of the elevators, as no level is more than two flights from the connecting bus shelter. Additional glass-enclosed stairs are located at the east and west ends of the garage. All of the glass used on the parking structure is lined with a ceramic striped pattern to reduce bird strike fatalities.

The north, east, and west sides of the garage are screened with perforated aluminum panels that limit wind, rain, and snow entering the garage while allowing sunlight in. Photovoltaic (PV) panels make up the entire façade of the south side of the facility, and the roof consists of a prefabricated steel joists and truss girders supporting a PV panel canopy placed over metal roof decking.

The garage includes 90 preferred parking spaces for carpoolers and vanpools, 90 preferred spaces for low-emitting vehicles, and 36 spaces with electric charging stations. Water conservation features include a stormwater drainage system to a new detention pond, a drainage swale on the south side of the structure to encourage ground infiltration of stormwater and snow, and native and drought-resistant landscaping. Other site improvements include a new Site Entrance Building designed to achieve LEED Platinum certification, a recycling drop-off center for paper, plastic, glass, batteries, and electronics; parking for 30 bicycles, and 20 lockers for bicyclists.

The parking structure surpasses aggressive energy goals set by NREL due to very efficient LED lighting, day lighting design, occupancy controls, and a traffic management system. From the beginning, the design team and owner focused on the goal of adequately lighting the parking structure using minimal energy. A daylighting model created specially for the garage includes a combination of increased floor-to-floor height, an open cast-in-place structural system, perforated exterior panels, reflective surfaces, and large light wells, providing enough light to ensure the lighting system is turned off during the day. After dark, occupancy sensors detect pedestrians and vehicles as they move through the building, and quick-response LED lights turn on as they’re needed.

Other energy-saving features include natural ventilation, no mechanical system, and energy efficient parking barrier gates. The parking structure uses less than 160 kBTUs of energy per parking space per year and is 90 percent more efficient than a standard garage built to code. The project satisfies the goal of net-zero energy use for the parking structure and a nearby Research Support Facility with the PV panels,
which bring 1.13 MW of solar power to the campus. The PV panels also help offset the energy used by the electric vehicle charging stations.

The project team also selected building materials for sustainability and durability. The perforated panels are made from recycled aluminum that can be recycled again. About 35 percent of the building materials contain recycled content and more than 10 percent are regionally available, and it also incorporated low-VOC paints, stains, and sealers. Approximately 75 percent of the construction materials were recycled.

The garage was designed to meet the standards of LEED certification, and achieved the equivalent of LEED Gold certification, despite no available points for a mechanical system. If the parking structure had a mechanical system, it likely would have achieved the equivalent of LEED Platinum certification. The construction cost was $25.51 million, which equates to a cost per space of $14,172 for 1,800 spaces. Even with the new parking structure, NREL continues to offer bus passes and encourages its staff to carpool, bike to work, work alternative schedules, and telecommute when possible.

Notes

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PARKING SYSTEMS AND CONCEPTS

BOISE STATE UNIVERSITY BIKE FARM
Owner: Boise State University
Location: Boise, Idaho

About the Project:
Home to approximately 20,000 students, Boise State University is a metropolitan campus located in the heart of the state capital of Idaho. Bound by the river to the north and major roadways in the other three directions, access to campus can be hampered by limited available parking. Automobiles directly compete for space with the need for academic centers. The Campus Master Plan highlighted the need to enhance safety for cyclists and pedestrians, including improvements to the cross-campus bicycle and pedestrian routes that will help reduce modal conflict.

Boise State University implemented a comprehensive bicycle master plan. The Boise State Bike Farm not only encourages bicycle use, but also supports the bigger picture of making bicycling more attractive and safe.

The Boise State Bike Farm consists of three programs to increase ridership on campus.

◆ The Bike Barn: a secured parking area installed inside an auto parking garage.
◆ The Bike Corral: a valet parking program for on-campus events.
◆ Bike Pens: on-street parking bike parking areas made to increase bike parking and enhance pedestrian safety.

Bike Barn

The Bike Barn is a fenced-in facility installed inside one of two of the university’s parking garages. Its purpose is to provide long-term, secure bike storage for the campus community. To make room for the Bike Barn, the university converted underutilized car parking spaces underneath one of the garage ramps to accommodate bike parking.

Vertical mounted bike racks are located inside the fenced-in area. Users access the facility via key cards. An area that previously accommodated four car parking spaces now stores 65 bicycles and has room for 100. This not only secures the bikes from theft and vandalism, but offers protection against inclement weather conditions. Since opening in the fall of 2010, the use of the bike barn has tripled. In addition, due to the popularity of the first, the university added a second bike barn to a new parking facility constructed in 2011.

Bike Corral

The second feature of the Bike Farm is the Bike Corral. Adapted for the campus environment, the Bike Corral is a valet bicycle parking facility used during major campus events. The service is free, but donations are accepted. Student organizations provide volunteer valet services in exchange for the donations generated by users. Boise State also offers the Bike Corral for use during home football games, weather permitting.

Bike Pen

Bike Pens are three-sided bike racks placed in and against the curbs of the right-of-way of streets. Cyclists enter from the open side of the Pen from the sidewalk, where they are protected against vehicular traffic. The Bike Pen is an alternative option for areas without adequate space to accommodate bicycle parking in physically constrained areas.

When installed on the vehicular approach to a crosswalk, the Bike Pen can improve pedestrian sight lines and improve crosswalk safety. Rather than venture into the street to see around a parked car, pedestrians can see over the Bike Pen from the sidewalk. One pen accommodates 16 bicycles. In addition, the pens are custom made locally.

Boise State University’s goal is to increase the share of total trips to and from campus by bicycle. Not only does this support the university’s environmental objectives, but it provides for the opportunity to save valuable resources in deferring the construction of parking facilities, while potentially reducing the overall demand for parking on campus. This approach has helped encourage the use of bicycles on campus by applying creativity and seeking out best practices elsewhere.

UNIVERSITY OF COLORADO AT BOULDER PARKING AND TRANSPORTATION SERVICES (PTS)

Implementer: University of Colorado at Boulder
Location: Boulder, Colo.

About the Project:

At the University of Colorado at Boulder, commitment to sustainability and greening the environment are more than just words. They are a value statement that has endured for more than 30 years.

Parking and Transportation Services (PTS) is central to the university's sustainability efforts. Since the early 1990s, PTS has played a significant role in offering a variety of innovative transportation demand management solutions and sustainable programs. In spite of growing faculty and staff numbers, PTS' efforts have resulted in improved campus access, reduced carbon impact, and better use of scarce parking resources.
Eighty percent of CU’s 31,000 students and 55 percent of faculty and staff arrive by environmentally-preferable modes of transportation.

Use of the employee Ecopass has freed more than 1,000 parking spaces since the program’s start 12 years ago. Ecopass allows free bus and light rail rides throughout the Regional Transportation District’s service area. CU was among the first universities to produce and use biodiesel in its transit fleet of 22 Buff Buses. The buses provide 1.4 million rides annually, linking 6,000 residential areas to main campus classrooms and activities.

More than 1,300 new bike parking spaces were added to the campus in the past two years. Today, the number of bike spaces equals vehicle parking spaces on main campus. Biking and walking are safer with a major grade separated bike path. The CU Bike Station, in collaboration with the CU Environmental Center, offers repairs, loaners, mobile mechanic services, and information from experts (cyclists) at no charge to registered bike owners. The bike station registers 3,000 new bikes every year.

PTS re-lamped and re-wired its two parking garages to reduce energy consumption and take advantage of natural daylight resources. Improvements resulted in $30,000 in reduced energy costs per year and an investment payoff of three years. CU’s newest parking garage, under construction, will be its most environmentally-friendly, featuring LED lighting and pre-wiring for electric charging stations.

Other PTS innovations include a revolutionary porous pavement system made of recycled glass and aggregate that limits groundwater pollution, and car share and ride share programs. The car share program, a collaboration with a local non-profit, is offered to employees and departments as well as to students as young as 18.

PTS’ efforts in conservation and sustainable programs will continue with ambitious goals to minimize our environmental impact and maximize options and services for its customers.

2010 WINTER OLYMPIC AND PARALYMPIC GAMES BUS NETWORK

Implementer: SP Plus Gameday
Location: Vancouver, British Columbia, Canada

About the Project:

Within the event industry, it is well documented that the transportation function has one of the greatest environmental effects. This is especially true for major international events such as Super Bowl and multi-sport, multi-venue events such as the Olympic Games. In 2008, SP Plus® Gameday, a division of Standard Parking Corporation, was selected as the overall transportation master planner for the 2010 Winter Olympics in Vancouver. In this role, they designed cost-effective and environmentally-friendly ways to move constituent groups between accommodations and venues within Whistler and Vancouver, Canada. This also involved moving spectators and Olympic workforce from the greater Vancouver areas to the alpine and sliding events in Whistler and Cypress Mountains venues.

Accommodations and parking were in short supply in and around the mountain venues, and while the public transit systems were excellent, they needed to be enhanced as there was not enough equipment or personnel to support the thousands of additional people. To accommodate this mass of people, a network of buses running on scheduled services moved athletes, media, broadcasters, spectators, sponsors,
Olympic family, and workforce. To efficiently manage these tasks, SP Plus Gameday used its patented CNPR System (CNPR). The innovative, web-based travel demand management system became known as the Olympic Bus Network, or OBN. OBN served as the parking and bus reservation system influencing constituent behavior, resulting in responsible economic and environmentally sustainable efficiencies all while easing community impact.

The CNP>R System powered the Olympic Bus network (OBN) reservation process. The challenging roadway infrastructure, limited space for load zones, limited parking at venues, budget constraints, and the commitment to sustainability were the majority of the planning criteria and concerns. CNPR addressed and provided solutions to all concerns including the International Olympic Committee. By using buses instead of cars, the system moved people more efficiently and economically, while reduced the environmental effects. For each busload of 50 people, the system removed approximately 18.4 cars off highway.

The project began with the creation of a French/English website where customers entered event session codes. Depending on the event, CNPR displayed specifically assigned departure hub locations and departure times, as well as routing information for the constituent to their appropriate departure hub which saved drivers time while reducing emissions in the Vancouver area. All departure hubs were in close proximity to public transit modes, further reducing the Olympic Theater’s reliance on individual cars.

OBN provided actual data, allowing the team to more efficiently manage assets and allocate equipment, space and staffing resources more efficiently. Taking vehicles off the road and adding passengers to high-occupancy vehicles decreased traffic congestion and lowered GHG emissions. Routing information and providing other travel options guided customers to the departure hub, decreasing impacts on local neighborhoods.

With more than 5,500 athletes and team officials, 1,400 international federations, 51,900 workforce, 12,700 media, 3,300 Olympic family, 34,000 sponsors, and 1.2 million ticketholders, the CNP>R System allowed for a detailed and carefully integrated plan for each venue and system proved invaluable throughout the Olympic games. Levels of background traffic, public transport, park and ride, pedestrian traffic, and on- and off-street parking were unprecedented in a Winter Olympic Games.
for members of the community and visitors. However, they also resulted in the closing of some roadways, alterations to building access points, the informal movement of vehicles on pedestrian paths, and other undesirable habits related to materials management, service, and deliveries.

A set of reasonable compromises was needed between the goals of the campus plan, the desire for a safer and more sustainable campus, and the realities of the activities that are necessary for the daily operations of the institution.

In response, a campus-wide access management plan was developed to cover on-campus deliveries (central stores, mail, food), on-campus services (facilities services, accessible van deliveries, recycling), and vendor deliveries (materials, food, FedEx, UPS, etc.). The assessment process included:

- Documenting existing conditions, including cordon counts of vehicles entering the campus core, vehicle dwell times, and identification of campus and external vehicles.
- On-site interviews of members of the campus community responsible for services and deliveries.
- Review of existing policies, directives, and contracts.
- Identification of specific conflict areas needing resolution.

A comprehensive building access and delivery information system was developed, including access instructions, maps, and building-specific access and loading details. No truck idling, more direct access routes, less traffic, and fewer environmental impacts are major goals of the new system.

Working with the university’s IT and facilities departments, the new information products were developed for web access by campus departments and all vendors serving UConn. Vendors are now required to follow strict routing and delivery procedures, and enforcement is handled through Campus Police and a newly reorganized Transportation, Logistics, and Parking Department.

UConn’s new president and its COO created a campus appearance committee that reached unanimous consensus to adopt the access management plan. The committee recommended priority funding for the plan’s implementation, which included a communication campaign for public service announcements and training for university staff to ensure compliance with the plan’s provisions.
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