Principles of Sustainable Transportation in the National Parks

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Introduction

Transportation and national parks are intimately linked. For example, nearly 300 million visitors per year travel to and within the US national parks. Moreover, American national parks comprise over 80 million acres of public land and include extensive networks of transportation corridors—roads, trails, bike paths, waterways, and public transit—that link a vast array of iconic attraction sites—viewpoints, historical and cultural sites, visitors centers, campgrounds, and gateway communities. The inherent complexities of this intersection between transportation and national parks demand more explicit research and management attention.

But transportation is more than a means of access to national parks. It can be a form of recreation itself, offering most visitors their primary opportunities to experience and appreciate the natural and cultural landscapes embodied by national parks. For example, the iconic roads of many of the "crown jewel" national parks—Going-to-the-Sun Road in Glacier, Tioga Road in Yosemite, Trail Ridge Road in Rocky Mountain, and the Park Loop Road in Acadia—were designed for visitors to experience the parks in their cars and are important manifestations of the historic and contemporary linkages between transportation and national parks (Louter 2009; Runte 2010). In fact, entire units of the national park system, such as Blue Ridge Parkway, have been designed specifically for this purpose. All of these roads were a response to demand for "driving for pleasure," historically one of America's most popular recreation activities (Manning 2011).

Transportation can be even more than this: it is also a potentially powerful tool for managing the national parks. The transportation networks and linkages in parks help determine where park visitors travel (and where they don't) and can be used by park managers to help deliver the "right" number of visitors to the "right" places at the "right" times (Manning 2007; Lawson et al. 2009; Manning 2009). In this way, transportation can be used to manage national parks in a sustainable way by protecting park resources and the quality of the visitor experience.

Interest in these linkages between transportation and national parks has led to a growing body of scientific and professional literature on this topic. The studies referenced in this

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paper are representative of a growing body of knowledge. These studies address the interface between transportation and a diverse group of national parks, use natural and social science methods, and address a range of transportation systems and issues. They draw on the scientific and professional literature in the fields of transportation and parks and outdoor recreation. While study of transportation in the context of national parks is in its early stages, a set of principles to help guide transportation management in national parks is beginning to emerge. Based on our review of the scientific and professional literature, we develop and present a set of principles for sustainable transportation in the national parks.

Principles of managing sustainable transportation in the national parks

Principle 1. Transportation and national parks are inextricably linked. This is the initial premise of this paper, and the growing scientific and professional literature bears this out in multiple ways. In their early history, transportation—by horse, stagecoach, and railroad at first and later and more generally by automobile—provided public access to the parks that was needed to build widespread societal appreciation and support (Louter 2009; Runte 2010). Even today, roads and to a lesser extent trails are the primary ways in which the vast majority of visitors experience and enjoy the national parks. But ease of access has led to a number of contemporary issues regarding the impacts of large and growing use of the parks, as well as the impacts of conventional transportation itself, primarily in the form of automobiles. (These issues are described more fully in Principles 2 and 3 as well as subsequent related principles). National parks have entered a new era in which transportation management is evolving to address these issues; examples include many forms and innovative applications of alternative transportation systems (ATSs; e.g., shuttle buses) and more deliberative and purposeful management of transportation to more fully meet the array of issues associated with contemporary park management. Examples include recent programs of interdisciplinary research at Yosemite (Meldrum and DeGroot 2012; White et al. 2012; Reigner et al. 2012) and Denali National Park and Preserve (Phillips, Hooge, and Meier 2010; Phillips, Mace, and Meier 2010; Manning and Hallo 2010; Morris et al. 2010) where research is helping guide transportation planning and management to protect foundational park resources (e.g., wildlife), enhance the quality of the visitor experience, and employ transportation as a powerful park management tool.

Principle 2. Transportation is central to the foundational two-fold mission of the National Park Service (NPS). National parks are to be managed in ways that protect park resources and the quality of the visitor experience while providing public access for enjoyment and appreciation. But under conditions of high and growing demand, these objectives can often conflict. There was little concern over road building in the early history of the national parks because use levels were low and parks were primarily considered to be monumental scenery (Runte 2010). However, as use of the national park system now approaches 300 million visits annually, transportation is an increasingly vital manifestation of the tension between use and preservation. Roads and other components of park transportation systems largely dictate the levels and types of uses the national parks accommodate. Moreover, these roads and other elements of the transportation systems in parks can themselves impact park

resources and the quality of the visitor experience (these resource and experiential impacts are addressed more fully in Principles 5 and 6, respectively). A growing number of studies of transportation in the national parks describe these issues and how they are playing out across the landscape of the national park system. Yosemite is often considered the poster child for the issue of use versus preservation, and the defining role of transportation in Yosemite is described in several recent studies and papers (Youngs et al. 2008; Meldrum and DeGroot 2012; White et al. 2012; Reigner et al. 2012). Similarly, a number of studies have addressed the role of transportation in meeting the two-fold mission of national parks at a diversity of other parks, including Denali (Phillips et al. 2010; Phillips et al. 2010; Manning and Hallo 2010; Morris et al. 2010), Rocky Mountain (D'Antonio et al. 2013; Lawson et al. 2011; Park et al. 2009–2010; Pettebone et al. 2011), Acadia (Roof et al. 2002; Pettengill et al. 2012; Hallo and Manning 2010; Holly et al. 2010), and Zion (Roof et al. 2002; Mace, in press). These studies are designed to help guide transportation planning and management through development of ATSs and using transportation in purposeful ways to deliver the "right" number of visitors to the "right" places at the "right" times.

Principle 3. Transportation is central to the foundational issue of carrying capacity of the national parks. This principle follows directly from Principle 2. Carrying capacity is a long-term and increasingly urgent issue in the national parks and is generally defined as the amount and type of use that can be accommodated in parks without unacceptable impacts to park resources and the quality of the visitor experience (Manning 2007). Principle 2 suggests that transportation plays a vital role in mediating and managing the inherent tension between use and preservation that is at the heart of the carrying capacity concept. Transportation networks (e.g., roads) and services (e.g., ATSs) dictate the amount and distribution of park use and thus the impacts of this use. As noted in Principle 2, several studies have been conducted on the relationship between transportation and carrying capacity in Yosemite, the park that is often thought of as most representative of that issue (Youngs et al. 2008; Meldrum and DeGroot 2012; White et al. 2012; Reigner et al. 2012). Contemporary management of the park aspires to use the transportation network to deliver the "right" number of visitors to the "right" places at the "right" times as informed by a program of research. Likewise, studies of the role of transportation in the carrying capacity of national parks have been conducted on the Denali Park Road (Burson et al. 2000; Phillips, Hooge, and Meier 2010; Phillips, Mace, and Meier 2010; Manning and Hallo 2010; Morris et al. 2010). In this case, it's the carrying capacity of the road itself that's an important part of the issue: how many vehicles can use the road without unacceptable levels of disturbance to the park's iconic wildlife and while maintaining the wilderness character of the road experience? These and related issues permeate the scientific and professional literature.

Principle 4. Transportation management in the national parks should be guided by a management-by-objectives framework that incorporates formulation of indicators and standards of quality. Several conceptual and organizational frameworks have evolved in the scientific and professional literature on parks and outdoor recreation and transportation (Manning 2011; Transportation Research Board 2010). Examples include the concept of carrying capacity, indicators and standards of quality, and levels of service (LOS). These

frameworks have contributed to development of a broader, management-by-objectives framework to guide transportation management in the national parks. This framework comprises three primary steps: (1) formulating management objectives and associated indicators and standards of quality; (2) monitoring indicator variables; and (3) taking management actions to ensure that standards of quality are maintained (Manning 2007). A growing number of papers incorporate this approach to transportation management in the national parks and support formulation of transportation-related indicators and standards of quality. Examples include studies at Denali (Phillips, Hooge, and Meier 2010; Phillips, Mace, and Meier 2010; Manning and Hallo 2010; Morris et al. 2010), Yosemite (Meldrum and DeGroot 2012; White et al. 2012; Reigner et al. 2012), Acadia (Roof et al. 2002; Pettengill et al. 2012; Hallo and Manning 2010; Holly et al. 2010) and Rocky Mountain (D'Antonio et al. 2013; Lawson et al. 2011; Park et al. 2009–2010; Pettebone et al. 2011). All contribute to transportation-related programs of research aimed at supporting and implementing the management-by-objectives framework described above, including formulating indicators and standards of quality.

Principle 5. Transportation in the national parks can have important environmental implications. Transportation, primarily in the conventional form of private automobiles, can have important environmental impacts on park resources. For example, an NPS-wide survey estimates well over 10,000 vehicle–wildlife collisions over a recent 18-year period (Ament et al. 2008). Research at Denali has documented changes in wildlife behavior related to traffic on the Denali Park Road (Burson et al. 2000; Phillips, Mace, and Meier 2010). Impacts on soil and vegetation caused by unauthorized parking, along with other traffic-related issues, led the NPS to close the road in Zion Canyon to private autos and institute a shuttle bus system (Mace, in press). Studies at Rocky Mountain, Zion, and Acadia document the noise generated by transportation, which can impact animals and detract from the quality of the visitor experience (Park et al. 2009–2010; Roof et al. 2002). And, of course, there are substantial air pollution and greenhouse gas problems associated with the cars and other vehicles visitors use in national parks (Roof et al. 2002).

More sustainable transportation, primarily in the form of ATSs, can lead to substantial environmental benefits. For example, the shuttle bus system in Denali has been designed to limit the number of vehicles on the park road, reducing the chance of collisions with and disturbance of wildlife (Phillips, Mace, and Meier 2010). In particular, the scheduling of shuttle bus service allows for the vehicle-free intervals needed by Dall sheep to safely cross the road corridor. A sophisticated modeling approach demonstrates the substantial reductions in both air pollution and human-caused noise that have been gained by use of shuttle bus systems at Zion and Acadia (Roof et al. 2002).

However, poorly planned ATSs can lead to unanticipated environmental impacts (or "downstream effects") as described in studies at Rocky Mountain (D'Antonio et al. 2013; Park et al. 2009–2010). In this case, the shuttle bus system delivered more visitors to sites in the Bear Lake area of Rocky Mountain than these areas could accommodate, and this has resulted in substantive impacts to soils and vegetation along trails and at attraction sites.

Principle 6. Transportation in the national parks can have important experiential implications. Given the strong historic and contemporary linkages between transportation and

the national park experience as described in Principle 1, transportation can affect the quality of the visitor experience in many ways. When visitor-use levels are relatively low, visitors can leisurely drive uncongested park roads, stopping and parking at iconic park attractions, hiking uncrowded trails, and experiencing park resources that are protected in their natural condition. However, when visitor-use levels are high, park roads can become congested, visitors can have difficulty finding a place to park, and park resources can become degraded, particularly at iconic park attractions and trails. These kinds of traffic conditions and associated impacts on the quality of the visitor experience are characteristic of a growing number of national parks. ATSs can help maintain high-quality visitor experiences by substantially reducing traffic congestion and parking problems. But even ATSs can be subject to crowding, can be inconvenient or otherwise stressful (e.g., run on an infrequent schedule), and can deliver too many visitors to selected locations, causing crowding and resource impacts and degrading the quality of the visitor experience (as described at Rocky Mountain in Principle 5). Transportation must be planned and managed in ways that create and maintain high-quality visitor experiences.

Principle 7. Transportation is an important form of recreation in the national parks. Following on Principle 6 and emphasizing its importance, transportation is a form of recreation for the vast majority of national park visitors. As described earlier, the iconic roads of many of the national parks were designed to facilitate enjoyment and appreciation of the parks. Driving for pleasure has long been a favorite American pastime, and nowhere is this more true than in the national parks. Of course, ATSs can be added to the list of transportation networks that are vital to shaping the quality of the visitor experience. A growing number of studies illustrate ways in which transportation can be planned and managed to help ensure high-quality visitor experiences. For example, several studies suggest standards of quality for traffic congestion on roads in Acadia, Denali, and Yosemite (Pettengill et al. 2012; Hallo and Manning 2010; Manning and Hallo 2010; White et al. 2012). These studies also suggest standards of quality for trail use in these parks. Other studies suggest standards of quality for ATSs at Acadia (Pettengill et al. 2012), and illustrate the extent to which ATSs have (or can) reduce air and noise pollution at Zion, Acadia, and Rocky Mountain (Park et al. 2009–2010; Roof et al. 2002). These and related studies offer guidance on planning and managing transportation to help ensure the quality of the visitor experience.

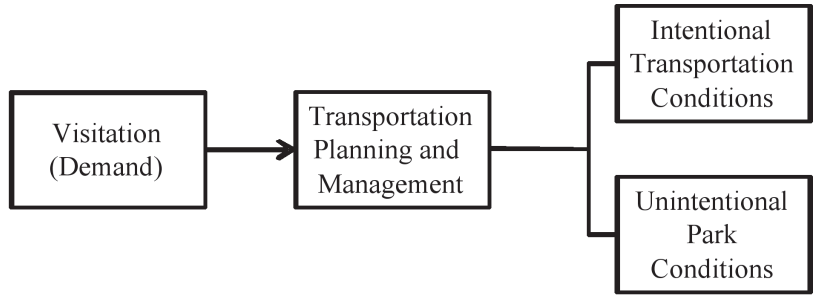
Principle 8. Transportation can be an effective management tool in national parks. Given the linkages between transportation and visitor use in the national parks, as described above, transportation can and should be used as a potentially powerful park management tool. Several studies offer good examples of the ways in which this can be done. For example, the ATS program at Denali has been designed to limit the impacts of vehicles on wildlife along the Denali Park Road (Phillips, Hooge, and Meier 2010; Phillips, Mace, and Meier 2010; Manning and Hallo 2010; Morris et al. 2010). ATSs are also effective at reducing air pollution and greenhouse gas emissions at Zion, Acadia, and Rocky Mountain (Lawson et al. 2011; Roof et al. 2002), and reducing noise pollution at Rocky Mountain (Park et al. 2009–2010). Simulation modeling at Acadia suggests that traffic congestion on the Park Loop Road could be substantially mitigated by eliminating parking in the right-hand lane

(though this would also reduce availability of parking at several key attraction sites) (Hallo and Manning 2010). Research programs at Rocky Mountain and Yosemite illustrate the way in which transportation can and probably should be used to help manage the carrying capacity of national parks by delivering the "right" number of visitors to the "right" places at the "right" times (Meldrum and DeGroot 2012; White et al. 2012; Reigner et al. 2012; D'Antonio et al. 2013; Lawson et al. 2011; Park et al. 2009–2010).

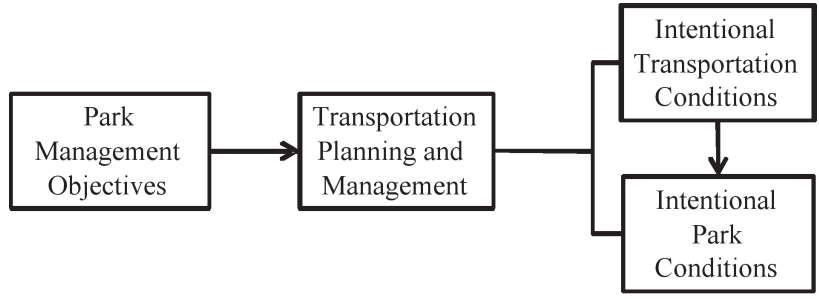
This is in contrast to the more conventional "demand-driven" approach to transportation management as illustrated in a study at Grand Canyon (Byrne and Upchurch 2011). At Grand Canyon, parking facilities were developed at the park's new visitor center based on estimates from a robust statistical model of the number of parking spaces needed to accommodate visitor demand. This study was well designed and executed and has helped solve the parking problem. However, it is unknown whether the new parking lot is sized to accommodate the "right" number of visitors (i.e., a sustainable level of visitation), or results in levels of visitor use that cause unacceptable impacts to park resources and/or the quality of visitors' experiences at nearby attraction sites and trails.

Other studies illustrate a more deliberative and ultimately informed management approach by using transportation to help achieve park management objectives. For example, studies at Rocky Mountain, Denali, and Yosemite have identified standards of quality for traffic congestion on key park roads, the number of hikers on key trails, and the number of people-at-one-time at iconic attraction sites (White et al. 2012; Reigner et al. 2012; Manning and Hallo 2010; Lawson et al. 2011; Hallo and Manning 2010). In this way, park transportation infrastructure and programs—amount and location of parking, design and scheduling of ATSs, hiking permit systems—can be planned and managed to help meet park management objectives related to minimizing impacts to park resources and the quality of the visitor experience. This approach to using transportation as a park management tool, in contrast to a conventional demand-driven approach, is illustrated graphically in Figure 1.

Principle 9. There is growing use and support for ATSs in the national parks. Several studies describe early and relatively large ATS programs at Acadia (Roof et al. 2002; Pettengill et al. 2012; Holly et al. 2010), Rocky Mountain (D'Antonio et al. 2013; Lawson et al. 2011; Park et al. 2009–2010; Pettebone et al. 2011), Denali (Phillips, Hooge, and Meier 2010), and Zion (Roof et al. 2002; Mace, in press). These are widely regarded as successful models for the national park system. Beyond these high-profile examples, many other units of the national park system have adopted large and small ATS programs that involve shuttle buses, ferries, and historic and specialized vehicles. Some of the ATS programs are voluntary and others are mandatory, while some charge a fee and others are "free" (though, of course, all must be paid for in some way). There is a growing body of evidence that ATSs are well received by most visitors and that ATSs can be designed to serve the needs of both park management and visitors. For example, visitors overwhelmingly support the mandatory shuttle bus system at Zion (Mace, in press). At Grand Canyon, more visitors are choosing to use the voluntary shuttle bus system than expected (Byrne and Upchurch 2011). At Great Smoky Mountains, a general population survey found that 75% of respondents supported a mandatory (but free) shuttle bus system at iconic Cades Cove, and over 50% reported they would



a. Conventional Transportation Management Model



b. Sustainable Transportation Management Model

Figure 1. Conventional and sustainable transportation management models.

pay a fee for this service (Sims et al. 2005). Moreover, the value of the improved services to visitors (e.g., reduced traffic congestion) was estimated to be $32 million.

Several studies identify desirable properties of ATSs that encourage visitors to choose them over private autos. For example, a study at Yosemite (Youngs et al. 2008) found that ease of use (e.g., frequent scheduling), perceived freedom (e.g., ability to reach desired destinations), and stress reduction (e.g., less concern over issues such as parking) were highly desirable characteristics of ATSs and would help persuade visitors to choose them over their cars. Another study at Rocky Mountain found that visitors were more inclined to use ATSs when they were aware of the ways ATSs would improve the quality of the visitor experience: less traffic congestion, less crowding on trails, and no parking problems (Pettebone et al. 2011). Day visitors to Acadia suggested that desirable qualities of ATSs include frequent service (intervals of 15-to-25 minutes between buses), perceived freedom (convenient stops), knowledge of the environmental benefits of ATSs, and availability of educational/interpretive programming on shuttle buses (Holly et al. 2010).

Finally, successful use of ATSs seems to lead to a reinforcing cycle of more support of them. For example, at Zion, 98% of visitors who rode the park's shuttle bus system reported that they would use ATS programs at other parks as well (Mace, in press). The study at Yosemite described above also found that experience with ATSs in parks leads to greater support for and use of them (Youngs et al. 2008).

Principle 10. Conventional guidelines for managing transportation may need to be re-registered in the context of national parks. Transportation is generally managed according to guidance contained in the *Highway Capacity Manual* (HCM) (Transportation Research Board 2010). Research underlying the HCM has been conducted primarily in the context of "utility" trips where the primary objective is to provide the most efficient way to travel from origin to destination. However, these guidelines will often need to be re-registered in the context of national parks and related areas where driving, walking, biking, public transit, and other forms of transportation are designed to offer a more leisurely experience to allow greater enjoyment and appreciation of the landscape and associated park attractions and features. A study at Acadia is especially instructive by developing density-related standards of quality for three modes of transportation in the park: driving on the Park Loop Road, hiking and biking on the park's carriage roads, and riding the park's Island Explorer shuttle bus system (Pettengill et al. 2012). Study findings were overlaid with a conventional HCM LOS framework, and results suggest that for driving and hiking/biking, LOS A and B define a high-quality experience in the park context, LOS C and D define cautionary or "yellow light" conditions, and LOS D and E are unacceptable to visitors in the context of the national park. Results are similar but more complex for public transit. Moreover, findings from a study of the social carrying capacity of the Acadia Park Loop Road also provide compelling evidence that LOS needs to be registered in the context of national parks (Hallo and Manning 2010).

Principle 11. Transportation research and management in the national parks should be as integrative as possible. Carrying capacity in the context of national parks has both environmental and experiential components and these components are often interrelated. Moreover, the scientific and professional literature on transportation and parks and outdoor recreation should be integrated where possible. Principle 8 suggests that transportation can (and often should) be an important management tool. Finally, research methods can be integrated in ways that complement one another and offer synergistic advantages. Several studies offer illustrations of all these integrative approaches. For example, as described in Principle 10, the framework of indicators and standards of quality from the park and outdoor recreation literature was combined with the LOS framework from the transportation literature to develop insights into the quality of transportation in the context of national parks (Pettengill et al. 2012). As described in Principle 8, park transportation has been integrated with park and outdoor recreation management objectives and associated indicators and standards of quality in a coordinated program of research designed to use transportation as a park management tool at Yosemite (Meldrum and DeGroot 2012; White et al. 2012; Reigner et al. 2012), Denali (Phillips, Hooge, and Meier 2010; Phillips, Mace, and Meier 2010; Manning and Hallo 2010; Morris et al. 2010), and Rocky Mountain (Lawson et al. 2011). All of these programs of research incorporate both resource (e.g., impacts to soil, vegetation, and wildlife) and experiential (e.g., crowding) components.

Principle 12. Transportation management in the national parks should be conducted at a park-wide, regional, or landscape scale where appropriate. Impacts on parks from outdoor recreation often manifest themselves first at selected sites, such as iconic attractions and popular roads and trails. However, these areas and issues should be studied and man-

aged in a more geographically inclusive way to help prevent problems from arising elsewhere. In fact, "fixing" a problem in one area can sometimes simply shift the problem to another area. Several of the research and management programs described in the scientific and professional literature offer good examples of more geographically expansive approaches. For example, research at Rocky Mountain illustrates how the ATS system in the Bear Lake corridor has helped solve the road congestion and parking problems in this area, but has caused "downstream" problems of resource and experiential impacts at selected attraction sites and trails served by the transit system (D'Antonio et al. 2013; Lawson et al. 2011). Research and management attention has now shifted to identifying other sites in the park (and perhaps sites on public lands outside the park) where some park visitors might be diverted from the Bear Lake area. Transportation management at a larger, regional scale is illustrated in studies at Zion (Mace, in press; Manning and Anderson 2012) and Cape Cod National Seashore (Anderson and Manning 2012). At Zion, the park's shuttle bus system serves both the park and the gateway town of Springdale, offering convenience and "connectivity" for both visitors to the parks and residents who are employed in the park. At Cape Cod, all regional transportation providers cooperate and coordinate their schedules and services to offer the possibility of "car-free" vacations to the park and the surrounding region.

Principle 13. Transportation should be incorporated into comprehensive park management plans. Following on several of the above principles, transportation is an integral and vital component of national parks: it is an important form of recreation and park appreciation, and transportation can be an effective park management tool. Moreover, there are important environmental and experiential implications of transportation. Given the centrality of transportation to park management, transportation should be given explicit consideration in park planning and management. NPS has recently begun a program of preparing long-range transportation plans and this has the potential of being a very constructive initiative.

Principle 14. Transportation offers important opportunities to deliver information, education, and interpretive programs to park visitors. Visitors use many forms of transportation to travel to and through national parks, and information, education, and interpretive programming can be used to reach visitors during all phases and modes of transportation. Conventionally, visitor centers and wayside exhibits are used to communicate with visitors as they travel by personal vehicle through the park, and they can be effective. However, ATSs offer opportunities that may be especially efficient and effective in communicating with visitors. Public transit, by definition, gathers groups of visitors who may then be reached very efficiently. Moreover, a study of a proposed extension of the Island Explorer shuttle bus system to parking areas outside the Mount Dessert Island section of Acadia found that many potential transit riders placed a high value on interpretive services designed to inform and enhance the quality of their park visit (Holly et al. 2010). The highly successful ATS program at Zion has made the shuttle bus system an important visitor attraction in and of itself, in part due to the audio and personal interpretive programming delivered to visitors on the buses (Mace, in press).

Principle 15. Transportation management in the national parks should be conducted in a proactive manner. Like all good planning and management, transportation should be

used to avoid problems before they arise. Perhaps the best example of this is management of the Denali Park Road (Phillips, Hooge, and Meier 2010). With construction of a new highway in Alaska in the early 1970s that would make Denali much more accessible, park staff instituted a limit on the annual number of vehicle trips that could be taken on the Denali Park Road, the principal means of visitor access to the park. This limit was instituted to protect park wildlife and the quality of the visitor experience. This proactive approach to transportation planning has been a cornerstone and effective component of park management as use has increased dramatically over the past several decades.

Principle 16. Transportation management in the national parks should be as informed as possible. The management-by-objectives framework described in Principle 4 is fundamentally adaptive; that is, it encourages managers to make decisions based on the best information available. Moreover, through long-term monitoring of indicators of quality, the framework allows managers to update, revise, and refine management as new information becomes available. However, this shouldn't be used as an excuse not to seek out the best information possible. The growing number of studies on transportation in the national parks represent good-faith efforts on the part of park and transportation planners, managers, and scientists to help create a foundation of knowledge about managing transportation in national parks. The emerging set of principles presented in this paper is an effort to further this process.

Principle 17. Transportation management in the national parks can draw on an array of research methods and approaches. The studies described in this paper use highly diverse research methods to address a range of transportation-related problems and issues. These research approaches employ natural science methods when assessing environmental impacts of park use and use social science methods to address human dimensions-related issues. Methods common to many studies include qualitative and quantitative surveys of park visitors, park managers, and the general public; visual simulations of a range of park conditions; GPS-based tracking of visitor travel patterns; GPS-based tracking of park wildlife; traffic and parking data collection and analysis; computer simulation models of visitor travel patterns; acoustic modeling; and sophisticated statistical analyses. These and other research methods can be productively used to better inform transportation management in the national parks.

Principle 18. Transportation management in the national parks should be based on partnerships with important stakeholders. Transportation management at Cape Cod is an excellent example of this principle (Anderson and Manning 2012). The park is deeply embedded in the surrounding towns of the Outer Cape and it has successfully partnered with all levels of government, a variety of nongovernmental organizations, regional planning commissions, the local congressional delegation, a local university, and several businesses to create an increasingly coordinated transportation network that serves the needs of park management, park visitors, and local residents. Similarly, the public transit systems at Zion (Mace, in press; Manning and Anderson 2012) and Acadia (Pettengill et al. 2012; Holly et al. 2010) have worked closely with gateway communities to build strong elements of connectivity that serve the needs of park visitors and surrounding towns.

Principle 19. Transportation management in the national parks needs strong leadership. Strong leadership is a prerequisite of most successful planning and management proj-

ects, and transportation is no exception. Though this leadership is not always obvious in the papers that comprise the scientific and professional literature, it is more evident to those who have been involved in these efforts and understand and appreciate the vital role of key individuals and organizations; national park superintendents, planners, resource managers, and program directors; community leaders; non-profit groups; and congressional delegations. For example, at Cape Cod, the Cape Cod Commission (especially Clay Schofield) and the Massachusetts congressional delegation (especially US Representative William Delahunt) have been instrumental in building and supporting the coalition of park-related transportation partners on the Outer Cape (Anderson and Manning 2012).

Principle 20. Transportation management in the national parks should address traditionally underserved populations. National parks are important symbols of our nation's commitment to democracy; they are icons of our shared natural and cultural history, and they should be accessible to all people. Transportation management at Cape Cod represents one manifestation of this issue (Anderson and Manning 2012). In this case, the park is using beach wheelchairs and wheelchair-accessible beach paths to help ensure access to mobility-impaired visitors. However, there are other groups in society, particularly racial and ethnic minorities, who are substantially underrepresented in the national parks (Floyd 1998). Research suggests that transportation to national parks may be a barrier to visitation, and more research and planning are needed to help ensure equal opportunities to visit the national parks (Solop et al. 2003). Transportation management has an important role in this issue.

Principle 21. Transportation in the national parks should be managed by design, not by default. The growing scientific and professional literature illustrates ways in which resource and experiential conditions in national parks are related to transportation. Transportation can exacerbate or help mitigate these impacts depending on how transportation systems are designed and managed. Transportation management can be guided in many ways, including the types of studies noted in this paper. However, management will often require exercise of professional judgment. As described in Principle 16, management should be as informed as possible, but there are inherent limits to our knowledge at any point in time.

After attempting in good faith to inform themselves of the problems and issues facing parks and outdoor recreation areas, park and transportation managers must ultimately exercise their professional judgment. Unfortunately, there will rarely be perfect knowledge about the types of problems that exist in parks and their seriousness, the causes of these problems, and the effectiveness of alternative management practices. Nevertheless, park and transportation managers should find courage in their knowledge of the burgeoning scientific and professional literature, the conceptual and management frameworks that have emerged from this literature, the inherently adaptive nature of park and transportation management, and in the responsibilities with which they have been entrusted. Management programs can (and should) be revisited and revised based on monitoring and advances in scientific and professional knowledge. But the seriousness of transportation and related park and outdoor recreation issues in the national parks—the tension inherent in two-fold mission of the national parks, the growing urgency of carrying capacity, the need to formulate indicators and standards of quality—will require strong and deliberate management action.

Sustainable transportation in the national parks

Sustainability has emerged as a vital concept for the contemporary world, and for good reason: we must learn to live within the constraints posed by our environment or face the possibility of grave consequences in the form of a degraded planet and diminished quality of life. What better place to address this issue than in the national parks, iconic symbols of our commitment to protecting the environment? What better issue than transportation, one of the world's greatest consumers of fossil fuels and contributors to air and noise pollution and greenhouse gases? Sustainable transportation in the national parks makes good, common sense.

In important ways, the national parks have been at the forefront of sustainability for decades. National park management has been historically based on its foundational two-fold mission: to foster public use and appreciation of the parks while protecting their environmental and experiential integrity. This is at the heart of sustainability. In the context of the national parks, this issue is often called *carrying capacity*—how much and what kinds of use can be accommodated in the national parks without unacceptable impacts to park resources and the quality of the visitor experience? With annual visitation to the national parks nearing 300 million, this is an increasingly urgent question.

In the context of national parks, carrying capacity/sustainability has multiple dimensions: concern for the quality of the environment, concern for the quality of the visitor experience, and attention to the opportunities and constraints of management. This multidimensional framework is in keeping with the emerging body of scientific and professional literature on sustainability more broadly. For example, the earliest expression of sustainability in the contemporary environmental literature suggested that it had two important dimensions: ecological and social (Bruntland Commission 1987). More recent treatments of sustainability are based on what are often called the "three pillars" of sustainability, or the "three E's", or the "triple bottom line" (Elkington 1997). All of these frameworks suggest that comprehensive consideration of sustainability must address matters of environment, society, and economy. In the case of transportation in the national parks, the scientific and professional literature is beginning to address all of these dimensions. Most studies address the relationship between transportation and the environment and the quality of the visitor experience. However, less is known about the economic dimension of sustainable transportation. Long-term funding of public transit in the national parks is likely to be challenging, although research at Great Smoky Mountains found substantial willingness to pay for the benefits of ATSs (Sims et al. 2005), and Acadia's Island Explorer shuttle bus system is heavily subsidized by philanthropic giving, a model that might be more broadly used across the national park system.

Alternative transportation systems are one of the most promising manifestations of sustainable transportation in the national parks. The national parks feature many innovative and prominent forms of ATSs. Other national park ATS programs use ferries, trains, vans, historic vehicles, and other conveyances. Many of these ATS vehicles use alternative, less-polluting fuels. Of course, ATSs can mean pedestrian and bicycle travel as well. Properly planned and managed, ATSs can reduce many of the environmental impacts of private automobiles while maintaining and even enhancing the quality of the visitor experience. Many visitors will take

these positive experiences with more sustainable transportation back home with them, and be more prepared to support sustainability in all forms. This will be good for national parks and the greater world.

This paper illustrates ways in which transportation management in the national parks is becoming more sustainable and can become even more so. There is greater understanding of the potential impacts of transportation on park resources and the quality of the visitor experience. Programs of natural and social science research in the national parks are providing a stronger theoretical and empirical foundation for formulating indicators and standards of quality for defining and measuring the sustainability of transportation in the national parks. This research is also testing the effectiveness of a range of management actions designed to maintain standards of quality. This growing body of work draws on the literature in the fields of both parks and outdoor recreation and transportation, and integrates this work where possible. In particular, the conventional paradigm of demand-driven transportation is being revolutionized by a more sustainable approach in which management objectives for park resources and visitor experiences serve as the foundation upon which transportation systems are designed and managed (see Figure 1). While a great deal more research on sustainable transportation in the national parks is warranted, the scientific and professional literature on this topic is beginning to reach a critical mass as reflected in the emerging principles described above.

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