A Systems-based Approach to Address Unintended Consequences of Demand-driven Transportation Planning in National Parks and Public Lands

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A Systems-based Approach to Address Unintended Consequences of Demand-driven Transportation Planning in National Parks and Public Lands

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Running Head: Consequences of Demand-Driven Transportation Planning
ABSTRACT

In most cases, transportation planning in national parks and public lands might most appropriately be termed “demand-driven”. In this approach, rigorous analyses of park visitation, traffic, and parking data are used as a basis for transportation planning to accommodate current and projected future visitor demand, within financial constraints. Performance measures used to assess the quality of transportation systems in national parks are generally related to “moving people” efficiently. This approach is based on well-established principles for transportation planning in urban and rural communities. However, a demand-driven approach to transportation planning may not be suitable in national parks and public lands because it may enable levels of visitation that cause visitor crowding, resource impacts, and other unintended consequences. This paper introduces a more sustainable, systems-based transportation planning approach developed in Rocky Mountain National Park (ROMO) to help the park operate its shuttle bus system efficiently and conveniently, and according to thresholds for visitor crowding and resource impacts at sites serviced by the shuttle system. The transportation planning approach developed in this study for ROMO is more suitable and sustainable for national parks and public lands than a demand-driven approach, and is readily adaptable to other locations. Correspondingly, the approach is now being applied in several other national parks and public lands recreation areas.
1. INTRODUCTION

In most cases, transportation planning in national parks and public lands might most appropriately be termed “demand-driven”. In this approach, rigorous analyses of park visitation, traffic, and parking data are used as a basis for transportation planning to accommodate current and projected future visitor demand, within financial constraints (Byrne and Upchurch 2011; National Park Service 1999; Turnbull 2003). Performance measures used to assess the quality of transportation systems in national parks and public lands are generally related to operational efficiency, safety, and cost. This approach is based on well-established principles for transportation planning in urban and rural communities (Meyer and Miller 2000).

Planning for shuttle and transit systems (referred to hereafter as alternative transportation systems or “ATS”) in national parks and public lands illustrates particularly well the conventional, demand-driven approach to transportation planning. Over the past several decades, the US National Park Service (NPS) has increasingly relied on ATS to address traffic congestion, parking shortages, and other transportation-related problems in US national parks. Some of the most well-known examples of this include the ATS in Grand Canyon, Zion, Yosemite, and Acadia National Parks. Generally, ATS operations and facilities in national parks and public lands are scaled to the amount and timing of visitor demand that is expected to be displaced to ATS from parking facilities as a product of changes in transportation management and policies (Federal Transit Administration 2008). When visitor demand grows to exceed the capacity of an ATS, facilities and services are expanded to meet demand to the extent of available funding.

The conventional demand-driven approach to ATS planning, design, and operation in national parks and public lands is intended to maximize operational efficiency, provide convenient service, and minimize cost. Correspondingly, performance measures used to assess
the effectiveness of ATS systems in national parks and public lands include passenger volumes, passengers per vehicle mile, operating cost per passenger, and other metrics related to “moving people” efficiently. This approach is based on well-established principles for ATS planning in urban and rural communities, and constitutes best practices in these conventional settings (Ceder 2007; Vuchic 2005). However, it may also enable levels of visitation that cause visitor crowding, resource impacts, and other unintended consequences in national parks and public lands (Ament et al. 2008; Burson et al. 2000; Roof et al. 2002; D’Antonio et al. 2013; Pettengill et al. 2012; Taff et al. 2013; Lawson et al. 2009; Lawson et al. 2011; Park et al. 2009-2010). The ATS at Rocky Mountain National Park (ROMO) provides one of several examples throughout the US National Park System of the potential for demand-driven transportation planning to have unintended consequences for park resources and the quality of visitors’ experiences.

Rocky Mountain National Park was one of the first national parks in the USA to adopt an ATS, initiating a system in the Bear Lake Road Corridor in 1978 (Figure 1). As part of the initial implementation of the park’s ATS in 1978, a park and ride lot was constructed with 208 parking spaces (referred to hereafter as the Bear Lake Park and Ride Lot), and shuttle bus stops were designated at several popular visitor destinations and trailheads in the Bear Lake Road Corridor (National Park Service 2006). Despite this, a 1999 transportation study found the shortage of parking to meet visitor demand was the most significant transportation problem in the park, and that parking shortages were particularly pronounced in the Bear Lake Road Corridor (Parsons et al. 2000). For example, the study found that about 46% of summer visitors seeking to park at popular trailheads in the Bear Lake Road Corridor could not find a designated parking space. Furthermore, the study found that when parking lots at these popular trailheads were full, visitors often parked in unendorsed locations, including parking spaces designated for accessible parking.
only, on road shoulders, and on alpine tundra. Consequently, parking shortages and unendorsed parking were resulting in impacts to park resources, creating risks to public safety, and causing visitor frustration.

INSERT FIGURE 1 HERE

To address the issue of parking lot shortages at popular trailheads in the Bear Lake Road Corridor, while accommodating growing numbers of park visitors, ROMO expanded their ATS service in 2001 (Newman, Lawson, and Monz 2010). In particular, the Bear Lake Park and Ride Lot was expanded to 340 parking spaces, and the ATS service was increased to a 10-vehicle shuttle bus system. Prior to 2001, approximately 156,000 people rode the park’s ATS annually; in 2006, ridership increased to around 270,000 passengers. This deliberate expansion of the park’s ATS to help address the transportation-related impacts of steadily increasing annual park visitation is a compelling example of the demand-driven approach to transportation planning in national parks and public lands. Moreover, the day-to-day operation of the park’s ATS has been according to visitor demand; as the number of visitors waiting at the Bear Lake Park and Ride Lot to board shuttle buses increases through the course of the day, the number of buses operating within the system is increased until there are no more buses available. This approach is designed to reduce waiting times at shuttle bus stops and onboard crowding, potentially increases the convenience of using the shuttle service, and is according to best practices for transit service operations in urban and rural communities.

The expanded shuttle service in ROMO has effectively eliminated unendorsed overflow parking in the Bear Lake Road Corridor and corresponding impacts to park resources, public
safety, and visitors’ experiences (Newman, Lawson, and Monz 2010). In this way, ROMO’s ATS is an excellent example of how the conventional demand-driven approach to transportation planning can be effective at addressing transportation-related issues in national parks and public lands. However, the demand-driven growth of ROMO’s shuttle service also serves as an example of how this conventional approach to transportation planning in national parks and public lands may have unintended consequences for park resources and the quality of visitors’ experiences. In particular, the park’s expanded ATS has enabled levels of visitation to trailheads in the Bear Lake Road Corridor that are double what they would be with automobile access only (Figure 2). Yet, the ATS was expanded in ROMO without first evaluating whether or not sites serviced by the system could sustain a doubling of visitation without unacceptable resource impacts, visitor crowding, and/or other unintended consequences.

The demand-driven expansion of the ATS in ROMO is illustrative of the conventional transportation planning process in national parks and public lands, generally. Resultant ATS systems in ROMO, Zion, Acadia, and other public lands recreation areas have been documented to perform very well, with respect to operational and financial efficiencies of “moving passengers” (Turnbull 2003). However, as the ROMO example suggests, the effects of these very successful ATS on park resources and visitors’ experiences are not known and may conflict with park management objectives.

A more sustainable approach to ATS planning in national parks and public lands is needed to avoid the unintended consequences of responding to traffic and parking congestion...
issues simply by designing and operating transportation system capacities to meet present and
forecasted future demand. In particular, transportation planning in national parks and public
lands must be according to management objectives for resource conditions and the quality of
visitors’ experiences, rather than being based on visitation alone.

The purpose of this study is to develop a systems-based approach to transportation
planning that is more suitable for national parks and public lands than the conventional demand-
driven approach. In particular, a conceptual model was developed and applied empirically in this
study to evaluate and help refine ROMO’s ATS according to management objectives for park
resources and visitors’ experiences, rather than simply to accommodate visitor demand. This
systems-based approach developed and applied in ROMO can be generalized to other national
parks and public lands to design and operate transportation systems to maximize efficiency,
safety, and convenience, while protecting natural resources and the quality of visitors’
experiences.

2. METHODS

2.1. Study Area

Established in 1915, ROMO protects 265,873 acres of the southern Rocky Mountains of
Colorado, USA (National Park Service 2006). The park is approximately 75 miles northwest of
Denver, Colorado and is bordered to the East by the town of Estes Park, Colorado. Annually,
ROMO accommodates approximately 3.5 million visitors, with intensive visitation during the
summer months. The Bear Lake Road Corridor in ROMO is one of the most popular areas in the
park, offering scenic views of dramatic mountain landscapes and easy access to a number of
alpine lakes (Figure 3). The Bear Lake and Glacier Gorge Trailheads are the most popular visitor
destinations in the Bear Lake Corridor, with an average of approximately 1,900 and 1,300
visitors per summer weekend day, respectively. The Bear Lake Trailhead provides access to an easy, half-mile hike around Bear Lake, and more strenuous hikes to Nymph Lake, Dream Lake, and Emerald Lake. The Glacier Gorge Trailhead provides access to Alberta Falls, which is a popular scenic overlook located approximately two miles from the trailhead. Visitors also use both trailheads to access the park’s backcountry for rock climbing, bouldering, and overnight backpacking trips.

INSERT FIGURE 3 HERE

The Bear Lake area is accessed via the Bear Lake Road, a 7 mile two-lane road constructed in 1917 that ends at Bear Lake (Figure 4). In 1929, a 100-space parking lot was constructed at Bear Lake, and over time, the parking lot at Bear Lake was expanded to its current capacity of 235 spaces. As noted, in 1978 ROMO introduced an ATS serving the Bear Lake Road Corridor and constructed the Bear Lake Park and Ride Lot with a capacity of 208 spaces. The park’s ATS was expanded in 2001, and the size of the Bear Lake Park and Ride Lot was increased to 340 spaces, plus approximately 50 overflow spaces. Currently, the ATS operates in the Bear Lake Road Corridor during the summer months, with a total of four stops, including: 1) Bear Lake Park and Ride Lot; 2) Bierstadt Lake Trailhead; 3) Glacier Gorge Trailhead; and 4) Bear Lake Trailhead. Since 2006, the park has also operated an ATS route between the gateway community of Estes Park’s Visitor Center and the Bear Lake Park and Ride Lot (referred to as the “Hiker Shuttle”).

INSERT FIGURE 4 HERE
2.2. Conceptual Approach

As noted, this study was designed to evaluate and help refine ROMO’s ATS according to management objectives for park resources and visitors’ experiences. The conceptual and analytical framework for this study (Figure 5) consists of four interrelated research components. First, survey research was used to identify visitor-based standards of quality for crowding on selected trails and at popular visitor destinations in the Bear Lake Road Corridor. Second, traffic micro-simulation was used to model personal vehicle and ATS vehicle traffic in the Bear Lake Road Corridor. The traffic model was designed to generate a suite of transportation performance measures used to evaluate transportation effectiveness. Traffic model outputs include the number of visitor arrivals, by mode of transportation and time of day, to the Bear Lake and Glacier Gorge Trailheads. Third, traffic model estimates of visitor use at the Bear Lake and Glacier Gorge Trailheads were simulated with visitor use models to estimate the extent of crowding that occurs as a result of ATS operations and corresponding visitor use levels in the park. Fourth, spatial models of resource impact from recreation ecology assessments were integrated with visitor use models to estimate the extent of visitor-related resource impact in the study area associated with ATS operations and corresponding visitor use levels in the park. The integrated modeling system developed in this study provides a platform for a systems-based approach to evaluate the park’s ATS in terms of transportation system performance, the condition of park resources, and the quality of visitors’ experiences. The specific methods used to conduct the study are described in the following subsections.

INSERT FIGURE 5 HERE
2.3. Visitor-based Standards of Quality

Visitor surveys were administered in ROMO to assist the NPS in formulating indicators and standards of quality for popular trails and recreation sites in the Bear Lake Road Corridor. Within the surveys, a visual approach was used to measure visitor-based standards of quality for crowding-related indicators of quality, including: 1) people at one time (PAOT) at attractions and 2) people per viewscape (PPV) on trails (Manning and Freimund 2004; Newman et al. 2005, Manning 2007; Manning 2011; Pettebone et al. 2011; Gibson et al. 2014). A series of computer edited photographs was prepared for each study site showing a range of visitor use levels (e.g., Figure 6). Respondents were asked to rate the acceptability of each photograph on a scale that ranged from +4 (“very acceptable”) to -4 (“very unacceptable”) and included a neutral point of 0. In addition, respondents were asked to identify the photograph within each set that depicted the amount of use they would prefer to see. Summary statistics computed from responses to these questions serve as visitor-based standards of quality for crowding-related indicators. These visitor-based standards were used in this study to evaluate the effects of the park’s ATS operations and corresponding visitor use levels on the quality of visitors’ experiences in the study area.

INSERT FIGURE 6 HERE

2.4. Traffic Micro-simulation Model

A detailed traffic micro-simulation model of the Bear Lake Road Corridor and the surrounding Estes Park area was developed to evaluate transportation system performance and model visitor arrival patterns at popular destinations in the Bear Lake Road Corridor (Lawson et
The traffic model was developed using Paramics microscopic traffic simulation software (Swanson and Chamberlin 2010) and replicates transportation patterns between the hours of 7:00 AM and 5:00 PM. The model is calibrated to traffic volumes on a “typically busy” summer day at ROMO, but not the busiest day. Traffic volumes on the model road network are driven by demand between origin and destination zones representing areas of traffic generation within the study area (Oppenheim 1995). The model incorporates both personal vehicle and ATS access to the study sites and, as noted, was designed to link with visitor use models described in the next section.

2.5. Computer Simulation Modeling of Visitor Use

Computer simulation models of visitor use were developed for the Glacier Gorge Trail to Alberta Falls and the Dream Lake Trail to Emerald Lake using discrete-event systems simulation software (Diamond et. al. 2002; Gimblett and Skov-Petersen 2008; Hallo and Manning 2010; Manning and Hallo 2010; Lawson et al. 2003; Lawson 2006; Lawson et al. 2009; Lawson et al. 2011; Manning et al. 2003; Manning et al. 2002). These two sites were selected for visitor use modeling because they are among the most popular destinations in the Bear Lake Road Corridor, are thought to be important to the quality of visitors’ experiences of the area, receive intensive amounts of visitor use during the summer, and are accessed by visitors via personal vehicle and ATS modes of transportation.

Using visitor survey data collected during the peak summer season, the site-specific models for the Glacier Gorge Trail and Dream Lake Trail were structured to simulate visitor use and behavior of the study sites, including arriving at access points, hiking on trails, lingering at attraction sites, and exiting to the ROMO ATS or other mode of transportation. The models were
also programmed to monitor crowding-related indicators of quality, including PAOT at attractions and PPV on trails throughout the course of simulated visitor use days.

The visitor use modeling interface was designed to allow the user to specify visitor arrival schedules based on hourly personal vehicle and ATS arrivals to the study sites generated from the traffic micro-simulation model, thus providing a linkage for integrated transportation and visitor use modeling. This integrated modeling system was used to generate PAOT and PPV estimates to quantify visitor crowding at popular destinations associated with the park’s ATS operations and corresponding visitor use levels at the study sites.

2.6. Ecological Impact Assessments

Intensive recreation resource assessments were conducted at Alberta Falls and Emerald Lake, including a quadrat-based, image analysis sampling technique (Booth et al. 2005) to measure vegetation and ground cover. The resource assessments involved three field components: 1) identification and mapping of an area of probable recreation use; 2) creation of a stratified random-grid of sampling locations using ArcGIS software; and 3) navigation to sample locations with the GPS and obtaining digital images of 1m² quadrats for subsequent image analysis of ground cover classes. The current degree of recreation disturbance was also estimated for each quadrat and a susceptibility to resource damage score was calculated based on the type and proportion of groundcover present based on experimental tolerance indices found in the literature (Cole 1995a and b). Finally, using ArcGIS software, overall area level susceptibility was estimated with kriging techniques, and an overlay of spatially accurate visitor use density was used to determine locations where use levels may be resulting in groundcover disturbance. This use density was estimated using output from the aforementioned visitor use models and GPS tracking of visitors’ off-trail behavior at destinations. For full details on the above
procedure and findings on the full assessment refer to Newman, Lawson, and Monz (2010) and D’Antonio et al. (2010).

2.7. Integrated Transportation and Visitor Use Modeling Scenarios

As noted, the integrated transportation, visitor use, and natural resource modeling system developed in this study was used to quantify the effects of ROMO’s demand-driven ATS operations on park resources and visitors’ experiences on trails and at attractions serviced by the ATS. Modeling results include quantitative estimates of visitor crowding on the Glacier Gorge Trail to Alberta Falls and the Dream Lake Trail to Emerald Lake and visitor-caused resource impacts at Alberta Falls and Emerald Lake.

3. RESULTS

3.1. Visitor-based Standards of Quality

Visitor-based standards of quality derived from responses to surveys administered in ROMO during the peak summer season are presented in Table 1 and Table 2. “Acceptability” standards of quality were derived by plotting average acceptability ratings for each of the visitor use levels shown in the simulated photographs for each study site. The PAOT and PPV standards of quality reported in the tables are points at which average acceptability ratings cross the “0” or neutral point on the acceptability scale (i.e., fall out of the “acceptable” range and into the “unacceptable” range). “Preference” standards of quality were derived by calculating the average number of people in the photographs selected by visitors in response to the “Preference” question described in the Methods section. For example, results for Alberta Falls reported in Table 1 are based on visitors’ average acceptability ratings and responses to the “Preference” question associated with the computer-edited photographs depicted in Figure 6. These results suggest
visitors generally consider it to be unacceptably crowded when there are more than 25 PAOT at Alberta Falls.

3.2. Traffic Micro-simulation Model

As noted, the traffic micro-simulation model was used to generate information about personal vehicle and ATS-based visitor arrival patterns to the Glacier Gorge Trail to Alberta Falls and the Dream Lake Trail to Emerald Lake. The personal vehicle and ATS-based visitor arrivals schedules generated from the traffic micro-simulation model are reported in Table 3 and Table 4, respectively. These arrivals schedules were programmed into the visitor use models to simulate visitor use patterns and estimate visitor crowding at the study sites associated with existing visitor use levels and ATS operations during the peak summer season.

3.3. Computer Simulation Modeling of Visitor Use

The first series of visitor use simulations was conducted to estimate the percentage of time the visitor-based standards of quality reported in Table 1 and Table 2 are exceeded under existing visitor use levels and ATS operations on peak summer weekend days. Results of the
visitor use model simulations for existing conditions at Alberta Falls and on the Glacier Gorge Trail to Alberta Falls are presented graphically in Figure 7 and Figure 8, respectively. The graphs depict how PAOT at Alberta Falls and PPV on a 50 meter section of the Glacier Gorge Trail to Alberta Falls varies throughout a “typical” weekend day during the peak summer season. The horizontal line in each graph denotes the “Acceptability” standard for the corresponding crowding-related measure. Results in Figure 7 suggest that the “Acceptability” standard for PAOT at Alberta Falls is exceeded by existing visitor use for a substantial proportion of the day (approximately 20% of the time during a typically busy summer day). Results in Figure 8 suggest conditions rarely exceed the “Acceptability” standard for PPV on the Glacier Gorge Trail to Alberta Falls (approximately 2% of the time during a typically busy summer day). In the interest of space, graphs are not presented for Dream Lake and the Trail to Dream Lake, but the results suggest the “Acceptability” standard for PAOT at Emerald Lake is exceeded more than half (52%) of the time during a typically busy summer day, while the “Acceptability” standard for PPV on the Dream Lake Trail to Emerald Lake is exceeded less than 2% of the time.

INSERT FIGURE 7 HERE

INSERT FIGURE 8 HERE

In coordination with park staff at ROMO, it was assumed that when the visitor-based “Acceptability” standard is exceeded more than 15% of the time, it is not consistent with management objectives for the quality of visitors’ experiences in this area of the park. Accordingly, the visitor use model simulation results noted suggest that existing levels of
visitation on the Glacier Gorge Trail to Alberta Falls and the Dream Lake Trail to Emerald Lake do not conform to management objectives for these locations. Thus, a series of simulations was conducted to estimate the maximum number of visitors that can be accommodated on the Glacier Gorge Trail to Alberta Falls and the Dream Lake Trail to Emerald Lake without exceeding the visitor-based “Acceptability” standards more than 15% of the time; these crowding-related capacity estimates are presented in Table 5. The results suggest visitation to the Glacier Gorge Trail to Alberta Falls would need to be reduced by about 4% from current use levels to ensure crowding-related “Acceptability” standards were not exceeded more than 15% of the time. Further, the crowding-related capacity estimates suggest visitation to the Dream Lake Trail to Emerald Lake would need to be reduced by more than one-third (38%) to ensure crowding-related “Acceptability” standards are not exceeded more than 15% of the time.

INSERT TABLE 5 HERE

Conversations with NPS officials at ROMO suggest that there are no plans to reduce the size of parking lots in the Bear Lake Road Corridor. Thus, any reductions in visitor use to the Glacier Gorge Trail to Alberta Falls and the Dream Lake Trail to Emerald Lake would be achieved, at least in the short-term, by reducing the number of visitors “delivered” to these destinations by the park’s ATS. Using information collected in this study about the proportion of visitors who use personal vehicles to access the two study sites, and assuming that there will be no reduction in the number of visitors who access these sites by personal vehicles, estimates were made of the number of ATS passengers that would need to be “displaced” on busy summer weekend days to conform with the crowding-related capacities in Table 5.
The results of this analysis suggest that the Dream Lake Trail to Emerald Lake can sustain the existing number of visitors who access the site via personal vehicles (Table 6). However, to conform to the site’s crowding-related capacity based on the “Acceptability” standards, essentially 100% of existing shuttle bus riders who hike on the Dream Lake Trail on busy summer weekend days would have to be displaced to other locations. On the Glacier Gorge Trail to Alberta Falls, it is estimated that an average of about 50 ATS passengers per day on busy summer weekend days (roughly 7% of existing ridership) would need to be displaced from the Glacier Gorge Trail to Alberta Falls to conform to the crowding-related capacity for this site based on “Acceptability” standards.

INSERT TABLE 6 HERE

3.4. Recreation Resource Assessments

Given the transportation and visitor use components of this project, an important aspect was to develop an understanding of the ecological consequences of visitor use in select areas. One such destination area, Alberta Falls (Figure 9) is illustrative of a backcountry destination, served by the park’s transportation and trail network, where the potential for ecological change was not well understood prior to this investigation. Observations at this destination suggested that visitor use was not confined spatially to durable surfaces, resulting in an expansion of the use area off the established trail and into areas where disturbance could result in rapid resource change as suggested by use-impact theory (Monz et al. 2013)

Our analysis integrated the assessment of groundcover composition and associated substrate fragility with visitor densities based on use modeling output in order to illustrate
specific locations under a high potential for resource change (Figure 9). For example, areas where the groundcover is intolerant of trampling and that experience high visitor densities are depicted in dark grey shading; lighter shades of grey illustrate locations of high durability and/or low use densities.

**INSERT FIGURE 9 HERE**

**4. DISCUSSION**

This study provides a conceptual and empirical framework for transportation planning in national parks and public lands that constitutes an advancement over the conventional demand-driven approach. Specifically, the conventional approach to ATS planning may lead to enhanced transportation facilities and services, but may also unintentionally lead to degraded park resources and diminished quality of visitors’ experiences (Figure 10). As the results of this study demonstrate, the demand-driven growth of the ATS in ROMO doubled visitor access to sites in the Bear Lake Road Corridor, which in turn, enabled levels of visitation that cause unacceptable levels of crowding and resource impacts.

**INSERT FIGURE 10 HERE**

The distinguishing characteristic of the framework for transportation planning developed in this study is that management objectives for park resources and visitor experience quality, rather than visitation alone, are the basis from which transportation system improvements are derived (Manning et al. 2014b). Correspondingly, transportation improvements (e.g., ATS,
parking management, etc.) are designed and implemented in a manner to help manage visitor use according to thresholds for visitor crowding and resource impacts in the park. In this way, the approach developed in this study is more suitable for transportation planning in national parks and public lands, in that it leads to intentional improvements not only to transportation conditions, but also intentionally protects park resources and the quality of visitors’ experiences (Figure 11).

INSERT FIGURE 11 HERE

Importantly, the integrated modeling system developed in this study bridges the gap between transportation planning and visitor use management in ROMO, specifically, and national parks and public lands, generally. In particular, decisions about how many, when, and by what modes of transportation visitors are provided with access to various locations throughout a national park are fundamental elements of both transportation planning and visitor use management. To date, transportation planning in the US national parks and public lands has addressed these questions with respect to demand, while visitor use management efforts have approached these questions in terms of the amount and types of use that can be accommodated without unacceptable impacts to park resources and the quality of visitors’ experiences. Consequently, operational decisions about transportation facilities and services are not always made according to visitor use management objectives.

The framework and modeling system developed in this study provides a scientifically rigorous approach to conduct integrated transportation planning and visitor use management in national parks and public lands. The key components of this approach include 1) identifying
standards of quality or thresholds of impact to park resources and the quality of visitors’
experiences that reflect management objectives; 2) establishing quantitative estimates of the
amounts and types of visitor use that can be accommodated without violating impact thresholds;
and 3) developing operational and financial plans for transportation system services and facilities
for the “right” number of visitors in the “right” places at the “right” times (Lawson et al. 2011;
Manning et al. 2014a and b; Meldrum and DeGroot 2012; Reigner et al. 2012; White et al.
2012). The study methods and results illustrate, empirically, the application of this integrated
transportation planning and visitor use management approach. Specifically, visitor-based
standards of quality were derived from survey response data to identify crowding thresholds;
traffic micro-simulation was used to model visitor use volumes and patterns through the
transportation network, including the park’s ATS; and visitor use models were used to estimate
the degree of crowding at recreation sites caused by existing levels of visitor use and the
maximum amount of use that could be accommodated at these sites without unacceptable
impacts. This information was used to specify changes to the park’s ATS operations that would
be required to prevent unacceptable crowding at recreation sites serviced by the ATS.

The results of this study suggest the park’s ATS is, in fact, operating at levels of service
that cause unacceptable crowding at popular recreation sites in the Bear Lake Road Corridor.
Thus, unintended consequences of the demand-driven approach to transportation planning in
national parks and public lands are occurring in ROMO. These results, however, should not be
interpreted as an indictment of the park’s ATS, or of ATS as a tool to address transportation-
related issues in national parks and public lands, generally. In fact, the traffic micro-simulation
model developed in this study was used in a separate analysis of planning scenarios in which a
greater proportion of visitors used the park’s ATS, rather than personal vehicles to visit the Bear
Lake Road Corridor (Lawson et al. 2011). In each of the two scenarios, the total number of
visitors to the Bear Lake Road Corridor was held constant at visitation levels under current (i.e.,
equal to the visitor use levels used in the modeling presented in this paper), but the proportion of
visitors using the ATS was increased (by 10% and 25%, respectively). The results of this
analysis suggest there are a number of transportation-related benefits of shifting visitors from
personal vehicles to the park’s ATS, including reduced vehicle miles traveled in the park, lower
transportation-related greenhouse gas emissions, and reduced parking congestion at popular park
destinations. In addition, results of the analysis suggest that the mode shifts would not exacerbate
crowding at popular visitor use destinations in the park. These results suggest the park should
seek strategies to shift visitors to the park’s ATS, while at the same time, managing the overall
number of visitors according to thresholds they establish for crowding and resource impacts.

In response to findings from this study, the NPS is considering a suite of strategies to
implement transportation-related solutions to crowding and resource impacts in the Bear Lake
Road Corridor. In particular, the NPS is considering the use of Intelligent Transportation
Systems (ITS) and Travel Demand Management (TDM) to direct visitors to less crowded areas
of the park and encourage use during less busy periods (Ritter et al. 2006). In addition, the NPS
is considering potential destinations to which new ATS routes could be established to divert
some visitors from crowded destinations in the Bear Lake Road Corridor. The objectives of these
strategies would be to reduce crowding and resource impacts at intensively visited destinations
currently served by the park’s ATS without restricting visitation to the park or reducing overall
ATS service. However, these strategies present a risk that the crowding and resource impact
issues in the Bear Lake Road Corridor will simply be shifted to other locations in the park or
region.
The integrated modeling system developed in this study provides a framework to evaluate the operational, financial, and resource management-related capacity of potential substitute recreation sites in the park and region to accommodate additional use. In particular, several interrelated components of work are now being done to support the NPS in expanding their use of ATS solutions to improve transportation system operations in accord with desired visitor experiences and resource management objectives. This approach provides the NPS with the information needed to refine existing shuttle service in ROMO, and implement new ATS solutions that are financially, administratively, and environmentally sustainable. Moreover, the Federal Highway Administration Central Federal Lands Highway Division (FHWA-CFL) is currently developing a Transportation Recreation Opportunity Spectrum (TROS) planning tool, which is designed to assess, at a regional level, existing and desired levels of visitor access to and within public land recreation areas. Thus, the TROS could serve as an important tool to identify substitute recreation sites in the vicinity of ROMO where there is the capacity to accommodate additional visitor use without unacceptable impacts.

While the focus of this study is the ATS in ROMO, the conceptual and empirical framework for transportation planning developed in this study is adaptable to other units of the US National Park System, and to public lands recreation areas generally. Recent examples from other US national parks suggest this study is part of a growing trend away from the conventional demand-driven approach to integrated transportation planning and visitor use management (White et al. 2012; Reigner et al. 2012; Manning and Hallo 2010; Lawson et al. 2011; Hallo and Manning 2010). Correspondingly, public lands recreation areas managers will become increasingly capable of using transportation improvements to help manage visitor use according to management objectives for park resources and the quality of visitors’ experiences.
ACKNOWLEDGEMENT

This research was funded through a grant from the Alternative Transportation in Parks and Public Lands program. We thank our many Rocky Mountain National Park colleagues for their valuable contributions especially Larry Gamble for his constant dedication to this work. We also thank our graduate students and research associates for considerable help with the field work, analysis, and modeling including Logan Park, Karen Hockett, Ashley D’Antonio, David Pettebone, Derrick Taff, Adam Gibson, Bob Chamberlin, Brett Kiser, Ben Swanson, and Janet Choi.

REFERENCES


Figure 1. Map of ROMO and the Bear Lake Road Corridor
Figure 2. Number of Visitors at Bear Lake Trailhead, by Time of Day and Transportation Mode of Access
Figure 3. Map of recreation sites and attractions, Bear Lake Road Corridor, ROMO.
Figure 4. Map of ATS routes and facilities, Bear Lake Road Corridor, ROMO.
Figure 5. Integrated Transportation, Visitor Use, and Natural Resource Modeling Framework
Figure 6. Examples of computer-edited Photographs of People per Viewscape on the Glacier Gorge Trail to Alberta Falls
Figure 7. Visitor Use Model Estimate of PAOT at Alberta Falls – 2008 Visitation and Shuttle Service
Figure 9. Areas of potential resource change at Alberta Falls
Figure 10. Conceptual Model of Demand-driven Approach to Transportation Planning in National Parks and Public Lands
Figure 11. Conceptual Model of Sustainable Approach to Transportation Planning in National Parks and Public Lands
<table>
<thead>
<tr>
<th>Visitor Based Standards</th>
<th>Glacier Gorge Trail to Alberta Falls (PPV)</th>
<th>Alberta Falls (PAOT)</th>
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<td>Acceptability</td>
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<td>25</td>
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<tr>
<td>Preference</td>
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Table 2. Visitor-based Standards of Quality for PPV on the Dream Lake Trail to Emerald Lake and PAOT at Emerald Lake

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<th>Visitor Based Standards</th>
<th>Dream Lake Trail to Emerald Lake (PPV)</th>
<th>Emerald Lake (PAOT)</th>
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<td>Glacier Gorge Trailhead</td>
<td>Dream Lake Trailhead</td>
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<td>Dream Lake Trailhead</td>
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<td>520</td>
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Table 5. Daily Crowding-related Capacity Estimates of Study Sites with Alternative Visitor-based Crowding Standards

<table>
<thead>
<tr>
<th>Standard of Quality</th>
<th>Glacier Gorge Trail to Alberta Falls (1,367)\textsuperscript{a}</th>
<th>Dream Lake Trail to Emerald Lake (1,099)\textsuperscript{a}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceptability</td>
<td>1318\textsuperscript{b} (-4%)\textsuperscript{b}</td>
<td>684\textsuperscript{b} (-38%)\textsuperscript{b}</td>
</tr>
</tbody>
</table>

\textsuperscript{a} Average weekend daily visitor use under existing conditions.

\textsuperscript{b} Percentage change from average weekend daily visitor use under existing conditions.
Table 6. Estimated Number and Percentage of ATS Passengers per Day on Busy Summer Weekend Days Needed to be Displaced to Conform to Crowding-related Capacities

<table>
<thead>
<tr>
<th>Standard of Quality</th>
<th>Glacier Gorge Trail to Alberta Falls</th>
<th>Dream Lake Trail to Emerald Lake</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of Displaced Shuttle Bus Riders</td>
<td>Percentage of Displaced Shuttle Bus Riders</td>
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<tr>
<td>Acceptability</td>
<td>52</td>
<td>7%</td>
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