Assessing and Modeling Visitors' Evaluations of Park Road Conditions in Yosemite National Park

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Introduction

Park visitors' travel choices and behavior are longstanding concerns for the National Park Service. Travel behaviors can affect natural and cultural resources and the quality of the visitor experience. Driving park roadways has been central to the American national park experience since the earliest days of park preservation. As historian David Louter (2006) argued in his book *Windshield Wilderness,* "We cannot understand parks without recognizing that cars have been central to shaping how people experience and interpret the meaning of national parks, especially how they perceive them as wild places" (p. 164). Youngs et al. (2008) concurred, adding, "We cannot understand national parks without understanding transportation systems more broadly." Understanding transportation in parks is thus critical to both the recreational use and preservation mandates of the National Park Service.

Nowhere are these issues more prominent than in Yosemite National Park, which has struggled with an appropriate balance between automobile access and park preservation since the turn of the 20th century (Havlick 2002). Roads were first built into Yosemite Valley in the 1870s and by 1913 the first cars entered the valley. During the 1930s, park roads were improved, widened, and paved (Runte 1990). Meanwhile the popularity of auto tourism in America expanded (Colten and Dilsaver 2005), sparked by the "See America First" campaign (Shaffer 2001) and the increase in personal automobile ownership. Private automobiles have since become entrenched in park management and visitor culture, leading to what

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Dilsaver and Wyckoff (1999) have called a "spiraling of interdependent development and use" (p. 76). According to Youngs et al. (2008), this "has produced a cultural landscape in portions of Yosemite Valley and other areas of the park that is dominated by roads and automobiles and fostered a widely shared and scripted visitor experience, best described as a 'travel narrative.'" (p. 805). Many Yosemite visitors consider scenic driving to be an important activity (NPS 2009) and they value the sense of freedom, convenience, and access driving provides (White 2007).

There are, of course, also longstanding concerns about the impacts of an automobile-dominated transportation system on visitors' experiences and park resources. Issues include perceived crowding, conflict, traffic congestion, air pollution, vegetation loss, degradation of scenic views, and visitor displacement. To address these problems, Yosemite managers have implemented strategies to improve the transportation system by adjusting traffic patterns, removing cars from the eastern section of Yosemite Valley, initiating a free public bus service in the valley (Greene 1987), and, during periods of extreme congestion, diverting inbound vehicles away from the eastern portion of Yosemite Valley. Despite these efforts, the lingering effects of geography, park design, visitors' preferences for private automobiles, and intensive use continue to challenge the best efforts of park managers.

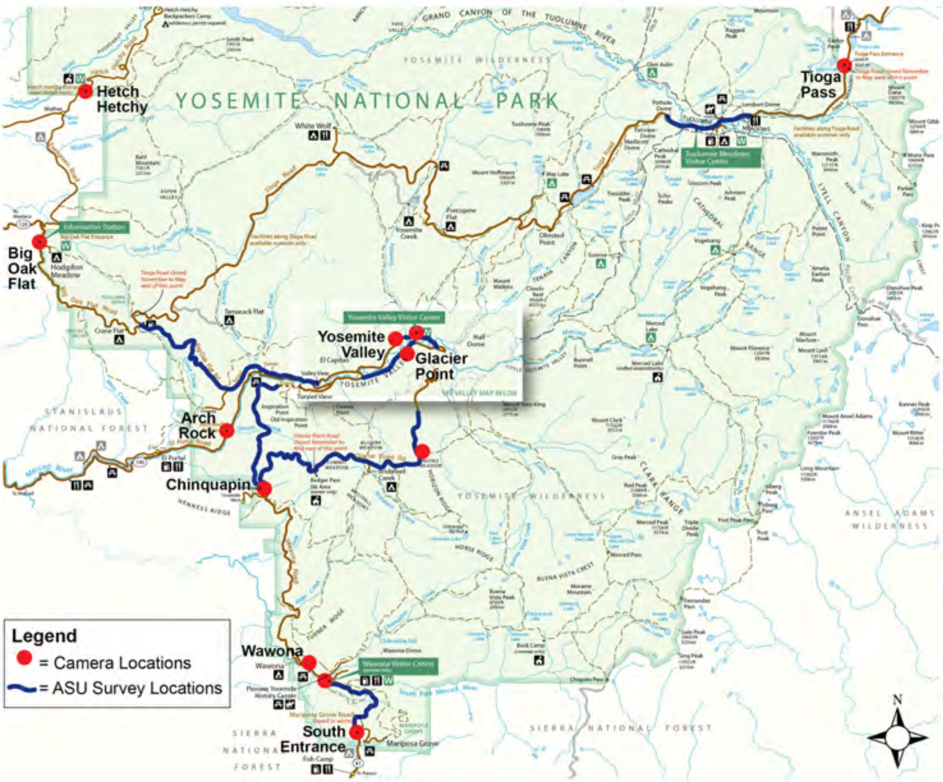
To deal with these ongoing challenges, Yosemite has in recent years undertaken a program of coordinated research and planning aimed at an integrated transportation capacity assessment (Meldrum and Degroot, this volume). This program has been informed by contemporary thinking on capacity and visitor-use management in national parks (e.g., Graefe et al. 2011; Whitaker et al. 2011) and by an adaptive visitor-use management framework of management objectives and associated indicators and standards of quality (NPS 1997; Manning 2001). Generally, this approach includes: (1) crafting specific goals and objectives in terms of desired conditions and empirically based indicators and standards; (2) monitoring visitor-use levels and associated conditions of experiential quality; and (3) evaluating use levels and experiential quality in comparison with visitor-informed standards of quality to assess achievement of management objectives. This process requires research on current and potential future conditions of visitor use and their relationship to the quality of visitors' transportation experiences. The research that informs this management by objectives, indicators, and standards of quality follows the conceptual models outlined by Meldrum and DeGroot in the introduction to this special edition of *The George Wright Forum*. This effort is also informed by long-standing traffic engineering research, modeling, and practice, which have developed indicators and standards for the quality of transportation service, largely based on measures of travel time and delay (TRB 2010).

In this paper, we present research to monitor transportation and experiential conditions on park roadways and to model elements of the relationship between use level and quality within this system. First, we describe the formulation of indicators and visitor-based evaluative standards to guide monitoring for visitors' experiences on Yosemite roadways. This evaluative research is conducted with survey research methods. Second, we discuss descriptive modeling of roadway conditions that develops relationships between roadway use levels and indicators of quality. Additionally, this simulation modeling can be used to simulate different conditions of use and quality to assess alternative transportation management scenarios. Evaluative survey research and simulation modeling can be integrated to facilitate empirically based, visitor-informed, proactive management to assess the types and levels of visitor use that can be accommodated under varying assumptions or potential management actions while maintaining desired conditions. In the final section of the paper, we describe implications of this research for park planning as well as research on transportation experiences in national parks.

Methods

Evaluative survey research. For the evaluative survey research component of this project, we employed a cross-sectional design (Creswell 2009) with data collected via on-site, surveyor-assisted questionnaires. To ensure the study findings were representative of visitors to the park during the study period (July 2010), we employed a stratified random sampling strategy with three-stage selection (Lohr 2009). First, we divided the park into eight geographic zones based on segments of the transportation system (see Figure 1). Second, we randomly

Figure 1. Map of Yosemite National Park with survey sampling locations and modeling data collection sites.



selected sample dates within the sample period for each site, stratified by weekday/weekend. Third, each sampling day was then partitioned into morning and afternoon sampling blocks, and a block of time within each day was randomly selected. Surveyors followed a traffic control plan and flagged and pulled over motorists to administer the questionnaire at roadside pullouts, scenic overlooks, and parking areas. The questionnaire scales and visual simulation methods used in this study are well-established in the field and supported by peer-reviewed scientific literature. Several previous studies have used similar methods and questions (see Manning 2011 for a review). Specific examples include visitor surveys in Yosemite (White et al. 2011) and at Acadia National Park (Hallo and Manning 2009). We obtained 1,054 completed questionnaires with an overall response rate of 64%. The survey has a margin of sampling error of +/–3% at the 95% confidence interval. Results of a non-response bias analysis, coupled with the high response rate, ensure that there are no systematic differences between groups who did participate in the survey and those that refused, thus enhancing the generalizability of the results.

In a prior study, researchers used open-ended interviews to identify salient aspects of visitors' transportation experience by asking them to report on what added to or detracted from the quality of their experience of driving cars on the park roadways. The findings revealed that visitors value convenience, perceived freedom, access, personal control, and opportunities to experience nature. Negative influences included feelings of stress, traffic congestion, difficult route finding, crowding, and conflict (White 2007). A subsequent study documented travel mode choices and travel patterns in Yosemite, identified the importance and satisfaction of travel by various modes, examined visitors' perceptions of the experiential dimensions of traveling via car versus park shuttle bus, and identified visitors' preferences regarding transportation management options (White et al. 2011). Based on these studies, and in consultation with park officials, the team selected two key variables to serve as indicators of quality for visitor experiences and to guide future monitoring and management: vehicles per viewshed (VPV) and travel time.

Vehicles per viewshed. To represent varying levels of congestion on park roadways realistically, we used a visual measurement approach to assess VPV (Manning et al. 1996; Manning and Freimund 2004). We prepared two sets of photographs: one with a representative Yosemite Valley roadway viewshed and another with a representative high-alpine roadway viewshed. The images, which embody the VPV indicator of quality, showed a range of roadway conditions varying from free-flow (0 VPV) to full roadway capacity (24 VPV). The photographs were prepared using digital editing software (see Figure 2).

Respondents were shown the photographs in random order and asked to rate each photograph by indicating how acceptable it was based upon the number of vehicles shown using a nine point scale ranging from –4 ("very unacceptable") to +4 ("very acceptable").

Travel times. In addition to VPV, visitors were asked to evaluate the acceptability of travel times on park roadways. Respondents were flagged and pulled over at the terminus of a study road segment, and asked to report the amount of time it had taken to travel that segment. Then, they rated the acceptability of that travel time on a nine point scale ranging from –4 ("very unacceptable") to +4 ("very acceptable").

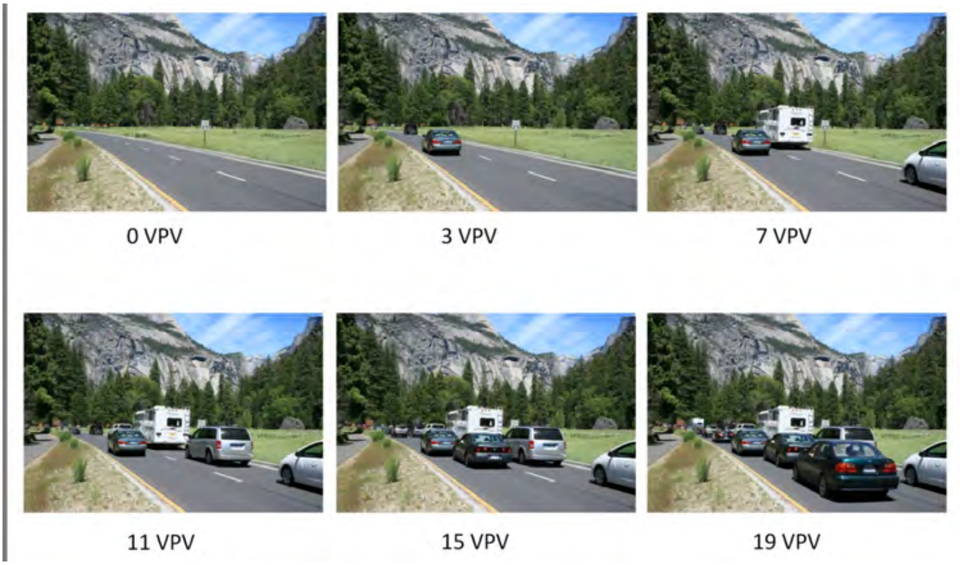


Figure 2. Sample study photographs showing a range of vehicle use on park roadways.

Standards of quality, benchmarks by which the achievement of management objectives can be judged, are formulated from visitor evaluations of the VPV and travel time indicator variables (Shelby and Heberlein 1986; Vaske et al. 1986). This approach posits that individuals have standards for evaluating social and environmental conditions and that empirical research can measure these standards and describe the distribution in groups. This information can then be used to inform a range of potential management standards.

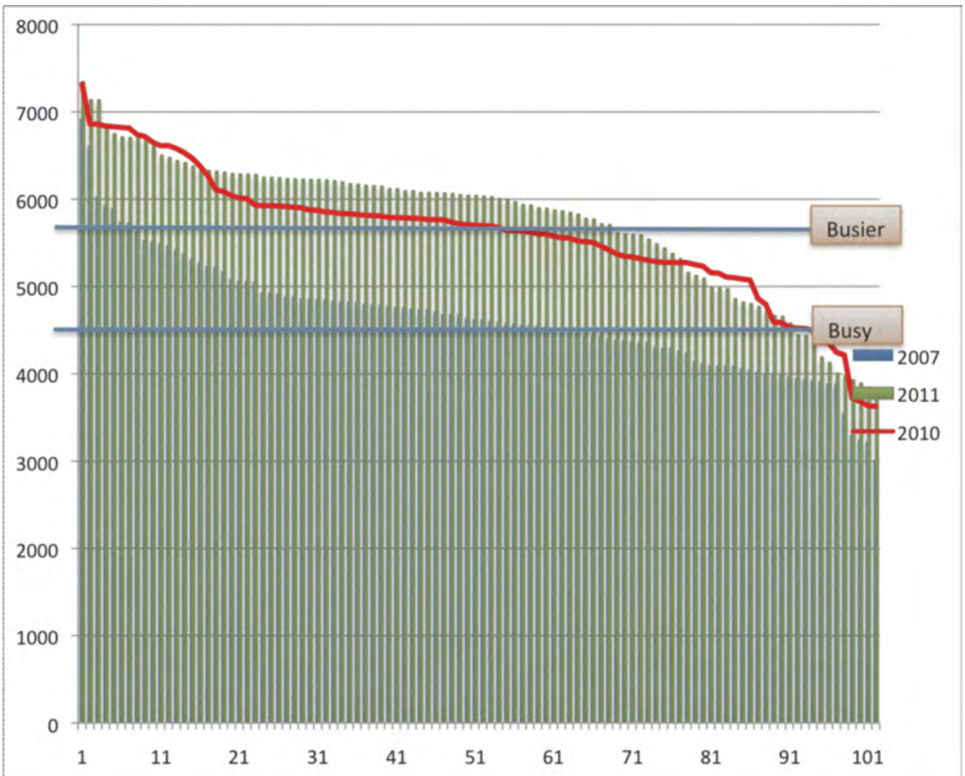
Descriptive modeling research

Coinciding with visitor surveys (July 2010), we also conducted a license plate study to record and match vehicles traveling past 23 cameras placed at the entrance stations and key locations within the park. We used a license plate recognition program to match plates captured at two or more cameras and constructed a database to identify matches for any given route across camera locations. The final dataset included a total of 71,120 license plate data points with approximately 15,100 license plates matches. Traffic counts from each license plate data collection location showed that capture rates varied by location. Generally, capture rates around 90% were achieved. The information generated by this license plate study, combined with traffic counters deployed along the park's road network, supplied counts of vehicles arriving to the park and road segments of analytical interest.

In previous work, traffic engineers developed a TransCAD travel demand model for Yosemite Valley (Smith et al. 2003) and a VISSIM transportation simulation model for the Yosemite Valley roadway network (Chase 2006). For the current project, engineers updated and expanded these demand and simulation models to include all major roadways within the park. Next, we used the license plate data and traffic counts collected in July 2010 to validate the models. The travel demand and simulation models were developed to estimate volumes and simulate vehicular traffic along the park roadways at different levels of visitor use and under different traffic management strategies. These estimates of experiential conditions along park roadways can be translated into indicators of quality, facilitating evaluation against the standards of quality formulated from the survey research described above.

The evaluation of seasonal visitation in Yosemite focused on the 100 busiest days of the summer peak use season. Figure 3 shows the number of vehicles per day entering eastern Yosemite Valley, as recorded by permanent traffic counters located near the Yosemite Chapel on Southside Drive. Data are presented for 2007, 2010, and 2011, with the days ordered from the highest entering volume to the lowest entering volume for each 100-day peak season. In 2007, benchmark volumes were established, including the "busiest day," (i.e., highest volume), a "busier day" (i.e., 7th highest volume) and a "busy day" (i.e., median volume). The travel demand and simulation models generally follow the "busier day" traffic scenario

Figure 3. Vehicles per day entering Yosemite Valley: Summer 2007, 2010, and 2011.



with traffic volumes in the 90th to 95th percentile of the summer season volumes. The park-wide models were initially developed for a 2007 "busier day" traffic scenario and the current project updated the models to calibrate to the data collection time period, which was the fourth-highest visitation day of the 2010 summer season.

Survey findings and modeling results:
Visitors' evaluations of transportation experience indicators of quality

Vehicles per viewshed. To explore the range of visitor evaluations of VPV conditions as potential inputs for managerial standards, respondents were asked evaluate the series of VPV photographs and to identify the photograph that represented: (a) the number of vehicles they preferred to see; (b) the number of vehicles on the roadway that would be so unacceptable that they would no longer visit that area of the park; (c) the number of vehicles that the National Park Service should allow on this roadway; and (d) the number of vehicles they typically saw on that day. The results for evaluation of each depicted VPV level are summarized in the graph in Figure 4, which is constructed using the mean acceptability ratings of respondents. Figure 5 summarizes visitors' evaluations of the roadway conditions on multiple dimensions. For instance, the findings show that:

- The *preferred condition* for valley and non-valley sites was 0 VPV. Thus, this is the optimum condition, which received the highest acceptability by the aggregate sample.
- The *range of acceptable conditions* for valley sites is 0 to 11 VPV; for non-valley sites, 0 to 14 VPV. Thus, all of the conditions represented in this range meet some level of acceptability by about half the respondents.
- The *minimum acceptable condition* for valley sites is approximately 11 VPV; for non-valley sites, 14 VPV. At this point, about half the sample finds these conditions acceptable.

In both sub-samples (valley and non-valley), visitors expected to encounter more vehicles than they actually reported experiencing. It is noteworthy that valley respondents identified their expected condition (11 VPV) as the point at which NPS management should take action. In both subsamples, respondents rated the photo with maximum congestion as the point at which they would no longer visit that area of the park.

Travel times. Results of travel time indicator of quality evaluations suggest that, in aggregate, acceptability ratings for six of the eight segments were above 3.0 on the scale, indicating that the respondents found the travel times to be acceptable to very acceptable. For another site, Northside Drive–Curry Village to Camp 6, the mean rating was 2.88, still in the acceptable range but lower than the other sites. The mean rating for Chinquapin to Tunnel View Point was 0.86, near the unacceptable point of the scale. The results also demonstrated that the correlation between travel time and acceptability ratings was $r = -.287$ ($p<.001$, $N=1029$), indicating a small to moderate inverse relationship. That is, for each one-unit (one-minute) increase in travel time there is a corresponding –.287 unit decrease in the acceptability rating.

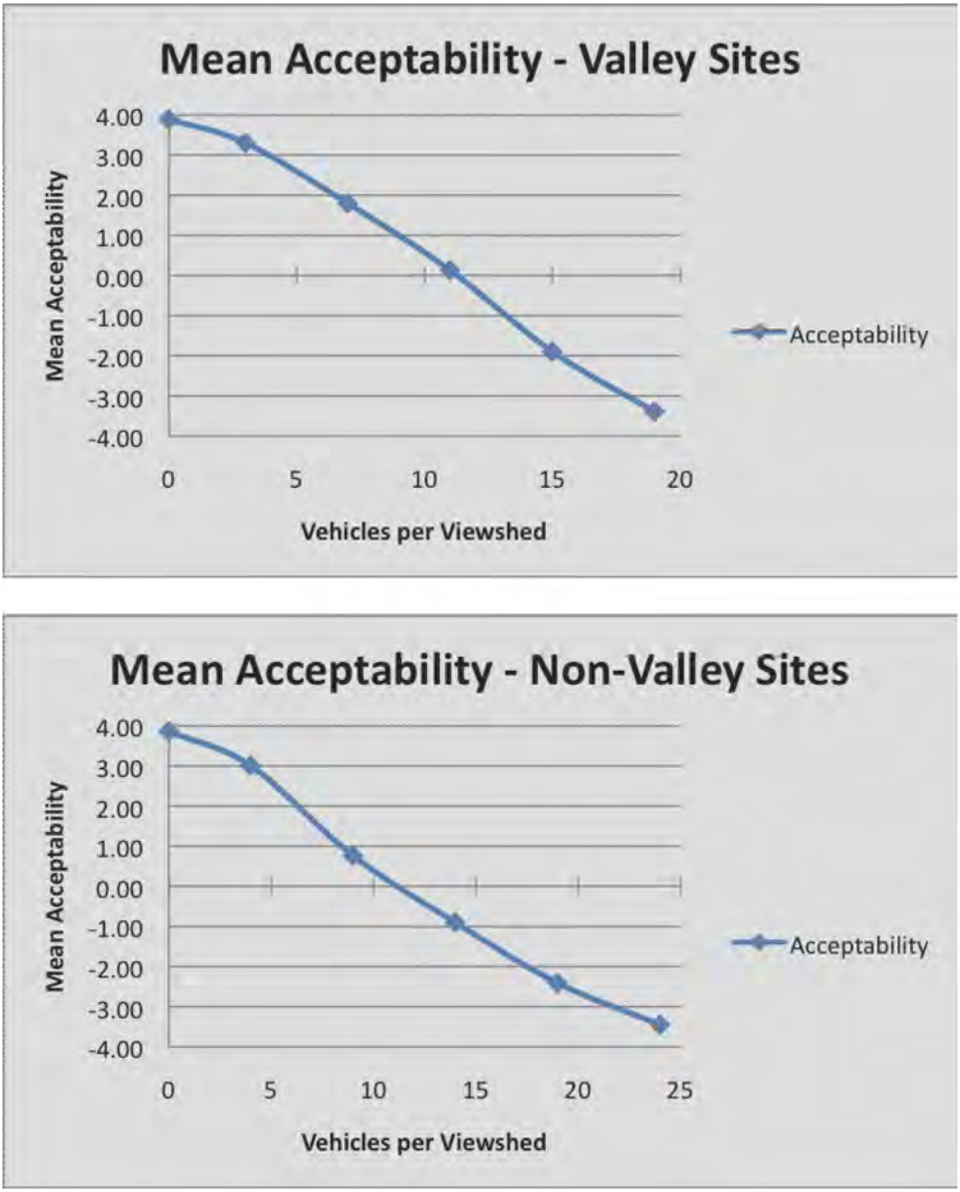


Figure 4. Respondent acceptability ratings for a range of VPV on Yosemite roadways.

As with VPV, respondents were asked to identify (a) the amount of time they would prefer it to take to travel that road segment; b) the amount of time that would be so unacceptable that they would no longer visit that area of the park; and (c) the amount of time that the National Park Service should allow. The results, shown in Table 1, provide managers with

	Median VPV for Valley (Sites 1-3)	Median VPV Non-Valley (Sites 4-8)
Preferred	 0 VPV	 0 VPV
Expected	 11 VPV	 9 VPV
Experienced	 7 VPV	 4VPV
Management action	 11 VPV	 14 VPV
Displacement	 19 VPV	 24 VPV

Figure 5. Summary of visitors' evaluations of VPV.

information on current conditions as well as visitor-based evaluations of travel time across a range of dimensions. It is important to note that not all respondents were able to express a personal standard for travel time for the management action and displacement dimensions. Depending on the road segment and sub-sample, 1–7% of respondents answered "don't know" on these items. Furthermore, across the entire sample for the acceptability dimension, 16% said no amount of time would be so unacceptable that they would no longer visit this area of the park; for the management action standard, 7% responded that no amount of time is so unacceptable as to restrict vehicles using the roadway; and 13% said the number of

	Free-flow	Self-reported	Preference	Management action	Displacement
Roadway segment			Mean (Mins)		
Northside Drive – Sentinel Bridge to Camp 4	3.25	6.78	4.46	17.33	21.46
Northside Drive – Curry Village to Camp 6	2.36	5.26	4.36	23.08	38.91
Southside Drive – Bridalveil Falls to Chapel	7.16	8.66	6.73	24.95	30.65
South Entrance to Wawona	8.43	9.73	8.99	18.72	31.16
Chinquapin to Washburn Point (Glacier Point Road)	—	32.03	26.64	76.16	66.03
Chinquapin to Tunnel View Point	—	43.40	36.30	82.40	101.80
Crane Flat on Hwy 120 to its intersection with Hwy 140	10.08	26.23	24.23	51.41	64.36
Tioga Road – Lembert Dome to Pothole Dome	—	11.04	8.72	23.65	28.86

Table 1. Summary of visitors' evaluations of travel times.

vehicles using the roadway in this area should not be restricted at all. These respondents are not included in the calculations for travel time standards.

Modeling transportation indicators—linking monitoring with evaluation

We then compared visitor-based evaluative standards of quality for the travel time indicator derived from the survey study with traffic modeling results using traffic volume data from both 2007 and 2010. This allowed us to evaluate multiple scenarios of varying use levels and the potential effects on visitors' experiences. Using travel demand and simulation models developed in 2007, we simulated travel times for a representative roadway segment within Yosemite Valley, Northside Drive from Sentinel Drive to Camp 4 (see Table 2). (Note that this roadway segment was also one of the segments for the survey research.) Comparing modeled travel times with the visitor-based evaluations for the Northside Drive segment, the results show that travel time conditions on the "busy day" scenario (3.6 minutes) were within standard for the visitor-based preference dimension (4.46 minutes). The visitor preference standard, however, was not met under the "busier day" (7.0 minutes) and "busiest day" (9.0 minutes) conditions. None of the simulated conditions exceeded the visitors' standard for management action (17.33 minutes).

Traffic volumes entering Yosemite National Park, however, have increased since 2007. For instance, the average daily volume of traffic entering Yosemite Valley for the 100-day peak season has increased by about 24% overall. Traffic volume on the median day has increased about 30% overall, with the median day having more than 6,000 vehicles entering eastern Yosemite Valley in 2011. While the average and median traffic volumes have

Scenario: Northside Drive – Sentinel to Camp 4	Modeled Travel Time (minutes)	Visitor Evaluation (minutes)
Free-flow conditions	2.8	
2007 Busiest day	9.0	
2010 Busiest day (4th busiest day)	9.1	
2007 Busier day (7th busiest day)	7.0	
2007 Busy day (median busiest day)	3.3	
2010 Visitor preference		4.46
2010 Visitor management action		17.33
2010 Visitor displacement		21.46

Table 2. Simulation model results: Travel time on Northside Drive.

increased substantially, there has been relatively less of an increase in traffic on the maximum day. This is likely reflective of the fact that the roadway system and parking areas in the East Valley have a physical capacity which is being attained on the highest use days. In addition to the constraints on traffic from the roadway system, park management takes action to redirect traffic away from the eastern portion of the valley when congestion reaches severe levels. Diverting traffic away from eastern part of the valley tends to limit the total number of vehicles that can enter over the course of a busy day. Furthermore, observations at the park entrance stations on very busy days indicate that when very long queues of vehicles form at the entrances, some visitors turn around and depart without entering the park.

To evaluate the effects of the recent increase in traffic volume, we updated the simulation models with 2010 traffic conditions for the roadway segment along Northside Drive from Sentinel Drive to Camp 4 (see Table 2). As shown, the travel time on the roadway segment is 30% higher than the same day during the 2007 summer season, due to the general increase in traffic volumes within the park. Comparing these travel times with the visitor-based evaluations of travel time for the Northside Drive segment, the results show that the visitor preference standard was not met, but the travel time remains well under the management action standard. Future research will assess of the relationship between modeled VPV conditions and visitor standards of quality.

The park is currently installing permanent traffic counters at the entrance stations and other locations within the park to establish a traffic monitoring program. The program will use the counters to measure real-time traffic volume data within key sections of the transportation system. These counters can supply the data to facilitate ongoing application of the conceptual models employed in this research to monitor use, estimate experiential conditions, and evaluate their quality. The program will also provide a more complete and reliable historical record of traffic volumes for enhanced analysis of trends and relationships among volumes at various locations in the park. This real-time monitoring will inform park staff whether management objectives are being achieved or if visitor-informed standards of quality may be violated by roadway use levels. The travel demand and simulation models can be used to proactively evaluate the impacts of different management alternatives on roadway traffic volumes, travel time, and the associated impact on visitor-based evaluations.

Conclusion

In recent years, there has been a sharpening focus by researchers and planners on transportation experience in national parks (Hallo and Manning 2009; Holly et al. 2010; White 2007; White et al. 2011; Youngs et al. 2008). Indeed, transportation management is now considered an essential aspect of capacity and visitor use management in national parks (Daigle 2008; Lawson et al. 2009). In recognizing that transportation and recreation are often synonymous in parks, this paper illustrates a process of integrating traffic engineering modeling with transportation experience indicators and standards of quality to evaluate roadway conditions in terms of experiential quality.

In this study, visitors' experiences of travel times and VPV along park roadways were within the range of acceptable conditions. Modeling results indicate, however, that recent visitation patterns threaten to push conditions outside of that acceptable range. Looking forward, researchers and planners will develop and assess multiple scenarios of potential future use levels and model the impact of alternative management actions on visitor experiences. This fosters an anticipatory approach to management that allows for decisions to be made that are robust against a wider range of future conditions.

References

Chase, I. 2006. *East Yosemite Valley Transportation Modeling Simulation Model Assumptions and Results. Technical Memorandum*. N.p.: David Evans and Associates, Inc.

Colten, C.E., and L.M. Dilsaver. 2005. The hidden landscape of Yosemite National Park. *Journal of Cultural Geography* 22(2): 27–50.

Dilsaver, L.M. and W. Wyckoff. 1999. Agency culture, cumulative causation and development in Glacier National Park, Montana. *Journal of Historical Geography* 25(1): 75–92.

Creswell, J.W. 2009. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches.* 3rd ed. Thousand Oaks, CA: Sage.

Graefe, A.R., K. Cahill, and J. Bacon. 2011. Putting visitor capacity in perspective: A response to the capacity work group. *Journal of Park and Recreation Administration* 29(1): 21–37.

Greene, L. 1987. *Historic Resource Study: Yosemite; The Park and its Resources—A History of Discovery, Management, and Physical Development of Yosemite National Park, California,* 3 vols. Washington, DC: National Park Service.

Hallo, J.C., and R. Manning. 2009. Transportation and recreation: A case study of visitors driving for pleasure at Acadia National Park. *Journal of Transport Geography* 17(6) 491–499.

Havlick, D.G. 2002. *No Place Distant: Roads and Motorized Recreation on America's Public Lands.* Washington, DC: Island Press.

Holly, F.M., J.C. Hallo, E.D. Baldwin, and F.P. Mainella. 2010. Incentives and disincentives for day visitors to park and ride public transportation at Acadia National Park. *Journal of Park and Recreation Administration* 28(2): 74–93.

Lawson, S., P. Newman, J. Choi, D. Pettebone, and B. Meldrum. 2009. The numbers game: Integrated transportation and user capacity research in Yosemite National Park. *Transportation Research Record* 2119: 83–91.

Lohr, S.L. 2009. *Sampling: Design and Analysis*. 2nd ed. Boston: Brooks/Cole.

Louter, D. 2006. *Windshield Wilderness: Cars, Roads, and Nature in Washington's National Parks.* Seattle: University of Washington Press.

Manning, R. 2001. Visitor experience and resource protection: A framework for managing the carrying capacity of national parks. *Journal of Park and Recreation Administration* 19: 93–108.

Manning, R. 2011. *Studies in Outdoor Recreation.* 3rd ed. Corvallis: Oregon State University Press.

Manning, R., and W. Freimund. 2004. Use of visual research methods to measure standards of quality for parks and outdoor recreation. *Journal of Leisure Research* 36(4): 552–579.

Manning, R., D. Lime, W. Freimund, and D. Pitt. 1996. Crowding norms at frontcountry sites: A visual approach to setting standards of quality. *Leisure Sciences* 18(1): 39–59.

National Park Service. 1997. *VERP: The Visitor Experience and Resource Protection (VERP) Framework—A Handbook for Planners and Managers.* Denver: National Park Service.

National Park Service. 2009. Yosemite National Park visitor study, Summer 2009 (no. 215). Moscow, ID: National Park Service Park Studies Unit.

Runte, A. 1990. *Yosemite: The Embattled Wilderness*. Lincoln: University of Nebraska Press.

Shaffer, M.S. 2001. *See America First: Tourism and National Identity, 1880–1940.* Washington, DC: Smithsonian Institution Press.

Shelby, B., and T.A. Heberlein. 1986. *Carrying Capacity in Recreation Settings.* Corvallis: Oregon State University Press.

Smith, S., G. Ritter, A. Seetharaman, and S. Peterson. 2003. *Yosemite National Park Traffic Information System Network Model.* Washington, DC: National Park Service.

TRB [Transportation Research Board]. 2010. *HCM 2010: Highway Capacity Manual.* Washington, DC: Transportation Research Board of the National Academies.

Vaske, J., A. Graefe, B. Shelby, and T. Heberlein. 1986. Backcountry encounter norms: Theory, method, and empirical evidence. *Journal of Leisure Research* 18: 137– 153.

White, D.D. 2007. An interpretive study of Yosemite National Park visitors' perspectives toward alternative transportation in Yosemite Valley. *Environmental Management* 39(1): 50–62.

White, D.D., J.F. Aquino, M. Budruk, and A. Golub. Visitors' experiences of traditional and alternative transportation in Yosemite National Park. *Journal of Park and Recreation Administration* 29(1): 38–57.

Whittaker, D., B. Shelby, R. Manning, D. Cole, and G. Haas. 2011. Capacity reconsidered: Finding consensus and clarifying differences. *Journal of Park and Recreation Administration* 29(1): 1–20.

Youngs, Y. L., White, D. D., and Wodrich, J. A. (2008). Transportation systems as cultural landscapes in national parks: The case of Yosemite. *Society and Natural Resources* 21(9): 797–811.

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