Modeling Support for National Park Planning:

Initial Results from Glacier National Park

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Abstract

This paper describes the role of systems modeling in the National Parks. The parks have been described as *America's Best Idea,* and they are celebrating their 100th year anniversary. Systems thinking and system dynamics can help the parks plan for the second century.

The paper begins by contrasting the system perspective with the focus on external factors that often dominates park discussions. The paper then reviews the extensive use of models for parks around the world. The review is conducted with an eye toward the best role for system dynamics.

A system dynamics based, integrated modeling system is proposed to address both short-term operations and long-term visitor management. The paper describes initial steps to create such a system at Washington State University.

The main case study simulates operational issues at Glacier National Park. The model simulates vehicles, buses and people in the heavily used *Going to the Sun Road* corridor for a typical day in July. The model is used to show the simulated impacts from the park's shuttle system. The Glacier study demonstrates that system dynamics can address concrete operational questions while providing support for the development of a long-term model for visitor management.

1. America's National Parks

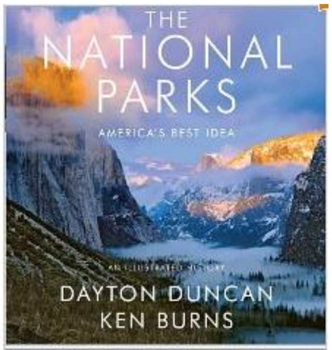

Photo 1

The story of America's national parks is told in a recent film which celebrates the parks as *America's Best Idea* (Duncan and Burns 2009). The photo shows a winter view of Yosemite, one of the most famous parks. It opened in 1906 with around 5 thousand visitors. Ninety years later, annual visitation exceeded 4 million (Fig 1). Yellowstone is America's first national park. It experienced dramatic growth (Fig 2) as well. Yellowstone opened in 1904 with around 14 thousand visitors. By 2010, it received over 3.6 million visitors.

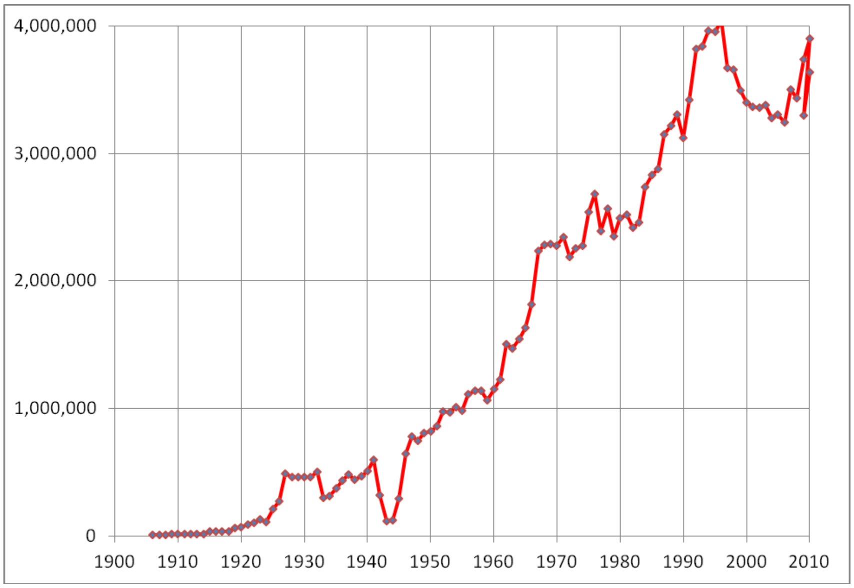

Figure 1. Annual visitors to Yosemite National Park

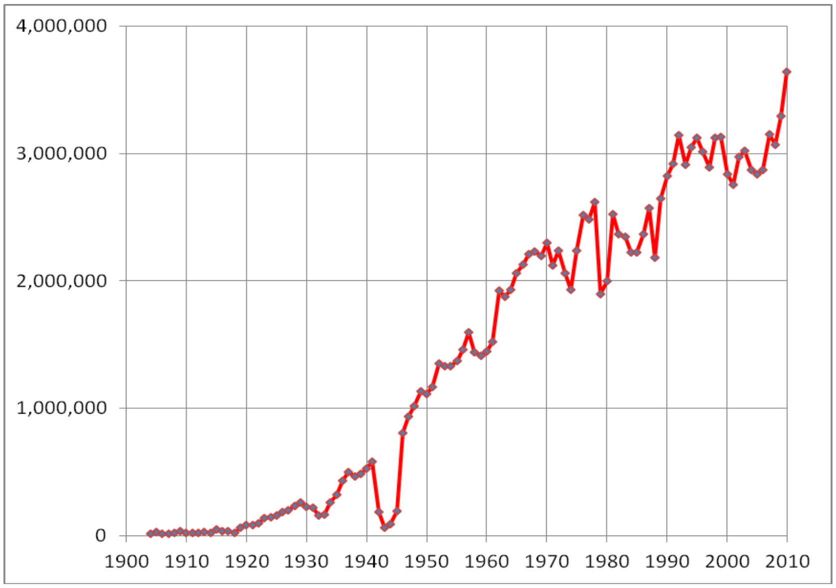

Figure 2. Annual visitors to Yellowstone National Park

Fig 3 shows visitation to Glacier National Park, the park described in this paper. Glacier opened in 1911 with 4 thousand visitors. By 2010, Glacier received over 2 million visitors. Fig 3 compares the Glacier data with the logistic equation[1] for annual visitation. The equation gives a reasonable fit when Glacier's *carrying capacity* is specified as 2 million visitors per year. Similar fits can be obtained for Yellowstone (carrying capacity = 3 million visitors per year) and Yosemite (carrying capacity of 3.5 million visitors per year).

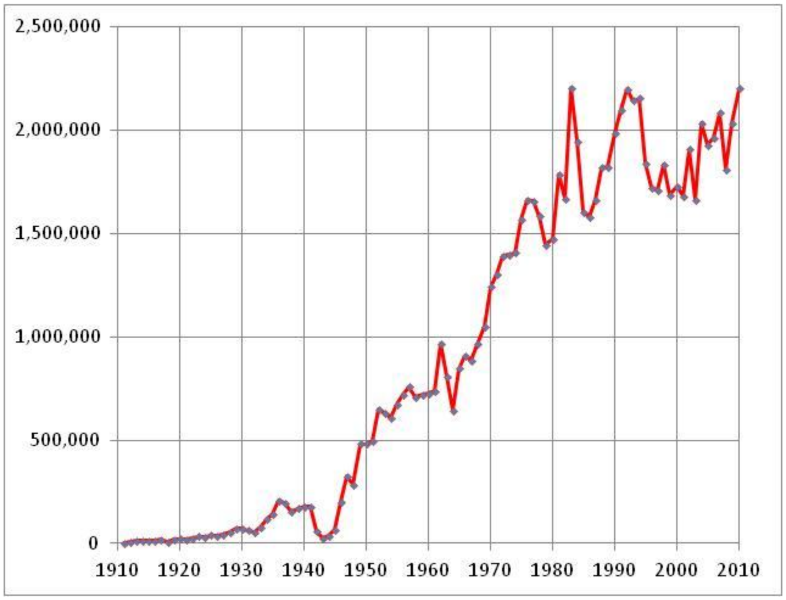

Figure 3. Annual visitors to Glacier National Park

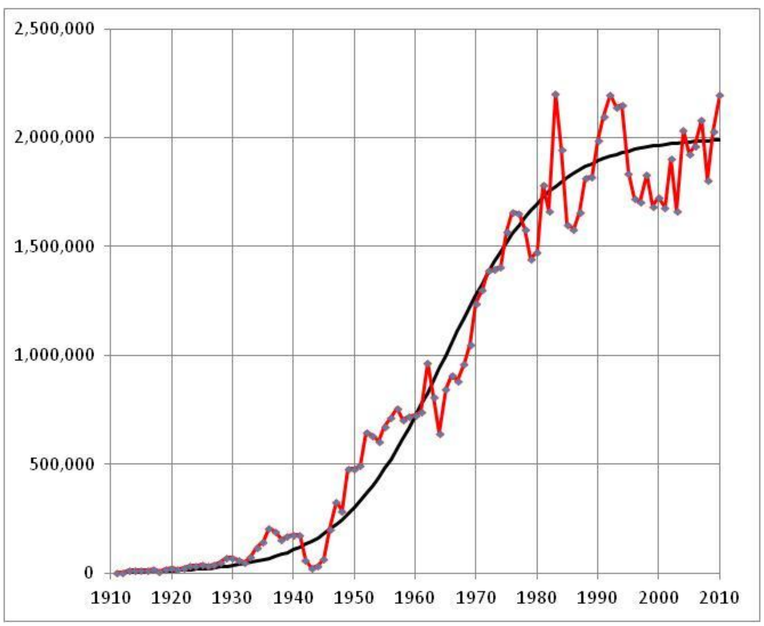

Figure 4. S-shaped growth in annual visitation to Glacier National Park

[1] The logistic equation for annual visitation is $AV(t) = AV_o e^{rt}/(1+(AV_o/K)*(e^{rt}-1))$ as explained by Ford (2009, p 80). The r is the intrinsic growth rate that dominates when the system is small. The K represents the eventual size of the system and is often called the system's *carrying capacity*.

2. The System Dynamics Perspective on S-shaped Growth

System dynamics investigators use computer simulation to increase understanding of general patterns of change over time. Figure 5 shows six of the most common time patterns. Understanding exponential growth is of special interest in countries looking for rapid growth in newly created parks. However, in the USA, S-shaped Growth and The Overshoot are more relevant as the parks plan for the second century.[2]

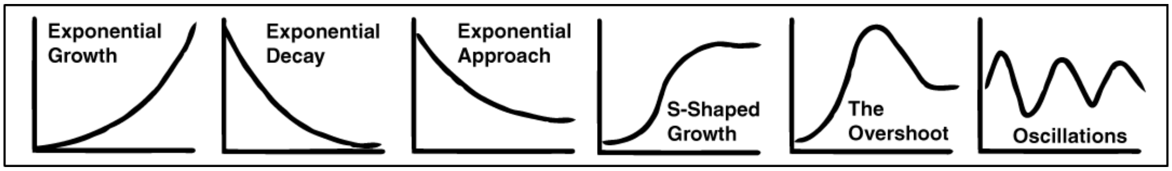

Figure 5. Six patterns of dynamic behavior (Ford 2009, p. 8)

S-shaped growth is a special form of growth in which the system senses its limitations in a smooth, continuous manner. This allows the system to reach a state which can be sustained indefinitely into the future. The S-shaped pattern is one of the fundamental time patterns that System Dynamics modelers think about in the early stages of model conceptualization. They look to positive feedback mechanisms to create the exponential growth portion in the early years; and they look to density-dependent negative feedbacks to allow the system to feel its limitations in a way that achieves a sustainable state.

Modelers also look to previous system dynamics studies for insight on the feedback structure to allow a system to reach a sustainable state. In the case of America's national parks, we would look for models that simulate many decades of historical behavior and then project many decades in the future. System dynamics has a strong history with such models; the most-widely known examples deal with the overshoot pattern in urban systems (Forrester 1969) and in the global system (Forrester 1971, Meadows 1972).

The system dynamics perspective looks inside the system for an explanation of whether we should expect S-shaped growth or an overshoot. This perspective is second nature to the participants in the 2012 conference, but it is not necessarily shared by investigators of the parks. A more common tendency is to look for external factors to explain visitation.

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2. Promoting visitation was certainly the goal in the USA in the early years of the previous century, as explained in the *Going Home* episode of the Duncan and Burns (2009) film: http://www.pbs.org/nationalparks/history/ep4/ The film describes Stephen Mather, the first director of the National Park Service, as "willing to try almost anything to attract publicity and lure more visitors." *Going Home* describes the director's determination to increase visitation:

Mather found solace and rejuvenation [in the parks], and he wanted all Americans to experience that healing power. But he realized that until more people started showing up, Congress would never create more parks, or even support the existing ones. "There could never be too many tourists for Stephen Mather," Horace Albright remembered. "He wanted as many as possible to enjoy his 'treasures.'"

Mather and his young assistant, Horace Albright, would ally themselves with the machine that had already begun transforming American life: the automobile. Their efforts would bring Americans to the parks as never before. But for some, allowing cars into the parks was the equivalent of allowing the serpent into Eden. While it was an easy decision for Mather, many park supporters worried that he had made a pact with the devil.

Figure 6 illustrates the external factors approach with a word-and-arrow diagram focused on visitation. This approach encourages list making, with the apparent goal of listing as many factors as possible. The end result is an overwhelming list of factors that would deter any attempt at cause-and-effect modeling. How then, does one proceed in the face of such a daunting list? One approach is depicted in Fig 7. The investigator assumes that the effect of all the external factors is embedded in the recent number of visitors. This assumption opens the door to the autoregressive statistical model whose basic assumption is that the best indicator of next year's visitation is the average visitation over the past few years.

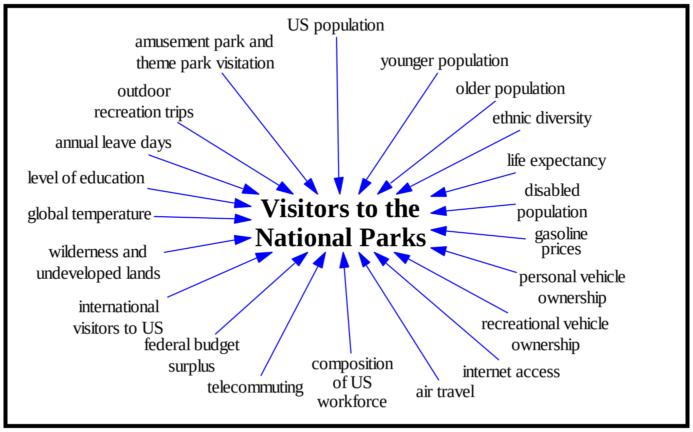

Figure 6. List of external factors that could influence park visitation.[3]

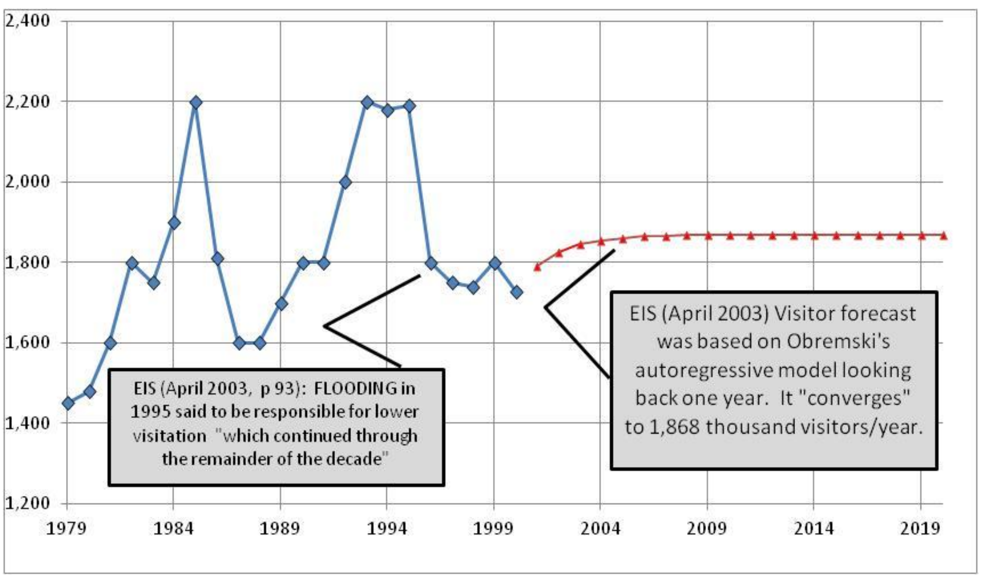

Figure 7. Statistical forecast of future visitors to Glacier National Park.

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3 This list was background for the visitation forecast in the Environmental Impact Statement (EIS) for the *Going to the Sun Road* rehabilitation project. (We added arrows to show the list in a word-and-arrow diagram familiar to conference participants. The arrows have not been labeled as + or – since the influence of each factor on visitation was not explained.) The base line forecast indicated 1.868 million visitors per year. Visitation in recent years has been significantly higher, and there has been considerable volatility in visitation from year to year. Nevertheless, the 1.868 million forecast was a reasonable base line for the calculation of impacts for the rehabilitation options in the EIS.

The statistical approach was taken in the Glacier EIS, and the forecast provided a reasonable bench mark for impact analysis. But the statistical model does not yield insight on whether the parks can avoid the overshoot pattern in the future. And the statistical model does not help management anticipate the impact of policies that might influence visitation. A more productive approach is to look inside the parks for a characterization of its attractiveness to visitors.

Work by Manning (2007, 2011) and Freimund (2002, 2011) suggests that attractiveness may be characterized by social norm curves for different types of visitors. Surveys and regression studies of indifference curves reveal generally robust patterns for three types of visitors: those primarily in search of solitude, others looking for easy access, and a third group seeking a tradeoff between solitude and access. Fig 8 shows a hypothetical breakdown of the Glacier Park logistic curve into these groups:

- The solitude curve is the lower curve. As a hypothetical example, we assume the solitude-oriented percentage is 25% for first 50 yrs, falling to 10% in next 50 yrs.

- The access oriented group is at the top of the graph. They comprise 25% in the first 50 years, with their percentage growing to 45% in the next 50 years.

- The middle group is the tradeoff-oriented visitors. They could comprise 50% for the first 50 years, falling to 45% for the next 50 years.

This hypothetical composition is one way to depict the displacement that we believe is underway at Glacier. Solitude oriented visitors are likely to be declining because of the increased congestion on the remote trails and destinations. Their displacement takes many forms. It may occur in space (where they avoid the crowded trails), during the season (when they avoid the busy months of July and August), over the decades (when they visit less frequently) or by not returning in the future.

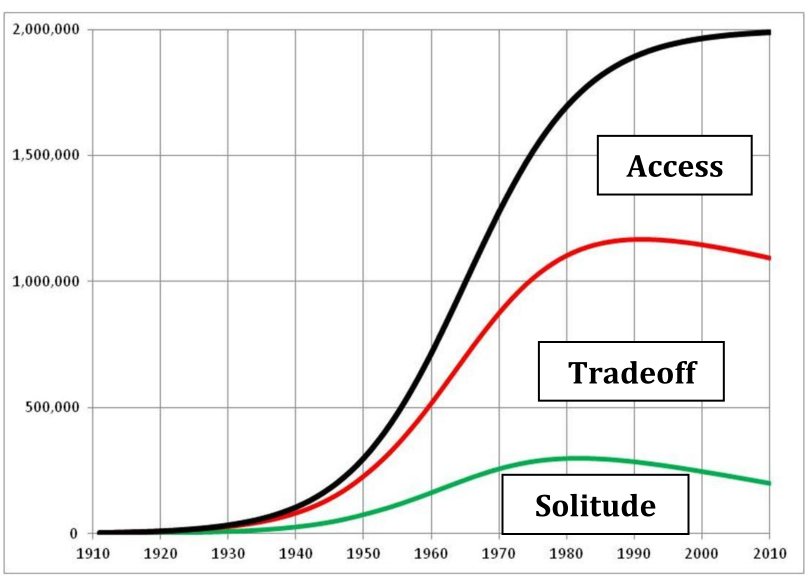

Figure 8. Hypothetical composition of Glacier's historical visitation.

Figure 9 turns our attention to the future. The graph shows the three trajectories for the first 100 years at Glacier National Park, but the next 50 years is left blank. System dynamics modelers will see the blank space as an invitation to sketch the *reference mode*, the target pattern of behavior for a model. Some readers may sketch a renewed pattern of growth with visitation increasing well beyond a "carrying capacity" of 2 million visitors per year. They may argue that recent events (ie, depressed economic conditions and higher gasoline prices) have created only a temporary slowdown in visitation.

Other readers may expect annual visitation to decline in the next 50 years. Increased crowding on the popular trails may discourage return visits by those seeking solitude. Increased problems with road and parking congestion may discourage return visits by those needing convenient access. Perhaps the next 50 years will be a period of declining visitation. The overall pattern from 1910 to 2060 would then resemble The Overshoot pattern in Figure 5.

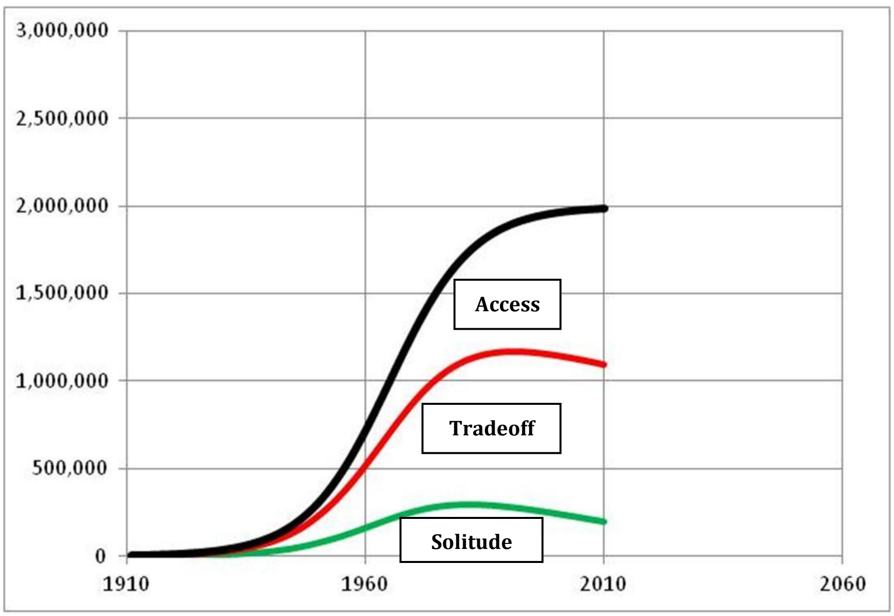

Figure 9. Looking to the future: how will the curves change in the next 50 years?

Readers may have different outlooks for Glacier, but they should all agree that future visitation will be shaped by a variety of factors, both external and internal. And most readers would agree that the future trajectories can be shaped to a certain extent by the visitor management plan developed by the park. In simplest terms, visitor management is an on-going process to develop answers to three, fundamental questions associated with Figure 9:

- What pattern is likely to occur with the current visitor management plan?
- What pattern would we like to see?
- What strategies will coax the system in the desired direction?

These questions can be addressed by systems thinking, as proposed by Peter Senge and other members of the National Park's second century commission (NPS Second Century Commission, 2009). They can also be addressed by system dynamics modeling, which is often best used in combination with systems thinking.

3. Computer Simulation and the Parks

Computer simulation has been put to good use in parks and other recreational or protected areas. We now summarize previous modeling methods with an eye for the best way to use system dynamics. We begin with the Table 1 summary of work on tourism management[4] by our colleagues in the system dynamics community.

Software	Study area and time horizon	Authors
Stella II	Yucantán Peninsula, Mexico, 20 years	Kandelaars, 1997
Vensim	Guilin, China, 30 years	Honggang & Jigang, 2000
Powersim	Ria Formosa Natural Park, Portugal, 35 years	Videira et al., 2003
Powersim	Hypothetical resource based tourism, 12 years	Chen, 2004
Stella	The Commonwealth of Dominica, 19 years	Patterson et al., 2004
Vensim	Basque Country, Northern Spain, 10 years	Bald et al., 2006
Vensim	Ranthambhore National Park, India, 100 years	Dayal, 2007
Vensim	Jamaica, 70 years	Ishutkina, 2009
Vensim	South European Island, 720 months	Xing & Dangerfield, 2011

Table 1: System Dynamics models used in conservation and tourism management.

The Ria Formosa National Park study is the most important of the projects because of Nuno Videira's extraordinary effort to engage stakeholders in the modeling process. Most model developers have some interaction with stakeholders, but their principal interactions are usually with managers, experts and, of course, the person who commissioned the study. Videira's project was different. His goal was to engage a large group of stakeholders[5] to help shape the model focus, to develop the model structure and to assess the credibility and usefulness of the results. This modeling process is often called *participatory modeling* or *collaborative modeling*. Participatory projects require more time and effort than traditional modeling projects,[6] but the

[4]A system dynamics model of the Grizzly Bear population of Yellowstone National Park was constructed by Rosemary Jackson, as described by Faust (2004). The model focused on land use decisions in the GYE, the Greater Yellowstone Ecosystem. Her model is not included in this review since it focused on wildlife management rather than tourism management.

[5]Sixty groups were represented by stakeholders engaged in an 18 month project. The participants spend approximately 48 hours in 4 workshops. They helped with data collection as well as model development (Videira 2003; Beall 2007).

[6] Participatory modeling efforts are described by van den Belt (2004), Vennix (1996) and Stave (2002). The processes followed in nine participatory projects dealing with environmental systems are compared by Beall (2007) and by Beall and Ford (2010).

extra time pays dividends in the form of increased understanding and shared learning.[7] In the Ria Formosa study, participants came to view visitor access to the park as a key factor to be simulated in the model. The stakeholder involvement in the model design and the simulation results made them aware of the tradeoffs from improved access. By the end of the project, many stakeholders voiced their opposition to transportation projects because of the impacts that would follow in the wake of improved access.

The Southern European Island model is noteworthy for simulating the interaction between tourist flows, tourism labor, hotel and the public utilities (airports, energy, water and waste disposal). The interactions were described by a weighted attractiveness index that comprised tourism price, social stability, low density and infrastructure attractiveness indices. This study described the connection between tourists, social and environmental conditions. Xing and Dangerfield (2010) used the model to test the impact of changes in charter flights and the imposition of a tourist tax. The simulations revealed that a high fraction of charter flights are associated with packaged tours and cheaper accommodations. The packaged approach is favored by large tour operators, and it results in a tourism market dominated by customers who prefer inexpensive holidays. The authors describe the end result as a downward spiral of a tourist industry that sends more and more tourists greater distances to earn less and less profit. Xing and Dangerfield (2010) showed that a tourist tax brings complexities in collecting tax and distributing funds to environmental projects. A high tax can reduce arrivals and subsequent tax revenues. They then simulated a policy to promote luxury tourism by regulations limiting the construction of budget hotels. The simulations indicated that this third policy could control the expansion of mass tourism and deliver what the authors called *sustainable tourism*.

A common feature of the system dynamics applications is the long-time horizon. Several simulations run for 50, 60 or 70 years and one simulation runs for 100 years. The Basque Country study has a 10 year time horizon, the shortest of the models. We turn now to other modeling methods, where a common denominator is the focus on dynamics that unfold over a much shorter span of time.

Table 2 shows 17 studies using agent-based modeling (ABM) and other modeling methods. Several of the models simulate a typical day at the park, so their time horizon is one day (or a portion of the day). Two models simulate dynamics over a 3 month time horizon. The simulations for the John Muir Wilderness covered 92 days, while the simulations for the River of No Return Wilderness covered 89 days.

Table 2 lists particular models that have been applied in multiple locations. The travel simulation model, which uses the Extend software, has been applied in seven locations. One of the notable applications represented visitor use on the carriage roads in Acadia National Park. The main indicator of the Visitor Experience and Resource Protection (VERP) framework at Acadia was people per viewscape. Later modeling applications included front country hiking,

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[7] Participatory modeling requires software that emphasizes the clarity of stocks and flows and provides a common language that can be understood by stakeholders, managers, scientists, etc. System dynamics software (such as Stella) has become a common platform for participatory modeling of environmental systems (Ford 2009, p 313).

backcountry camping and public transportation in park. The VERP indicators also include the number of visitors at a particular location at a certain time (Cole, 2005).

Starting in 2001, Gimblett et al. developed the RBSim simulator, the second main category in Table 2. RBSim is a specialized tool to build simulations of recreation behavior which can be integrated with a GIS to allow both probabilistic simulations and agent-based simulations. RBSim was applied to the Sierra Nevada, Colorado River in the Grand Canyon and the Twelve Apostles of Port Campbell National Park, Australia (Cole, 2005). Other agent-based models include iRAS (Intelligent Recreational Agent Simulator) developed by The University of Melbourne (Loiterton and Bishop, 2008) and MASOOR (Multi Agent Simulation of Outdoor Recreation) developed by Alterra Green World Research and Wageningen University in The Netherlands (Jochem et al., 2008).

Model/ Software	**Study area and time interval**	**Authors**
Travel simulation model (Extend)	John Muir Wilderness, 92 days	Lawson et al., 2005
	Yosemite Nat. Park, 1 day	Manning et al., 2005
	Alcatraz Island, 3 days	Valliere, Manning, Wang 2005
	Arches Nat. Park, 1 day	Lawson et al., 2005
	Isle Royale Nat. Park, 3 weeks	Lawson and Manning, 2003
	Acadia Nat. Park Carriage Road, 8 hours	Wang and Manning, 1999
	Acadia Nat. Park Scenic Road, 50 days	Hallo, Manning, Valliere, 2005
RBSim (Swarm & ArcView)	Broken Arrow Canyon, 1 day	Gimblett et al., 2001
	Bighorn Crags in the Frank Church River of No Return Wilderness, 89 days	Gimblett et al., 2005
	Misty Fjords Nat. Monument in the Tongass Nat. Forest, 59 days	Gimblett et al., 2005
	Port Campbell Nat. Park, Australia, 1 day	Itami, 2005
	Prince William Sound, Alaska, 60 days	Lace et al., 2008
	Colorado River, Grand Canyon Nat Park, 7 days	Gimblett, Daniel, Roberts, 2000
MASOOR	Lobau (Danube Flood plains Nat Park), Vienna, Austria	Taczanowska, Arnberger and Muhar, 2008
	Amsterdamse Waterleidingduinen, The Netherlands, 1 day	Pouwels, Jochem and Verboom, 2008
	Dwingelderveld Nat. Park, The Netherlands	Jochem et al., 2008
iRAS	Royal Botanic Gardens, Melbourne, Australia	Loiterton and Bishop, 2008

Table 2: Summary of other models used in conservation and tourism management.

Probabilistic simulation models have been used for various purposes in wilderness management such as describing current use patterns (Bighorn Crags, Misty Fjords, Grand Canyon and John Muir), predicting maximum sustainable use (Isle Royale, Yosemite, Alcatraz Island and Arches), forecasting the impact of increased use levels on crowding-related variables

(Acadia and Twelve Apostles), and finding ways to collect visitor data in difficult circumstances (Mt. Rainier). However, there are still challenges in application to-date. Those models are partially validated, lacking statistically comparison of simulation results to observation data and lacking numerical confidence in predictions (Cole, 2005).

4. A System Dynamics-Based System for Visitor Management

Comparing the time horizons in Tables 1 and 2 would suggest that long-term simulation is the natural domain for system dynamics. Indeed, a 50 year time horizon would match the future portion of the visitation graph in Fig. 8. One could argue that system dynamics should concentrate on the long-term and leave short-term operational modeling to others. But visitors' experiences during a single day at a national park can shape their impressions and their decisions to return in the future. Their impressions can also shape the stories shared with their friends and neighbors and influence their decisions on visiting the park. A short-term model that sheds light on daily conditions could generate important insights on visitor impressions.

We believe visitor management could be supported by an integrated modeling system like the one depicted in Fig. 10. The key is to put system dynamics to use on both long-term and short-term dynamics. The system dynamics ideas of stocks, flows and feedbacks apply in both time domains, and the icon-based software to depict the stocks and flows would promote understanding of short-term as well as long-term dynamics. Furthermore, the software can be used to design user-friendly interfaces to promote interactive simulation in both time domains.

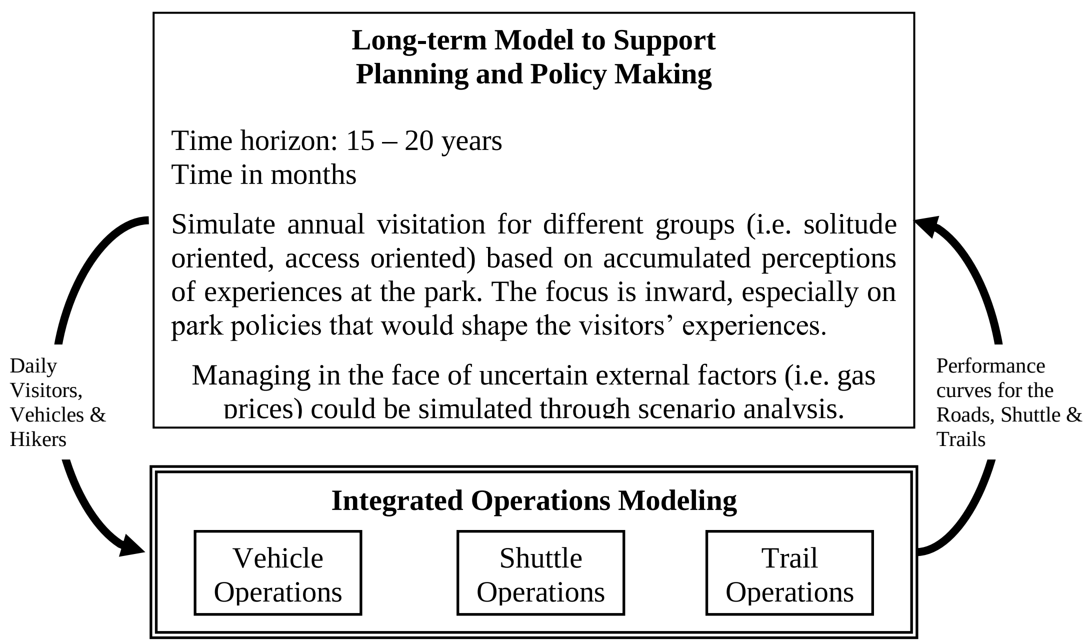

Figure 10. An integrated system for modeling support of park planning.

The upper box in Fig. 10 depicts a long-term model, a model which fits within the historical traditions of system dynamics work in the parks. The time horizon would stretch 15-20 years into future, or even longer, depending on the planning horizon of park managers. The long-term model might be designed to simulate visitation of the three groups depicted in Figure 9. It would focus on conditions within the parks, especially those conditions that can be shaped by visitor management strategies. External factors could be included as well. These might include changes in the price of gasoline, the growth of the economy and changes in the weather.[8] These external factors would certainly influence the simulation results, perhaps causing major variations about an underlying pattern (such as S-shaped growth). The long-term model could be used to study the effectiveness of the visitor management plan in the face of multiple uncertainties in the external environment.

System dynamics has been put to good use in operational modeling, as explained in business texts by Forrester (1961) and Sterman (2000). Fig. 10 shows an integrated operation model to simulate vehicles, shuttle buses and hikers. The operational model would simulate a typical day in the summer season, with inputs on visitors and vehicles from the long term model. Results from the operational model could be converted to performance curves needed in the long-term model. The appeal of the integrated system is the increased learning that will occur when the same concepts appear at both the operational and the planning levels. Learning will be enhanced when the same software is used at both levels. An integrated, system dynamics-based modeling system would provide a useful contribution to applied research on park management. Research at Washington State University (WSU) is underway to create such a system. We are following a pragmatic, case study approach in which modeling ideas are tested with concrete examples.

5. The Northern Territory Case Study

The first case dealt with long-term dynamics of visitation to multiple destinations in the Northern Territory of Australia. The attractiveness of different destinations could be influenced by their costs, travel time requirements, cultural features, natural beauty, recreational opportunities, hotel and dining facilities and a variety of other factors. The central challenge in long-term models is simulating attractiveness in a reasonable and internally consistent manner (Kang 2010, Maani 2010, Honggang 2010).

We believe the multi-nomial logit model (Ford 2009, p. 214) is well suited to meet this challenge. The model is well established[9] with the coefficients for attractiveness normally estimated from revealed preferences or stated preferences. These data were lacking in our case study, so the coefficients were based on expert judgment. The approach was demonstrated in a simulation of visitation to Alice Springs, the town near the famous Ayers Rock (known as Uluru by the indigenous people, for whom the rock is a sacred place).

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[8] Weather conditions are particularly important at Glacier. Flooding in 1995, for example, is said to be responsible for the lower visitation in the late 1990s (see Fig. 7). Snow fall is also an important external factor since high heavy snow accumulation can delay the opening of the Going to The Sun Road.

[9]The multinomial logit has been called the "workhorse" of choice models (Ford 2009, p. 215). A simple, multinomial logit was used in the Alice Springs model. However, we learned that tourists often visit Alice Springs in conjunction with visits to another location during the same vacation. The linked nature of the designations suggests that a nested multi-nomial logit function be used in the future.

Photo 2. Uluru/Ayers Rock.

Map 1.

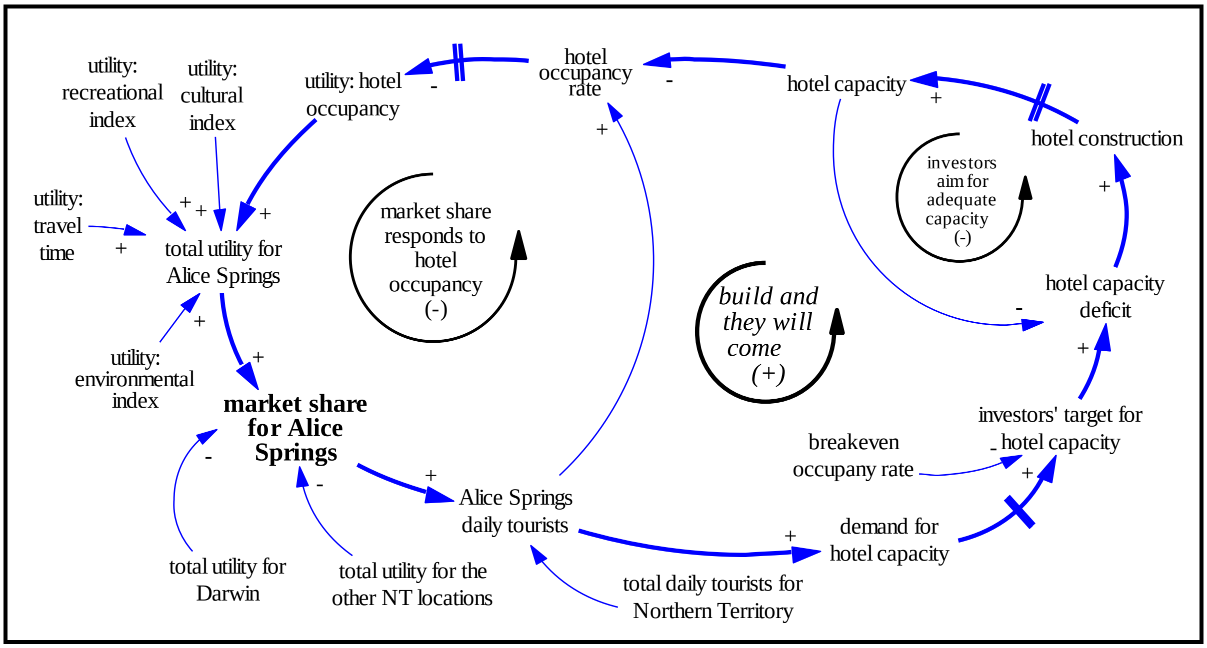

Figure 11. Three of the feedback loops in the Alice Springs model.

The model simulated the competition for visitors between Alice Springs, the city of Darwin and other popular destinations in the Northern Territory of Australia. The utility (attractiveness) of each location depended on the travel time, the hotel occupancy rate and indices for cultural, recreational and environmental conditions. The market share for Alice Springs (MS_{as}) makes use of the multi-nomial logit function, with U representing the utility of the three destinations (the town of Alice Springs, the city of Darwin, other locations).

$$MS_{as} = e^{Uas} / (e^{Uas} + e^{Ud} + e^{Uo})$$

Fig. 11 draws our attention to the impact of a high occupancy rate (crowded hotels lower the attractiveness and market share for Alice Springs). The positive feedback loop is highlighted in bold in Figure 11. It can contribute to growth in tourism, growth in hotel capacity and further growth in tourism. This loop is labeled *build and they will come* since this slogan reflects the thinking of some of the promotional participants in the system. A variety of promotional policies have been advocated by the cities and by the Northern Territory provincial government. The model was used to shed light on both the intended and unintended consequences of the policies.

The Alice Springs case study was conducted by Amphone Sivongxay (2010) as part of MS studies at WSU. Her study was a short, but insightful demonstration of the use of system dynamics to simulate relative attractiveness of special places and their neighboring communities.[10] She suggested that future modeling efforts should follow a participatory approach with active involvement of stakeholders, and she pointed to the work by Beall and Zeoli (2009) as an example.[11]

6. The Glacier National Park Case Study

The second case study was conducted by Thuy Nguyen (2012) as part of PhD studies at WSU. Her study provides a detailed and insightful demonstration of the use of system dynamics for integrated operations modeling, as depicted in the lower box of Figure 10. The Glacier model focuses on a typical day in July. It represents the vehicles and shuttle buses using the roads in the Going to the Sun Road Corridor. And it represents the visitors and their use of trails at the popular destinations.

6.1. The Modeling Process

Our policy focus is the shuttle system that was introduced during the rehabilitation of the Going-to-the-Sun Road. The shuttle has helped reduce road congestion and facilitated visitors' travel within the park. Indeed, many shuttle users have expressed their hope that the shuttle system would be continued after the road rehabilitation is completed. However, there has been concern over increased trail congestion from shuttle riders. Whether to cancel or continue the shuttle is being addressed in the park's ongoing process of visitor management. Our goal was to develop a model that could shed light on both the intended and unintended impacts of the shuttle system.

The model was developed in an iterative process with frequent contributions from Glacier staff over a 12 month interval. Initial discussions were facilitated by a model of a hypothetical shuttle system serving a simple route between a park entrance and a mountain top destination. The simple model illustrated the look and feel of simulations with an interactive, user-friendly interface. The introductory model also showed a straight-forward method to simulate the *latent* (unserved) demand for the shuttle system.

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[10]Sivongxay observed that tourism policy discussions inevitably involve multiple, often conflicting goals, especially those of the tourism operators and the local or indigenous people. For example, there is a tension between the Uluru traditional owners and the associated tourism operators. Uluru is a sacred place for the traditional owners, and they have struggled to pass a ban for climbing. In contrast, tourism operators are generally against the ban because of possible impact on tourist visitation. Sivongxay believed that regional tourism policy was slanted in favor of tourism development rather than reinforcing the protection of the cultural uniqueness and indigenous identity. She argued that participatory modeling would help the Northern Territory develop policies to promote sustainability as well as meet the goal of increased tourism.

[11]Participatory modeling (aka, collaborative modeling) has also been pursued by the Commonwealth Scientific and Industrial Research Organization (CSIRO) in their Central Australian tourism Futures (CATF) model (Walker 1999; CSIRO, 2002).

Feedback from staff led to a simulation of the daily operations at Glacier. The new model divided visitors (and their cars) into five groups in order to send them to appropriate locations within the park. The shuttle sector was designed with ten buses serving three routes with the main focus on the number of additional visitors to Logan Pass. The visitors at Logan Pass were sent to one of three destinations before returning to their cars or to the bus station. Additional discussions with Glacier led to a model with six types of visitors, a shuttle system with fifteen buses serving four routes, and a Logan Pass sector with multiple choices for short and long hikes.

6.2. Model Design

Figure 12 provides an aggregated stock and flow diagram to depict the main feedback loops in the operational model. This diagram was created with the Vensim software, with cars in black and people in blue. The model was implemented with Stella software, making extensive use of conveyor stocks and arrays. The parking lot constraint loop in Figure 12 is implemented at the main parking lots on the west-side of the park.[12] The dynamics of searching for a parking space unfold in short time span, so a small step-size (DT) is required for accurate simulations.[13]

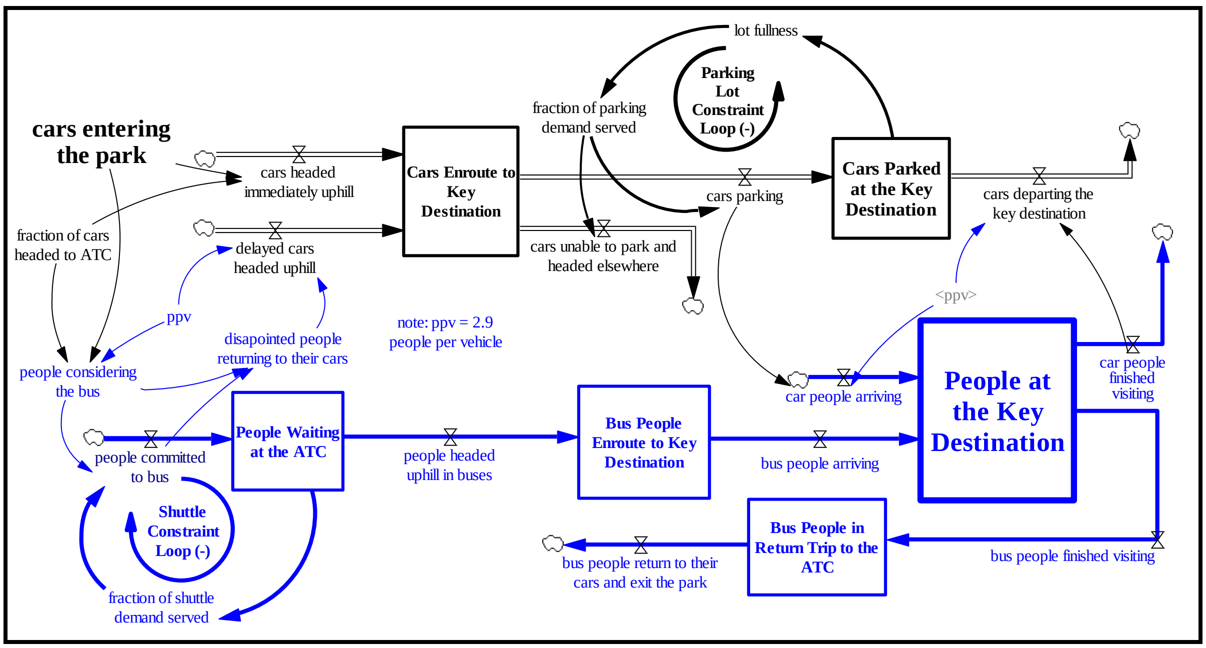

Figure 12. Aggregate representation of the stocks, flows and feedbacks in the Glacier model.

[12] The four parking lots shown in Fig. 14 are simulated for west side operations. East side lots are not included. We represent east side visitors arriving at Logan Pass with a simple proportionality rule. Glacier National Park staff have asked for a model expansion to represent east-side operations with explicit treatment of the main parking lots.

[13]DT is 1/8th of a minute, and we use Euler integration. A simulation from 7am to 7pm covers 720 minutes and requires over 5,000 calculations, an unusually large number of calculations for system dynamics models (Ford 2009, p.44). A typical simulation requires around 30 seconds on a laptop computer. The simulations are sufficiently fast to promote interactive experimentation, especially when we take time to view results as the simulated day unfolds in one-hour increments

Figure 12 provides an overview of the key feedbacks by combining people and vehicles into aggregate categories. Figure 13 reveals some of the details for the stock of people at the key destinations. Discussions with park staff led to a focus on trail use at Logan Pass. The model simulates car people and bus people arriving at this popular destination.[14] This diagram shows one Stella's "sector" icon to enclose the stocks and flows of bus people visiting Logan Pass.[15] We use conveyor stocks as a convenient way to keep track of hikers on different segments of the Logan Pass trail system.

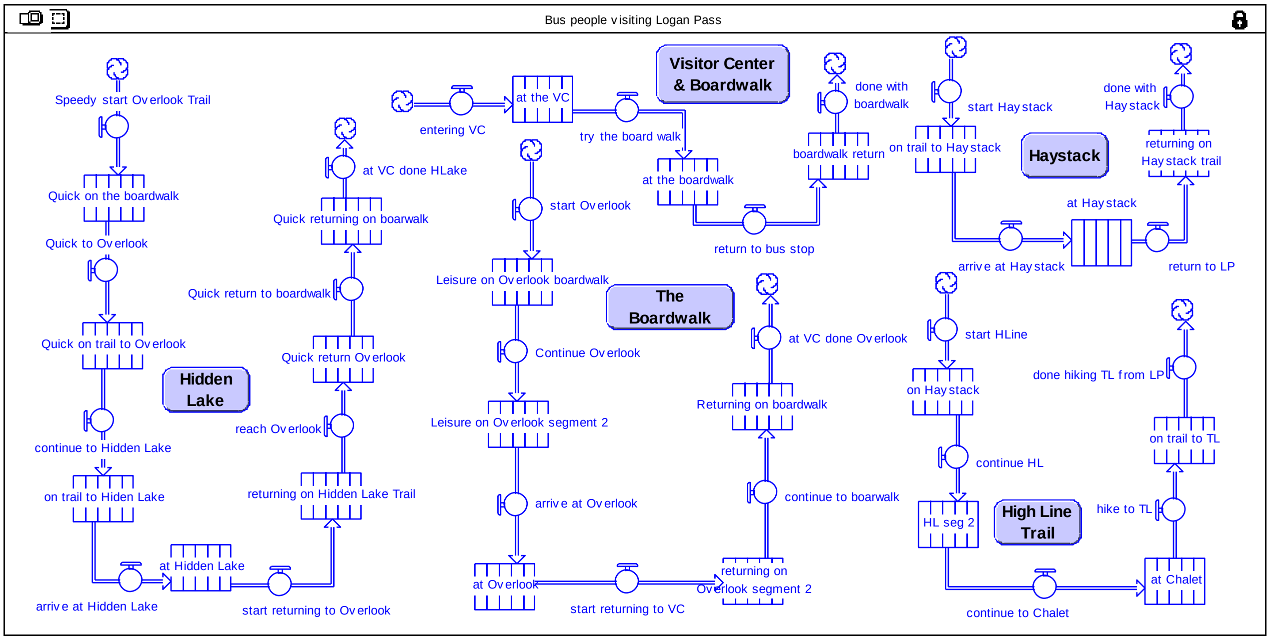

Figure 13. Stocks and flows to representing the "Bus People" visiting Logan Pass.

6.3 Initial Results from the Glacier Case Study

Our goal is to provide a learning environment to aid in operational planning. Toward this end, the model has been designed with Glacier visuals and convenient input devices. Figure 14 shows an example. This is the *traffic map* of the west side of the Going-to-the-Sun Road with parking lots at the Apgar Visitor Center, Avalanche, The Loop and Logan Pass. The numerical displays in pink show the cars parking at each parking lot; the numerical displays in blue show cars traveling the road. The simulation is paused at 10 am, a time when staff expects most parking lots to be full. The red lights in Figure 14 confirm that the base case simulation fills the key parking lots by 10am on a busy day in July.

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[14] Car people arrive early in the morning before the parking lot is full. The Logan Pass lot holds 254 cars with an average of 2.9 people per vehicle. So the car people inflow is around 740 people who start their activities by 10am or earlier. Additional car people arrive later in the day, but their arrivals must await the creation of vacancies in the parking lot by departures of the early arrivals. Bus people arrivals are spread out during the day, depending on the bus schedule.

[15] Stella's hide feature was used to hide the converters and connectors in Figure 13. This allows the eye to concentrate on the typical hikes undertaken by visitors to Logan Pass.

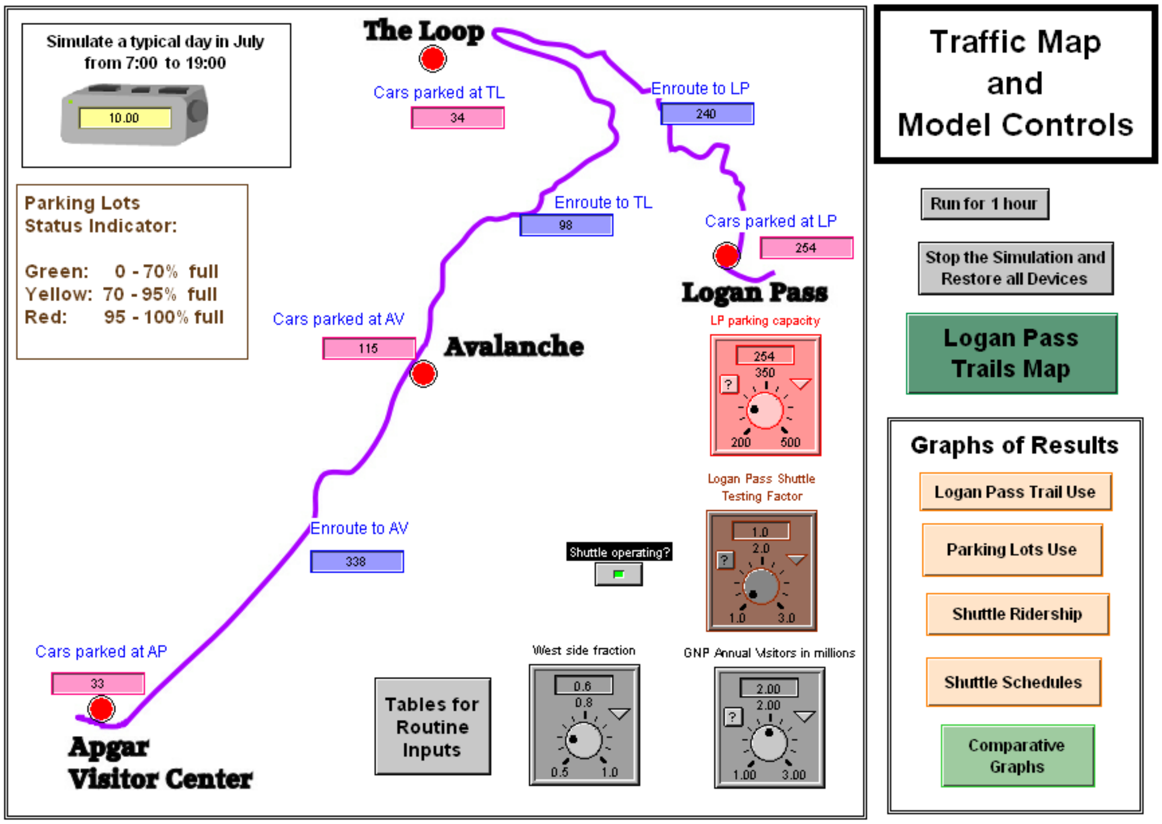

Figure 14. Traffic Map showing model controls and results at 10am in the base case simulation.

The Logan Pass parking lot is of most concern in our case study. Figure 14 shows all 254 parking spaces are taken at 10am. This is a familiar situation to Glacier staff and a good check on the simulation model. A significant fraction of visitors want to visit Logan Pass, and parking lot congestion is a chronic problem. This is apparent from the Fig. 14 results at 10am. The parking lot is already full, and there are 240 cars on the road segment from The Loop to Logan Pass. These cars would probably hold around 700 people; they are among the many that will not be able to park at their intended destination during a typical day in July.[16]

Parking lot congestion is depicted in the time graph from 7am to 7pm shown in Fig. 15. Total cars parked at Logan Pass reaches the 254 car limit just before 10am. Parking at Avalanche (AV) is full by around 9am. The time graph shows small variations in the number of parked cars from 10am to around 3pm. These small wiggles in the time graph represent the departure of cars and the quick replacement of the empty space by a newly arriving car. Significant vacant space in the key parking lots does not appear until around 3:30 or 4:00 pm.

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[16] Glacier has an average of 2.9 persons per vehicle, so the 240 cars could hold 696 people. The model keeps track of different groups of people based on their destination(s). People encountering a full parking lot at their intended location are sent "elsewhere" (i.e. outside the model boundary). The model keeps track of the total number of cars that will not be able to park at the intended destination. They amount to 70 to 80% of the cars entering on the west-side of the park.

Visitors to Logan Pass can avoid parking lot constraints by using the free shuttle system. Potential demand for the west-side shuttle has been estimated at 10% of the visitors entering at the west entrance. The blue curve in Figure 16 shows the number of potential riders climbing to 930 by the end of the day. The green curve shows the served demand, measured as the number of potential riders who board a bus at the Apgar Transit Center and begin a journey on the Going to the Sun Road. The red curve keeps track of the visitors who are discouraged by the long waiting line at the ATC and return to their cars to drive the road instead. The base case simulation showed that the west side shuttle system could serve 77% of the potential demand.

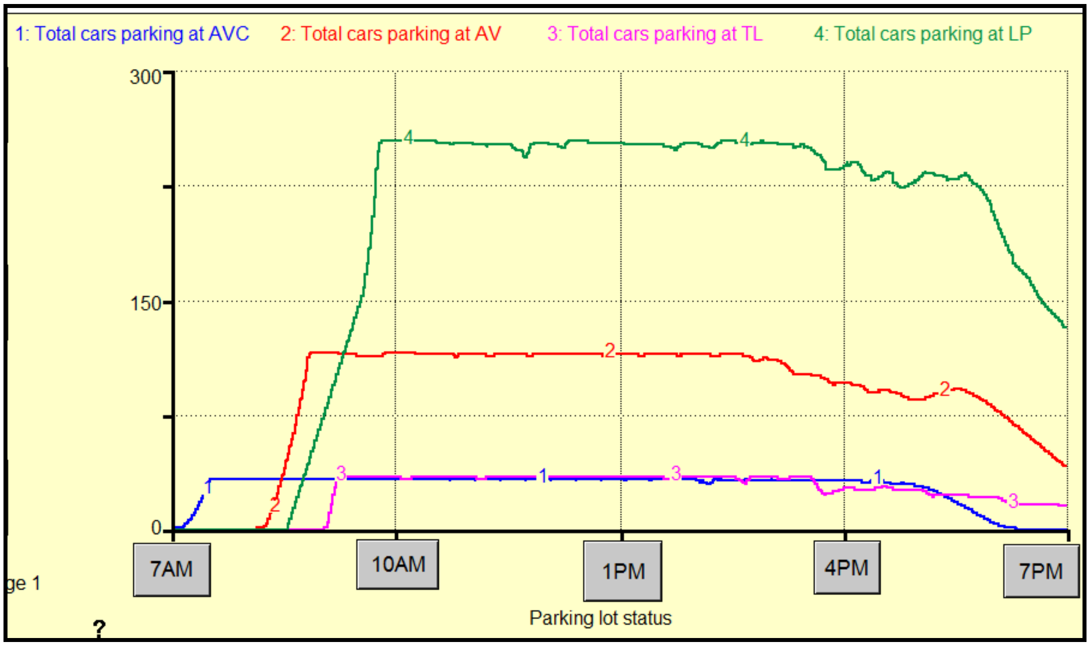

Figure 15: Parking lot status for a typical busy day of July from 7am to 7pm.

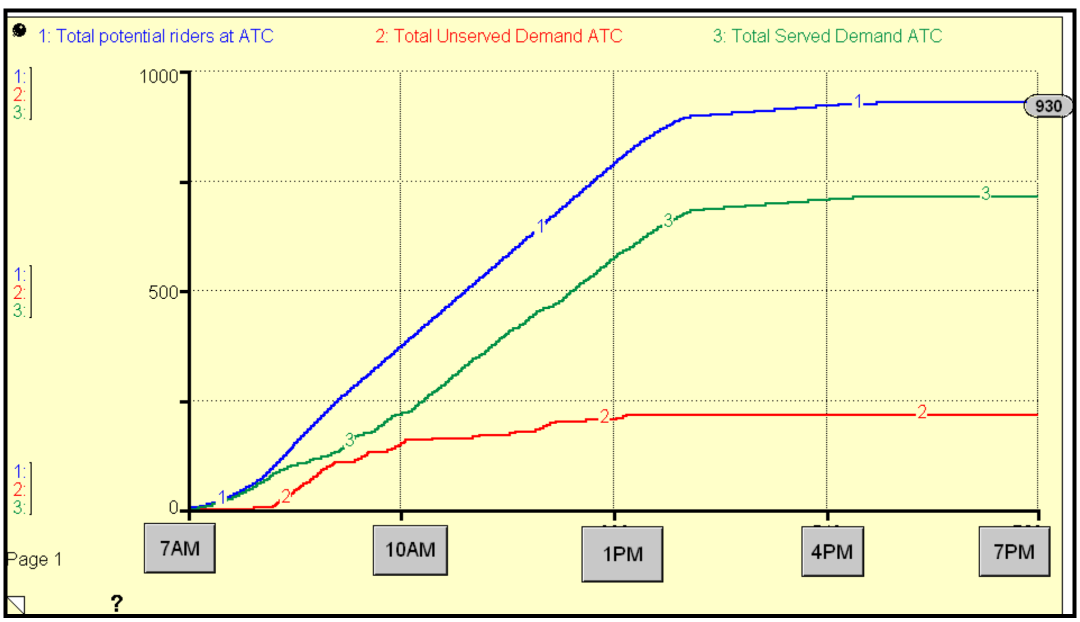

Figure 16: Potential riders on the West Side shuttle system grows to 930 per day.

Figure 17 shows the *Logan Pass Trails Map* on the model interface. The model is paused at 10am in the base case simulation, the same situation as shown in Figure 14. The numerical displays show 198 people at the visitor center, the jumping off point for the trails. The boardwalk is the most popular trail, both for those seeking short walks and others looking for a longer hike to the Overlook or to Hidden Lake. Figure 17 shows 228 people on the Boardwalk and 212 people at the Overlook (or on the trails to and from the Overlook). By this early hour of the day, only 17 people have reached the trail segment from the Overlook to Hidden Lake.

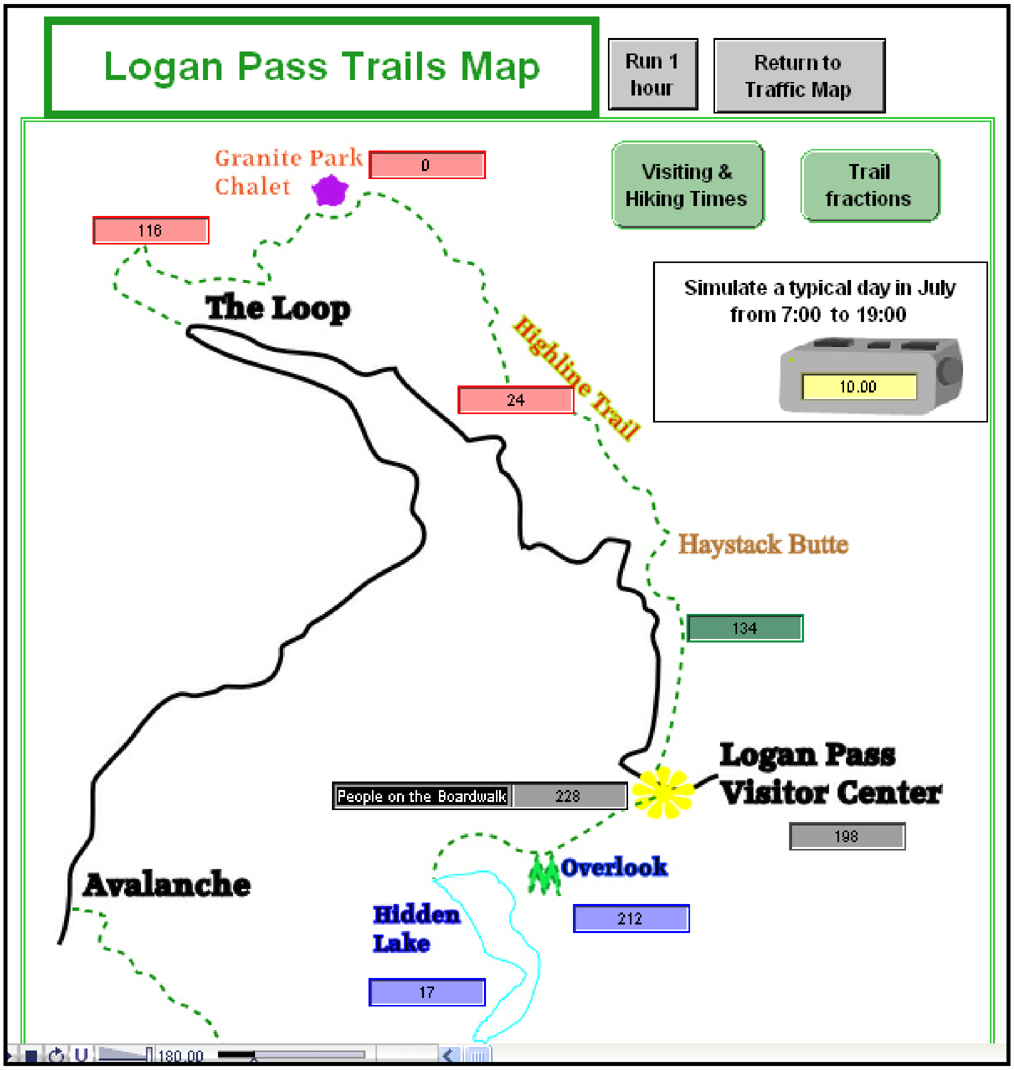

Figure 17: Logan Pass Trails Map results at 10am for a typical day in July.

The Highline Trail heads in a north, north-westerly direction from the visitor center. A popular viewing point along the trail is Haystack Butte. Figure 17 shows 134 hikers on the Highline Trail prior to Haystack Butte; 24 hikers have passed Haystack and are headed northwest toward the Granite Park Chalet. Another 116 hikers are on their way up the Highline Trail toward the Granite Park Chalet. It is only 10am, so we know that these are mostly people who parked their cars at The Loop and are now hiking toward the Granite Park Chalet.

Hikers on the Logan Pass trails may be viewed on the *Logan Pass Trails Map* or in time graphs for the 7am to 7pm day. The time graphs are dominated by the surge of hikers who arrive by car and fill up the parking lot between 9:30 and 10:00 am. They depart in several different directions, some taking day-long hikes, while others enjoy the visitor center and a short hike on the Boardwalk. The initial surge of arrivals leads to large variations in the number of hikers on particular trails at different hours of the day. [17] Congestion on trails is sometimes measured by the peak number of hikers or by the number of encounters[18] expected during a hike. Congestion can also be measured by the total number of hikers for the day, as shown in Figure 18.

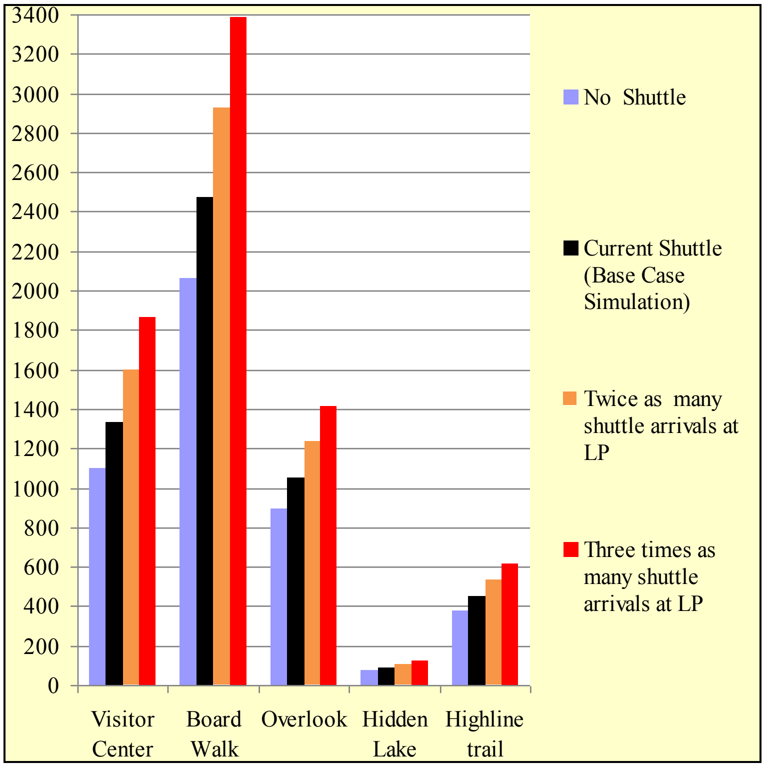

Figure 18: Simulated impact of the shuttle system for a typical day in July.

The blue bars in Figure 18 show total daily trail use in a simulation without the shuttle system. The black bars show the base case simulation with the current shuttle in operation. The heaviest use is on the popular Boardwalk trail (over 2,000 hikers in the simulation without the shuttle). The shuttle system increases daily use of the Boardwalk by 20%. Similar percentage increases are simulated for the Overlook, Hidden Lake and Highline trails.

[17] The short-hikers return to their cars, and their departure opens up spaces in the parking lot. This allows another surge of people to park their cars and begin their hikes at Logan Pass. The end result is an echo pattern, which is most pronounced on the Boardwalk (the hike with the shortest turn-around time). The first peak on the Boardwalk appears around 10:30am. An echo peak appears around 1pm, and a second echo peak appears around 3pm.

[18] The number of encounters is a popular measure, and several of the agent based models in Table 2 simulate encounters. Simulating encounters is not easily done with the standard stock and flow formulations of system dynamics. On the other hand, the stocks are a natural way to represent the people on different trail segments (sometimes called PAOT, people at one time). The system dynamics model delivers a PAOT for different trail segments, and a proportionality rule may be used to estimate the number of encounters.

The orange and red bars in Figure 18 show trail use from simulations with an expanded shuttle system that would deliver two or three times as many visitors to Logan Pass. The expanded shuttle system would have the greatest impact on the Boardwalk, where total daily use would be nearly 3,400 if the shuttle system were to deliver three times as many visitors to Logan Pass. The simulated impacts in Figure 18 demonstrate the usefulness of the operational model to provide relevant information for the ongoing discussion of whether to continue the shuttle system.[19]

6.4 Sensitivity Analysis and Performance Curves

The Glacier operations model has been tested under a variety of assumptions to learn which results are most sensitive to changes in assumptions. Figure 19 shows an example with four simulations without a shuttle system. The total annual visitation ranges from 1.5 to 3.0 million. (This doubling in visitation translates into a doubling of the number of cars entering the park on a typical day in July.) The bar chart shows total daily use at the Overlook and Highline trails and at the Visitor Center. Figure 19 shows surprisingly little variation in total daily use despite the doubling in annual visitation. This sensitivity test reveals the importance of the parking lot constraint loop (see Fig 12) in controlling trail use at Logan Pass. Higher annual visitation would not translate into greater trail congestion at Logan Pass in simulations without the shuttle system. Instead, the main impact is an increase in the number of visitors who fail to park at their intended destination.

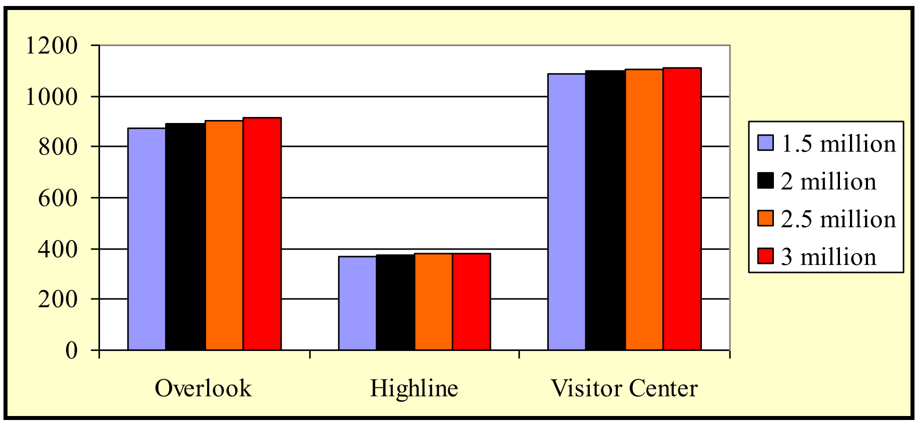

Figure 19. Testing the sensitivity of daily trail use to changes in annual visitation (in simulations without the shuttle system).

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[19]The increased loads on the trails may be viewed as good or bad, depending on one's perspective. The increased number of hikers at Logan Pass would be viewed as a good result by visitors concerned primarily with access.

On the other hand, increased numbers of hikers (and their impact on trail widening and hill-side erosion) would not be viewed favorably by people seeking solitude at Glacier.

We make no value judgments about the simulated impacts in Figure 18. Such judgments are best rendered with stakeholders' use of multi-attribute evaluation methods (Gardiner and Ford 1980). These evaluation methods are beyond the scope of our case study.

Sensitivity testing can improve our understanding of dynamic behavior for a typical day in the park. They can also help us specify performance curves for a long-term simulation of visitation decades in the future. Figure 20 shows an example by displaying the simulated performance of the west-side shuttle system from six simulations with different assumptions on the potential demand. The potential demand in the base case is 930 riders/day, the highlighted point in Fig 20. Long lines at the Apgar Transit Center cause 214 of these potential riders to return to their cars and drive instead. The served demand is 716 riders/day, as noted by the highlighted point in Fig 20. The performance curve shows small increases in the served demand with increases in the potential demands.[20] The far-right result in shows an extreme case with a potential demand of 2,787 riders/day at the west side. The shuttle system would accommodate 888 riders, thus serving only 32% of the potential demand.

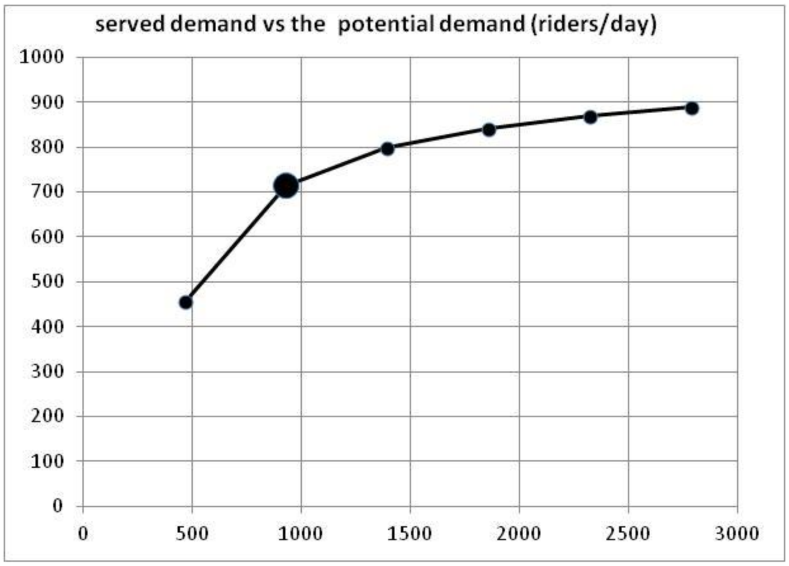

Figure 20. Example of a performance curve obtained by sensitivity testing of the daily model.

Figure 20 is one of several ways to summarize the performance of the shuttle system. Different curves would be generated depending on the goals and design of the long-term model. If an expanded shuttle system were under consideration, for example, the performance curve could be used to show served demand as a function of the capacity of the buses to accommodate riders at the Apgar Transit Center.

Shuttle system performance is only one of many variables that could be represented by performance curves in a long-term model. For access-oriented visitors, a key factor is the ability to park at the intended destinations. Figures 14 and 15 draw our attention to the large number of people who would fail to park at Logan Pass. The base case result (around 70 to 80%) can be examined in sensitivity analysis, and the results summarized in a performance curve. Figures 18 and 19 draw our attention to the trail loads. Performance curves for remote trail loads would also be a key part of a long-term model.

[20] Higher potential demands may be created by changing the assumption on annual visitation. Higher demands may also be created by changing the percentage of visitors wishing to use the shuttle. The six simulations in Figure 19 were generated with annual visitation fixed at 2 million and the potential use of the shuttle set at 5%, 10%, 15%, 20%, 25% and 30%.

7. Discussion: Systems Thinking and the National Park Service

The case studies described in this paper illustrate the potential for system dynamics modeling to contribute to long-term planning for a national park. The parks are part of the National Park Service,[21] an organization whose mission is to

conserve the scenery, the natural and historic objects,
and the wildlife in United States' national parks, and
to provide for the public's enjoyment of these features in a manner that will leave them
unimpaired for the enjoyment of future generations.

The National Park Service (NPS) and the parks have a century of experience implementing this conservation mission while dealing with the many interpretations of value-laden terms like *public enjoyment* and *unimpaired*. As it turns to the 2nd century, NPS faces additional challenges that go beyond conservation of features within the park boundaries:

The agency must assume leadership in realizing a strategic view of a future and effective park system. Such a National Park System can only succeed as part of a larger interconnected system of protected lands. Achievement of this larger system will require new skills and knowledge on the part of all stakeholders. Political decision making must be integrated with rapidly evolving analytic tools that permit measurements of global scale phenomena…

Community building approaches must be developed. New incentives must be found. The role of protected lands in mitigating climate change must be defined. Management will take place in a larger landscape, not defined by park boundaries. The forces that shape the future will become increasingly global in scope. This will call for personnel at all levels in the organization who are skilled in collaboration and consensus building.

(NPSCC 2009, Committee Report, p 74)

Systems thinking and dynamic modeling can help the National Park Service deal with the new challenges:

National Park Service leadership must be outfitted for outreach
to park neighbors and visitors on difficult complicated issues.
Systems thinking and development of integrating tools
such as multi-stakeholder dynamic models will allow National Park Service to engage
stakeholders in communally assessing future outcomes of land use decisions.

(NPSCC 2009, Committee Report, p 15)

[21] The NPS is part of the federal Department of the Interior. The NPS oversees 397 National Parks, 582 National Natural Landmarks, 2,461 National Historical Landmarks, 27,000 historic structures and 84 million acres of land. http://www.nps.gov/aboutus/index.htm The NPS mission statement appears at http://www.nps.gov/aboutus/mission.htm

Systems thinking and dynamic modeling are best developed and sustained through collaborative processes. Collaborative modeling provides the opportunity to explore and discuss uncertainties, feedbacks and time lags. Collaborative modeling is an educational process that can be used beyond the park boundaries to support "front and center" education between and among important stakeholders. Collaborative modeling utilizes technical science and translates the science into a common and transparent language.[22] Interactive simulation of a collaboratively developed model can promote shared understanding among scientists from different disciplines, park managers, and stakeholder groups.

In addition collaborative modeling may be used to support environmental impact assessment (EIA). Management alternatives are often complex combinations of a variety of factors that integrate tradeoffs between biophysical, social and economic parameters while recognizing the need for adaptation over time. Adaptive management recognizes that there is inherent uncertainty in the reaction of a system to any given management protocol. Collaborative modeling and the ensuing simulations can be used to build group understanding in support of adaptive management.

8. Summary and Future Work

This paper proposes the development of an integrated system for system dynamics support for National Park planning. The system would be comprised of a short-term model of daily operations combined with a long-term model of visitation many years into the future. Case studies conducted at Washington State University demonstrate the approach. The Northern Territory case demonstrates a useful approach to simulating park attractiveness based on conditions in the park and in the neighboring community. The Glacier National park case study demonstrates the use of system dynamics to simulate daily operations with a focus on the impacts of the park's shuttle system. The Glacier case study is especially important as it shows the usefulness of system dynamics in a time domain normally dominated by other methods. The Glacier study is also noteworthy for delivering important insights on the impacts of the park's shuttle system.

Discussions of the shuttle system continue as part of the development of the General Management Plan at Glacier National Park. The discussions are wide ranging and conduced following EIA practices suitable for the development of an Environmental Impact Statement (EIS). The operational model described in this paper will be expanded, improved and applied to support the environmental impact assessment. The near-term objective is to expand the representation of the cars, buses and visitors on the east-side of the park.

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[22] For example, insights about wildlife population numbers from biological models such as population viability analysis can be combined with insights from an economic model about park visitation impacts on gateway communities. Examples of biological models coupled with land-use and economic modeling are reported by Faust (2004) and by Beall and Zeoli (2009). Parks that are popular for wildlife viewing could utilize collaborative modeling in this manner to illustrate potential long-term impacts of visitation in sensitive wildlife habitat and how that disturbance feeds back to potentially lower wildlife populations, and eventually to a declining visitor experience, and thus to gateway community economics over the long term.

References

Baker, M. and Freimund, W. (2008). *Initial season of the Going to the Sun Road Shuttle System at Glacier National Park: Visitor Use Study*. Department of Society and Conservation. University of Montana.

Bald, J., Borja, A. and Muxika, I. (2006). A System Dynamics Model for the Management of the Gooseneck Barnacle in the Marine Reserve of Gaztelugatxe (Northern Spain). *Ecological Modelling, 194,* 306 – 315.

Beall, A. (2007). Participatory Environmental Modeling and System Dynamics: Integrating Natural Resource Science and Social Concerns. PhD dissertation, Washington State University, Pullman, Washington.

Beall, A. and Ford, A., 2010. Reports from the Field: Assessing the Art and Science of Participatory Environmental Modeling. *International Journal of Information Systems and Social Change,* Vol. 1(2), pp. 72-89.

Beall, A., and Zeoli, L., 2009. Participatory modeling of endangered wildlife systems: Simulating the sage-grouse and land use in Central Washington. *Ecological Modeling*, Vol. 68. pp. 22-33

Belnap, J. (1998). Choosing Indicators of Natural Resource Condition: A Case Study in Arches National Park, Utah, USA. *Environmental Management, 22 (4)*, 635 – 642.

Chen, K.C. (2004). Decision Support System for Tourism Development: System Dynamics Approach. *Journal of Computer Information System*, 104 – 112.

Clark, R.N. and Stankey, G.H. (1979). *The Recreation Opportunity Spectrum: A Framework for Planning, Management and Research*. (USDA Forest Service General Technical Report PNW-98). Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Chang, Y C., Hong, F W., and Lee, M T., 2008. A system dynamic based DSS for sustainable coral reef management in Kenting coastal zone, Taiwan, *Ecological Modelling*, Vol. 211. pp. 153-168.

Cole, D.N. (2005). *Computer Simulation Modeling of Recreation Use: Current Status, Case Studies, and Future Directions*. (USDA Forest Service General Technical Report RMRS-GTR-143). Rocky Mountain Research Station.

CSIRO 2002, Central Australian Tourism Futures, Final milestone report- November 2002, Commonwealth Scientific and Industrial Research Organization, Australia.

Dimond, A. and Freimund, W. (2009). *Recreational Use of Selected Viewpoints on the Going to the Sun Road*. Department of Society and Conservation. University of Montana.

Duncan, D. (Producer), Burns, K. (Director). (2009). *The National Parks: America's Best Idea* [Motion picture]. United States: Florentine Films & WETA Television.

Faust, L, Jackson, R., Ford, A., Earnhardt, J., and Thompson, S. (2004). Models for Management of Wildlife Populations: Lessons from Spectacle Bears in Zoos and Grizzly Bears in Yellowstone, *System Dynamics Review*, Vol. 20, Nu. 2, Summer, 2004.

Ford, A. (2009). *Modeling the Environment (2nd Ed).* Washington, DC: Island Press.

Forrester, J. (1961). *Industrial Dynamics*, Waltham, MA: Pegasus Communications.

Forrester, J. (1969). *Urban Dynamics*, Waltham, MA: Pegasus Communications.

Forrester, J. (1971). *World Dynamics*, Waltham, MA: Pegasus Communications.

Freimund (2011), Personal communication with Wayne Freimund, Professor, Department of Society and Conservation, University of Montana, Missoula, Montana.

Freimund (2004). Freimund, W, Vaski, J, Donnelly, M, and Miller, T. (2002). Using Video Surveys to Access Dispersed Backcountry Visitors' Norms. *Leisure Sciences*, 24:349-62.

Gardiner, P. and Ford, A. (1980). Which Policy Run Is Best? And Who Says So? *System Dynamics: TIMS Studies in the Management Sciences*, Vol. 14, pp 241-257, Amsterdam, North Holland Press.

Gimblett, R and Skov-Petersen, H. (Eds.). (2008) *Monitoring, Simulation, and Management of Visitor Landscapes*. Tucson: The University of Arizona Press.

Gimblett, R., Cable, S., Cole, D.N. and Itami R.M. (2005) Recreation Visitation and Impacts in the Bighorn Crags Portion of the Frank Church—River of No Return Wilderness. In Cole, D.N. (Ed.). *Computer Simulation Modeling of Recreation Use: Current Status, Case Studies, and Future Directions* (p. 18 – 22). USDA: Rocky Mountain Research Station

Gimblett, H.R., Richards, M.T. and Itami, R.M. (2001). RBSim: Geographic Simulation of Wilderness Recreation Behavior. *Journal of Forestry, 99* (4), 36 – 42.

Gimblett. R., Daniel, T.C., and Roberts, C. (2000). Grand Canyon River Management Simulating Rafting the Colorado River through Grand Canyon National Park Using Spatially Explicit Intelligent Agents. Proceedings from *The 4th International Conference on Integrating GIS and Environmental Modeling (GIS/EM4): Problems, Prospects and Research Needs*. Banff, Alberta, Canada.

Hallo, J.C, Manning, R.E. and Valliere, W.A. (2005). Acadia National Park Scenic Roads: Estimating the Relationship Between Increasing Use and Potential Standards of Quality, In Cole, D.N. (Ed.). *Computer Simulation Modeling of Recreation Use: Current Status, Case Studies, and Future Directions* (p. 55 – 57). USDA: Rocky Mountain Research Station

Honggang, X. and Jigang, B. (2000). A System Dynamics Study of Resort Development Project Management in Tourism Region: A Case Study of Guilin. Proceedings from ICSTM 2000: *The First International Conference on Systems Thinking in Management*. Geelong, Australia.

Honggang (2010). Personal communication with Xu Honggang, Professor, School of Tourism, Sun Yat-sen University, Guangzhou, China.

Ishutkina, M.A. (2009). Analysis of the Interaction between Air Transportation and Economic Activity: A Worldwide Perspective. (Doctoral dissertation), Massachusetts Institute of Technology, Retrieved from dspace.mit.edu.

Itami R.M. (2005). Port Campbell National Park, Australia: Predicting the Effects of Changes in Park Infrastructure and Increasing Use. In Cole, D.N. (Ed.). *Computer Simulation Modeling of Recreation Use: Current Status, Case Studies, and Future Directions* (p. 57 – 64). USDA: Rocky Mountain Research Station.

Johnson, M., Dimond, A. and Freimund, W. (2010). *Going to the Sun Road Shuttle System and Visitor Study Synthesis Report*. Department of Society and Conservation. University of Montana.

Kandelaars, P. (1997). *A Dynamic Simulation Model of Tourism and Environment in the Yucatán Peninsula*. Interim Report. International Institute for Applied System Analysis.

Kang (2010). Personal communication with Chih-sheng Kang, Lecturer, Leisure and Tourism Studies, Sun Yat-sen University, Kaohsiung, Taiwan.

Lace, S., Gimblett, R., Poe, A. and Crowley, D. (2008). Applying Agent-Based Modeling for Simulating Spring Black Bear Hunting Activities in Prince William Sound, Alaska. In Gimblett, R and Skov-Petersen, H. (Eds.), *Monitoring, Simulation, and Management of Visitor Landscapes* (pp. 295 – 313). Tucson: The University of Arizona Press.

Lawson, S.R., Itami, R.M., Gimblett, R. and Manning, R.E. (2005). John Muir Wilderness: Describing the Spatial Distribution of Backpacking Use on a System of Trails and Campsites. In Cole, D.N. (Ed.). *Computer Simulation Modeling of Recreation Use: Current Status, Case Studies, and Future Directions* (p. 31 – 35). USDA: Rocky Mountain Research Station.

Lawson, S.R., Manning, R.E., Valliere, W.A., and Wang, B. (2005). Arches National Park: Describing Visitor Use Patterns and Predicting the Effects of Alternative Transportation Systems. In Cole, D.N. (Ed.). *Computer Simulation Modeling of Recreation Use: Current Status, Case Studies, and Future Directions* (p. 42 – 46). USDA: Rocky Mountain Research Station.

Lawson, S.R. and Manning, R.E. (2003). Research to Guide Management of Backcountry Camping at Isle Royale National Park: Part 1 – Descriptive Research. *Journal of Park and Recreation Administration, 21* (3), 22 – 42.

Li, J. and Jian, H. C. (2010). Exploring the Long-Term Development of Festival Tourism and Culture Policies- a Case of the Hakka Tung Blossom Festival. Proceedings from *The 28th International Conference of the System Dynamics Society*. Seoul, Korea.

Loiterton, D. and Bishop, I. (2008). Simulation, Calibration and Validation of Recreational Agents in An Urban Park Environment. In Gimblett, R and Skov-Petersen, H. (Eds.), *Monitoring, Simulation, and Management of Visitor Landscapes* (pp. 107 – 122). Tucson: The University of Arizona Press.

Maani (2010), personal communication with Kimbiz Maani, Professor, School of Integrative Systems, The University of Queensland, Brisbane, Australia

Mai, T. (2010). Toward a shared systems model of stakeholders in tourism development in the Cat Ba biosphere reserve of Vietnam. Proceedings from *The 28th International Conference of the System Dynamics Society*. Seoul, Korea.

Mai, T. and Maani, K. (2010). Systems Thinking for Sustainable Tourism in the Cat Ba Biosphere Reserve of Viet Nam, Proceedings from *The 28th International Conference of the System Dynamics Society*. Seoul, Korea.

Manning, R.E. (2007). *Parks and Carrying Capacity: Commons without Tragedy*. Washington, DC: Island Press.

Manning (2011), personal communication with Robert Manning, Professor, Rubenstein School of Environment and Natural Resources, University of Vermont, Burlington, Vermont.

Meadows, D. H., Meadows, D. L., Randers, J. and Behrens, W. (1972), *The Limits to Growth*, New York: Universe Books.

Miller, T.A. and McCool, S.F. (1994). *The Glacier National Park Visitor Use Study*. Research Report 36. Institute for Tourism and Recreation Research. University of Montana.

National Parks Second Century Commission. (2009). *Advancing the National Park Idea - Committee Report*. Retrieved October 5, 2009 from www.npca.org.

National Park Service Public Use Statistics Office. (2011). NPS stats. Retrieved February 21, 2012 from http://www.nature.nps.gov/stats/

National Park Service. (2007). *Visitor Experience and Resource Protection Program: 2007 Indicators and Pilot Studies*. Retrieved November 15, 2009 from http://www.nps.gov/yose/parkmgmt/upload/verp507.pdf

National Park Service. (2003). *Record of Decision: Rehabilitation of the Going-to-the-Sun Road, Glacier National Park, a Unit of Waterton-Glacier International Peace Park Flathead and Glacier Counties, Montana*. Retrieved March 05, 2011 from http://www.nps.gov/glac/parkmgmt/planning.htm

National Park Service and Federal Highway Administration. (2003). *Going-to-the-Sun Road Rehabilitation Plan/Final Environmental Impact Statement*. Retrieved March 05, 2011 from http://www.nps.gov/glac/parkmgmt/planning.htm

Nguyen, N. Bosch, O. and Maani, K. (2010). Creating Learning Laboratories for Sustainable Development for UNESCO Biosphere Reserves, Proceedings from *The 28th International Conference of the System Dynamics Society*. Seoul, Korea.

Nguyen, T. (2012). System Dynamics Simulation for Park Management: A Case Study of Glacier National Park, Montana. Doctoral Thesis, School of the Environment, Washington State University.

Patterson, T., Gulden, T., Cousins, C. and Kraev, E. (2004). Integrating Environmental, Social and Economic Systems: A Dynamic Model of Tourism in Dominica. *Ecological Modelling, 175*, 121 – 136.

Pouwels, R., Jochem, R. and Verboom, J. (2008). Linking Ecological and Recreation Models for Management and Planning. In Gimblett, R and Skov-Petersen, H. (Eds.), *Monitoring, Simulation, and Management of Visitor Landscapes* (pp. 253 – 268). Tucson: The University of Arizona Press.

Senge, P.M. (1990). *The Fifth Discipline: The Art and Practice of the Learning Organization.* New York: Currency Doubleday.

Sivongxay, A. (2010). A System Dynamics Study of Australia's Northern Territory, Masters Project, School of Earth and Environmental Sciences, Washington State University.

Stankey, G.H., Cole, D.N., Lucas, R.C., Petersen, M.E., Frissell, S.S. (1985). *The Limits of Acceptable Change (LAC) System for Wilderness Planning*. (USDA Forest Service General Technical Report INT-176). Intermountain Forest and Range Experiment Station, Ogden, Utah.

Stave, K. (2002). Using System Dynamics to Improve Public Participation in Environmental Decisions, *System Dynamics Review*, Vol. 18, Nu. 2, p. 139-167.

Sterman, J. (2000). *Business Dynamics*, Boston: Irwin McGraw-Hill

Taczanowska, K., Arnberger, A. and Muhar, A. (2008). Exploring Spatial Behavior of Individual Visitor as a Basis for Agent-Based Simulation. In Gimblett, R and Skov-Petersen, H. (Eds.), *Monitoring, Simulation, and Management of Visitor Landscapes* (pp. 159 – 174). Tucson: The University of Arizona Press.

Valliere, W.A., Manning, R.E., and Wang, B. (2005). Alcatraz Island: Estimating the Maximum Use That Can Be Accommodated Without Violating Standards of Quality. In Cole, D.N. (Ed.). *Computer Simulation Modeling of Recreation Use: Current Status, Case Studies, and Future Directions* (p. 39 – 42). USDA: Rocky Mountain Research Station.

Van den Belt, J. (2004). *Mediated Modeling*. Washington, DC. Island Press.

Vennix, J. (2006). *Group Model Building: Facilitating Team Learning Using System Dynamics*, New York, Wiley.

Videira, N., Antunes, P., Santos, R. and Gamito, S. (2003). Participatory Modeling in Environmental Decision Making: The Ria Formosa Natural Park Case Study. *Journal of Environmental Assessment Policy and Management, 5* (3), 421 – 447.

Walker, A P., Greiner, R., McDonald, D., and Lyne, D., 1999. The Tourism Futures Simulator: a systems thinking approach, *Environmental Modelling and Software*, Vol. 14. pp. 59 -67.

Wang, B. and Manning R.E. (1999). Computer Simulation Modeling for Recreation Management: A Study on Carriage Road Use in Acadia National Park, Main, USA. *Environmental Management*, *23*(2), 193 – 203.

Washington Infrastructure Services. (2001). *Going-to-the-Sun Road Transportation and Visitor Use Study*.

Xing, Y. and Dangerfield, B. (2011). Modeling the Sustainability of Mass Tourism in Island Tourist Economies. *Journal of the Operational Research Society*, 62: 1742-1752.