Managing Parking on Campus: Agent-Based Models

By Emmanuel Frimpong Boamah

In many cities, university staff and students account for a significant proportion of the population. The provision of transport infrastructure, of which parking facilities form an important component, has been a major responsibility for university campuses.

University campuses also present a particular problem because they combine pedestrian and vehicular travel modes, necessitating planning to reduce conflicts. Yet as author Richard Dober notes, the standard texts on campus planning are silent on campus parking and pedestrian/vehicular travel. Although limited in supply and costly to provide, on-campus parking has not been planned to make the most economic sense.

Economic agent-based models can be used to resolve issues involved in planning for campus parking. Parking demand determination is about identifying variables — such as parking fees, transit fees, parking supply, parking users, and trip generation and distribution — and establishing cause-and-effect linkages among these variables. Each of these variables becomes an "agent" that interacts with the others in deciding the final output of the desired outcome.

As seen by researchers John Sokolowski and Catherine Banks, agent-based models or agent-based simulation modeling enables such an interaction among these parking variables by allowing for "the observation of aggregate behaviors that emerge from the interactions of large numbers of autonomous actors." As researcher Eric Bonabeau puts it, "Even a simple agent-based model can exhibit complex behavior patterns and provide valuable information about the dynamics of the real-world system that it emulates."

The Parking Demand and Pricing Dilemma on Campuses

Determining parking demand is pivotal in travel demand management (TDM) because vehicles spend more time in parking spaces than on roads. Researcher Donald Shoup estimates that "the average car is parked 95 percent of the time." Researcher Todd Litman also opines that a "typical automobile is parked for 23 hours each day." Predicting the need for parking spaces is useful for ensuring that the origin and destination of trips are in sync — i.e., that traffic flow to a destination matches the area's capacity to support that traffic once the vehicles come to rest.

As important as parking is in transportation and other infrastructure designs, limited resources constrain the ability of campuses to provide parking facilities. Both Shoup and Litman point to pricing of available parking spaces as one means of rationing the parking resources on campuses. The pricing method frequently is not used, however, and parking supply is mostly determined using a conventional approach of complying with parking requirements, often those stated in zoning codes.

This neglect of pricing in the conventional approach to parking supply determination is often cited by authors like Shoup, Don Pickrell, and Jeffrey Tumlin as a major deficiency in determining the demand for parking. This deficiency manifests itself in either an over-supply or under-supply of on-campus parking spaces. Parking over-supply results from meeting the seemingly insatiable parking demands — not necessarily the true needs — of a population dependent on single-user private vehicles. As Shoup and Litman note, such an over-supply has environmental costs, as paving land results in stormwater management needs and loss of green spaces and aesthetic values.

The largest parking facility at Minnesota State University (MSU), Mankato, occupies around 13 acres of land. Photo Emmanuel Frimpong Boamah.
Resolving the Dilemma Using Agent-Based Models: The Case of Minnesota State University, Mankato

At Minnesota State University, Mankato, a quantitative model was recently developed to analyze parking data — parking spaces supplied, permit purchases of various permit categories, annual revenue, and operations and maintenance cost of parking — collected from the university’s facilities management office. Parking occupancy surveys were also conducted over a three-day period for 19 parking lots. These lots comprised 3,613 parking spaces, representing about 80 percent of the total off-street parking spaces on campus. The idea of determining demand, driving, and presence ratios from the survey data was adapted from a methodology used by Walker Parking Consult in its 2005 parking feasibility study at Iowa State University.

Using regression analysis to determine the relationships among the variables (parking demand, supply, price, and non-parking users), an economic model of parking behavior was designed using Vensim PLE software. Using the input from the parking demand model, the economic model was further elaborated to consider the relationship between costs and benefits in meeting parking demands of the range of users. Simulations were then run to answer the question "How do we price parking permits to minimize parking supply surpluses/shortages on campus and still meet the cost of parking?"

Figure 1

An example of the Vensim-based parking demand, supply, and pricing model. Image Emmanuel Frimpong Boamah.

Figure 2
The study results indicated that there is an over-supply of some types of parking spaces and an under-supply of other types when parking demand is determined only by expected permit purchases without considering the peak use of parking facilities. The over-supply of parking spaces at peak times leads to excess parking costs — in terms of annual operating and maintenance costs — and the under-supply leads to peak time shortages of parking spaces for users. By running these simulations, an "optimum parking price level" — the price that minimizes supply excesses and shortages while ensuring that revenue generated meets at least the annual operating and maintenance costs — was determined for each parking permit category.

Implications for Parking Policy Making
The study results indicated that parking demand on campus is increasing. However, such demand increases are not enough to warrant an increase in supply. In fact, any future supply increases would only add to the supply surplus accumulated over the years. Based on the parking occupancy survey, almost all parking facilities recorded significant excess of not less than five percent of their total parking supply during peak times. Such supply excesses impose unnecessary costs to either the university or the parking users.

Figure 3

The overall demand for parking at Minnesota State University from the 2002/2003 academic year through the 2010/2011 academic year. Image Emmanuel Frimpong Boamah.
Based on a model simulation run, with a proposed increase in fees, demand can be expected to decrease and then start increasing if price remains constant. This means that, in order to minimize supply excesses or shortages, annual demand predictions will be necessary to adjust parking supply to meet demand. Because the university groups and prices parking spaces based on their proximity to campus, the use of an economic model like this one can help determine what price or supply levels should be designated for each parking group annually.

Figure 4

Annual parking demand and supply from the model simulation run. Image Emmanuel Frimpong Boamah.

In the long term, however, campuses like Minnesota State Mankato should consider moving toward "smart parking" systems. As described by researchers Donald Shoup, Jeremy Nelson, and Jason Schriber, these systems enable hourly predictions of parking demand using electronic meters, sensors, and information strategies. Smart parking ensures that demand, supply, and pricing are regulated by the hour instead of by the semester or year. Examples include SFpark in San Francisco, which relies on parking sensors, smart meters, and information strategies to create "demand responsive pricing"; and LA ExpressPark in Los Angeles, which is in the process of establishing smart meters and sensors.

The Future of Agent-Based Modeling and Parking/Transportation Planning

Cities, like campuses, constantly deal with managing parking demand. The complexity of modeling parking demand in cities has to do with a multiplicity of variables that are both quantitative and qualitative in nature. Determining traffic generated by land uses and impacts of alternative transportation modes on private vehicle use becomes crucial for any meaningful parking demand modeling in cities.

In studies of methods for incorporating the necessary multiple variables and their effect on each other in making accurate transportation predictions, the use of agent-based models comes in handy. For instance, researcher Eric Bonabeau notes that the TRansportation ANalysis SIMulation System (TRANSIMS), an agent-based modeling package, "provides planners with a synthetic population’s daily activity patterns (such as travel to work, shop, and recreation, etc.), simulates the movements of individual vehicles on a regional transportation network, and estimates air pollution emissions generated by vehicle movements."

A major advantage of using agent-based models lies in their flexibility in establishing multiple relationships among variables and identifying the most significant variable (or variables) for the determination of the desired outcome. For instance, the ideal level of parking supply on campus — as the outcome variable — can be determined by identifying how it is affected by such variables as the number of users available, the price per parking space, the number of parking spaces available, and the availability of transportation alternatives.

As cities and campuses move away from conventional approaches in projecting transportation needs for planning purposes, agent-based modeling is one approach for studying emergent issues. Particularly for campuses — where parking policy making can be subjective and political — an agent-based model can help parking authorities better understand the current and future economic and
land use implications of their decisions and propose reasonable, sustainable measures to deal with parking, transit, and other transportation and land use planning issues on campuses and in cities.

Resources


Emmanuel Frimpong Boamah, recently awarded the APA Minnesota Chapter’s Gunnar Isberg Scholarship, is a second-year graduate student in urban studies at Minnesota State University, Mankato. He recently defended his master’s thesis, supervised by Professor Anthony Filipovitch, on "Modeling Parking Demand: A Systems Approach to Parking Policy Analysis on Campus." He is currently assisting with research on modeling teacher supply and demand in Mankato as a graduate research assistant at the College of Education. He is also a community and economic development intern at the Region Nine Development Commission in Minnesota.