Evaluation of the Spatial Distribution of Activity Center Parking Facilities

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Many existing and proposed activity centers, such as research complexes, university campuses, and commercial and industrial centers, have large numbers of employees, clients, and visitors who drive automobiles and compete for desirable parking spaces. Most drivers tend to base the desirability of parking spaces on their proximity to an ultimate destination; that is, they attempt to minimize walking distances. As the activity center grows, additional parking facilities must be added; however, locations for new parking facilities that will minimize walking distances for all or selected groups of users are not easily selected. Decisions on the best locations for additional parking facilities for a large activity center are, therefore, difficult. An algorithm describing traveler choices of available activity center parking spaces was implemented in a simulation model and applied to a typical case study. Survey data describing actual traveler parking choices and walking distances were collected and compared with simulation predictions before the simulation was used in the decision process.

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JOHNSON SPACE CENTER CASE STUDY

The National Aeronautics and Space Administration's (NASA's) Johnson Space Center (JSC) in Houston is a typical example of a large activity center with multiple employment sites and parking facilities. The central portion of JSC is called the mall area and is the employment site for roughly 7,000 people. As the mall developed over the last 3 decades, locations of new buildings and parking facilities were controlled by a master planning process that did not attempt to quantify parking-related walking distances.

Faced with concerns about parking availability and walking distances and anticipating expansion of the existing work force, JSC officials commissioned a study of parking and access conditions for the entire JSC. Principal questions to be answered by the study were the following: Is there a shortage of parking spaces? What are current walking distances? If additional parking spaces are needed, where should they be constructed?

The first two questions were answered through primary data collection, including traffic and parking accumulation counts and two user surveys. These data indicated the current total supply of parking spaces is slightly greater than the peak accumulated demand. Walking distances reported by survey respondents were large, with a mean of almost 800 ft and a 90 percentile approaching .25 mi.

With current peak parking demands only slightly less than the available supply, anticipated work force expansion of 1,000 to 1,500 people would clearly create the need for more parking facilities. However, many options were available for expanding the parking space supply. These included many small or few large facility expansions that could be located many different places. The definition of "best" recommended expansion was determined to be that with the largest positive impact on walking distances per dollar of facility cost. To estimate the effect on walking distances of the many options and combinations, a robust methodology was needed.

An algorithm describing the traveler's decision process in choosing a parking space with developed and implemented in a computer simulation model. Development of the algorithm and simulation model is described next.

PARKING SPACE SELECTION CRITERIA

Employees driving to work at JSC or another activity center choose a parking location on the basis of several criteria. Like most commuters, however, their primary consideration is probably the proximity of the available parking space to their work sites, or, in other words, their walking distance. However, only in rare cases can commuters walk the straight line distance from their parked automobiles to their work sites because of obstructions, including other parked automobiles, buildings, trees, lakes, and permitted street crossing locations. Therefore, the simulation process was designed to use a rectangular distance computed as the sum of the absolute values of the differences of the X and Y coordinates of parking facilities and building work sites.

Most, if not all, commuters would likely prefer to choose a parking space in the facility closest to their work site. However, one parking facility may be closest, or best, by the walking distance criterion, for several work sites. The combined parking demands for these work sites may exceed the capacity of that one facility. Therefore, some drivers simply cannot select the closest, or best, choice. Further, two or more parking facilities may differ in walking distance to a given work site by only a small amount. Assuming that all drivers destined for that work site would chose the marginally closest facility would be unreasonable, especially if the nearly equidistant parking areas are large.

The simulation process sequentially assigned small increments of parking demand, associated with each work site, to the most likely available parking facilities. Assigning all demand to the marginally closest facility would exemplify both problematic situations described in the previous paragraph. The algorithm implemented here uses a probability of drivers selecting each facility that is inversely related to the walking distance raised to an exponent. This means that two facilities that are nearly equidistant from a work site will have nearly equal probabilities and will therefore receive nearly equal parking assignments. It also means that some parking demand is not assigned to the closest facility, but this is reasonable, considering human variability and parking facility spatial size.

The increment of parking demand from each destination site assigned to each parking facility at each simulation step could be identified as A_{ij} and is determined by the following relationship:

$$A_{ij} = aB_iq_{ij}$$

where

a = 1/number of simulation increments,
B_i = parking space demand for Building i
= number of Building i automobile travelers, or automobile occupancy, and
$q_{ij} = (1/D_{ij}^P)/\Sigma_{j=1}^{n} (1/D_{ij}^P)$
= probability of travelers destined for Building i selecting Parking Facility j during this simulation step

where

$D_{ij} = \text{ABS}(Y_i - Y_j) + \text{ABS}(X_i - X_j)$
= sum of absolute values of differences of respective cartesian coordinates for Building i and Parking Facility j,
P = exponent of rectangular walking distance, and
n = number of parking facilities.

As each parking demand increment is added to any parking facility, the assigned demand is compared with the facility capacity, and if the whole increment or any part causes the assigned quantity to exceed the capacity, the excess is withheld until the next simulation step at which probabilities are revised. Additionally, after each increment of parking demand is allocated to available parking facilities during the incremental assignment process, probabilities are recomputed. At every incremental stage of the simulation, every available (unfilled) parking facility has a nonzero chance of receiving drivers from all work sites. The magnitude of the probability for more distant facilities compared with those closer to the work site depends on the relative rectangular distances and the exponent to which the distance has been raised.

WALKING DISTANCE EXPONENT

The magnitude of the exponent for distance effectively simulates the degree to which drivers respond to walking distance. As the exponent for rectangular distance increases, differences in walking distance produce greater allocation probability differences. In an area like the JSC mall, where many parking facilities have similar walking distances for any one work site, a small magnitude exponent means that drivers for each work site would be allocated to many different facilities. That is, drivers are not sensitive to walking distance. As the exponent increases, differences in walking distances among alternative parking facilities produce greater sensitivity or greater assignment probability differences. Effects of increasing the exponent are shown in Figure 1, where the numbers of parking facilities to which drivers are allocated are plotted against the walking distance exponent magnitude.

The figure indicates that as the exponent increases from 3 to 9, sensitivity of drivers to walking distances increases dramatically and the number of facilities receiving parking allocations correspondingly decreases. However, as the exponent is increased above 9, little additional sensitivity is gained. On the basis of this sensitivity study and analyses of the JSC mall user surveys, a value of 9 was tentatively selected for the walking distance exponent.

INCREMENTAL STEP SIZE

The magnitude of the parking demand increment allocated during each successive simulation step is also important. The number of drivers allocated from each work site to each parking facility during each simulation step is the product of this

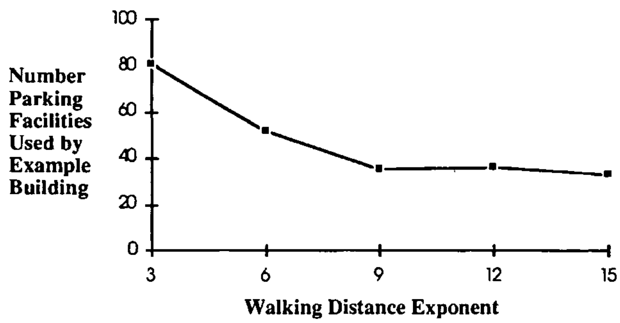

FIGURE 1 Simulated number of parking facilities used by drivers for one JSC mall building versus walking distance exponent.

step size (expressed as a decimal percentage), the probability associated with each parking facility and the work site total parking demand. The maximum step size must produce a number, through this multiplication, that is less than the capacity of the smallest parking facility. For the JSC mall area, a step increment of 0.01 is small enough to satisfy this criterion and results in a maximum of 6 or 7 drivers being allocated from each large work site during each simulation step. Sensitivity analyses of the step size for the JSC mall indicate that values smaller than 1 percent did not significantly improve the allocation accuracy.

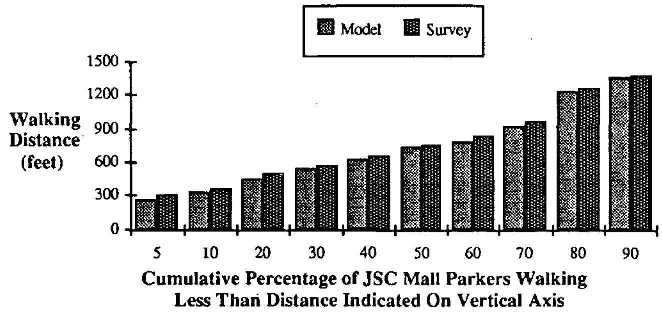

FIGURE 2 Comparison of survey- and simulation-derived mall area walking distances.

JSC MALL AREA DESCRIPTION FOR SIMULATION ANALYSES

Like other behavioral models, the accuracy of the parking simulation model improves as the data describing sources and sinks are disaggregated. That is, smaller spatial descriptions of work sites and parking facilities produce a more realistic simulation. Therefore, current work sites in the JSC mall area were described as 51 separate entities, each with coordinates and parking demand. Parking facilities were disaggregated to form 97 separate parking areas.

Current total parking space demand in the mall area was estimated at 6,429, and total available spaces were counted at 7,089. The demand total was developed through vehicle accumulation in JSC estimated from hourly counts of all entering and exiting traffic and work site employment figures. These data sources yielded an estimated vehicle occupancy of 1.1 persons per vehicle.

Additionally, surveys of civil service and contractor employees in the mall area were conducted during April and May 1991. A total of 612 persons responded to the survey, for a response rate of 71 percent, which is phenomenal for this type of data-acquisition process. In addition to a number of opinion-oriented questions, respondents indicated the locations of their respective work and parking sites by marking each on a mall area map, which was part of the survey instrument. Observations of walking paths from parking facility to work sites confirmed the assumption that the density of buildings in the mall generally requires those paths to follow the legs of right triangles instead of the hypotenuse. Therefore, walking distances were calculated from survey results using this path characteristic.

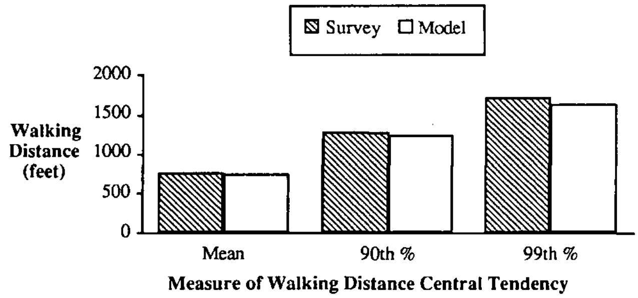

FIGURE 3 Comparison of survey and simulation values of mall area walking distances.

COMPARISON OF SIMULATION AND SURVEY WALKING DISTANCES

The survey data were used as the basis for a simulation model validation process. Comparative frequency distributions for simulation model and survey based mall area walking distances are shown in Figure 2.

Comparisons of mean and 90th and 99th percentile walking distances produced by simulation and survey are presented in Figure 3. As in the previous figure, agreement between the simulation and survey data is good.

In addition to the visual comparisons of the model and survey walking distances, differences between the two were tested using the nonparametric method of the Kolmogorov-Smirnov two-sample test (*1*). The null hypothesis that the simulation and survey walking distances were drawn from the same population could not be rejected at a 0.2 or higher confidence level. On the basis of the results of both the visual and statistical comparisons, the simulation procedure was accepted as being valid. A second survey and comparison of simulation model and actual walking distances further confirmed this conclusion.

APPLICATIONS

The simulation technique was used to examine the potential effects on walking distances of a series of parking facility additions and modifications. In addition to the rather extreme walking distances for many current employees, the situation was further complicated by a planned increase in JSC employment. Many options for additional surface parking facilities around the periphery of the mall area were available, as were several potentially desirable parking structure sites. A multitude of options including combinations of both surface and structures were compared. The simulation methodology provided a convenient means of evaluating the effects of each alternative on employee walking distances. A recommended program of improvements was finally developed and featured a mixture of surface parking facility expansions, carpooling, and conventional transit options.

SUMMARY

A computer simulation–based methodology for evaluating the effects of alternative parking facility locations on walking distances in an activity center has been developed. The technique has been tested using actual survey data from NASA's JSC in Houston. Following verification of the procedure, it has been used to develop a program of parking facility improvements for the JSC mall area.

REFERENCE

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