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Internalizing Travel by Mixing Land Uses

Study of Master-Planned Communities in South Florida

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Planners, public officials, and large-scale land developers increasingly promote mixed-use developments as an alternative to sprawl. They list among the benefits of such developments the "internal capture" of trips; that is, trips that would otherwise have filtered onto the regional road network will remain on site. Yet, so little information is available about internal capture rates that traffic impact studies for mixed-use developments become little more than exercises in speculation. In an attempt to advance basic knowledge of the subject and move toward better prediction methods, 20 mixed-use communities in south Florida were studied to determine the effect of land use mix on internal capture rates. The sample of communities studied had internal capture rates ranging from 0 to 57 percent of all trip ends generated. When modeled in terms of land use and accessibility variables, both the scale of a development and regional accessibility proved significant, with the former directly related to internal capture and the latter inversely related to internal capture. The best-fit model explained just under half of the variance in internal capture rates. Controlling for scale and regional accessibility, land use mix and density did not have independent predictive powers. Whether because of limitations of the data set, model specification, or method of analysis, the benefits of mixed-use development were not borne out.

Since the late 1980s studies have linked the "suburbanization of congestion" to land use patterns often characterized as suburban sprawl, that is, low-density, single-use, scattered development patterns. As an alternative to sprawl, planners, public officials, and large-scale land developers increasingly promote mixed-use developments. They list among the benefits of such developments the "internal capture" of trips; that is, trips that would otherwise have filtered onto the regional road network will remain on site, thereby limiting the amount of external travel that must be mitigated.

Although the assumed benefits of mixed-use development are plausible, few studies have determined actual capture rates of mixed-use developments, and none (to the authors' knowledge) has modeled capture rates as a function of land use mix. Developers interested in gaining development approval and minimizing impact fees naturally lean toward liberal estimates of internal capture. Local governments and metropolitan planning organizations concerned about future capacity requirements lean toward conservative estimates.

The stakes are high, and the truth is that without more research on the topic, traffic impact studies for mixed-use developments are little more than exercises in speculation. Even ITE's *Trip Generation* manual, the authority on trip generation rates, provides limited information on internal capture for mixed-use developments (*1*).

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In an attempt to advance basic knowledge of the subject and move toward better prediction methods, 20 mixed-use communities in south Florida were selected for study. All were built within the last 40 years and include housing, shopping, services, and recreational facilities. Some have basic employment as well. They vary sufficiently in location, size, and land use mix as to promise significant variation in internal capture rates, which, in turn, should allow internal capture rates to be modeled in terms of the same variables.

SELECTING COMMUNITIES

To identify developments appropriate for study, metropolitan and municipal planners in Dade, Broward, and Palm Beach Counties in Florida were interviewed. They were asked for lists of master-planned communities with a mix of housing, shopping, services, and recreational facilities. The interview process produced a list of 26 communities, including both family-oriented and retirement communities. Residential subdivisions adjacent to commercial strips were excluded, as were urban redevelopment projects, because the authors were specifically interested in the trip reduction benefits of master-planned communities. Figure 1 shows the locations of communities within the tricounty region.

EXTRACTING TRAVEL RECORDS

Travel data for the present study came from the Southeast Florida Travel 2000 Survey, conducted for the tricounty region by the Florida Department of Transportation. For the sample of communities, boundaries were delineated on traffic analysis zone (TAZ) maps. Then, all trip records involving these TAZs were extracted from the 2000 travel diary database. Although larger developments, such as Weston and Wellington, had hundreds of trip records, most developments had less than 100.

The desire for the largest possible sample of communities had to be balanced against the need to moderate sampling errors for individual communities. Ultimately, only communities with more than 30 trip records were included in the present study, leaving a sample of 20. Because of the relatively small sample sizes of trips for some developments and the imperfect fit of TAZs to development boundaries in a few cases, inaccuracies are inevitable.

COMPUTING INTERNAL CAPTURE RATES

To make the present study conform to standard definitions of internal capture and standard methods of traffic impact analysis, all trip ends that fell within the boundaries of each community were counted.

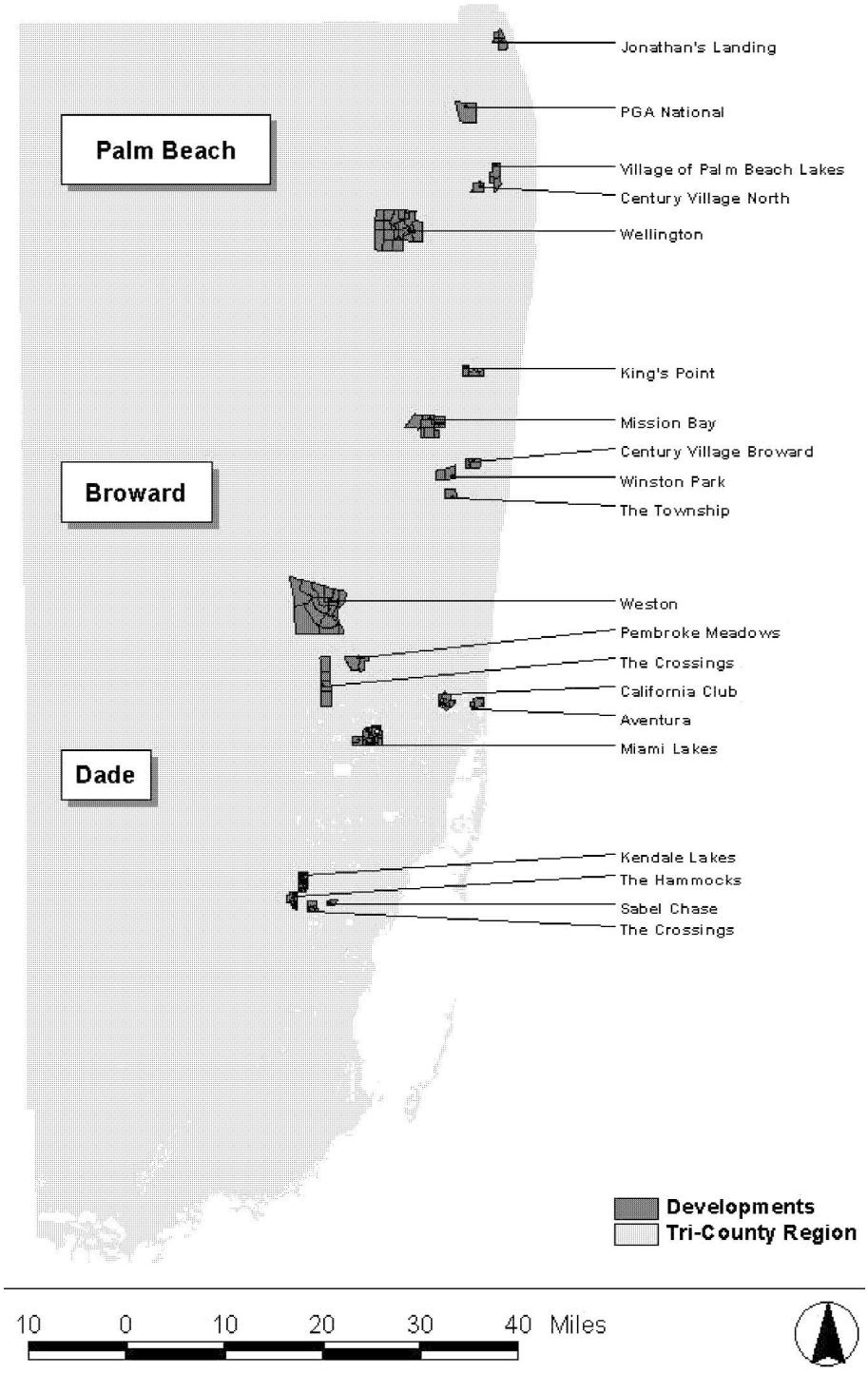

FIGURE 1 Locations of communities within the tricounty area (1 mi = 1.61 km).

Internal trips have both ends within a community. The internal capture rate is just the number of trip ends for trips internal to the community divided by the total number of trip ends produced or attracted by the community.

Internal capture rates range from 0 to 57 percent (Table 1). More than half of all trip ends are internal for two large, outlying master-planned communities, Weston and Wellington.

ACQUIRING LAND USE DATA

To model the variation in internal capture rates among the sampled communities, land use data were obtained from metropolitan planning organizations and the Florida Department of Transportation. These are the same base year data used to calibrate the regional travel demand model. Data for Broward and Palm Beach Counties were

TABLE 1 Internal Capture Rates

Community	County	Sample Size	Internal Capture Rate
Wellington	Palm Beach	432	.57
Weston	Broward	484	.52
Century Village Broward	Broward	70	.43
The Township	Broward	43	.41
Century Village North	Palm Beach	92	.40
Village of Palm Beach Lakes	Palm Beach	128	.34
Winston Park	Broward	95	.30
The Hammocks	Dade	85	.28
Silver Lakes	Broward	104	.27
Miami Lakes	Dade	206	.25
Mission Bay	Palm Beach	418	.18
PGA National	Palm Beach	128	.17
Aventura	Dade	74	.17
Jonathan's Landing	Palm Beach	60	.13
Sabel Chase	Dade	43	.13
Kendale Lakes	Dade	127	.12
Kings Point	Palm Beach	39	.10
Pembroke Meadows	Broward	44	.09
The Crossings	Dade	35	.06
California Club	Dade	70	.00
			Mean: 0.25
			Median: 0.22

1999 estimates. Data for Dade County were 1996 estimates. At the time of the study, Dade County had not yet completed updating of its land use inventory. Land use patterns typically change slowly over time, so this should not do damage to the results. Population and employment for the sampled communities are reported in Table 2.

DERIVING LAND USE MEASURES

The following measures were derived from the land use database and regional model.

Size Measure

The overall size of the community was represented by the sum of population and employment:

$$SIZE = POP + JOBS$$

where *POP* is the population of the community, and *JOBS* is the employment in the community.

Density Measure

On the basis of TAZ boundaries, geographic information systems were used to calculate the gross area of each community. Although estimates of net developable land area would have been preferable, only the gross area was known. Furthermore, information regarding the amount of land dedicated to each land use was not available. This meant that net densities could not be computed for individual land uses. Given these data limitations, an overall density measure (*DENSITY*) was calculated as the sum of population and employment divided by the gross area (*AREA*) of the community:

$$DENSITY = (POP + JOBS)/AREA$$

Entropy Measure

The concept of entropy, borrowed from the physical sciences, relates to the degree of randomness versus order within a spatial pattern. First applied to land use patterns by Robert Cervero, an entropy measure captures the degree of land use mixing within a development. Entropy values range from 0 to 1, with higher values for more even mixes. Entropy is computed as follows:

$$\begin{aligned} ENTROPY = -[&PROPCOM \cdot \ln(PROPCOM) \\ &+ PROPSER \cdot \ln(PROPSER) \\ &+ PROPIND \cdot \ln(PROPIND)]/\ln(k) \end{aligned}$$

where

$PROPCOM$ = proportion of commercial jobs;
$PROPSER$ = proportion of service jobs;
$PROPIND$ = proportion of industrial jobs; and
k = number of land use categories, which in this case is three.

TABLE 2 Community Characteristics

Community	Gross Acreage	Population	Employment
Aventura	692	8303	5965
California Club	1234	13649	1869
Century Village	934	12781	534
Century Village North	716	10246	331
The Crossings	662	6036	965
The Hammocks	863	13801	1338
Jonathan's Landing	1205	4211	3127
Kendale Lakes	985	12207	2588
Kings Point	845	12523	771
Miami Lakes	2541	12918	17862
Mission Bay	3851	10598	7869
Pembroke Meadows	1687	5638	1032
PGA National	2421	9178	2324
Sabel Chase	325	4984	1120
Silver Lakes	3210	11329	1593
The Township	715	4267	556
Village of Palm Beach Lakes	1475	8215	1818
Wellington	10727	34267	5220
Weston	15517	44199	9206
Winston Park	1464	8017	440

NOTE: 1 acre = 0.405 ha.

Balance Measures

Balance at the community level is defined as having the same ratio of employment to population as that for the county as a whole. Balance measures, in a sense, represent the degree of self-sufficiency achieved by a master-planned community. The balance measures range from 0 for a community with residents but no jobs to 1 for a community with the same ratio of jobs to population as that for the county as a whole. One balance measure was computed for jobs in total, that is, jobs in all sectors combined:

$$BALANCE = 1 - [\text{ABS}(JOBS - a \cdot POP)/(JOBS + a \cdot POP)]$$

where a is the countywide ratio of jobs to population. Another balance measure was computed for commercial jobs only:

$$CBALANCE = 1 - [\text{ABS}(COMJOBS - b \cdot POP)/(COMJOBS + b \cdot POP)]$$

where b is the countywide ratio of commercial jobs to population.

Accessibility Measures

The accessibility measures used in the present study came from the regional travel demand model for the tricounty area. Values are for 1996, the latest year for which the model has been calibrated. Like entropy, the calculation of accessibility is based on a physical analogy. Accessibility indices are computed in the four-step process and appear as the denominator in a conventional "gravity" model. For each trip purpose and TAZ, the accessibility index is just the sum over all TAZs of jobs and other trip attractions multiplied by a friction factor related inversely to travel time between the zones. The more attractions and the closer the attractions are to a given zone, the higher the accessibility index. For ease of interpretation, accessibility values were normalized on a scale from 0 to 1 by dividing the computed accessibility index for each TAZ by the highest accessibility value in the region. Values were derived for the following trip purposes:

- Home-based work ($ACCESS_{HBW}$),
- Home-based shopping ($ACCESS_{HBS}$),
- Home-based social/recreational ($ACCESS_{HBSR}$),
- Home-based other ($ACCESS_{HBO}$), and
- Non-home based ($ACCESS_{NHB}$).

MODELING INTERNAL CAPTURE

Various combinations of independent variables were tested to arrive at a best-fit model, one with the expected signs for all coefficients, significant t-statistics for all coefficients, and the best possible explanatory power as reflected in the R^2 statistic. The resulting model is presented in Table 3. It explains just under half of the variance in internal capture rates across communities, which is less than ideal but perhaps as much as can be expected given the relatively small sample sizes of trips to or from some communities and the approximate nature of the 1996 to 1999 land use estimates for these communities.

TABLE 3 Final Model

Variable	Dependent Variable: Internal Capture Rate		
	standardized coefficient	t-statistic	significance level
SIZE	0.511	2.925	.009
$ACCESS_{HBSR}$	- 0.432	-2.472	.024

Number of observations = 20
R-squared = .485

Community size and one accessibility measure are the only variables in the final model. The selected accessibility measure, for home-based social and recreational trips, is fairly broad based; it accounts for trip attractions in three land use categories: commercial, service, and residential. The results confirmed the expectations: internal capture rates increase with size and decrease with accessibility to other regional trip attractions. From this limited standpoint, the most successful communities are large and remote. Obviously, however, these remote communities are likely to generate longer trips that are made almost exclusively by automobile. So, despite high internal capture rates, they may place greater demands on the regional road network than more accessible communities will.

One final attempt was made to improve the explanatory power of the model by distinguishing between family-oriented and retirement communities. Three of the communities included in this study—Century Village Broward, Century Village North, and King's Point—cater specifically to retirees. Others, particularly those with golf as their signature amenity, have disproportionate numbers of retirees among their residents (e.g., PGA National). Because they have more leisure time than working residents, a large retirement population that makes many home-based social and recreational trips should boost internal capture rates. Eyeballing trip records for the sampled communities suggested as much. In Century Village North, for example, internal social and recreational trips accounted for 11 percent of all trip ends.

To test the effect of retirement population, the proportion of retirees was computed for each community from the 2000 travel survey sample. Regression analysis was then rerun by including this new variable. The proportion of retirees did not prove significant after controlling for size and regional accessibility.

SPECULATING ABOUT EXCLUDED VARIABLES

The present study began with the expectation that land use mix and, possibly, density would be significant determinants of internal capture rates. They did not prove to be, at least after controlling for size and regional accessibility. Indeed, the commercial jobs-population balance variable, *CBALANCE*, entered with the "wrong" sign at a statistically significant level in early regression runs; and with the exception of density, the other land use measures have the wrong signs on their partial correlation coefficients after controlling for size and regional accessibility. The question is why?

The issue of sampling error in the trip database has already been discussed. So has the fact that, in a few cases, community boundaries do not exactly line up with TAZ boundaries. It has been hinted that land use data, which come from the individual counties, may not be estimated with as much precision as one might wish. Beyond these problems, there may be issues of construct validity in the way in which density and land use mix were measured. The density measure does not represent the actual density of development "on the ground." It considers the entire area of the community, whether developed, undeveloped, or even undevelopable. Water bodies and wetlands end up in the calculation, as do vacant tracts awaiting development. The land use mix and balance measures may have construct validity problems that arise from the classification of uses. Included in the "commercial" category are building supplies, automobile dealers, apparel stores, and furniture and home furnishings. These are hardly convenience commercial uses aimed primarily at local residents but, rather, serve larger regional markets.

CONCLUSION

The present study examined the benefits of mixed-use developments from the standpoint of internalizing trips. The 20 communities evaluated for the study had internal capture rates that ranged from 0 to 57 percent of all trip ends generated by the community. To understand this tremendous variation, internal capture rates were modeled in terms of land use and accessibility measures. The best-fit equation explained 49 percent of the variation in internal capture rates among the sampled communities.

The variable that proved most strongly related to internal capture was neither land use mix nor density but the size of the community itself. The two communities with the highest internal capture rates, Wellington and Weston, are also the largest, each having more than 30,000 residents and 5,000 jobs. Indeed, these two communities are large enough to recently have incorporated as their own small cities. The second most important variable was regional accessibility, which was inversely related to internal capture rates. Both of these communities are on the western edge of development in southeast Florida, far from other population centers.

Because of size and inaccessibility, these communities capture a much higher percentage of trips internally than does, say, the higher-density and better-mixed Miami Lakes (see Figures 2 and 3 for contrasting images). Miami Lakes doubtless generates shorter automobile trips and many more walking, bicycling, and transit trips than the other two. Its overall impact on the regional road network is almost certainly less. The research of Ewing and colleagues shows a strong inverse relationship in south Florida between regional accessibility and vehicle hours of travel per household (*2, 3*). Thus, this paper ends not only with a call for more empirical work on internal capture but also with a plea for greater consideration of trip length and mode split in traffic impact research and assessment.

FIGURE 2 Wellington with high internal capture (57 percent).

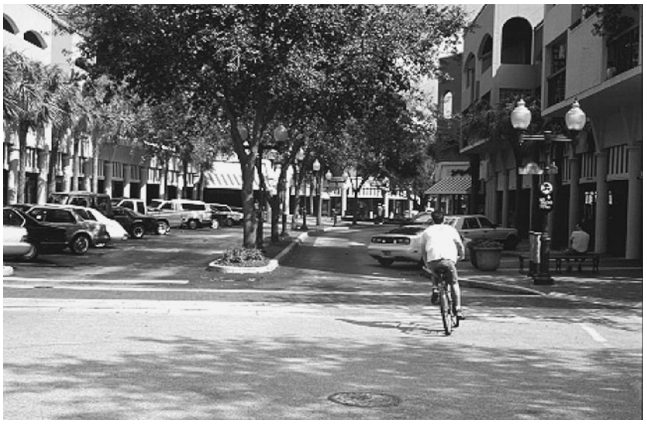

FIGURE 3 Miami Lakes with lower internal capture (25 percent).

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