Activity Center Definitions Based on Trip–Attracting Properties and their Application to the Philadelphia Pennsylvania Metropolitan Area

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Introduction

The motivation for this research arose from an effort to assess regional transportation system performance in the Philadelphia, Pennsylvania metropolitan area. The approach taken in that research was to preselect a series of origin destination pairs for which public transportation might compete well with private automobile, and test the sensitivity of modal split, and overall system performance, to changes in transit service provided and the cost of auto travel. A review of the literature suggests that transit is most competitive in high-density commercial, and to a lesser extent residential, areas (Pushkarev and Zuppan, 1982). To preselect the origin and destination pairs, it was necessary to have a quantitative definition of "high-density" areas.

The urban studies literature contains definitions of activity centers, typically defined as areas with higher than adjacent concentrations of employment at the Traffic Analysis Zone (TAZ) level. This definition has proven satisfactory in the analysis of polycentric areas' employment patterns, residential location theory, and overall economic analysis.

These criteria were adopted by the authors for their work in Philadelphia. Several areas known to be significant transportation centers were not identified using employment-only activity center definitions. One possible source for these omissions was that the traditional activity center definition tends to underestimate the

transportation impacts of certain disaggregate employment types present in an activity center.

The research presented here proposes a simple extension to a commonly used activity center definition to improve that definition's applicability to transportation research. This extension involves identifying activity centers based on the trip-attracting strength of disaggregate employment types within TAZs. This approach identifies areas that are responsible for a disproportionate number of regional trips. The proposed methodology has two positive characteristics. First, the approach computes attraction strengths using standard socio economic data available at the Metropolitan Planning Organization (MPO) level. Second, employment is still the fundamental unit of the activity center definition, and the pedagogical approach of identifying subareas that exceed certain thresholds remains unchanged.

To verify the improvements which this method offers, the Philadelphia, Pennsylvania metropolitan area is analyzed with the standard and revised activity center definitions. The results using the disaggregate employment weightings identify six transportation activity centers that were not recognized using traditional definitions, but are regionally significant in terms of trip attraction. Lastly, a brief analysis is presented on the characteristics of the trip associated with these centers, and the potential to achieve regional improvements by addressing these trips.

Literature Review

A review of the literature on urban decentralization and the formation of suburban activity centers suggests that two distinct research areas have emerged. Research conducted by economists and regional scientists has sought to explain the economic motivation for (Ladd and Wheaton, 1991) and patterns of (Helsley and Sullivan, 1991) activity centers formed outside of urban cores. More specifically, researchers have analyzed the effects of activity centers on parameters such as land values, population distribution, and to a lesser extent travel patterns (Hartwick, 1974) (Odland, 1978) (Fujita,1982). Research has been conducted in many cities: Houston (Smith and Mieszkowski, 1991), Dallas (Skukla and Waddell, 1991), and Chicago (McDonald and Prather, 1994) (McMillen and McDonald, 1997) for example.

Transportation planners and engineers have studied the transportation impacts of suburban agglomerations of activity. (NCHRP, 1989) analyzed six suburban activity centers in the United States to develop a comprehensive database on travel characteristics: origins, destinations, trip purpose, length and mode. (TRB 1990) measured suburban congestion, evaluated suburban trip generation and modal split, and enumerated policy needs for more efficient activity centers. (Cervero, 1989) identified 57 suburban activity center sites throughout the United States from which he developed tremendous aggregate data on the transportation infrastructure that support these SACs.

The main product of his data collection was a stepwise regression analysis of SAC size, form and location input variables to transportation choice output.

As noted above, one commonality between the two fields is the need to systematically define activity centers. Early research from transportation planners failed to produce a standardized definition. In the regional science literature, two methodologies have been taken. The first approach, typically credited to (Giuliano and Small, 1991), defines an activity center as a contiguous set of zones, each with employment density and total employment greater than a threshold value. In studying southern California, the authors established limits of 10 employees per acre and 10,000 total employees for sub centers and lower values of 10 and 7,000 respectively for what they define as "outer centers".

A second definition, developed by (McMillen 2001, 2003) adopts a spatial modeling approach, and seeks to identify zones with employment densities exhibiting statistically significant deviations from their model-predicted values. McMillen argues that establishing *a priori* threshold values for each urban area (and subsections of urban areas) weakens the transferability and comparability of findings between areas.

We concur with McMillen's assessment. However, the Giuliano and Small method has become popular, predominantly for its simplicity, amongst researchers in both fields. (Bogart and Ferry, 1999) adopted the Giuliano and Small definition based on employment density (which Bogart and Ferry refer to as φ) and gross employment

(ξ) at the TAZ level. For each cluster, they then add adjacent zones in order of decreasing employment density provided that the density of the total cluster remains greater than the threshold level φ. Each of these clusters (or single TAZs) that exceed the total employment criteria is then considered an employment center. Using an employment density of 5,000 employees per square mile (φ>7.81 employees/acre) and total employment greater than 10,000 (ξ>10,000/TAZ), Bogart and Ferry identified nine centers in the Cleveland region; they note that these nine centers represent more than 30% of the region's jobs. The researchers correctly state that "[A] way of illustrating the importance of employment centres is by considering the amount of traffic flowing to and from them." As a macro measurement, they identify the 10 busiest intersections in the Cleveland region and note that all 10 are either within or near zones contained in suburban activity centers.

(Cervero, 1998) adopted the Giuliano and Small definition for SACs in several reports analyzing the transportation impacts of SACs in northern California. Working at the census tract level, he defined the minimum employment density (D) to be 7.5 employees per acre and minimum gross employment to be 9,500 employees. His study concluded that between 1980 and 1990 employment in the region had become generally more decentralized, region-wide average commutes had grown longer, and the share of commuting trips made by transit had decreased.

Given the simplicity of the Giuliano and Small method, and its previous application to transportation analysis, we choose to adopt their approach in this work. The following section describes the modifications we are proposing to their activity center definitions.

Extension of the Bogart and Ferry Method

For this research, an extension of the Bogart and Ferry model is used to identify the Traffic Analysis Zones (TAZs) which constitute activity centers. Three principal changes to the Bogart and Ferry model are implemented. First, different threshold levels for employment and employment density are applied (as Giuliano and Small did in defining their "outer centers") to capture activity centers within major urban areas (large cities), secondary urban areas (smaller cities, but still urban development) and suburban areas. The following zones are defined:

1. Major Urban Center – zones contained within the primary urban core city limits.
    a. Employment density greater than 10,000 employees per square mile (φ>15.62 employees/acre).
    b. Total employment greater than or 20,000 employees per TAZ (ξ>20,000 employees/TAZ).
2. Secondary Urban Center – zones contained within secondary city limits.
    a. Employment density greater than 7,500 employees per square mile (φ>11.72 employees/acre);

b. Total employment greater than 15,000 employees (ξ>15,000 employees/TAZ).

3. Suburban Activity Centers, the Bogart and Ferry threshold limits are used:
    a. Employment density greater than 5,000 employees per square mile (φ>7.81 employees/acre);
    b. Total employment greater than 10,000 employees (ξ>10,000 employees/TAZ).

It is impractical to use the Bogart and Ferry methodology for adding adjacent zones to Major Urban or Secondary Urban Centers. Because the urban core zones have extremely high employment densities (in the Philadelphia case, more than 850 employees per acre is observed), it would require the addition of many zones to bring the weighted average below the employment density threshold. Thus, no adjacent zones are added to these centers. Only zones that meet the employment density threshold and are adjacent form urban activity centers.

Adjacent zones are added to suburban activity centers using the criteria defined by Bogart and Ferry with minor modifications. First, the adjacency requirement is relaxed such that any two zones are considered adjacent if they share a common border of any length. Second, adjacent zones are added to form clusters as long the total employment density remains above the threshold limit, and the individual zones being added meet a minimum employment density threshold, in this case 3.0 employees per

acre. This requirement avoids the case where open space adjacent to a high density employment center is considered part of a suburban activity center.

The third, and most significant change to Bogart and Ferry's methodology is to include a trip-attracting weighting factor for the disaggregate employment types present in the TAZs which constitute an activity center. This method is described under the heading Incorporating Trip-Attracting Characteristics below.

Identifying Activity Centers within the Philadelphia Metropolitan Region

The Philadelphia metropolitan region is made up of nine counties across two states (Pennsylvania and New Jersey). For modeling purposes, DVRPC has established 1371 TAZs within the region (at the time the research was conducted the number of TAZs was being increased significantly). The major urban center within the region is the city of Philadelphia. The region also has two secondary urban centers, Camden and Trenton, New Jersey. The region, highlighting these three urban areas is shown in Figure 1.

Figure 1 goes here

Major Urban Center – Philadelphia

Within the city of Philadelphia there are 407 TAZs. Of these 407 zones, 73 meet the employment density requirement. Applying the total employment criteria to

these zones eliminates nine zones. The results are two major urban activity centers (MUC), as shown in Figure 2.

Figure 2 goes here

A review of the larger activity center in Figure 2 provides some additional insight. The area contained in this activity center constitutes three distinct Philadelphia neighborhoods each with different transportation infrastructure / operating characteristics. The first area, known as West Philadelphia is geographically separated from the remainder of the city by the Schuylkill River. A second sub-area is the city's Central Business District, defined locally as the area between the Schuylkill River on the west, the Delaware River on the east, the Vine Street Expressway (I-676) to the north, and South St. to the south. The remaining area, north of Vine Street is known as the Fairmount section. In view of these local neighborhoods and transportation patterns, it is appropriate to treat this major urban activity center as three distinct centers. Table 1 summarizes these major urban activity centers. The delineation lines between the centers are shown in Figure 3.

Table 1 Major urban activity centers within the city of Philadelphia

Major urban activity center	Employment density $\overline{E}$ (jobs / acre)	Total employment E (jobs)	Area A (acres)	TAZs in center

1. Center City Philadelphia – CBD	224.1	287,550	1,283	49
2. Center City Philadelphia – Fairmount	40.3	26,141	648	6
3. West Philadelphia	59.1	51,109	865	5
4. Lower Northeast	55.6	20,986	377	4

Figure 3 goes here

Secondary Urban Centers – Trenton and Camden, New Jersey

The city of Trenton, New Jersey is composed of 24 TAZs, of which seven meet the employment density requirement of 11.7 employees per acre. These seven zones form a contiguous secondary urban activity center, as shown in Figure 4. Only three of Camden's 20 TAZs meet the employment density threshold, and as in Trenton, these three zones formed a contiguous secondary urban activity center. The Camden activity center is shown in Figure 5. The corresponding data for these centers are shown in Table 2.

Figures 4 and 5 go here

Table 2 **Secondary urban centers' statistics**

Secondary urban activity center	Employment density $\overline{E}$ (jobs / acre)	Total employment E (jobs)	Area A (acres)	TAZs in center
1. Camden, NJ	39.7	19,937	5,026	3
2. Trenton, NJ	33.2	44.242	1,335	7

Suburban Activity Centers

Analyzing the major urban center and secondary urban centers accounts for 451 of the region's 1371 TAZs. The remaining 920 zones are evaluated using the suburban activity center criteria. The results indicate that 69 zones exceed the employment density threshold of 7.81 employees per acre. These 69 TAZs produce 26 clusters (two or more adjacent zones) or single zones that are analyzed. For each of the 26 candidates, adjacent zones are manually identified using ArcGIS software. Suitable adjacent zones (employment density greater than 3.0 employees per acre) are added to the clusters and total employment is calculated. Fifteen suburban activity centers are identified; the SACs are made up of 79 total TAZs. The statistics for each SAC is shown in Table 3 and the regional map with all suburban activity centers is shown in Figure 6

Table 3 Suburban activity centers' characteristics

Suburban activity center	Employment density $\overline{E}$ (jobs / acre)	Total employment E (jobs)	Area A (acres)	TAZs in center
1. Media	17.9	12,535	700	3
2. "Southwest zones"	7.9	14,456	1,840	7
3. Lancaster Ave. west	10.0	10,787	1,077	4
4. Princeton, NJ	13.4	15,302	1,140	2
5. Upper Darby	8.0	11,263	1,400	8
6. Upland-Chester-Ridley	8.3	13,512	1,636	7
7. West Chester	8.7	19,883	2,297	6
8. Burlington-Bristol	11.3	11,469	1,011	3
9. Woodbury, NJ	7.9	10,635	1,342	3

Suburban activity center	Employment density $\overline{E}$ (jobs / acre)	Total employment E (jobs)	Area A (acres)	TAZs in center
10. Mount Holly, NJ	8.9	10,643	1,190	3
11. Cherry Hill, NJ	7.9	46,912	5,972	10
12. City Line Ave.	20.2	20,380	1,010	3
13. Upper Merion	9.1	32,706	3,575	2
14. Norristown	8.1	15,545	1,911	7
15. Horsham, NJ	7.7	54,621	7,122	11

Figure 6 goes here

One additional note is necessary regarding the City Line Avenue center. Strictly, this center should not be included in a suburban activity center; the total employment and the employment density meet the major urban center requirements and two zones are within the city limits. However, because this contains one suburban zone

and its total employment figures are more consistent with the suburban centers, it is included in this group.

Incorporating Trip Attracting Characteristics

It is widely understood that different land uses and therefore different employment types generate trips at different rates. For example, a hypothetical TAZ with 100 mining jobs generates far fewer trips than a TAZ with sufficient retail development to employ 100 persons. Furthermore, (Targa 2005) has shown that different employment types tend to respond to agglomerative location forces more readily than others, with retail amongst the most responsive. Thus, retail activities produce more trips, are more likely to agglomerate, and therefore are likely to have stronger impacts on regional transportation patterns.

One approach to identifying activity centers for transportation analyses is to include a quantitative weighting of trip attraction for each employment type with a candidate TAZ. In keeping with previous activity center definitions, those TAZs which exceed a pre-determined threshold would be considered "Transportation Activity Centers" (TACs). This threshold may be defined in terms of trips attracted, in which case the sum of the product of employment and trip attraction rate would be the test variable. This approach introduces a new scale of trip-based threshold levels, which may be orders of magnitude different from previously established and accepted employment- based threshold levels.

In order to maintain employment as the decision variable, and to utilize previously established threshold values, a unitless relative trip attraction strength can be computed for each employment type. The decision variable, then, would be modified total employment, *E*,* for a TAZ, given as the sum of the products of the number of employees of each type and its relative trip attracting index. Mathematically, the weighted total employment *E** can be written as:

$$E^* = \sum_i E_i \cdot \alpha_i \tag{1}$$

where α_i is the relative trip attracting index for each employment type, *i.*

It should be noted that the since transportation impacts of employment concentrations may be quite different from those of regional economics, there is no inherent reason why the same threshold levels should be appropriate in each case. Though this question clearly warrants further research, it is important to stress that the centers produced by these thresholds for the present case of Philadelphia are in fact quite plausible.

The steps necessary to compute α vary by the form in which the MPO publishes trip attraction rates. Our analysis required two minor modifications to the DVRPC rates; the method by which α is calculated in this research is summarized here.

DVRPC published trip attraction rates for "area type" classifications which are intended to adjust rates for zones within, adjacent to, or separated from the Region's CBD. These area types correspond well to the major urban, secondary urban and

suburban threshold limits established above. Thus, in our analysis, TAZs that were initially identified as major urban centers would attract trips at a rate associated with the region's CBD. Similarly, those TAZ belonging to suburban centers attracted trips at rates derived for areas away from a region's CBD.

DVRPC computes attraction rates for aggregate employment classifications that differ from the available employment data. DVRPC rates involve "Basic employment" or "Total employment;" employment data is disaggregated to 11 standard classifications[1]. Thus, the DVRPC classifications had to be disaggregated to create a trip attraction index for each employment type.

As noted above, it is desirable that α be a unitless relative index of trip attraction. Mathematically, this normalization is achieved by computing a hypothetical *mean trip-attracting* (MTA) *job*. To motivate this idea, suppose that there is a TAZ with exactly one job in each of the 11 disaggregate employment types. In this case, a total number of daily trips would be attracted to this zone, and an average number of trips per job could be computed. The relative strength of each employment type can be computed as the ratio of that employment type attraction to the mean attraction. This normalization by mean trip levels ensures that in the case of uniform employment (i.e. equal number of jobs of each type), the total MTA employment for a zone (as calculated by equation 1) will equal the actual total employment. More important for our present

[1] These standard 11 classifications are: Agriculture, Mining, Construction, Manufacturing and wholesale, Retail, FIRE, Service, Government and Military.

purposes is the fact that this normalizing convention maintains "jobs" as the basic unit of measure in expression (1). This allows the same employment thresholds (in units of MTA employees per TAZ) to be used in defining activity centers.

The MTA indices for all three activity center types are given in Table 4. It is interesting to compare the trip attraction rates for retail employment in different area types (see the highlighted row in Table 4). In major urban centers, retail attracts approximately 2.0 times as many trips per employee as a MTA job. In secondary urban centers, this relative attraction rate increases to around 2.5, and in suburban centers, it increases even further to 3 times as many trips. Here it seems unlikely that the number of trips attracted varies by this amount. What is more likely is that these relative attraction strengths represent motorized trips as opposed to total (motorized and non-motorized) trips. In particular, the difference in attraction strength is likely to be explained by the number of non-motorized trips in major and secondary urban centers.

Table 4 Final disaggregate employment trip attracting indices, α_i

Employment type	Area Types		
	Major Urban	Secondary Urban	Suburban
Agriculture (Ag)	0.729	0.645	0.491
Mining (Mn)	0.729	0.645	0.491
Construction (Cn)	0.729	0.645	0.491
Manufacturing	0.760	0.681	0.518
Transportation (Tr)	0.803	0.670	0.499
Wholesale (Wh)	1.153	1.156	1.296
Retail (Re)	2.003	2.555	2.912

Fire (Fi)	0.729	0.645	0.491
Service (Se)	1.122	1.120	1.270
Government (Gv)	1.122	1.120	1.270
Military (Mi)	1.122	1.120	1.270

Applying MTA Concept to the Philadelphia Activity Center Analysis

Using the indices above, an MTA employment for each zone in the Philadelphia metropolitan area is calculated, and employment density is determined. For the city of Philadelphia, the MTA employment data produces 10 zones meeting the employment density criteria for which the actual employment data had not. Of these 10 zones, three zones are contiguous with the original Central Business District center, and the center is simply extended to include these new zones. Similarly, two of the weighted zones are contiguous with the previously identified Fairmount center. Finally, two zones are added to the original Lower Northeast activity center.

In Trenton, New Jersey, one additional zone is identified that is contiguous with the original secondary urban activity center. As with the major urban center, the activity center is expanded to contain the newly identified zones. In Camden, New Jersey, the MTA employment density figures produces no additional zones.

Applying the MTA calculations to the suburban TAZs has a much more pronounced effect. With MTA employment, 45 additional TAZs meet the employment density requirement; one zone that met the threshold with actual employment density no

longer meets the threshold with MTA employment. Of these 45 zones, nine were already included in centers identified by the original SAC definition (by the addition of adjacent zones); 21 zones either independently or considering adjacent zones fail to meet the minimum employment criteria. The remaining 15 zones become part of six new activity centers, referred to henceforth as Transportation Activity Centers (TACs). The locations of these zones are shown in Figure 7 and their characteristics are shown in Table 5.

Figure 7 goes here

Table 5 Suburban Activity Centers identified as a result of weighted employment density

Suburban activity center	Actual employment density $\overline{E}$ (jobs/acre)	Weighted employment density, $\overline{E^*}$ (jobs/acre)	Total actual employ-ment E (jobs)	Retail employ-ment ER (jobs)	Area (acres)	TAZs in center
1. Lansdale	5.2	8.2	23,139	7,243	4,470	7
2. Conshohocken Plymouth Meeting	6.7	8.8	18,459	3,259	2,758	6

3. Malvern	6.7	8.4	13,996	2,115	2,085	3
4. Lancaster Ave. east	6.4	9.6	14,734	3,031	2,289	5
5. Moorestown, NJ	5.5	8.0	17,099	4,297	3,095	3
6. Evesham Township, NJ	6.7	10.1	15,177	4,065	2,276	3

These six TACs are composed of TAZs that meet two general categories. In some cases, the TAZs nearly met the original employment density threshold, and the MTA employment is sufficient to increase the employment density such that the minimum is met. In other cases, the presence of concentrated retail activity produces sufficient trip attraction that the MTA employment density is above the minimum. It should be noted that on the macro level, retail employment in these six additional suburban centers constitutes 23.4% of all employment; regionally, retail employment accounts for only 16.1% of all jobs.

Trip Volumes Associated with Transportation Activity Centers

An analysis of the trip volumes associated with these centers suggests that including trip attracting characteristics in defining an activity center identifies important metropolitan regions that would have been overlooked by the traditional definition. To

demonstrate this point, the trip characteristics of the six centers defined by the MTA method are compared to the 15 previously identified suburban centers.

DVRPC modeling estimates the following daily trip volumes associated with the six TACs. Internal trips are defined as trips that originate from and are destined for a TAZ contained in the transportation activity center.

Table 6 Trip volumes for the six transportation activity centers

	Daily Trips			
Center	Internal	Produced	Attracted	Total
Lansdale	46,264	56,549	117,803	220,616 (4)
Conshohocken Plymouth Meeting	18,005	50,789	93,169	161,963 (6)
Malvern	17,704	33,292	70,258	121,254 (11)
Lancaster Ave. East	17,283	54,367	77,416	149,066 (8)
Morristown	28,364	62,250	106,609	197,202 (5)
Evesham	19,158	38,887	80,036	138,081 (9)
			Total for all centers	988,182

Thus, these six centers account for nearly one million trips, or more than 5% of the daily regional trip volume (the Philadelphia region has more than18 million daily trips). The 15 previously identified activity centers account for approximately 2.16 million daily trips, or approximately 11% of the regional total.

Perhaps a more interesting comparison is how transportation activity center trip volumes compare to the volumes of trips from traditionally-defined suburban activity centers. We have identified 15 traditional suburban activity centers and six transportation activity centers for a total of 21 centers. The last column in Table 6 shows the trip volume rank for each of the transportation activity centers. For example, Lansdale's total of 220,616 trips is the 4th highest trip total for any activity center.

Similarly, Morristown and Conshohocken are the 5th and 6th highest trip volumes respectively; the lowest-ranking transportation activity center is the Malvern center, which ranks 11th. This suggests that the lowest ranking transportation activity center is still associated with more trips than 10 activity centers identified using employment only.

Analyzing trip volumes per area of activity center (trip density) is useful in identifying concentrations of trips, which for various reasons (discussed below) is important in transportation analysis. Table 7 shows the total trip volume (sum of internal, produced and attracted trips) per acre of activity center, as well as the trip volumes disaggregated by trip type. The number in parenthesis indicates the ranking of this output amongst the 21 centers identified.

Table 7 Trip densities disaggregated by trip type for transportation activity centers

	Daily Trips per acre			
Center	HBW	HBNW	NHB	Total
Lansdale	11.10 (21)	23.77 (16)	14.48 (20)	49.35 (21)
Conshohocken Plymouth Meeting	14.22 (18)	27.75 (13)	16.75 (10)	58.72 (14)
Malvern	13.32 (19)	28.27 (12)	16.56 (12)	58.16 (15)
Lancaster Ave. East	15.86 (15)	31.93 (6)	17.33 (6)	65.12 (7)
Morristown	13.14 (20)	32.85 (4)	17.73 (4)	63.72 (8)
Evesham	14.69 (16)	28.59 (11)	17.39 (5)	60.67 (13)
Average rank	18.2	10.3	9.5	13.0

The data in table 11 suggest that the Lancaster Ave East and Morristown transportation activity centers are associated with higher trip densities than nine of the original suburban activity centers; the trip density in Evesham, Conshohocken and Malvern exceeds five of the original suburban activity centers. On average, the transportation

activity centers rank 13th in total trip density. Only Lansdale is consistently weak; this may be a result of the large TAZs which compose the Lansdale activity center.

Also of importance is the average ranking disaggregated by trip type. The transportation activity centers have low Home Based Work trip density with an average ranking of 18.2. Only one traditionally-defined activity center has lower HBW trip density. This suggests that these transportation centers are not strong origins or destinations for typical commuting trips. In contrast, the transportation activity centers have much higher trip densities for Home-based non-work and non-home based trips. Morristown and Lancaster Avenue East rank 4th and 6th respectively in both of these categories, while Evesham has the 5th highest NHB trip density. One interpretation of these results is that these transportation activity centers serve a greater number of "discretionary" trips, i.e. intermediate commuting stops, or shopping trips.

One further analysis is presented regarding the transportation activity centers. Table 8 shows the percentage of trips which are internal to a transportation activity center, and again contains the ranking.

Table 8 Daily Internal Trips for the Transportation Activity Centers

	Daily Internal Trips (percent of total)			
Center	HBW	HBNW	NHB	Total
Lansdale	7.6 (4)	19.5 (2)	33.6 (2)	21.0 (1)
Conshohocken Plymouth Meeting	3.4 (12)	11.5 (10)	17.0 (11)	11.1 (11)
Malvern	4.2 (9)	15.0 (6)	22.2 (8)	14.6 (6)
Lancaster Ave. East	3.1 (15)	12.9 (8)	16.9 (12)	11.6 (10)
Morristown	4.1 (10)	15.0 (5)	20.7 (10)	14.4 (7)
Evesham	4.4 (7)	13.4 (7)	22.6 (7)	13.9 (8)
Average rank	9.5	6.3	8.3	7.2

The data in Table 8 illustrate the fact that the transportation activity centers produce higher numbers of internal trips than do the traditionally defined suburban activity centers. This is particularly true for non-commuting trips, both HBNW and NHB trip types.

Impacts of Activity Centers on Regional Transportation

The impacts of activity center trips on polycentric metropolitan areas is analyzed in a user equilibrium framework by (Casello 2003) and in companion papers by the authors. A brief review of TAC impacts on regional transportation is presented here.

As noted earlier, using the TAC methodology identifies six additional centers that contribute nearly one million daily trips to regional trip patterns. Excluding these centers overlooks concentrated trip origins and destinations for which more detailed transportation planning may be required. Several examples illustrate this point.

Several of the transportation activity centers are located in areas which evolved as low traffic volumes suburban areas (Morristown and Evesham, for example). As such, these centers are not directly served by major regional transportation infrastructure – either highway or transit facilities. Thus, these large trip volumes (197000 and 138000 daily trips in Morristown and Evesham, respectively) may exceed existing capacity and require means to improve the system performance.

The Conshohocken Plymouth Meeting transportation activity center is associated with more than 160,000 daily trips. These trips contribute to the demand for

some of the region's most critical transportation infrastructure: I-76, I-276 and I-476 (see Figure 7) which all intersect within the activity center area. Because of the high traffic volumes in the area, congestion on these regional links corresponds to very high person-hours of delay, and strongly negative environmental impacts. Recurring congestion is observed in this area. Again, the volume of trips associated with a TAC requires a response from Regional planners or engineers.

(Pushkarev and Zupan, 1982) and others note the strong correlation between employment density (and in turn trip density) and the propensity to ride transit. A second factor suggesting that transit services may be attractive is the relatively high percentage of trips internal to the TACs (14.4, 13.9 and 11.1 percent respectively). Internal trips are generally short-distance trips for which the absolute difference in travel time between transit and auto may be very small. It should be noted that non-commuting trips contribute strongly to the percentage of internal trips; in Morristown only 4% of HBW trips are internal, versus 15% and 21% of HBNW and NHB trips respectively. HBNW and NHB trips are often considered discretionary trips and may be parts of trip chains. In both cases, transit planners may consider different schemes, such as higher frequency in off-peak hours to capture a greater percentage of these discretionary trips.

Conclusions and Future Work

There is a substantial body of work on identifying areas within metropolitan regions that have higher employment density than their surrounding areas. This work on analyzing and defining suburban activity centers is extended in this research to:

1. Include definitions for major and secondary urban centers;
2. Identify zones not only on employment, but also on the relative trip attracting strength of employment types within a zone.

The employment only methodology is then applied to the Philadelphia metropolitan region where four major urban centers, two secondary urban centers and a total of 15 suburban centers are identified. By weighing employment types by their trip attracting strength, an additional six activity centers are identified; these centers generally contain high concentrations of retail employment.

Our findings from the Philadelphia region suggest that transportation research based on traditional activity center definitions may overlook zones with significant transportation impacts on the region. These six additional centers are associated with nearly one million daily regional trips, or more than five percent of total daily trips. The TACs also have similar trip densities as activity centers identified using the traditional definitions. The trip types, patterns and locations of SACs and TACs present both opportunities and challenges for increasing transit usage in the Philadelphia metropolitan area.

Additional work may focus on identifying appropriate MTA employment thresholds in different metropolitan areas. While in our research using standard employment thresholds produced plausible results, alternative threshold levels may be necessary to identify the most appropriate centers in other urban areas. Secondly, this research identifies areas that attract a disproportionate number of trips, and in a second step, analyzes the trip characteristics and the potential to improve system performance. A more robust formulation might combine these steps, to find high trip attracting areas with significant regional impacts and high potential for system improvement. For example, the formulation might include a consideration of the transportation (highway, transit, and non-motorized) capacity within the center, as well as the nature of trip patterns associated with the centers.

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Figure 1 The Philadelphia Pennsylvania Metropolitan Area with Camden and Trenton, New Jersey

Figure 2 Philadelphia city with two contiguous major urban centers

Figure 3 Final classification of the four major urban centers within the Philadelphia city limits

Figure 4 Trenton, New Jersey secondary urban center

Figure 5 Camden, New Jersey secondary urban center

Figure 6 Philadelphia metropolitan area suburban activity centers

Figure 7 New suburban activity centers based on weighted employment analysis