location decisions. The effects of changes in these nontransportation factors may offset or swamp the effects of transportation policy. Factors other than transportation that are significant in residential location choices include levels of real per capita income, public services (especially education), crime rates, and the racial composition of neighborhoods. The steady postwar growth in real per capita income is thought to have played an especially significant role in encouraging residential suburbanization. As per capita incomes grow, households usually purchase more and better-quality housing services; this, in turn, encourages households to locate in the suburbs where lots (which are considered by many to be an important quality improvement) are cheaper because land prices are lower and where newer (and thus often higher-quality) housing tends to be located. Thus, the effects of a future transportation policy designed to discourage residential suburbanization would be offset in part, if not entirely, by the continued rise in real per capita incomes.

The nontransportation factors that influence business-location decisions are probably more numerous (and more poorly understood) than those that influence residential changes. Rising wage rates and consequent changes in production technologies, for example, are thought to have been important factors in suburbanizing the location of businesses. As per capita income and wage rates increased, it became profitable for manufacturers to substitute capital for labor by using production lines and one-story plants; these new plants were space extensive, situated in suburban locations, built where land was cheap, and proved to be generally advantageous to employers and employees. Improvements in communication technologies may have also encouraged suburbanization of employment by making it more possible to locate central office, clerical, manufacturing, and other functions of a single firm on separate sites.

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Development of Truck Trip-Generation Rates by Generalized Land-Use Categories

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One method of truck trip-generation analysis—that is, the relation between the number of truck trips produced in or attracted to an area and the characteristics of that area—is land-area trip-rate analysis. This technique develops truck trip rates, usually on a per acre or per square mile basis, for each of the various land-use types in a study area. This study reviews previous research on land-area truck trip rates and develops additional land-area truck trip rates for several case-study cities. Use of these rates may prove valuable in the analysis of the impact of major truck generating activities in localized sections of an urban area. An examination of the developed truck trip rates shows that, in general, commercial and industrial land uses are the largest generators of truck trips. Much variation is apparent, however; only residential land uses exhibit any consistency when the results of this research and previously reported truck trip rates are compared.

Trip-generation analysis techniques are usually grouped into one of three categories (1):

1. Multiple-regression analysis, the most widely used of the three procedures, relates zonal trip ends to various socioeconomic and demographic characteristics of a traffic analysis zone through a mathematical modeling procedure.
2. Cross-classification, or category analysis, stratifies independent variables into several distinct groups creating an n-dimensional matrix. For example, averages of the dependent variable and trips per dwelling unit are then computed for each cell of the matrix and forecasts are made by summing the trip ends for the forecast proportions of the independent variables.
3. Land-area trip-rate analysis attempts to develop trip-generation rates—for example, trips per acre—for the various land-use categories existing in the study area. (Because data compiled for the four case-study cities discussed later in this paper were all in customary units, no SI equivalents are given either in the text or in the accompanying tables.)

The applications of each of these approaches to truck trip-generation analysis are varied but certain techniques have been more widely used than others. Cross-classification analysis, for instance, has had limited use as a truck trip-generation analysis procedure. Although some early work was reported in the Puget Sound Regional Transportation Study (2) and more recent federal guidelines have suggested a modified cross-classification approach for nonresidential trips (3), few specific applications have been made.

Multiple-regression analysis, in contrast, has had widespread use in truck trip-generation analysis. Typical examples of developed regression relations for urban truck trips are shown in Table 1 (4, 5). This table indicates that the earlier equations were often quite complex and involved a variety of independent variables, some with possible high intercorrelations. The Richmond example, however, reflects the continuing trend toward simplification through the use of only one equation for all internal trucks and a limited number of independent variables.

The third approach to truck trip-generation analysis has been the development of truck trip rates, usually truck trip ends per acre, for the general land-use types existing in an urban area. Application of these developed land-area truck trip rates rests not so much in long-range strategic planning on a regionwide, urban, or even networkwide basis, but rather in the short-run tactical

planning area. This approach has merit on a local level and may prove valuable in the analysis of the impact of major truck trip-generating activities in localized sections of an urban area.

The use of land-area trip-rate analyses, therefore, may be a valuable tool for evaluating transportation systems in general and the impact of truck movements in particular on an intermediate scale. The level of detail for this type of analysis would be more refined than that associated with the regression analysis techniques usually associated with large-scale areawide forecasting. Similarly, implementation time of the land-area trip-rate technique would be shorter than the long-term strategic planning generally associated with the regression analysis procedures, both because of the shorter time required for data collection and model development and the possibility of using "borrowed" rates previously developed for similar urban situations. Time requirements would be more in the tactical planning realm and results of analysis would be more readily available and easier to implement.

The scope and timing of the land-area trip-rate technique are less detailed and of longer range, respectively, than the use of truck trip-generation rates based at the business establishment level (6). The land-area trip-rate technique thus occupies a somewhat intermediate position in the array of options available for the analysis of urban truck travel demands. Use of truck trip rates by various land-use categories would enable local traffic engineers and planners to evaluate the truck traffic impact of a proposed industrial park, for example, even though the types of establishments that would eventually occupy the site could not be immediately determined.

The purpose of this research is the development of truck trip-generation rates by various stratified land-use categories. Previous applications of the land-area truck trip-rate approach are discussed and truck-trip origin-destination data from several case-study cities are analyzed by land-use type as well as by city size, economic base, and geographic location. Results of the study yield important information on local impact analyses relating to urban truck movements and may be valuable input to decisions at the sketch-planning level.

EARLY RESEARCH

Because of the short-term application of land-area trip-rate analysis and the traditional long-range orientation of the conventional transportation planning process, few applications of the land-area trip-rate approach have previously been made. Early research in the area has been summarized for several intermediate-sized urban areas by Smith (7). As expected, these studies showed that commercial land uses generated the greatest number of truck trips per acre; residential uses generated the fewest and also had the greatest stability across cities.

Another study (8) broke down land-area truck trip rates in Nashville by light and heavy truck vehicles. Again, the commercial land-use category had the highest rates, both overall as well as for each truck type. Industrial land uses also generated a significant number of heavy-truck trips; a large number of the residential truck trips were made by light truck vehicles.

A more recent example of the application of the land-area trip-rate approach is given in Table 2 in which Zavattero (9) summarizes truck trip-generation rates for the Chicago region. As might be expected, although commercial land uses represent only 3.5 percent of the developed land in the study area, they account for over 37 percent of the total truck trips. Manufacturing land uses account for another 12 percent of the truck trips and only an additional 4.4 percent of the developed land. Residential land uses account for almost 35 percent of the truck trips and use over 35 percent of the developed land; thus, they have a relatively small truck trip rate.

DATA AND CASE STUDIES

Truck-trip origin-destination data from four case-study cities (Flint, Michigan; Columbus, Ohio; Kenosha, Wisconsin; and Racine, Wisconsin) that included both destination land-use data and land area by land-use type on an areawide basis were used in the development of the land-area truck trip rates in this study. In addition to the trip-rate stratification by land-use type, the developed truck trip rates were also categorized by truck type. Thus, individual rates are available for light, medium, and heavy trucks, as well as for total trucks for each of the case-study cities. This breakdown by

Table 1. Typical truck trip-generation equations for zonal productions and attractions.

Study Area and Year	Regression Equation
Winston-Salem, North Carolina (1965)	Light trucks = 0.09 (population) + 0.24 (dwelling units) + 0.12 (employment, white collar) + 0.06 (employment, blue collar) - 0.24 (school enrollment) + 0.02 (retail sales, convenience) + 16.22 Heavy trucks = 0.04 (population) + 0.07 (dwelling units) - 0.16 (automobiles) + 0.19 (labor force, white collar) + 0.18 (employment, blue collar) - 0.08 (school enrollment) + 13.30 External trucks = 0.75 (automobiles) - 0.57 (labor force, blue collar) + 0.86 (employment, white collar) + 0.82 (employment, blue collar) - 0.18 (school enrollment) + 0.02 (retail sales, convenience) + 0.05 (retail sales, general) - 1.97
Richmond, Virginia (1974)	Truck productions or attractions = 43.84 + 0.180 (internal employment) + 0.370 (dwelling units)

Table 2. Truck trip-generation rates by land-use categories in the Chicago area.

Land Use	Land Area (acres)	Total Land (%)	Developed Land (%)	Total Truck Trips	Trips (%)	Truck Trips per Acre
Residential	335 307.1	11.3	35.8	428 941	34.8	1.28
Manufacturing	41 532.2	1.4	4.4	149 916	12.2	3.61
Commercial	32 449.6	1.1	3.5	462 380	37.6	14.25
Public buildings	78 933.7	2.7	8.6	31 545	2.6	0.40
Public open space	144 885.2	4.9	15.5	4 733	0.4	0.03
Transportation, communication, utilities	99 813.0	3.4	10.8	111 338	9.0	1.12
Highways-streets	181 174.3	6.1	19.4	26 076	2.1	0.14
Automobile parking	3 762.2	0.1	0.3	1 835	0.1	0.49
Total developed	939 017.4	(31.5)	100.0	1 216 757	(98.8)	1.30
Undeveloped	2 034 632.8	68.5		14 431	1.2	0.007
Total	2 973 650.2	100.0		1 231 188	100.0	0.41

truck type is particularly important in order to isolate the impact of the larger and heavier truck vehicles because they are often the critical units in terms of environmental considerations and roadway geometric constraints.

The study first discusses the findings of the land-use truck trip-rate development in each of the four case-study cities. A general comparison of the rates is then made across the case-study cities analyzed in this research as well as with the land-area truck trip rates developed in earlier research. Because the land-area truck trip rates in each of the case-study cities were developed using areawide land-use totals, no estimate of the variance of each of the land-area truck trip rates among the study areas' analytical zones was possible. In order to make such an estimate, area size by land-use type and truck trip ends by land-use type would have to be available for each of the traffic zones in the area. Such was not the case, unfortunately, and only areawide rates are reported.

Table 3. Truck trip rates by land use and truck type in Flint, 1966.

Land Use	Daily Truck Trip Ends per Acre[a]			
	Light Trucks[b]	Medium Trucks[c]	Heavy Trucks[d]	Total Trucks
Residential	1.68	0.20	0.09	1.97
Manufacturing	10.37	2.06	2.16	14.59
Transportation, communication, utilities	0.68	0.28	0.74	1.70
Wholesale	19.05	7.57	3.40	30.02
Retail	11.85	5.60	1.13	18.58
Services	4.92	1.19	0.18	6.29
Cultural, recreation, entertainment	0.31	0.10	0.01	0.42
Resource production and extraction[e]	0.04	0.01	-[f]	0.05
Undeveloped[g]	0.01	-	-	0.01

[a] Trip rates include both truck origins and destinations.
[b] Light trucks = all single-unit, single-rear-tire trucks.
[c] Medium trucks = all single-unit, dual-rear-tire and single-unit, three- and four-axle trucks.
[d] Heavy trucks = all combination units.
[e] Includes agricultural land.
[f] Less than 0.01.
[g] Vacant and water areas.

Table 4. Truck trip rates by land use and truck type in Columbus, 1964.

Land Use	Daily Truck Trip Ends per Acre[a]			
	Light Trucks[b]	Medium Trucks[c]	Heavy Trucks[d]	Total Trucks
Residential	0.48	0.38	0.11	0.97
Industrial	2.76	2.94	1.13	6.83
Communication, transportation, utilities	0.69	0.84	0.61	2.14
Commercial	11.93	8.58	1.28	21.79
Public facilities	0.52	0.49	0.13	1.14
Recreation, open space	0.30	0.23	0.03	0.56
Mining	-[e]	0.01	-	0.01
Agricultural and vacant	0.01	-	-	0.01
Water	0.28	0.20	0.05	0.53

[a] Trip rates include both truck origins and destinations.
[b] Light trucks = all panel and pickup trucks.
[c] Medium trucks = all other commercial trucks except combinations.
[d] Heavy trucks = all semi- and full-trailer combinations.
[e] Less than 0.01.

Flint

Truck trip rates by land use and truck type for the 405 367-acre Flint study area are given in Table 3 for the nine-category land-use breakdown coded on the Flint truck origin-destination records. An examination of the data in Table 3 reveals that wholesale land uses are the highest generators of truck trips, both overall and for each of the truck-type categories, with 30.02 total truck trip ends/acre and 19.05, 7.57, and 3.40 truck trip ends/acre for light, medium, and heavy trucks, respectively. Both retail and manufacturing land uses are also heavy-truck trip generators, although the retail category has relatively high trip rates for light and medium trucks (11.85 and 5.60 truck trip ends/retail acre, respectively) and the manufacturing land uses have high trip rates for the heavy truck vehicles (2.16 heavy-truck trip ends/manufacturing acre)—defined in this case as all combination (tractor-trailer) units. The relatively large trip rates for heavy vehicles in both the wholesale and manufacturing categories make sense because these land uses would be expected to produce or attract large shipments of either raw materials or finished products. It should be pointed out, however, that these land uses also generate a substantial number of light- and medium-truck vehicle trips, indicating the intensity of the overall truck use occurring on these particular sites.

In contrast to the large-truck trip rates for wholesale and manufacturing land uses in Flint, the retail, and to a lesser degree, the services land uses generate primarily smaller-truck vehicle trips. This, too, is logical because land uses of this type may be expected to contain comparatively smaller facilities with either service or delivery functions that are conducive to the operation of smaller truck vehicles. Land uses of this type may also have various access constraints, a central

Table 5. Truck trip rates by land use and truck type in Kenosha, 1972.

Land Use	Daily Truck Trip Ends per Acre[a]			
	Light Trucks[b]	Medium Trucks[c]	Heavy Trucks[d]	Total Trucks
Residential	1.20	0.52	-[e]	1.72
Manufacturing-nondurable	0.56	3.40	0.10	4.06
Manufacturing-durable and extractive	18.49	16.70	8.85	44.04
Transportation and utilities	0.16	0.11	0.10	0.37
Commercial wholesale and storage	1.94	3.00	0.04	4.98
Commercial retail and services	16.93	22.17	0.55	39.65
Institutional and government service	1.35	0.34	-	1.69
Recreation	-	-	-	-
Agricultural and related	0.02	-	-	0.02
Open land and water areas	-	-	-	-

[a] Trip rates include both truck origins and destinations.
[b] Light truck = under 8000 lb, except farm (under 10 000 lb).
[c] Medium truck = 8000-50 000 lb.
[d] Heavy truck = over 50 000 lb.
[e] Less than 0.01.

Table 6. Truck trip rates by land use and truck type in Racine, 1972.

Land Use	Daily Truck Trip Ends per Acre[a]			
	Light Trucks[b]	Medium Trucks[c]	Heavy Trucks[d]	Total Trucks
Residential	0.93	0.36	-[e]	1.29
Manufacturing-nondurable	1.94	2.00	0.15	4.09
Manufacturing-durable and extractive	12.81	8.75	0.36	21.92
Transportation and utilities	0.27	0.19	0.02	0.48
Commercial wholesale and storage	2.69	3.39	0.13	6.21
Commercial retail and services	19.07	22.93	0.13	42.13
Institutional and government service	2.22	0.82	-	3.04
Recreation	0.03	0.02	-	0.05
Agricultural and related	0.01	-	-	0.01
Open land and water areas	0.03	0.16	-	0.19

[a] Trip rates include both truck origins and destinations.
[b] Light truck = under 8000 lb, except farm (under 10 000 lb).
[c] Medium truck = 8000-50 000 lb.
[d] Heavy truck = over 50 000 lb.
[e] Less than 0.01.

business district location, for example, and thus preclude the operation of larger truck vehicles.

With perhaps the exception of residential land, which has some movement of light trucks (1.68 light-truck trip ends/residential acre), none of the other land uses in the Flint area generate truck movements of significant magnitude.

Columbus

Table 4 shows land-area truck trip rates by truck type developed for the Columbus study area of 344 111 acres. Commercial land uses, including both wholesale and retail categories, have the highest truck trip rates, both overall (21.79 total truck trip ends/commercial acre) and for each individual truck type (11.93, 8.58 and 1.28 truck trip ends/commercial acre for light, medium, and heavy trucks, respectively). Industrial land uses are the second highest generator of truck trips with 6.83 total truck trip ends/industrial acre and once again contain a high percentage of heavy-vehicle trips.

None of the other land-use types in Columbus have truck trip rates approaching the intensity of the commercial and industrial uses, although communication, transportation, and utilities (2.14 total truck trip ends/acre) and public facilities (1.14 total truck trip ends/acre) land uses have considerably higher rates than the others. Residential uses have a quite low truck trip rate of only 0.97 total truck trip ends/acre; the total rate, moreover, is somewhat spread across all three truck types with an unexpected nondominance of light-truck trips. This low rate may perhaps be due to the residential definition or, more likely, to the inclusion of personal business-type truck trips with the home-interview survey and their subsequent deletion from the truck survey (on which the truck trip rates are based).

Kenosha

The land area truck trip rates for Kenosha, a city with a 1972 population of 99 664 and a total area of approximately 86 miles^2, were developed from truck movement data from the Southeast Wisconsin Regional Planning Commission (SEWRPC) 1972 origin-destination study. Results of the Kenosha analyses are given in Table 5. Once again, manufacturing (in this case durable manufacturing) and commercial (retail and services) are the dominant land uses in terms of truck trip generations with total truck trip ends/acre of 44.04 and 39.65, respectively. Durable manufacturing has the highest truck trip-generation rate overall and is the only category with a significant number of heavy-truck trip generations (8.85 heavy-truck trip ends per durable manufacturing acre). Commercial retail and services has a high overall rate that is composed primarily of light (16.93 truck trip ends/acre) and medium (22.17 trip ends/acre) truck trips.

The other land-use categories with fairly high truck trip rates are commercial wholesale and storage, with a total truck trip rate of 4.98 trip ends/acre consisting primarily of medium-truck trips and containing an unexpectedly low rate for heavy-truck trip generations, and nondurable manufacturing, with a total rate of 4.06 truck trip ends/acre primarily composed of medium-truck trip ends (3.40 trip ends/acre). Residential land uses have a total rate of 1.72 truck trip ends/residential acre and are composed of mostly light-truck trip ends (1.20 light-truck trip ends/acre).

Part of the apparent difference in trip rates by land-use type between Kenosha and those for Flint and Columbus may be due to the definitions of light, medium, and heavy trucks. The Flint and Columbus origin-destination studies, for example, coded truck vehicles by vehicle type, i.e., panel and pickup trucks, other single-unit vehicles, and all combination units. The SEWRPC coding by comparison was according to vehicle weight—i.e., light trucks under 8000 lb, medium trucks of 8000-50 000 lb, and heavy trucks more than 50 000 lb. It is thus possible, although not very likely, for some single-unit trucks to have a gross weight of more than 50 000 lb and, conversely, for some combination units to weigh less than 50 000 lb. Tennessee's weight restrictions by vehicle type, for example, show a maximum allowable gross weight of 48 000 lb for a small truck-tractor semi-trailer combination, the "pup" vehicle being used more frequently in city deliveries (10).

Racine

Truck trip rates have also been developed for Racine, another city in the SEWRPC study area, with a 1972 population of 136 952 and an area of 100 miles^2. These rates are shown in Table 6. Commercial retail and services are the dominant land uses for the generation of truck trips in Racine with a total of 42.13 truck trip ends/acre. The retail and services rate, moreover, is almost exclusively composed of light (19.07 truck trip ends/acre) and medium (22.93 truck trip ends/acre) truck trips.

Heavy-truck trips, in fact, do not appear significant in any of the land-use truck trip rates in Racine. Even durable manufacturing, which has the second highest truck trip rate (21.92 truck trip ends/acre) in Racine and which generates a considerable number of heavy-truck trips in Kenosha, has a very small heavy-truck trip rate (0.36 heavy-truck trip ends/durable manufacturing acre). The low values for heavy-truck trips could be due to the economic makeup of the city that may preclude the need for the types of deliveries usually made by heavy trucks. Another explanation could be a large amount of total acreage in durable manufacturing use that would result in a low heavy-truck rate. If this were true, however, the rates for all truck types would also be much less; this does not seem to be the case.

Other land-use truck trip rates of significance in Racine include a commercial wholesale and storage rate of 6.21 total truck trips/acre and a residential rate of 1.29 total truck trips/acre. These seem comparable with the rates for the same categories in Kenosha.

COMPARING LAND-USE TRUCK TRIP RATES

In order to generalize about the use of land-area truck trip rates for truck travel forecasting, it is necessary to have an indication of the variability of these rates across a variety of urban areas from which such information is available. Unfortunately, land-area trip rates for truck movements are available from only a few sources in the literature on truck travel-demand forecasting; these have been summarized and reported on previously. In addition to the lack of previously published material on land-area truck trip-generation rates, financial constraints and time strictures limited the present analysis to the four previously described urban areas for which data were available.

The results of the comparison of land-area truck trip rates for total truck trips are shown in Table 7 for both the previously reported research and the research performed by this project. In order to make meaningful comparisons possible, it was necessary to double the rates reported by Smith (i.e., for Nashville, Richmond, Baton Rouge, Little Rock, Columbia, and Monroe) and those developed by Zavattero (Chicago) because they re-

Table 7. Comparison of land-use truck trip rates from selected urban areas.

Land Use	Truck Trip Ends per Acre												
	Chicago, IL	Columbus, OH	Nashville, TN	Flint, MI	Richmond, VA	Baton Rouge, LA	Little Rock, AK	Columbia, SC	Racine, WI	Kenosha, WI	Monroe, LA	Avg	SD
Residential	2.6	1.0	1.8	2.0	2.8	4.0	2.0	2.4	1.3	1.7	3.4	2.27	0.89
Industrial		6.8	5.0									5.90	1.27
Manufacturing	7.2			14.6	5.2	2.6	0.8	3.0			11.8	6.46	5.10
Nondurable manufacturing									4.1	4.1		4.10	0.00
Durable manufacturing and extractive									21.9	44.0		32.95	15.63
Commercial	28.5	21.8	29.6									26.63	4.22
Retail-wholesale trade					20.6	67.2	32.0	40.6			70.0	46.08	21.77
Wholesale				30.0								30.00[a]	
Commercial wholesale and storage									6.2	5.0		5.60	0.85
Retail				18.6								18.60[a]	
Commercial retail and services									42.1	39.7		40.90	1.70
Transportation, communication and utilities	2.2	2.1	1.9	1.7								1.98	0.22
Transportation and utilities									0.5	0.4		0.45	0.07
Transportation-warehouse					1.8	8.0		4.6			5.0	4.85	2.54
Service				6.3								6.3[a]	
Services, schools, government					8.0	5.2		6.4			10.4	7.50	2.25
Institutional and government service									3.0	1.7		2.35	0.92
Public buildings	0.8											0.8[a]	
Public land and buildings			1.0									1.0[a]	
Public facilities		1.1										1.1[a]	
Cultural, recreation, entertainment				0.4								0.4[a]	
Recreation									0.05	-[b]		0.05[a]	
Public open space	0.06											0.06[a]	
Recreation open space		0.6										0.6[a]	
Resource production and extraction				0.05								0.05[a]	
Mining		0.01										0.01[a]	
Highways and streets	0.3											0.3[a]	
Automobile parking	1.0											1.0[a]	
Agricultural and vacant		0.01										0.01[a]	
Agricultural and related									0.01	0.02		0.02	0.01
Open land and water		0.5							0.2	-		0.02	0.01
Other			0.06									0.06[a]	
Undeveloped	0.01			0.01								0.01	0.00

[a]Only one observation. [b]Less than 0.01.

ported on either truck trip destinations or truck trips, not on total truck trip ends.

Interpretation of the stability of the trip rates across urban areas is difficult because of the wide variety of land-use categories employed. Residential land use is the only common category over all 11 cities. Industrial or manufacturing uses, on the other hand, are sometimes coded as "industrial," "manufacturing," or sometimes broken down into durable and nondurable components. The same is true for the commercial uses, which are reported in as many as six different categories, and most of the other uses as well.

In order to minimize this problem and to make some comparisons as meaningful as possible, the land uses in Table 7 have been grouped into somewhat similar categories. Residential land-use truck trip rates are thus seen to have some stability across all 11 cities, averaging a little more than two total truck trip ends/acre of residential land. Industrial-related land uses, on the other hand, are seen to have no consistent pattern, ranging from 0.8 truck trip ends/manufacturing acre in Little Rock to 44.0 truck trip ends/durable manufacturing and extractive acre in Kenosha. Part of this vast difference in industrial rates may be explained by the exact types of trips included in the two different categories; additional differences may be due to the economic makeup, geographic location, and size of the cities being compared. One general conclusion, however, is that, unlike trip rates for passenger travel, truck trip rates exhibit little similarity between urban areas.

It is possible, nevertheless, to draw some general conclusions from the available truck trip rates. Commercial uses, for the most part, exhibit the highest land-use truck trip rates, averaging as much as 46 truck trip ends/acre for some retail uses. Industrial-type land uses are the second highest land-area truck trip generators, followed by service, transportation, communication and utilities, and residential. All types of trip rates, however, with the possible exception of the residential category, show tremendous variability.

SUMMARY

An examination of the developed truck trip rates shows that commercial and industrial land uses are the greatest generators of truck trips. Much variation is apparent, however, with only residential land uses exhibiting any consistency when a comparison across the results of this research and previously reported truck trip rates is made.

Part of the difficulty in comparing land-area truck trip rates across several urban areas and part of the reason for the tremendous variation in the land-use truck trip rates is the differing land-use categories used in the various study areas. Industrial land uses, for example, may be coded as industrial in one area and as manufacturing or durable manufacturing and nondurable manufacturing in another area. Similarly, commercial land uses may be classified into any number of commercial, retail, and wholesale categories. Such a lack of

precise definition could be resolved by reliance on one land-use coding scheme for all urban areas, such as the one proposed in the Standard Land Use Coding Manual (11).

An additional problem in definition arises when analyzing the effects of light-, medium-, and heavy-truck vehicles. Comparisons are likewise not possible in this regard because some studies have defined light, medium, and heavy according to vehicle weight; others have used vehicle type as the classifying vaniable. Here again a standard definition is needed.

Perhaps the most significant recommendation to result from the research is the need for the development of truck trip rates by land use and truck type for additional urban areas from which data may be available. This work would permit the development of an adequate data base for land-area truck trip rates and would perhaps enable some generalities to be stated for land-area truck trip rates over urban areas of comparable size, economic structure, and so forth. Results comparable to those already available for passenger trip generation by land use may be realized (12, 13).

CONCLUSIONS AND RECOMMENDATIONS

Major conclusions and recommendations of this research are listed below:

1. In the short-range tactical planning area, the use of land-area trip-rate analysis, which uses simple truck trip rates per acre or per square mile of a generalized land-use category, is appropriate in evaluating the truck-traffic impact of land-use decisions when specific establishment functions are not yet known.

It is recommended that land-area truck trip analysis techniques be used when time and resources necessary for large-scale costly procedures are not available. Also, the use of land-area trip-rate techniques in the solution of localized, as opposed to areawide, planning problems should be considered when establishment-level truck trip data are not available or appropriate. The evaluation of the truck-traffic impact of a proposed industrial park where the nature of the specific establishments occupying the site may be somewhat uncertain is an example.

2. Because of the great variation in land-area truck trip rates among the different urban areas studied, the use of "borrowed" rates, at least for the present time, seems rather risky.

Until data on land-area truck trip rates from additional urban areas allow the development of rates with widespread applicability, land-area truck trip rates developed for one's own particular area should be relied on. This development is easily accomplished if origin-destination data for the area transportation study has coded destination land use on its truck trip records.

3. An additional drawback to the use of average land-area truck trip rates is their variability within the generalized land-use categories. Commercial land uses, for example, include both wholesale and retail categories that may vary tremendously in their truck trip-generating ability due to specific function, location, size, and a range of other factors.

A finer level of analysis may be necessary, using individual business establishments, when the land-use trip-rate technique appears too gross for particular localized planning issues relating to urban truck traffic.

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