Parking and Traffic Characteristics of Suburban Industrial Developments

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This paper explores the relationships of parking, loading, and traffic generation with land, building areas, and employment. The data were gathered from a sample of 22 suburban industries ranging in size of developed land area from 20,400 to 860,000 square feet, with employment varying between 20 and 1000. The normal constraints of expansion problems found in fully developed areas were not present since most industries sampled had expansion room.

Parking characteristics were related to employment, land area, and building area. Traffic generation for automobiles and trucks was related to employment, land area, building area, parking demand, and loading facilities.

•HISTORICALLY, parking and loading requirements have evolved from past experience in reviewing existing industrial developments. Local zoning ordinances stipulating minimum parking and loading requirements have been drawn from either model ordinances or from firsthand experience and knowledge. The Institute of Traffic Engineers offers a guide for estimating parking requirements by means of an employment questionnaire, or by a rule-of-thumb measure of one car for every two employees per shift (1). Usually these practices have created efficient industrial developments. However, examples can be found where inadequate parking and loading facilities can create a multitude of traffic and parking problems.

A noticeable lack of actual field data on existing industrial parking and loading facilities and traffic generation is evident when examining the literature. Very few studies have been made which confirm typical zoning requirements (unlike the wealth of data for shopping centers, for example). Information of this nature should be useful to the land developer, architect, and planner.

DESCRIPTION OF STUDY AREA

Niles, Illinois, has a number of large areas zoned and developed as industrial. It is a suburb of nearly 30,000 population, adjacent to the City of Chicago, and borders several other close-in suburban communities.

Public mass transportation is nearly nonexistent. There are a few suburban bus lines with irregular and infrequent service. The Chicago Transit Authority operates a bus line along the Chicago-Niles border with regular service. This line is nearly a half mile from the study area, however, and its influence is quite small.

The industry study area encompassed over 0.4 square mile and included 22 companies. The industries sampled are typical of suburban developments. Figure 1 shows the general plan of the study area, giving the size of developed land area and general description of operation. The general location and description of each driveway is also shown in the figure.

Nine of the 22 companies are developed to the full extent of their land area. The remaining 13 plants range from 25 to 90 percent developed, with the average being 67

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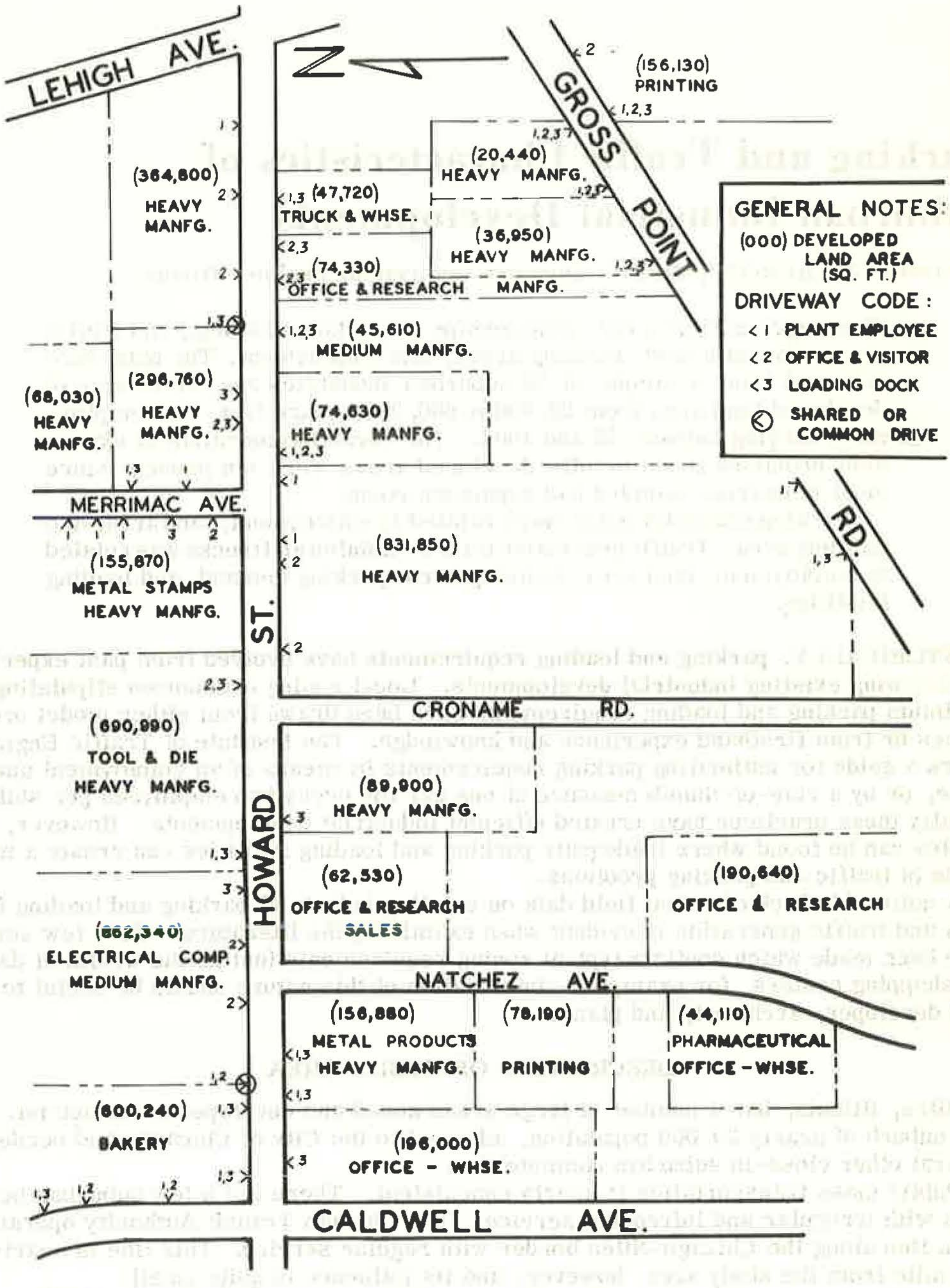

Figure 1. Study area—Niles, Illinois.

percent. This indicates the industries are generally expanding with sufficient land area and therefore do not have significant artificial restraints to restrict parking or loading supply.

STUDIES PERFORMED

The studies performed included traffic counts, parking lot accummulation and occupancy checks, and parking and loading facility inventories.

Traffic counts were conducted during the latter part of March, when it was assumed employment would be at a normal level and absenteeism due to vacations would be minimal. The counts were made at each driveway for 2 hours during each of the morning and evening peak periods, i. e., 7:00 to 9:00 a. m. and 4:00 to 6:00 p.m. If the individual driveway peak movements did not coincide with the normal count period, the driveway count was extended to cover that industry's peak movement. In all cases, where a parking lot or loading dock had more than one access point, each driveway serving the facility was counted simultaneously so that complete coverage could be maintained.

A few driveways served as common access to two separate parking lots. No attempt was made to specifically isolate the two groups. However, with extended counts (or in one case where a special study was conducted when one of the two plants was closed for vacation) estimates were made as to the contribution of each plant to the total driveway volume.

Parking lot occupancy checks were made before and after each counting period, and the highest value was used. As far as possible, the peak occupancy was found by this procedure. The method was particularly important for the two shift plants.

Complete data were not obtained for each industry. No driveway counts were taken at four of the plants, and only the loading facilities were observed at three others, due to limitations of the traffic count study. Employment data were not obtained from five companies. However, it was felt that in spite of these limitations, there were sufficient data to complete the analysis.

The purpose of this paper was to explore the relationships of parking, loading, and traffic generation with land and building areas and employment. The traffic volume and parking data have been analyzed for consistency, and where correlation is found, it may be used as a guide for planning future industrial developments fitting the same general criteria of a suburban development.

PARKING CHARACTERISTICS

In order to establish a common base for comparative analysis, only developed land areas were used. Undeveloped land was considered vacant land not being used for legal setbacks, buildings, parking lots, driveways, loading areas, or permanent landscaping.

The 22 samples were grouped into three ranges of developed land sizes to compare the portion that was occupied by buildings:

Total Developed Land Area (sq ft)	Percent Developed Land Occupied by Building
20, 000-100, 000	Mean 45
100, 000-500, 000	Mean 48
Over 500, 000	Mean 40
	Total Mean 45

An average of 55 percent of the developed land is devoted to driveways, parking and loading facilities, and landscaping. However, for individual industries, the range was 16 to 67 percent. A detailed analysis is given in Table 1, where building area is related to developed land area by similar types of industries.

The extreme cases are quite consistent with their use. For example, a truck storage and terminal has nearly 85 percent of its area devoted to trailer storage, driveways, etc. The two printing operations used an average of 61 percent of their area for building purposes, probably due to the large machinery involved.

TABLE 1

RELATIONSHIP OF BUILDING AREA TO DEVELOPED LAND

Industry Classification	Total Developed Land Area (sq ft)	Building Area (sq ft)	Percent Developed Land Occupied by Building
Bakery	600, 240	259, 890	43
Office and research	62,530	30,220	48
	74,330	35,160	47
	190,640	60,000	31
			Average 42
Office and warehouse	44,110	22,270	51
Truck storage and terminal	47,720	7,730	16
Printing	78,190	43,250	55
	156,130	104,940	67
			Average 61
Medium manufacturing and fabrication (electrical components, etc.)	45,610	18,540	41
	862,340	296,350	34
			Average 37.5
Heavy manufacturing and fabricating (machine, tool and die, metal stamp, etc.)	20,440	8,425	41
	36,945	20,240	55
	68,030	30,300	44
	74,630	34,650	46
	89,900	50,230	56
	155,870	59,860	38
	296,760	187,260	63
	364,815	161,850	44
	831,850	306,980	37
	690,990	321,590	47
			Average 47
			Mean 45

Building Area Relationships

The relationship of building area to parking demand and supply is given in the following, where the building areas are also grouped into three ranges, and the average values for the ratio of building area to parking and the inverse ration of parking per unit area of building are given:

Building Area (sq ft)	Sq ft of Building Area Per Parking		Parking Spaces Per 10, 000 sq ft of Building Area	
	Demand	Supply	Demand	Supply
0-30, 000	750	510	18. 0	22. 8
30, 000-100, 000	900	625	13. 0	18. 5
Over 100, 000	1020	760	11. 5	14. 6
Total Mean	910	640	14. 2	18. 6

It is significant that the mean value for building area per space increases with increasing building size and the inverse value correspondingly decreases. However, large variations within each group make the average values misleading. As expected, there was less variation with the parking supply values, due to the constraint caused by zoning codes. Because of this, only parking demand (spaces occupied) will be examined in detail and used for analysis. The values on supply are listed however, where appropriate.

TABLE 2

RELATIONSHIP OF BUILDING AREA TO PARKING DEMAND

Industry Classification	Building Area (sq ft)	Number of Occupied Spaces		Sq ft of Building Per Space	Occupied Spaces Per 10,000 sq ft of Building Area
Bakery	259,890	175		1480	6.7
Office and research	30,000[a]	34		890	11.2
	35,160	75		470	21.4
	60,000	122		490	20.4
			Average	620	17.7
Office and warehouse	22,270	14		1590	6.3
Truck storage and terminal	7,730	18		430	23.3
Printing	43,250	42		1030	9.7
	104,940	71		1480	6.8
			Average	1260	8.3
Medium manufacturing and fabrication (electrical components, etc.)	18,540	52		360	28.0
	296,350	670		440	23.6
			Average	400	25.8
Heavy manufacturing and fabrication (machine, tool and die, metal stamp, etc.)	8,425	18		470	21.4
	20,240	22		920	10.9
	34,650[b]	27		1280	7.8
	50,230	47		1070	9.4
	59,860	103		580	17.2
	76,020	55		1380	7.2
	153,830	141		1090	9.2
	195,550	182		1070	9.3
	306,980	370		830	12.0
	321,590	424		760	13.2
			Average	940	11.8
			Total Mean	910	14.2

[a]Training center for sales personnel.
[b]Company occupies approximately half of building; remainder either vacant or leased for storage.

Concerning the relationship of building area to parking demand, Table 2 shows the large spread. The average values appear in general to fit the industry classification, despite the wide range. The intensive uses, such as office and research, and electrical component manufacture (with limited machinery and extensive manual assembly), require more parking.

The largest sample size was represented by the heavy manufacturing group. Analysis showed that the values ranged from 7.2 to 21.4 occupied spaces per 10,000 sq ft of building area. The mean occupancy was 11.8 and the standard deviation, 4.24. At the 90 percent confidence level, the mean occupancy varied between 9.21 and 14.39. While it appeared to be a wide variation, the range of the probable mean value was still consistent with the heavy manufacturing data.

A study by Thompson and Stegmaier found a 2.3 parking space demand per 10,000 sq ft of building area (2). They studied a 1,913,000 sq ft Baltimore plant in 1948. Recently, Keefer tabulated floor area and parking supply data resulting from a manufacturing questionnaire (3). A sample of six industries had floor areas ranging from 1,090,000 sq ft to 2,174,000 sq ft, and had an average of 7.0 spaces provided per 10,000 sq ft of floor area with a range of 4.0 to 11.9. Another sample of 12 plants, with floor areas ranging from 185,000 to 964,000 sq ft, found an average of 19.5 spaces supplied for 10,000 sq ft of floor area. The values ranged from 6.4 to 55.8. The similarity of the decreasing parking demand per unit of floor area with increasing plant size should be noted.

A study by Latchford and Williams examined 4 plants and 6 industrial estates in Great Britain (4). Figure 2, the relationship between floor space and parking, was prepared to compare the data found in the Niles study and Keefer's sample with the British values. The British curve is lower, but is quite consistent with the United States studies. Both are based on parking demand. Note, however, that Keefer's values are for parking supply, rather than demand.

Developed Land Area Relationships

Developed land area is related to parking demand and supply as follows:

Developed Land Area (sq ft)	Ratio of Land Area to Parking (sq ft per space)		Parking Spaces Per 10,000 sq ft of Land Area	
	Demand	Supply	Demand	Supply
0-100, 000	1890	1390	6. 3	8. 4
100,000-500, 000	2040	1470	5. 2	7. 9
Over 500, 000	2140	1790	5. 3	6. 2
Total Mean	1980	1490	5. 7	7. 8

The relationship of developed land area with parking demand grouped within similar industrial uses is given in Table 3. The increase in parking demand per unit land area is similar to that of building area. The heavy manufacturing group sample indicates that the land area relationship provides better correlation than building area. The mean value of 5. 4 spaces per 10, 000 sq ft of land area has a standard deviation of 1. 48. Testing for confidence limits of 90 percent, the probable mean value lies between 4.5 and 6. 3.

Employment Relationships

Table 4 relates employment to parking demand. The value of 0. 54 car per employee is quite consistent with a standard deviation = 0.133. Assume all lots which were filled 80 percent of capacity could be at optimur balance between parking supply and demand for the individual industry. The mean for the condition is 0. 57 occupied spaces per employee with a standard deviation shows even better correlation.

The highest ratio found was one space for each 1. 27 employees (where nearly all drove). The lowest was nearly 3. 5 employees per space. The Niles zoning code requires 1 space for every 3 employees. The more frequently used rule of thumb of 1 space for each 2 employees generally applies for the study sample, but can be an underestimate.

Office, executive, and visitor parking was examined in Table 5 with the small amount of data available. The mean of 0. 69 office spaces occupied was higher than the overall mean of 0. 54 spaces occupied per employee. A higher standard deviation and broader range of values (from 0.20 to 1. 00 occupied spaces per employee) was also found in the limited office sample.

Also, two samples were available relating office building area to office parking demand. Seventeen occupied spaces per 10, 000 sq ft were found for a 5300-sq ft

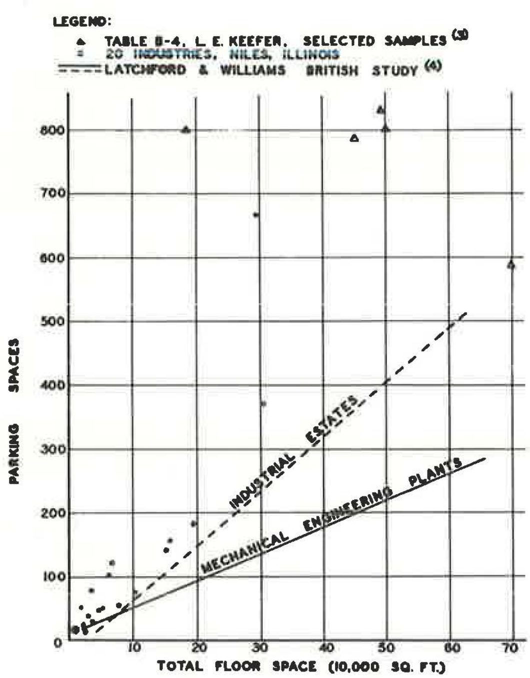

Figure 2. Parking related to building area.

TABLE 3
RELATIONSHIP OF DEVELOPED LAND AREA TO PARKING DEMAND

Industry Classification	Land Area (sq ft)	Number of Occupied Stalls	Sq ft of Land per Car	Occupied Parking Spaces per 10,000 sq ft of Land Area
Bakery	600,240	175	3430	2.9
Office and research	62,530	34	1840	5.4
	74,330	75	990	10.1
	190,640	122	1560	6.4
			Average 1460	7.3
Office and warehouse	44,110	14	3150	3.2
Truck storage and terminal	47,720	18	2650	3.8
Printing	78,190	42	1860	5.4
	156,130	55	2850	3.5
			Average 2350	4.5
Medium manufacturing and fabrication (electrical components, etc.)	45,610	52	880	11.4
	862,340	670	1290	7.8
			Average 1090	9.6
Heavy manufacturing and fabricating (machine, tool and die, metal stamp, etc.)	20,440	18	1140	8.8
	36,945	22	1680	6.0
	74,630	227	2760	3.6
	89,900	47	1910	5.2
	155,870	103	1510	6.6
	156,880	55	2850	3.5
	296,760	141	2100	4.8
	364,815	182	2000	5.0
	690,990	424	1630	6.1
	831,850	370	2240	4.4
			Average 1980	5.4
			Total Mean 1980	5.7

TABLE 4
RELATIONSHIP OF EMPLOYMENT TO OCCUPIED AND AVAILABLE PARKING SPACES

Total Number of Employees	Number of Spaces Occupied	Number of Occupied Spaces per Employee	Number of Available Spaces	Percent of Available Spaces Occupied
0-100				
20	14	0.70	25	56
33	18	0.55	23	78
50	27	0.54	57	47
70	42	0.60	50	84
75	22	0.29	35	63
75	47	0.63	46	102
85	34	0.40	70	49
92	52	0.57	65	80
		Average 0.54		
100-500				
120	76	0.63	68	112
130	103	0.79	134	77
193	122	0.63	175	70
240	71	0.30	132	54
240	141	0.59	187	75
400	182	0.45	265	69
465	175	0.38	209	84
		Average 0.54		
Over 500				
824	370	0.45	493	75
850	424	0.50	466	91
1000	679	0.68	763	89
		Average 0.54		
		Total Mean 0.54		
		Standard deviation 0.133		

office area, and 34 occupied spaces per 10, 000 sq ft for an 83, 600-sq ft office area. These were typical figures for a dense employment use.

Table 6 is presented to further show the consistent parking-to-employment relationship according to industrial classification. Interestingly, one of the highest ratios, 0. 70, is for a combination office and pharmaceutical warehouse. The absolute values within each category are presented to show the variation.

TRAFFIC CHARACTERISTICS

Automobile Generation

Nearly all of the traffic counts were conducted during the normal 2-hour morning and evening peak periods. However, four of the plants work on a staggered shift which did not coincide with the normal peak period. Special counts were conducted at these plants so the absolute peak driveway movement could be determined.

Table 7 shows industrial automobile traffic related to the three basic factors of developed land area, gross building area, and employment. These were shown for three critical time segments during both morning and evening peak periods. The most consistent values were found with employment.

The best correlation appears to be generation related to employment. The evening peak hour (which was higher than the morning) had a mean generation of 0. 34 vehicles per employee, with a standard deviation of 0. 160. The average factor for morning and evening combined was 0. 33, with a standard deviation of 0. 156. Note that the combined 30-minute flow rate was equal to 0. 44 vehicles per employee, or ⅓ higher than the peak hour.

Developed land area and gross building area related to generation showed consistent mean values similar to the employment relationship. However, inspection of individual values and standard deviations shows a wider spread, particularly for building areas.

TABLE 5

RELATIONSHIP OF OFFICE EMPLOYMENT TO OFFICE AND VISITOR PARKING

Number of Office Employees	Number of Spaces Occupied	Number of Occupied Spaces per Employee	Number of Available Spaces	Percent of Available Spaces Occupied
20	20	1. 0	26	77
25	9	0. 36	18	50
35	31	0. 89	34	91
	Average	0. 75		
225	130	0. 58	209	62
450	287	0. 64	322	89
	Average	0. 61		
	Total Mean	0. 69		
	Standard Deviation =	0. 228		

TABLE 6

RELATIONSHIP OF EMPLOYMENT TO PARKING DEMAND

Industry Classification	Number of Employees	Number of Occupied Spaces per Employee
Bakery	465	0. 38
Office and research	75	0. 63
	85	0. 40
	193	0. 63
	Average	0. 55
Office and warehouse	20	0. 70
	70	0.60
Printing	240	0. 30
		0. 45
Medium manufacturing and fabrication (electrical components, etc.)	92	0. 57
	1000	0. 67
	Average	0. 62
Heavy manufacturing and fabricating (machine, tool and die, metal stamp, etc.)	33	0. 55
	50	0. 54
	75	0. 29
	120	0. 63
	130	0. 79
	240	0. 59
	400	0. 45
	824	0. 45
	850	0. 50
		0. 53
	Total Mean	0. 54

TABLE 7

INDUSTRIAL AUTO TRAFFIC GENERATION CHARACTERISTICS

Factor	Average Morning Volume Generated			Average Evening Volume Generated		
	Peak 30 Min.	Peak Hour	Peak 2 Hours	Peak 30 Min.	Peak Hour	Peak 2 Hours
Developed land area (sq ft)	(per 10,000 sq ft)			(per 10,000 sq ft)		
0-100,000	3. 0	4. 5	6. 0	3. 8	5. 3	6. 7
100,000-500,000	2. 5	3. 9	5. 2	1. 7	2. 8	4. 2
Over 500,000	1. 8	2. 9	3. 9	2. 4	3. 8	5. 1
Total Mean	2. 4	3. 8	5. 2	2. 6	4. 1	5. 5
Building area (sq ft)	(per 10,000 sq ft)			(per 10,000 sq ft)		
0-30,000	10. 5	15. 6	19. 4	10. 4	15. 6	20. 8
30,000-100,000	6. 2	8. 6	11. 5	6. 3	7. 5	9. 8
Over 100,000	4. 4	7. 5	9. 8	4. 9	8. 4	11. 4
Total Mean	6. 5	10. 0	12. 8	6. 7	10. 1	13. 5
Employment	(per employee)			(per employee)		
0-100	0. 17	0. 25	0. 35	0. 20	0. 31	0. 39
100-500	0. 24	0. 37	0. 48	0. 20	0. 31	0. 47
Over 500	0. 19	0. 32	0. 42	0. 25	0. 42	0. 55
Total Mean	0. 21	0. 32	0. 42	0. 22	0. 34	0. 46

TABLE 8

RELATIONSHIP OF MAXIMUM PARKING DEMAND TO PEAK HOUR FLOW

Industry Classification	Maximum Peak Parking Demand	Morning Peak Hour			Evening Peak Hour				Peak Hour Flow (vph) As Fraction of Maximum Parking Accumulation	
		Two-Way Volume	Percent In	Percent Out	Two-Way Volume	Percent In	Percent Out		Two-Way	One-Way
Bakery	175[a]	57	65	35	68	22	78		0.39	0.30
Office and research	75	45	90	10	65	6	94		0.87	0.81
Truck storage and warehouse	18	20	65	35	13	31	69		1.10	0.72
Printing	72	58	69	31	29	24	76		0.81	0.56
Medium manufacturing	52	34	94	6	47	7	93		0.90	0.84
and fabrication (electrical	670	511	92	8	530	6	94		0.79	0.74
components, etc.)								Average	0.85	0.79
Heavy manufacturing	18[a]	11	100	0	12	50	50		0.67	0.33
and fabricating	22	10	90	10	12	8	92		0.55	0.51
(machine,	27[a]	9	78	22	10	10	90		0.37	0.33
tool and die,	55	44	84	16	34	21	79		0.80	0.67
metal stamp,	103	79	92	8	25	8	92		0.77	0.71
etc.)	141	127	86	14	115	12	88		0.90	0.77
	182	142	82	18	167	34	66		0.92	0.61
	370[a]	229	81	19	417	25	75		1.13	0.84
	424[a]	147	83	13	195	11	89		0.46	0.41
								Average	0.73	0.58
From Williams and Latchford (4), Table 1:										
Mechanical Engineering										0.71
Electrical Engineering										0.60
Plastics										0.48
Textiles and Clothing										0.78

[a]Plant on double shift.

Comparison of data was made with the Keefer study (3). The data were extracted from his tables for plant sizes between 185,000 and 500,000 sq ft. These were among the smallest plant sizes in his sample and were selected to correspond with Niles building areas. Using Keefer's data, a figure of 0.27 vehicles per employee for traffic generation related to employment was found, which was quite similar to the Niles evening peak hour figure of 0.34.

Another comparison with the Keefer study was made of automobile generation related to plant size. The range of plant sizes between 185,000 and 500,000 sq ft was again used and compared with the seven Niles samples for building areas over 100,000 sq ft. Wide variation was found within Keefer's peak hour data, with a range from 2.3 to 21.4 cars per 10,000 sq ft of building area. The mean value was 10.4, however, which compared closely with the 8.4 vehicles per 10,000 sq ft of building area for Niles.

Niles data were also compared with Keefer's daily traffic generation figures. From his data, an average of over 35 percent of daily traffic occurred during the peak hour. Studies of this particular industrial area in Niles have shown that about 27 percent of the traffic generated during a normal 12-hour period, 6 a.m. to p.m., occurs during the peak period. (No 12-hour counts were available at any of the individual plants, so no direct relation can be made.)

Also of interest, the same studies indicated that over 50 percent of the 12-hour traffic is generated in both of the 2-hour morning and evening peak periods. By adding the Niles morning and evening 2-hour peaks (Table 7), the employment generation was 0.88 trips per employee. In fact, for plants employing over 500 people, 0.97 trips per employee were found during the 4 peak hours. These figures far exceed the 50 percent value. However, no direct comparison can be made since some industries have well over a 1.0 ratio, if there are considerable sales or visitor trips, for example.

TABLE 9

PEAK HOUR TRUCK TRIP RELATIONSHIPS

Factor	Average Morning Volume Generated	Average Evening Volume Generated
Developed land area (sq ft)	(per 10,000 sq ft)	(per 10,000 sq ft)
0-100,000	0.37	0.55
100,000-500,000	0.20	0.26
Over 500,000	0.24	0.20
Total Mean	0.28	0.35
Building area (sq ft)	(per 10,000 sq ft)	(per 10,000 sq ft)
0-30,000	1.07	1.69
30,000-100,000	0.58	0.53
Over 100,000	0.48	0.55
Total Mean	0.63	0.76
Loading berths	(per dock)	(per dock)
1-4	0.74	1.01
5-10	1.15	1.55
Over 10	1.35	0.95
Total Mean	0.96	1.19

TABLE 10

RELATIONSHIP BETWEEN TRUCK GENERATION AND DEVELOPED LAND AREA, BUILDING SIZE, AND NUMBER OF LOADING DOCKS

Industry Classification	Morning Peak Hour Generation			Evening Peak Hour Generation		
	Per 10,000 sq ft Land Area	Per 10,000 sq ft Building	Per Dock	Per 10,000 sq ft Land Area	Per 10,000 sq ft Building	Per Dock
Bakery	0.6	1.4	1.5	0.3	0.7	0.7
Office and research	0.5	1.1	1.0	0.4	0.9	0.75
	0.3	0.7	1.0	0.2	0.4	0.5
Truck storage and terminal	2.9[a]	18.1[a]	1.2	3.1[a]	19.4[a]	1.2
Printing	0.1	0.2	0.3	0.8	1.2	2.2
Medium manufacturing and fabrication (electrical components, etc.)	1.1	2.7	2.5	1.1	2.7	2.5
	0.1	0.3	2.0	0.05	0.1	1.0
Heavy manufacturing and fabricating (machine, tool and die, metal stamp etc.)	0	0	0	1.0[a]	1.4[a]	1.0
	0.3	0.5	0.5	0	0	0
	0.4	0.9	1.0	0.1	0.3	0.3
	0.2	0.5	1.5	0.2	0.5	1.5
	0.1	0.3	0.7	0	0	0
	0.1	0.1	0.3	0.1	0.2	0.7
	0.4	0.9	1.6	0.3	0.6	1.1
	0.2	0.5	2.1	0.4	0.9	4.0
	0.4	0.1	0.75	0.05	0.1	1.0
Mean	0.28	0.63	0.96	0.35	0.76	1.19

[a]Not included in mean, due to biased sample.

Table 8 relates peak hour flow to maximum parking demand classified by similar industries. The double-shift industries can be quickly determined by their extreme high or low values. The high value designates a complete turnover of office and plant for the shift change, while low values represent only a portion of the plant, such as the factory, changing shifts while the office cars remain in place.

The one-way flow column for the peak hour was developed to compare Niles generation with values found in Great Britain (4). The values are quite similar.

TABLE 11

RELATIONSHIP OF LAND AREA AND BUILDING SIZE TO LOADING FACILITIES

Industry Classification	Total Developed Land Area (sq ft)	Building Area (sq ft)	Number of Truck Docks		Number of Berths Per 10,000 sq ft Land Area	Number of Berths Per 10,000 sq ft Building Area
Bakery	600,240	259,890	24		0.40	0.92
Office and research with warehouse	62,530	30,220	3		0.48	0.99
	74,330	35,160	4		0.54	1.14
	190,640[a]	60,000	1		0.05	0.17
				Average	0.36	0.77
Truck storage and terminal	47,720	7,730	12		2.52	15.52
Printing	78,190	43,250	2		0.26	0.46
	156,130	104,940	6		0.38	0.57
				Average	0.32	0.52
Medium manufacturing and fabrication (electrical components, etc.)	45,610	18,540	2		0.44	1.08
	862,340	296,350	5		0.06	0.17
				Average	0.25	0.62
Heavy manufacturing and fabricating (machine, tool and die, metal stamp, etc.)	20,440	8,425	2		0.98	2.38
	36,945	20,240	2		0.54	0.99
	74,630	34,650	3		0.40	0.87
	89,900	50,230	3		0.33	0.60
	155,870	59,860	2		0.13	0.33
	156,880	76,020	5		0.32	0.66
	296,760	187,260	6		0.20	0.32
	364,813	161,850	9		0.25	0.56
	690,990	321,590	7		0.10	0.22
	831,850	306,980	8		0.09	0.26
				Average	0.33	0.62

[a]Office and research only.

Truck Generation

Truck generation values are considerably more variable than the automobile data. Little correlation was found. This can be seen in Tables 9 and 10.

Within similar uses, and specifically heavy manufacturing, a peak hour truck movement of about 0.3 vehicles per 10, 000 sq ft of land appears consistent, however. Also, with relation to 10, 000 sq ft of building area, a mean of 0. 7 truck movements appears reasonable.

Reference is again made to the Keefer study, where a sample of four plants was used within a range of 185, 000 to 500, 000 sq ft. Considerable variation was found, ranging from 0. 10 to 1.03 truck movements per 10, 000 sq ft of floor area. The mean value of 0. 41 movements is reasonably close to the Niles mean of 0. 55 movements per 10,000 sq ft of building for this size group. Both means were calculated from peak hour data.

LOADING FACILITIES

The number of loading docks related to land area is shown in Table 11. Like the parking supply, the rate of berths generally diminishes with increasing land area. While the local zoning code serves as an artificial constraint, the rate of berths per 10, 000 sq ft varies considerably within similar industry types and building sizes. It would appear that loading dock requirements are highly dependent on the individual industrial operation regardless of similarity of type of operation. Unfortunately, the sample is much too small and lacks sufficient detail to establish any correlation.

SUMMARY AND CONCLUSIONS

As stated earlier, considerable information is available pertaining to zoning requirements. Little work has been performed to field test the actual needs.

The Keefer study concerned trip generation and trip prediction methods. The British study by Latchford and Williams examined traffic generation and parking demand, similar to the Niles study. However, conditions relating to motoring habits are different for each country, and direct comparison is difficult.

Parking

In all cases, building area relationships with parking characteristics in the Niles study were widely variable and produced only general trends. In general, parking requirements decreased with the size of building. This relationship appeared to be very sensitive to the type of industrial operation, because of the highly variable employment densities involved.

The statistical analysis for the heavy manufacturing group in Table 2 showed that the range of the expected mean at the 90 percent confidence level was somewhat consistent with the values found for the heavy manufacturing group. However, the spread of the expected mean was found to be 5. 18. Therefore, because of the variance found in the actual tabular values and the sample statistical analysis, the average values listed in Table 2 should be used only as general indicators.

Developed land area relationships with parking supply were more consistent. Using developed land area such as landscaping, driveways, and parking areas tended to reduce the influence of the unpredictable employment variable. If the type of industry is known, the influence of factors such as employment and machinery density tends to further decrease, reducing the variables and providing for better correlation. Therefore, the figures in Table 3 indicate a general range that could be expected for the specific type of industrial operation listed. The sample statistical analysis made for the heavy manufacturing group gave an expected range of ± 0. 9 for a mean value of 5. 4 spaces per 10, 000 sq ft at the 90 percent confidence level.

Employment had the best correlation of the three factors. It clearly showed that one space for each two employees was generally valid for suburban industrial developments. It should be considered minimum in such cases. Twelve industries had a parking demand in excess of 0. 5 spaces per employee, ranging up to 0. 79 spaces per employee. A condition was assumed where only a hypothetical optimum balance between parking supply and demand occurred. By analyzing only those parking lots, a mean of 0.57 occupied spaces per employee was calculated with a standard deviation of only 0.084.

Traffic

Traffic analysis produced slightly more favorable correlation than did parking relationships. There was some correlation between the Niles data and other studies.

Of the three factors studied, employment was again the most consistent. A mean value of about 0.33 cars per employee was generated during the peak hour. When averaged with the generation value of 0.27 extracted from the Keefer data, a peak hour generation factor of 0.3 cars per employee appears valid.

Because truck volumes were so low, and observations were made for such a relatively short period of the day, the truck generation factors are very questionable. However, the small sample was expected since normal truck deliverers avoid the peak traffic periods.

Considering the factors influencing truck generation, a relationship with the number of loading docks appears most significant. Truck traffic generation is affected considerably by the type of industrial operation with respect to building areas. Classification of industrial activity affects land area to a lesser degree, when considering the land area relationship to truck generation. Therefore, building area and land area relationships should only be considered within the same type of industrial classification. In general, one truck movement per dock seems to be a reasonable generation factor.

Considerably more field studies are needed over the country to develop additional data. This analysis has been made from a limited sample, and the results can only be generalizations. The small sample size also restricts the significance of the statistical analysis. However, there are indications that parking demand and traffic generation can be approximated by factors other than employment.

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