Commercial Vehicle Trip Generation in Chicago Region

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The results of an analysis of the relation between commercial vehicles and trip generation are presented. The analysis is aggregative and intended to be compatible with conventional urban transportation planning models. Relations between the volume of truck traffic generated (or attracted) to subareas of the Chicago region are estimated based on the land use characteristics of the area. Separate regression models for light-, medium-, and heavy-sized trucks and for six basic land use types are presented. The variation in truck trip generation across these categories is examined and the implications for urban goods movement modeling at the regional level are discussed.

The problem of urban goods movements has only lately begun to receive the attention that it deserves from transportation planners. Several conferences (1,2) have dealt with the problem, and a number of regional transportation studies have attempted data collection and/or modeling of goods or commercial vehicle movements. Significant improvement in the performance of the urban transportation planning process can be expected once goods traffic is successfully modeled. It has also been argued (3-5) that goods movements can be modeled in parallel fashion to the current treatment of person movements. This paper examines the problem of goods trip generation as a step toward such a comprehensive scheme for goods movements.

TRIP GENERATION MODELS FOR URBAN GOODS MOVEMENTS

A fundamental requirement of the transportation planning process is the estimation of the traffic generated by particular land uses. Since our interest is in goods movement generation by particular land uses, three points deserve mention. First, we must distinguish between the generation of shipments (or consignments) and the generation of commercial vehicle trips. Though the factors that influence both are likely to overlap, the magnitude of their effects and the form of the relation may differ. Second, we must consider the level of areal aggregation of the activities whose generation characteristics we wish to describe. Clearly, as we lower the level of aggregation and therefore obtain zones of an increasingly homogeneous nature, it becomes easier to isolate the important factors and possible to examine the effect of activity type on goods generation. To obtain this additional accuracy, however, we must sacrifice some degree of data availability and predictability. Finally, we should note that mode choice is one of the principal issues that complicates generation analysis. The technique of expressing generation properties as a function of land use parameters alone should be reserved for situations in which alternative modes do not exist or where the choice appears in simplified form. The truck being the only mode available for most urban freight movement (especially in the short run), we are able to concentrate attention on land use parameters for estimating goods-generation characteristics.

DATA

The analysis is aggregative in that it deals with zonal subareas of the region rather than with individual establishments. The eight-county northeastern Illinois and northwestern Indiana region, an area of approximately 5000 miles^2 and more than 8 million population, is subdivided into 64 districts. These districts are arranged in a ring-sector pattern around the Chicago central business district (CBD) and get progressively larger in area and less dense in development as distance from the CBD increases.

Truck travel data are provided by the Chicago Area Transportation Study (CATS) commercial vehicle survey (6). This survey consists of a 1 percent overall sample of all registered commercial vehicles in the Chicago region. Land use and employment data were provided by the Northeastern Illinois Planning Commission and the Northwestern Indiana Regional Planning Commission.

Truck trips to each district are stratified by vehicle size and land use at the destination. Truck types used in the analysis are (a) light for pickup and panel trucks (under 10 000 lb gross vehicle weight), (b) medium for other single-unit vehicles, and (c) heavy for tractor-trailer units (more than 36 000 lb). The following generalized land use categories are used: residential, manufacturing, commercial, public building, public open space, transportation-communications-utilities (TCU), and other developed land. Land area and employment are taken as measures of activity.

Regression analysis is chosen as the appropriate technique to develop the truck-trip-generation models. Districts are chosen as the geographic analysis unit at this stage primarily for the ease with which these data can be obtained and the manageable number of zones that result. The desired accuracy of the specific study should determine the degree of geographic detail. In the next section we examine the relation between truck trip and land use in general terms.

TRUCK TRIP CHARACTERISTICS

As seen in Table 1, there were more than 219 000 commercially registered vehicles in the Chicago region in 1970. The majority of these were classified as light trucks. Commercial vehicles made more than 1.2 million trips on the average day. The highest trip rates per vehicle were generated by the medium-class trucks, which are the vehicles typically used in the majority of urban pickup-and-delivery movements. These trucks also had the shortest average trip length, which indicates many zone-type trips. These trips represent travel within designated pickup or delivery zones with one or more return stem trips to the terminal. In contrast, the larger heavy-class vehicles average trip was nearly three times longer, which implies a somewhat different operation pattern for these trucks. Three-fourths of the registered vehicles are used for at least one round trip on the typical day.

Some basic characteristics of the relation between truck trip generation and land use are discernible in Table 2, which presents truck-trip-generation rates per hundred acres by land use category. An understanding of the functional relations that underlie this truck traffic is obtained by examining the wide variation in generation rates for different types of activities.

Of the nearly one million acres of developed land in the region, more than a third is devoted to residential land uses. However, residential land is a very low generator of commercial vehicle trips. As expected, public open space also generates relatively few truck trips. Public buildings generate commercial vehicle trips at a rate of 40 daily trips/100 acres, which is the approximate average for all types of land.

Table 1. Commercial vehicle survey summary.

Commercial Vehicle Type	No.	Percent	Daily Trips	Avg Use Rate (%)	Avg Daily Trips	Avg Trip Length (miles)
Light	118 653	54.0	479 210	76.0	4.0	5.5
Medium	80 887	36.8	622 507	70.4	7.7	3.9
Heavy	20 152	9.2	129 296	77.6	6.4	11.1
Total	219 692		1 231 473	74.1	5.6	5.3

Table 2. Commercial vehicle trips by land use.

Land Use Type	Commercial Vehicle Trips (%)	Commercial Vehicle Trips per 100 Acres
Residential	34.8	12
Manufacturing	12.2	361
Commercial	37.6	1425
Public building	2.6	40
Public open space	0.4	3
Transportation-communications-utilities	9.0	116
Other	2.2	15
All developed	98.8	130
Undeveloped	1.2	0.7

The heaviest generators are commercial, manufacturing, and TCU activities. These are the types of land uses that require large supplies of goods and ample freight transportation. Altogether, commercial and manufacturing activities attract nearly 50 percent of total commercial vehicle trips. These activities exhibit the highest truck-trip-generation rates with 1425 trips/100 commercial acres and 361 truck trips/100 manufacturing acres. Furthermore, the truck trips to manufacturing destinations are much more likely to be made by heavy vehicles. Overall, the breakdown of truck trips by weight category is 38.9 percent light, 50.6 percent medium, and 10.5 percent heavy. Commercial lands exhibit approximately the same distribution of trips by truck type as the overall category. The distribution of truck types for trips to manufacturing, however, is significantly higher, with 27.8 percent going to heavy vehicles and with light and medium trucks accounting for 25.6 and 46.5 percent, respectively. TCU land also generates a substantial amount of truck traffic and these are again weighted in favor of heavy vehicles. TCU land includes terminal and warehousing activities associated with the urban pickup and delivery aspects of freight distribution.

MODEL CALIBRATION AND RESULTS

We now consider several regression equations that quantify the relation between truck trip generation and land use and are presented in Table 3. The following notations are used for the equations in Table 3:

TTTOT = total truck trips to all land uses,
TOTEMP = total employment,
DEVLU = developed land use,
TTRES = total truck trips to residential areas,
DU = dwelling units,
RESLU = residential land use,
TTMAN = total truck trips to manufacturing areas,
MANLU = manufacturing land use,
MANEMP = manufacturing employment,
TTCOMM = total truck trips to commercial areas,
COMLU = commercial land use,
COMEMP = commercial employment,
TTPB = total truck trips to public buildings,
PBLU = public building land use,
TTTCU = total truck trips to TCU areas,
TCUEMP = TCU employment,
LTTOT = light-truck trips to all land uses,
LTRES = light-truck trips to residential areas,
LTMAN = light-truck trips to manufacturing areas,
LTCOMM = light-truck trips to commercial areas,
LTPB = light-truck trips to public buildings,
LTPOS = light-truck trips to public open spaces,
LTTCU = light-truck trips to TCU areas,
MTTOT = medium-truck trips to all land areas,
MTMAN = medium-truck trips to manufacturing areas,
MTCOMM = medium-truck trips to commercial areas,
MTTCU = medium-truck trips to TCU areas,
HTTOT = heavy-truck trips to all land areas,
HTMAN = heavy-truck trips to manufacturing areas,
HTCOMM = heavy-truck trips to commercial areas, and
HTTCU = heavy-truck trips to TCU areas.

Note that this analysis deals with truck trip destinations within each district. Of course, these destinations are simply the reverse end of the trip origins and this definition balance allows us to concentrate on the analysis of either trip end without substantially affecting the results. Separate regression equations were formulated for each truck type (stratified by weight class) and for total truck trips to the districts. Further, commercial vehicle trips within each truck-type class were subdivided by the type of land use at the destination. In some cases this classification scheme resulted in categories with no (or very few) trips, as in the heavy-truck trips to residential land uses category. Where this happened, it was not possible to run meaningful regression models; thus none were attempted.

In each case but one the estimated regressions were significant at the 0.1 level. In addition, the coefficient of variation is less than 1.00 in all but one case, although some equations display significantly lower variation about the estimated line than others. Of course, the lower the coefficient of variation, the more confident one can be about using the equation for forecasting. Undoubtedly, the fact that these equations are based on district level aggregations, which therefore include wide variations in both the dependent and independent variables, causes the standard error of estimate (and the coefficient of variation) to be higher than it would be with smaller, more homogeneous zones. This suggests that some improvement could be obtained by further analysis at the traffic-zone level.

The most significant total truck models were obtained for trips to all land uses and to manufacturing, commercial, and residential land uses. Total truck trips to all land uses, TTTOT, is best explained when related to total district employment (Equation 1). This model exhibits an R^2 of 0.50, which is significantly higher than the 0.40 displayed in Equation 2. A regression model that relates TTTOT to total district land was estimated but the results were very poor, primarily due to the

Table 3. Truck trip generation equations.

Equation No.	Equation	n	R^2	F	Coefficient of Variation (%)
Total Truck Models					
1	TTTOT = 4573.0 + 33.8 TOTEMP	62	0.50	59.2	51.0
2	TTTOT = 9726.8 + 84.4 DEVLU	63	0.40	40.8	52.0
3	TTRES = 416.7 + 16.0 DU	64	0.37	36.6	-
4	TTRES = 2288.1 + 77.4 RESLU	64	0.37	36.1	-
5	TTRES = 1078.6 + 56.5 RESLU + 11.7 DU	64	0.54	36.0	-
6	TTMAN = 881.8 + 302.8 MANLU	61	0.45	47.4	69.0
7	TTMAN = 730.6 + 9.7 MANEMP	64	0.58	85.4	-
8	TTCOMM = 4885.1 + 168.5 COMLU	61	0.22	16.7	59.0
9	TTCOMM = 2252.7 + 23.7 COMEMP	62	0.50	59.0	45.0
10	TTPB = 112.6 + 73.6 PBLU	64	0.43	47.4	-
11	TTTCU = 1384.1 + 10.3 TCUEMP	64	0.21	16.2	91.0
12	TTTCU = 995.5 + 387.05 ln(TCUEMP)	64	0.30	27.1	85.0
Light-Truck Models					
13	LTTOT = 2427.9 + 11.92 TOTEMP	62	0.32	27.3	67.5
14	LTTOT = 2918.5 + 41.03 DEVLU	63	0.50	60.5	57.5
15	LTRES = 762.7 + 5.43 DU	63	0.21	16.4	94.4
16	LTRES = 631.3 + 40.26 RESLU	63	0.50	60.2	75.5
17	LTRES = -188.8 + 35.38 RESLU + 2.86 DU	63	0.55	36.3	71.9
18	LTMAN = 163.4 + 96.16 MANLU	50	0.48	38.8	73.3
19	LTMAN = 253.8 + 2.10 MANEMP	64	0.25	21.2	98.3
20	LTCOMM = 1112.2 + 9.76 COMEMP	61	0.31	27.0	61.6
21	LTPB = 196.5 + 20.92 PBLU	42	0.17	8.0	61.6
22	LTPOS = 95.5 + 4.39 POSLU	14	0.50	11.9	67.1
23	LTTCU = 279.3 + 7.77 TCUEMP	48	0.65	84.8	61.7
Medium-Truck Models					
24	MTTOT = 2117.6 + 17.65 TOTEMP	62	0.41	41.3	63.4
25	MTTOT = 6232.6 + 29.76 DEVLU	64	0.18	13.5	74.3
26	MTMAN = 933.5 + 31.01 MANLU	61	0.07	4.3	96.3
27	MTMAN = 257.6 + 5.11 MANEMP	61	0.55	69.9	67.5
28	MTCOMM = 2492.1 + 3.60 COMEMP	64	0.34	32.6	61.9
29	MTTCU = 540.6 + 11.51 TCULU	62	0.16	11.7	94.1
Heavy-Truck Models					
30	HTTOT = 835.2 + 3.1 TOTEMP	62	0.20	14.6	84.0
31	HTMAN = 255.8 + 28.2 MANLU	60	0.47	51.9	63.0
32	HTMAN = 271.6 + 2.3 MANEMP	61	0.54	70.6	52.0
33	HTCOMM = 515.7 + 18.9 COMLU	61	0.17	12.2	81.0
34	HTCOMM = 305.7 + 2.2 COMEMP	62	0.18	13.5	81.0
35	HTTCU = 390.4 + 10.5 TCUEMP	59	0.21	15.4	102.0

Note: All equations except 26 significant at the 99 percent level by the F-test.

inclusion of substantial quantities of undeveloped land in the total land area measure.

Stratification of the trips by type of land use improved the results in the residential, manufacturing, and commercial categories over those obtained for the unstratified sample. Previous research has indicated that a homogeneous land use classification scheme was necessary for reliable truck-trip-generation models. It may be possible to improve the results by further disaggregation of these land use classes. Total truck trips to manufacturing activities, TTMAN, are best explained when related to manufacturing employment in the district (Equation 7). Employment at commercial sites also provides the most significant results for trips to commercial activities (Equation 9). In fact, it is only for the public building activities that land area performed better than employment in estimating these truck trip destinations. Interestingly, while TCU employment also provides the best estimates of total truck trips to TCU activities, the form of this relation is nonlinear (Equation 12). That is, there are apparently significant economies of scale in TCU truck trip generation at the aggregate level. This may be due to the fact that zones with large TCU employment include concentrations of commercial vehicle terminals and these transportation businesses are relatively more efficient in the use of their vehicles. For total truck trips to residential land, TTRES--a multiple linear regression that incorporates residential land area and number of dwelling units--provides the best results (Equation 5). Thus, for the more heavily freight-oriented activities, employment is seen to provide reasonable estimates of total truck trip ends while for the residential and public building uses land area measures were more significant.

Models were also specified and estimated for truck trips classified by type of vehicle, and these are also presented in Table 3 for light (Equations 13-23), medium (Equations 24-29), and heavy trucks (Equations 30-35). Examination of these results reveals several interesting points. Total employment continues to yield the best results for all truck-size categories in estimating truck trips to unstratified land use. However, the relation between heavy trucks and total employment (Equation 30) is considerably weaker than this equation is for other truck types. This supports the contention that subdivision of land use types would improve the results, particularly for the heavy-vehicle class. In fact, when heavy trucks to manufacturing activities are related separately to manufacturing employment (Equation 32), the results were much improved over the unstratified model. The relation between light trucks and manufacturing land area was most significant (Equation 18). This was not the case for medium trucks, where manufacturing land area yielded very poor estimates of medium-truck trips to manufacturing (Equation 26). Further research is needed to determine what factors may account for this finding.

There were very few medium- and heavy-truck trips to residential land areas; thus no regression equations could be estimated. Nearly 50 percent of the truck trips to residential land were made by light vehicles. Several equations for light trucks to residential activity were estimated (Equations 15-17). Again, the multiple regression with residential land area and dwelling units proved to be the best model and slightly improved the results obtained for total truck trips to residences.

The subdivision of truck trips by vehicle type did not improve the results in any case for trips to commercial land areas. Commercial employment provided the best-fitting models, although the relation for heavy vehicles was poor. This may indicate that further subdivision of the commercial category is needed in dealing with heavy trucks, since it is obvious that the retail, wholesale, and service activities now included in this aggregate category display substantial differences in the movement of goods that require heavy trucks. For the medium-truck class the best results were obtained when commercial employment was used as the explanatory variable (Equation 28). Finally, the sparse sample of medium and heavy trips to public buildings and public open space land prevented estimation of relations for these categories. Light-truck trips to these land uses, however, were significantly explained by public building and public open space land area, respectively (Equations 21 and 22).

SUMMARY AND CONCLUSIONS

The results obtained even at this rather aggregate level of analysis exhibit sufficient significance to warrant continued effort at a finer level of detail, both spatially and in land use categories. For most models, the statistical tests yielded positive results and support the adoption of this methodological framework for commercial vehicle trip generation analysis. The significant and regular variation in the truck trips per developed land acre and trips per employee ratios as distance from the CBD varies may indicate that adding an access measure to the models would improve their performance. The addition of zonal industrial composition may also improve the results. Such a measure would account for external economies that arise from similar activities being located next to each other and thereby affect their freight-transportation characteristics.

The overriding determinant of truck-trip-generation characteristics, however, remains the type of activity in the zone. We have observed substantial improvement over the unstratified results when trips were subdivided by type of activity. This was particularly evident in the total truck models but also appeared to a lesser degree in the models for individual truck types. In general, the weight-classification scheme for vehicle type did not seem to yield improved results. Except for the heavy-truck trips to manufacturing activities, better results were obtained with the total truck models. This preliminary finding, however, does not justify elimination of this truck-type factor from further consideration in the generation analysis. Because heavy and medium trucks tend to concentrate service to freight-oriented industries, future work will be devoted to analyze these heavy-freight generators. Finally, this analysis has proved encouraging and should be continued with effort devoted to resolving some of the problems that remain.

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Service and Supply Trips at Federal Institutions in Washington, D.C., Area

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Knowledge of the number and time distribution of goods and service trips is essential for the proper planning of dock and parking facilities at large employment sites. Federal office buildings in Washington, D.C., are typical of many large office complexes, particularly those of state governments. Federal warehouse operations have characteristics similar to those of large distribution centers. The results of a survey of goods and service vehicle trips to federal facilities in the Washington metropolitan area are presented and suggest specific guidelines for the planning and operation of similar facilities. Data were collected on vehicle trips that involved a service or supply function at 10 federal facilities in the Washington area. By using a combination of on-site observation and driver interviews, data on arrival and departure times, vehicle characteristics, trip purpose, origin of trip, and nature and size of load were obtained, analyzed, and used to develop planning guidelines.

Although the charge to analyze goods movements has been with urban transportation planning agencies since 1962, it was only in the 1970s that substantial attention was devoted to the issue. This period saw not only the undertaking of significant studies by several local planning groups but also