Twin Cities Metropolitan Area Heavy Truck Study

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Due to the growing significance of goods movement by heavy trucks in recent years, the Minnesota Twin Cities metropolitan area heavy truck study was conducted to update the Minnesota Department of Transportation data on heavy trucks. These data are needed for pavement design, heavy truck routing, and policy formulation. Similar data were obtained from a 1970 travel behavior inventory (TBI). The 1970 study surveyed 2 percent of all truck trips, but less than 1 percent of the trips were by heavy trucks. The results were of limited use in forecasting because of the small sample. This resulted in a poor distribution of trips when the sample was expanded. From the outset, the current study was constrained due to limited funding. Although the budget was enough for a survey of heavy commercial truck movements, innovative methods were needed to obtain data on the movement of heavy tax-exempt trucks and grain trucks. These data were produced through a combination of limited surveying and simulation. In addition to financial problems, two other constraints had to be overcome: (a) Minnesota's vehicle registration of tax-exempt trucks does not list vehicle weight; therefore, it was necessary to inventory heavy trucks; and (b) because of financial, personnel, and administrative problems, there was no external cordon-line survey conducted in conjunction with the heavy truck study; therefore, the data needed on external and through trips had to be developed by other means; i.e., they were simulated by applying growth factors to the 1970 data and then using 1980 truck counts at the external cordon lines as control totals. A comparison of the results of this study with the 1970 TBI reveals a substantial increase in external and through trips by heavy trucks and a substantial decrease in internal trips. The decrease in internal trips is probably due to the depressed economy, whereas the increase in external and through trips can be attributed to 1,560 miles of railroad track abandoned in Minnesota between 1971 and 1981. Final results of the study reveal that in 1981 there were 116,800 heavy truck trips per day in the metropolitan area, and in the year 2000 there are expected to be 265,300 trips/day.

In 1970 the former Minnesota Highway Department [today the Minnesota Department of Transportation (MnDOT)] conducted a travel behavior inventory (TBI) of the seven-county metropolitan area of the Twin Cities of Minneapolis and St. Paul. The purpose of this study was to collect and analyze travel data, such as vehicle occupancy rate, trips per person per day, transit ridership rate, that would be useful for future trip forecasting. As part of this study a 2 percent survey was conducted of all trucks in the metropolitan area. The results of the truck survey were of limited use in forecasting because of the small sample size and the unsatisfactory distribution of trips that resulted when the sample was expanded.

By 1980 the amount of rail abandonment and its impact on goods movement, and the rapid increase in Minnesota grain exports, made it mandatory to update the 1970 data, particularly as it applied to heavy trucks. This update was necessary because of the following reasons:

1. The 1970 survey had included all types of trucks and assumed that travel patterns for all trucks were similar. By 1980 travel patterns for heavy trucks had changed substantially, whereas travel patterns for pickups and vans had shown relatively little change.
2. Although the 1970 survey had a 2 percent sample, the sampling procedure and low trip rate of heavy trucks resulted in less than 1 percent of the heavy truck trips being sampled.
3. With the recent shifts in goods movement by heavy trucks there is need for more and better information for pavement design, heavy truck routings, and policy formulation.

(Note that for transportation planning purposes, the definition used for a heavy truck is a truck with at least dual rear wheels and a gross weight of more than 15,000 lb.)

In 1981 a new truck trip inventory was conducted as a joint effort of the MnDOT and the Metropolitan Council of the Twin Cities. This study focused exclusively on heavy truck forecasting needs.

The 1981 heavy truck study included three separate surveys: heavy commercial trucks, heavy tax-exempt trucks, and heavy grain trucks. The 1981 survey of commercial trucks differed from the 1970 survey in the following respects:

1. Only heavy trucks were included in the sample. In the 1970 survey all trucks were subject to sampling, including pickups, vans, recreational vehicles, and smaller units not essential to the analysis of freight movements and permissible routings.
2. The interview sample was about 7 percent of all heavy trucks in 1981 as opposed to less than 1 percent in 1970.
3. A decision was made to use a Fratar distribution model instead of the gravity model applied to truck trips in 1970. The reason for the change is the assumption that zonal accessibility is not a major factor in predicting heavy truck travel between zones. Instead, truck travel is related more to the established and forecast types of land use and the basic pattern of truck movements observed during the survey year.
4. The 1970 survey used an areawide expansion factor to expand the sample results. More precision was desired in the expansion of the interview samples to the population of trucks by subarea of the region. For the 1981 survey, the metropolitan area was stratified into 60 factoring areas. These factoring areas were created by analyzing heavy truck registrations and land use within postal zip code areas and then combining abutting and homogeneous zip codes where land use was similar; it was assumed that truck trip generation would be similar. Separate expansion factors were developed for each of the 60 factoring areas.
5. In 1970 the external growth factors were applied to cars and all types of trucks. In 1981 external travel was estimated by using different growth factors for heavy trucks than for cars. The external cordon of 31 stations was divided into 9 corridors. The growth factor developed for each corridor was applied to all external stations included within that corridor.
6. Control totals were imposed on 1980 heavy truck trips within the metropolitan area, although they were not imposed in 1970.

CONSTRAINTS

Although planners were committed to a heavy truck study, there were severe limitations on budget and available personnel. There was enough money available to have a consultant survey heavy commercial trucks, but other means were necessary to collect and use data on tax-exempt heavy truck movements and grain truck movements. Also, due to administrative, personnel, and budgetary limitations, it was impossible to conduct an external cordon-line survey. It was therefore necessary to develop innovative methods to inventory the external and through trips by heavy trucks.

SAMPLING PLAN FOR HEAVY COMMERCIAL TRUCKS

The sampling plan had the Department of Public Safety provide a listing of every tenth truck in its registration file. However, in order to ensure uniform sampling, the truck registrations were first divided into two weight classes and then stratified by county and zip code in the seven-county metropolitan area for each weight class; tax-exempt and farm trucks were excluded. These registration totals by zip code represented the total population of heavy trucks registered in the metropolitan area in 1981 to which the sample would be expanded; i.e., 14,830 vehicles in the 15,001- to 49,999-lb class, and 10,564 vehicles in the greater than 50,000-lb class, for a total of 25,394 vehicles.

It was decided that a sample of 5 to 7 percent would provide sufficient accuracy in compiling the necessary data. The survey was set up, however, so that a larger sample could be used if staff and funds were available. The 10 percent list of registrations in each weight class was selected in order to make up two 5 percent lists, i.e., a working list and a backup list created by putting every other registration on the backup list. Any unusable interview could be replaced by a registration with the same zip code from the backup list. In addition, where more sampling was deemed necessary, the truck could be selected from the backup list.

There are 161 zip codes in the metropolitan area. Some have many heavy truck registrations whereas others have few or none. Because the sampling was stratified within zip code areas, it was decided to expand the sample in a similar manner. The large number of zip code areas with a large variance in truck registrations was too unwieldy to work with and would not produce sufficiently accurate trip-predicting equations.

Therefore, abutting zip code areas of similar land use were combined, which resulted in 60 factoring areas. The division of heavy trucks into two weight classes had been done solely to obtain uniform sampling and not to obtain separate trip expansion factors for each weight class. The registrations of both weight classes were combined to produce total heavy truck registrations for each of the 60 factoring areas. Dividing the number of heavy truck registrations by the number of interviews produced trip expansion factors for each of the 60 factoring areas. The resultant trip expansion factors were used to factor heavy truck trips sampled to a factoring area total. The total of all expanded trips from all of the 60 factoring areas represented an average day of travel for heavy trucks registered in the metropolitan area.

Basis for Identifying Factoring Areas

Many zip code zones did not have enough trucks registered to provide an adequate basis for trip expansion. As a result, zip code zones were combined so that at least 60 vehicles weighing more than 50,000-lb gross weight or 100 vehicles between 15,000- and 50,000-lb gross weight were registered within each trip expansion factoring area.

Homogenous abutting zip code zones were grouped on the basis of the type of land use (and probable truck use) being similar. The basic premise was that the rate of truck trip generation for all zip code zones within a factoring area was similar.

Sample Selection Problems

After the initial truck samples had been selected (a 10 percent sample from each zip code zone), it was discovered that the Department of Public Safety registration lists were not current, as was initially thought. The lists had not been purged of expired registrations.

Because the registration lists are used primarily for law enforcement purposes, the Department does not purge the list of unregistered vehicles. The lists are necessary so that police may check on the owners of expired licenses to determine theft, illegal transfers, and trucks that were abandoned.

The unpurged registration lists wasted time and expense in the early stages of the survey. This problem was overcome by reproducing the same sample list with the registration expiration date inserted for each vehicle, which enabled interviewers to immediately see if a registration was valid.

In early 1981 the state and national economy was such that unemployment in the trucking industry, especially for the large carriers, was high. This probably increased the number of expired registrations compared to normal years (i.e., there was no need to register a truck not being used). In order to make a correction for the decline in truck registrations, the registration file was purged of expired registrations. This reduced the registration total by about 12 percent and was accepted as being more representative of current economic conditions.

Sampling Technique for Heavy Commercial Trucks

During a 1979 examination of the goods movement problems in the metropolitan area, a consultant recommended that a heavy truck survey be conducted. He also designed a survey plan (1) that was used to sample heavy commercial trucks. Every truck listed on the working list was contacted for surveying. In order to be included in the sample, it had to meet one of three criteria:

1. The truck was in service and had trips on the interview day,
2. The truck was in service but had no trips on the interview day, or
3. The truck was temporarily out of service on the interview day.

Any interview that met any of the three criteria was accepted in the sample. If it did not meet the criteria, a replacement with the same zip code was selected from the backup list.

All trips for 1 day by each heavy truck were recorded by an interviewer. The sample of trips was then expanded to represent the total population of trips made by heavy trucks registered within each factoring area. The expansion factor for a factoring area was assigned to each traffic analysis zone (TAZ) within the factoring area. The metropolitan area is divided into 1,058 TAZs. Each zone produces and attracts trip generation. The ultimate goal of the heavy truck survey was to create a table of heavy truck trips between TAZs. It would have been impractical to survey at the TAZ level because the registration addresses of the entire heavy truck population in the metropolitan area would have to be converted to a TAZ of registration in order to properly expand the sample. Instead, surveying was done at the factoring-area level and converted to the TAZ level by assigning the expansion factor from a factoring area to each TAZ located within the factoring area. By converting all trip data from factoring areas to TAZs and then expanding it to the population, it was possible to build a heavy truck trip table and distribute the trips properly.

Integration of Data Obtained from Supplementary Truck Sampling

There were many locations in the seven-county metropolitan area in which there were concentrations of truck fleets. Additional data on freight truck movements could be collected at little additional cost by referring to the trip sheet logs for extra trucks while the interviewer was at the fleet terminal to collect data on specific sample trucks. These supplemental data could be useful, if properly added to the sample data, in providing a more accurate distribution of interzonal truck trips; i.e., trips from the sample zone to more destination zones were reported. The expanded trip total for the zonal trucks remained the same but, by touching more destination zones, the data base for the Fratar expansion was improved. It was apparent that, when supplemental interviews were added, they represented additional truck travel; therefore, the trip expansion factors for these respective zones of truck registration were reduced accordingly. Therefore, after the trip expansion factors had been calculated, they were recalculated for only the TAZs that had supplemental interviews. The formula used was

$$X = (a)(c)/(a + b) \quad (1)$$

where

X = final trip expansion factor for the TAZ,
a = number of primary survey samples in the TAZ,
b = number of supplementary survey samples in the TAZ, and
c = preliminary expansion factor for the TAZ.

The final expansion factor replaced the preliminary expansion in all TAZs that had supplementary samples. Where there was no supplementary sampling, the preliminary expansion factor for a TAZ automatically became the final one. The supplementary trip data were then merged with the survey trip data. When the combined trip data were multiplied by the respective TAZ trip expansion factors, the resulting trip table represented 1 day of truck travel. The data in Table 1 summarize the results of the interviews attempted. The 10 interview codes used in the table are listed below:

1. Completed interview with trips.
2. No trips, but otherwise complete.
3. Truck is garaged outside of the metropolitan area.
4. Truck is temporarily out of service for repair.
5. Truck has been sold.
6. Truck has been scrapped.
7. No contact made with truck owner.
8. Unable to locate or out of business.
9. Refused interview.
0. Other (farm use, nonroad hauler use, nonrenewal of license, and so on).

Although there were a total of 2,214 interviews for purposes of this study, only those with an interview code of 1, 2, or 4 were used. Therefore, 1,307 primary and 377 supplementary interviews were found usable--a total of 1,684 interviews.

Table 1. Interviews grouped by interview code.

Interview Code	No. of Interviews: Primary	Supplementary	Total
1	622	377	999
2	645	0	645
3	165	0	165
4	40	0	40
5	82	0	82
6	10	1	11
7	85	0	85
8	108	0	108
9	53	2	55
0	24	0	24
Total	1,834	380	2,214

Table 2. Distribution of heavy trucks by county.

County	No. of Heavy Trucks by Weight: 15,001 to 49,999 lb	≥15,000 lb	Total
Anoka	1,078	618	1,696
Carver	344	125	469
Dakota	1,505	1,049	2,554
Hennepin	7,246	4,895	12,141
Ramsey	3,470	3,062	6,532
Scott	536	320	856
Washington	651	495	1,146
Total	14,830	10,564	25,394

Summary of Major Findings of Heavy Commercial Truck Survey

1. There were 25,394 heavy commercial trucks as of July 31, 1981, that had current year (1981) registration in the seven-county metropolitan area. This figure did not include the 2,677 heavy farm trucks currently registered that were excluded from the sample to be modeled separately.
2. Heavy trucks were registered by county, as shown by the data given in Table 2.
3. The average number of trips per heavy truck, including those that had no travel on the survey day, was 4.02 trips/truck, whereas the trucks that traveled on that day had averaged 6.77 trips. Fifty-nine percent of the sampled heavy trucks were in use on the day of the survey.
4. Although 2,214 truck owners were surveyed for an initial sampling percentage of 8.72, only 1,684 were legitimate interviews because they had trucks garaged in the metropolitan area and they also had a current registration; therefore, the final usable sampling percentage was 6.63.

HEAVY TAX-EXEMPT TRUCKS

Tax-exempt heavy trucks comprise 6.55 percent of all heavy trucks registered and garaged in the seven-county metropolitan area. Tax-exempt trucks were found to average fewer trips per truck per day. They accounted for about 5 percent of all heavy truck trips in the metropolitan area; therefore, the number of internal heavy truck trips would be underreported without their inclusion. Data on tax-exempt trucks were collected through a combination of surveying and simulation. This combination accounted for an estimated 64 percent of heavy tax-exempt trucks in the metropolitan area and nearly all of the heavy tax-exempt truck trips in the metropolitan area.

The procedure adopted was to inventory all of the tax-exempt heavy trucks registered to Minneapolis, St. Paul, Hennepin County, and Ramsey County. Analysis of the data obtained from these surveys produced patterns of the ratio of heavy trucks to total

Table 3. Distribution of heavy trucks and trips per truck in sample of tax-exempt heavy trucks.

Agency	Total No. of Trucks	No. of Heavy Trucks	No. of Trips	No. of Trips per Truck	No. of Heavy Trucks per All Trips
County					
Hennepin	171	82	375	4.57	0.48
Ramsey	78	18	68	3.78	0.23
Total	249	100	443	4.43	0.40
City					
Minneapolis	353	236	690	2.92	0.67
St. Paul	297	62	171	2.76	0.21
Total	650	298	861	2.89	0.46

trucks, and also trips per truck per day, which were used to simulate heavy truck trips for cities and counties in the metropolitan area that were not inventoried.

In addition to the inventory previously mentioned, an inventory was also done for heavy trucks registered to the post offices of Minneapolis and St. Paul and for heavy trucks registered to metropolitan districts of MnDOT. Due to the unique nature of the trips involved, these trips could not be simulated and data obtained from their trips could not be used to simulate trips by heavy trucks from other agencies. However, these separate surveys were used in reporting final totals for all trucks. The distribution of trucks and heavy truck trips in the cities and counties that were surveyed is given in Table 3.

In analyzing the data in Table 3, two patterns emerged that were useful in estimating heavy trucks registered to other metropolitan area cities and counties and in simulating trips made by these trucks:

1. Forty percent of the county-registered trucks and 46 percent of the city-registered truck were heavy trucks, for a combined weighted average of 44 percent; and
2. The average number of trips per day was 4.43 per registered heavy truck for the counties whereas it was 2.89 for the cities.

A high correlation was discovered between the number of trucks registered to a city or county and the number of TAZs within the city or county. This is because in defining TAZs, the original aim was to have the population size of all TAZs as uniform as possible. Therefore, if the population of an area is more dense, the TAZ is smaller and more TAZs are required to make up a city or county. The concentration of population indicates more travel on roads and, in general, more need for public services; therefore, more trucks are required. Conversely, in the more sparsely populated areas the TAZs tend to be larger; thus there are fewer of them in a city or county. With less population there is less need for public service, thus fewer trucks are required.

This relation between number of TAZs and number of trucks in a city or county was used in the simulation and distribution of heavy truck trips. By using the data in Table 1, it is revealed that a reasonable estimate of heavy trucks is 44 percent of the total trucks owned by a city or county; thus the relation between number of TAZs and number of trucks would also hold true for heavy trucks. The data in Table 3 also reveal that there are 4.43 trips/day for each county-registered heavy truck, and 2.89 trips/day for each city-registered heavy truck. Analysis has indicated that the total heavy truck trips estimated could be simulated with approximately the same accuracy by assuming, for the counties, one round trip from the TAZ where the truck is garaged to each other TAZ in the city. The advantage of this method of reproducing trips is that they are uniformly distributed, as one might expect them to be, throughout the course of a year. The results of this analysis are given in Table 4.

There are an estimated 1,780 heavy tax-exempt trucks in the metropolitan area. The data in Table 5 reveal that 1,141 (64 percent) of the estimated 1,780 tax-exempt heavy trucks are accounted for. The rest of the heavy trucks in the metropolitan area belong to agencies such as the Department of Natural Resources or the University of Minnesota, which do little highway travel, or else they belong to small cities and towns where they are used for local street repair and snow plowing; i.e., they make short trips and rarely leave the municipal boundaries. It is reasonable to assume that 64 percent of the heavy tax-exempt trucks account for most of the heavy tax-exempt truck trips in the metropolitan area.

Table 4. Estimates of truck trips by using truck counts and zones.

Agency	No. of Trucks	Estimated Heavy Trucks	No. of TAZs	Estimate of Truck Trips: Rate per Truck	Estimate of Truck Trips: Rate per Zone
County					
Anoka	70	31	69	137	136
Carver	36	16	25	71	48
Dakota	75	33	96	146	186
Scott	34	15	24	66	46
Washington	62	27	61	120	120
Total	277	122	275	540	536
City					
Anoka	39	17	9	49	32
Bloomington	83	37	27	107	104
Brooklyn Center	27	12	11	35	40
Brooklyn Park	21	9	10	26	36
Columbia Heights	52	23	7	66	24
Coon Rapids	25	11	8	32	28
Eden Prairie	27	12	10	35	36
Edina	29	13	20	38	76
Fridley	25	11	9	32	32
Golden Valley	27	12	10	35	36
Hopkins	15	7	6	20	20
Inver Grove Heights	19	8	8	23	28
Maplewood	58	26	18	75	68
Minnetonka	32	14	19	40	72
Rosemount	36	16	5	46	16
Roseville	35	15	20	43	76
St. Louis Park	29	13	15	38	56
South St. Paul	19	8	8	23	28
West St. Paul	20	9	8	26	28
White Bear Lake	50	22	11	64	40
Total	668	295	239	853	876

Table 5. Distribution of tax-exempt heavy trucks.

Agency	No. of Heavy Trucks	Analysis
Minneapolis	275[a]	Survey
St. Paul	62	Survey
Hennepin County	82	Survey
Ramsey County	18	Survey
MnDOT District 5	145	Survey
MnDOT District 9	87	Survey
Minneapolis post office	35	Survey
St. Paul post office	20	Survey
Five other metropolitan counties	122	Estimate
Twenty other metropolitan cities	295	Estimate
Total	1,141	

[a]Includes 39 fire trucks.

HEAVY GRAIN TRUCKS

Although there are few heavy grain trucks registered in the metropolitan area, they account for about 14 percent of the heavy trucks entering the metropolitan area between mid-March and mid-November because this is the season for shipping grain by barge. During the other four months they average less than half this amount. In anticipation of the Mississippi and Minnesota rivers opening to barge traffic, out-of-state grain elevators increase their grain truck shipments to the metropolitan area grain elevators starting in mid-March. Because grain shipping is not as seasonal as it was 10 years ago, grain is shipped to the metropolitan area in large volumes consistently throughout the barge season. During the other four months of the year, grain truck shipments to the metropolitan area are cut in half because barge traffic is closed and grain is either shipped out of the metropolitan area by train or is stored for shipment during the barge season.

In order to simulate a summer day of grain truck travel in the metropolitan area and create a trip table to represent this travel, several assumptions had to be made that pertain to metropolitan area grain elevators and grain trucks:

1. Only grain elevators that receive grain by truck were considered;
2. Because grain elevators would not release data on the amount of grain each one processed per year, elevator capacity was used for determining how to prorate the destinations of grain trucks entering the metropolitan area;
3. It was assumed that, regardless of where grain trucks entered the metropolitan area, their trips to grain elevators could be prorated based on the capacity of the elevators; and
4. It was assumed that each grain truck trip from the cordon station to a grain elevator had a return trip to the same cordon station.

The data obtained from the Minneapolis Grain Exchange are given in Table 6; the data reveal the monthly distribution of 278,000 grain trucks that entered the metropolitan area in 1978.

The heaviest trucking season for grain in 1978 was mid-May to mid-November, when approximately 190,000 truck loads (approximately 68 percent of the grain trucks) entered the metropolitan area. This means that from mid-May to mid-November there were 1.33 times as many grain trucks per day entering the metropolitan area as there would be if they were uniformly distributed throughout the year. Because there are 256 working days in a year, a uniform distribution would produce 1,086 grain trucks/day, but in 1978 it produced 1,450 grain trucks/day from mid-May to mid-November. Because of the emphasis on barge shipping of grain, it is expected that the trend will continue, where a summer work day will have 1.33 times as many grain trucks entering the metropolitan area as on an average work day.

Table 6. Monthly distribution of grain trucks entering the metropolitan area in 1978.

Month	No. of Grain Trucks	Month	No. of Grain Trucks
January	9,800	August	35,700
February	9,800	September	27,000
March	13,600	October	39,000
April	16,500	November	27,000
May	25,500	December	12,600
June	32,100	Total	278,000
July	29,400		

A 1979 grain movement study by the University of Minnesota revealed that in 1979 approximately 328,000 grain trucks entered the metropolitan area, where more than 1,700 grain trucks entered on an average summer day. This number is at least 250 higher than the 1978 estimate, but is a better estimate for current conditions, even though 1979 was a banner year for crop productions. (Note that all data for this study were collected at the elevators, and there was no longer the Russian grain embargo that had existed in 1978.)

In order to allocate the grain trucks to the proper routes at the cordon line, seasonally adjusted heavy truck counts from 1980 were used in conjunction with class counts to determine how many grain trucks were at each cordon station. The class counts were 16-hr counts taken in the summer and were not seasonlly adjusted. The class counts gave an estimate of grain trucks at each cordon station as a percentage of heavy trucks. The percentages were then multiplied by the heavy truck counts at each cordon station to produce an estimate of 1980 grain trucks at each cordon station.

EXTERNAL AND THROUGH TRIPS FOR HEAVY COMMERCIAL TRUCKS

Although the 1970 internal truck survey produced unfavorable results, the 1970 cordon-line survey of external and through trips by trucks produced excellent results. More than 50 percent of the heavy trucks were surveyed, and when the data were processed the results gave a valid distribution of heavy truck trips. Therefore, it was not crucial to have a 1981 survey to update the 1970 cordon-line survey. The areas that generated trips for heavy trucks changed little over a 10-year span, so the 1970 distribution pattern could be used with some confidence to distribute 1980 cordon-line heavy truck trips.

In order to expand the 1970 cordon-line survey data to 1980, growth factors were developed for each of the 31 external stations to represent the 10-year growth in heavy truck volume. Heavy truck counts at each station for a 30-year period (1948 to 1978) were used as input data to develop linear regression predicting equations. When each equation was solved for the 1980 prediction and the predicted number of heavy trucks was divided by the 1970 TBI heavy truck count at that station, the result was a 1970 to 1980 growth factor for heavy trucks at each external station. The correlation coefficient for the regression equations was improved by grouping the 31 external stations into 9 districts on the basis of traffic corridors. Regression equations were developed for each district, and the same growth factor was applied to all external stations included within a district.

To verify the accuracy of the growth factors, the factored 1970 counts at the external stations were compared with 1980 counts. Results revealed that the accuracy of the factored 1970 counts were within 6 percent of the 1980 counts for the total cordon line. The 1980 cordon line of all 31 external stations had a total of 24,434 heavy trucks whereas the factored 1970 counts had a total of 22,991 heavy trucks.

AGGREGATION OF TRIPS AND NETWORK ASSIGNMENT

The calculation of the distribution of all heavy truck trips at the cordon line resulted in the creation of a 1980 trip table of external and through trips for heavy trucks. This was the final trip table needed to complete the trip distribution. A 1980 heavy truck network (alternate 3TC) was created by deleting from the 1980 traffic network (alternate

3C) all links that represented routes on which heavy truck travel was barred. To make the heavy truck traffic assignment, the following trip tables were added together and assigned to alternate 3TC:

1. Heavy commercial truck, internal trips;
2. Heavy commercial trucks, external and through trips;
3. Heavy tax-exempt trucks, internal trips; and
4. Heavy grain trucks, external trips.

The 1980 assignment to the heavy truck network was compared with 1980 ground counts of heavy trucks to assess the probable validity of the assignment. When this was done, necessary corrections were made to validate the network. The major step left to complete the heavy truck study was to expand the trip tables to the year 2000 and assign them to a year-2000 network.

YEAR-2000 FORECAST: EXPANDING 1980 TRIP TABLES FOR HEAVY TRUCKS TO YEAR 2000

The 1980 heavy truck distribution was expanded to a year-2000 distribution by using growth factors for each of the 1,058 internal TAZs and 31 external TAZs. Previous analysis had shown that better future trip predictions through the use of regression models could be made if the internal TAZs were grouped into 108 districts, whose larger size reduced sampling errors. The external TAZs were similarly grouped into 9 districts based on traffic corridors. Thus the confidence level on predictions was much higher with regression analysis applied at the district level instead of the TAZ level.

A regression model was used to develop trip-predicting equations for internal trips by heavy commercial trucks at the district level:

$$\text{Productions} = 85.89938 + 0.22575(X) + 0.05168(Y) + 0.21246(Z) \quad (2)$$

$$\text{Attractions} = 78.75956 + 0.22618(X) + 0.05179(Y) + 0.21964(Z) \quad (3)$$

where

X = manufacturing and wholesale employment,
Y = total population, and
Z = transportation, communication, and utility employment.

When the trip-predicting equations were developed, the forecast year-2000 socioeconomic data were added into the equations. The result was year-2000 district forecasts of heavy commercial truck trips for the 108 internal districts. The predicted year-2000 trips for each district were used as control totals. The year-2000 forecast of trip generation for each district was prorated to the TAZs within the district according to the distribution of the 1980 internal trip table. Each TAZ now had a year-2000 forecast of trip generation. To get a year-2000 trip table of internal trips by heavy commercial trucks, the 1980 trip table matrix was multiplied by the growth factor at each end of every trip. It was then redistributed by means of a Fratar model. The resultant trip table had an estimated 260,000 internal trips for the year 2000.

Another regression model based on the predicted number of heavy trucks in the year 2000 and the trip rate per truck produced an independent estimate of 192,000 trips/day by heavy commercial trucks. This number would normally be used as a control total, but because it was extrapolated from a depressed 1981 economy, it was decided to use the midpoint of the two estimates as a control total. Therefore, the year-2000 trip table of internal trips by heavy commercial trucks was factored down from 260,000 trips to 226,000.

Obtaining a year-2000 trip table of internal trips by heavy tax-exempt trucks was simpler. The 1980 distribution of these trucks was the best estimate of how the trips would be distributed in the year 2000; therefore, the use of growth factors was not applicable. A regression model revealed that there would be 1.888 times as many heavy tax-exempt trucks registered in the metropolitan area in the year 2000 as in 1980. Therefore, the 1980 trip table of heavy tax-exempt truck trips was multiplied by 1.888 to produce the year-2000 trip table.

External and Through Heavy Truck Trips

The 31 external TAZs had been grouped into 9 districts on the basis of traffic corridors in order to develop growth factors. A regression model that used 30 years of heavy truck counts for the districts as independent variables was used to predict 1980 and year-2000 heavy truck counts for each district. The growth factors developed by this model were applied to the 9 districts and resulted in control totals at the 31 external stations for external and through trips by heavy commercial trucks.

The expansion of the 1980 trip table of heavy grain trucks to the year 2000 assumed there would be no growth in the number of grain trucks and only a slight redistribution due to the construction of a large new terminal grain elevator in Savage. Therefore, no external or internal growth factors were applied to the 1980 grain truck trip table. Any growth in grain truck movements would be dependent on unpredictable future variables such as weather conditions, changes in land use, future government farm policy, future foreign demand for grain, effect of new user fees on barge traffic, and the amount of rail abandonment.

The number of trips in each heavy truck trip table for years 1980 and 2000 is given in Table 7.

Assignment to Year-2000 Traffic Network

After all heavy truck trip tables for the year 2000 had been built and internal trips had been calibrated to the control totals, they were added together and assigned to a year-2000 heavy truck traffic network (alternate 3TE). This network was identical to the region's policy plan approved year-2000 network (alternate 3E), except that approximately 1,800 links, which represented routes where heavy trucks are banned, had been deleted. The traffic assignment was analyzed for logical routings and general validity. Because the minimum time paths for the trees

Table 7. Heavy truck trip table totals for years 1980 and 2000.

Heavy Truck Trips	Heavy Truck Trip Table Totals by Year	
	1980	2000
Internal		
Commercial	89,114	226,034
Tax exempt	4,632	8,801
Total	93,746	234,835
External		
Commercial	18,113	24,933
Grain	3,502	3,502
Tax exempt	28	57
Total	21,643	28,492
Through–commercial	1,402	1,954
Total	116,791	265,281

had been built on the heavy truck network, any errors in routing resulted in corrections to the network, not the assignment.

SUMMARY

With the development of new heavy truck trip tables for the year 2000, the old year-2000 forecast trip tables were discarded. The old forecasts had been developed from data from the 1970 TBI. Because of the small sample of heavy trucks in the 1970 internal trip survey, the old year-2000 forecast of distribution was considered unreliable. Furthermore, the old trip tables of heavy truck trips had been distributed by a gravity model, whereas the new trip tables were distributed by a Fratar model, which was more realistic because heavy truck trips are not a function of zonal accessibility.

For the total year-2000 assignment (with the discarding of the old heavy truck trip tables), the gravity model will have to be recalibrated to distribute the trips by automobiles and light trucks on the policy plan network. The next step is a combined total assignment of automobiles, light trucks, and heavy trucks on the network. This can be done even though minimum time paths for heavy trucks were built on the heavy truck network and time paths for automobiles and light trucks were built on the policy plan network. This is because both networks are similar in every detail except for the deleted links on the heavy truck network. For heavy trucks, the deleted links from the heavy truck network do not exist; therefore, heavy trucks do not use these links on the policy plan network after being assigned to it. Automobiles and light trucks, which have had minimum time paths built on the policy plan network, are free to use any link. To combine all of the trip tables for the total assignment, use is made of an FHWA PLANPAC computer battery program called WTLOAD.

An advantage of this type of assignment is that it reveals a more accurate picture of the total traffic, which is useful in analyses such as volume/capacity ratios. However, note that the assignment is built from two combined path building files. If a selected link is needed, it cannot be traced from this combined file. One of the original path building files would have to be used; either the one built for automobiles and light trucks or the one built for heavy trucks.

It is especially useful to use a combined automobile and heavy truck assignment, where heavy trucks use only allowable heavy truck routings, to analyze alternatives of the construction of I-35E through St. Paul. The Minnesota Legislature has mandated I-35E to be a parkway with no heavy trucks allowed. A bypass route of the central business district (CBD) for heavy trucks has been planned for construction in the future, but not until after 1990. This route will run from Warner Road, southeast of the CBD, to north of the CBD where it will join I-35E at the Pennsylvania Avenue intersection. This route is in the year-2000 network. Assignments of year-2000 traffic can be made to the year-2000 network with the CBD bypass in place or with it removed from the network. Analysis of these assignments will then show where the heavy truck travel will go until the bypass is built, and what capacity problems may be created for streets in and near the CBD. Also, a comparison of these assignments with the 1980 assignment would be useful in developing a trend to indicate how soon the CBD bypass would be a necessity.

REFERENCE

1. Design for a Freight Truck Study, Final Report. Roger Creighton Associates, Inc., New York, 1979.

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Abridgment

Strategic Motor Freight Planning for Chicago in the Year 2000

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The major components of a motor freight planning model that was recently developed to help the Chicago Area Transportation Study evaluate alternative year-2000 physical planning policies are described. The current model allows the planner to evaluate alternative terminal clustering and primary truck route designation plans, both as they affect terminal accessibility to service demands, and as the greater separation of person and goods traffic movements affects highway volumes, speeds, fuel use, and emissions.

Although the daily operating characteristics of carriers are their own concern, serious consideration has to be given to the cumulative impacts of current daily urban goods movement (UGM) practices. Therefore, roadway maintenance costs (both financial and resource based), mixed person-goods traffic interaction, and appropriate land use mixes are the major policy issues discussed in the paper.

The only way to properly appreciate and measure such cumulative impacts is by means of a system's approach to UGM planning, i.e., start with a properly integrated strategic plan. Such an approach is being considered by the Chicago Area Transportation Study (1) based on a simulation model developed by Southworth and others (2). This model was built to allow the testing (through simulation) of a range of UGM systems based on the following three-component plan:

1. The clustering of for-hire freight terminals with zones of high accessibility to truck service demands;
2. The channelization of daily heavy freight vehicle flows along a designated truck route network; and