AN ANALYSIS OF THE PROCEDURES USED IN THE
MANHATTAN, KANSAS TRANSPORTATION STUDY

by

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SYNOPSIS

Analysis of many travel habit studies indicate that zonal trip interchanges can be determined, within reasonable limits of accuracy, by the application of mathematical formulas, called "traffic distribution models." If certain characteristics about an urban area are known, it is possible to compute an estimate of its trip distribution patterns by utlizing mathematical model techniques.

To get the basic parameters needed, with considerable less time, money, and efforts, for utilizing these mathematical models, new techniques are developing. The estimating equations for trip production and attraction as developed by Prof. Bob L. Smith for their use in gravity model are given in this report. The methodology used by Wilson & Co. in using these equations in the Manhattan transportation study is discussed extensively.

INTRODUCTION

As the demands to construct new urban roads and streets, or to improve existing ones, are increasing, considerable time, money, and effort are usually expended in the planning and design of such improvements. For the most part the planning work is carried on within the framework of an urban transportation study. Significant improvements in both basic study philosophy and analysis methodology have greatly contributed to a better understanding of the urban transportation problem.

Many studies conducted in the last ten years have indicated and recognized that urban traffic patterns now, or in the future, are a function (1)* of:

1. The type and extent of the transportation facilities available in an area.
2. The pattern of land use in an area, including the location and intensity of use.
3. The various social and economical characteristics of the people who make trips.

This recognition has resulted in a concerted effort toward the development of a transportation planning process which utilizes these interrelationships to provide quantitative information on the

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*Numerals in parenthesis - thus; (1) - refer to corresponding items in the References Cited.

travel demands created by alternate land use patterns and transportation systems in an urban area. Such information can then be used by various agencies to make decisions about when and where improvements should be made in transportation networks to satisfy the present and future travel demands and to promote desirable land development patterns.

Studies of travel habits have led to the development of mathematical formulas or traffic models which can satisfactorily reproduce zonal trip interchange estimates obtained through comprehensive home interview traffic studies. Several formulations of traffic models have been developed for the estimation of future interchanges, particularly in large metropolitan areas, but much additional research is needed to evaluate and verify the various models in cities of all sizes. Many different types of traffic models are now in existence and currently being utilized in transportation studies, but the most widely used model to date is the gravity model.

In order to apply the gravity model theory to a given city, it is generally considered necessary to conduct, as a minimum, a comprehensive origin-destination (O-D) survey and to calibrate or adjust the model to reproduce, at an acceptable level, the trip distributions found in the O-D survey. In applying a gravity model trip distribution formula to urban studies today, full use is made of the experiences of the early research. Recent research conducted

(2) has indicated that a gravity model can be adequately formulated using only a small sample of O-D data.

For developing a transportation plan for Manhattan, Kansas, an engineering consulting firm, Wilson & Co., Salina, Kansas, first considered conducting an external and internal O-D survey. But in consideration of time and money it would involve, the gravity model was given preference. There were about 11,000 dwelling units in Manhattan. Considering a 20 per cent sample for interviews and assuming $10 cost per interview, it would have cost $22,000 for only the home interviews in the O-D survey. This cost was more than the entire study cost under the gravity model. Gravity model seemed to be the cheaper and quicker method. The Bureau of Public Roads also agreed upon the use of a gravity model. Therefore, finally it was decided to prepare a transportation plan for Manhattan with the help of a gravity model.

Purpose

Wilson & Co. used the estimating equations developed by Prof. Bob L. Smith in his research project "An Application of Gravity Model Theory to a Small City in Kansas Using a Small Sample of Origin-Destination Data" (2). There were two sets of estimating equations, one for trip production and the other for trip attraction (see Appendix A). These equations were developed from the data gathered in the internal O-D survey and the land use study in the Hutchinson, Kansas Metropolitan Area. Wilson & Co. used these equations in the Manhattan transportation study without conducting an O-D survey. The purpose of this report was to document the methodology used by Wilson & Co. in using these equations.

Scope

This report was limited to a documentation of the methodology used by Wilson & Co. in the Manhattan Transportation Study. This report covers the methodology used in estimating 1963 trip productions, attractions, travel time factors for use in the gravity model formula, and the testing of the model against the present-day trip distribution.

STUDY PROCEDURE ADOPTED BY WILSON & CO.

It is customary to develop the parameters in the gravity model formula individually for each urban area under study. Furthermore, these parameters are developed for each of several different categories of trips. These categories take into account the basic freason for making trips and are generally referred to as trip purpose categories. In his research Prof. Smith used three trip purpose categories: Home-Work, Home-Other, and Non-Home. Therefore, Wilson & Co. also used these three trip purpose categories. They considered students trips to university as home-work trips.

The trip interchanges were calculated by the following gravity model formula:

$$T_{i-j} = \frac{P_i \quad A_j \quad F_{i-j}}{\sum_{x=1}^{n} A_x \quad F_{i-x}} \qquad \text{(Equation A)}$$

where:

T_{i-j} = Trips produced in zone i and attracted to zone j

P_i = Trips produced by zone i

A_j = Trips attracted by zone j

F_{i-j} = An empirically derived travel time factor which expresses the average areawide effect of spatial separation on the trip interchange between zones. The measure of distance or spatial separation between zones is usually the total travel time between the centroids of zones i and j.

n = Total number of zones

From the above gravity model formula, it can be seen that four separate parameters were required before the trip interchanges (T_{i-j}) could be computed. Two of the basic parameters were concerned with the use of the land in the study area and with the social and economic characteristics of the people who made trips. These were the number of trips "produced" (P_i) and the number of trips "attracted" (A_j) by each traffic zone in the study area. The number of trips produced referred to the number of trips originated in and returned to a given zone; the number of trips attracted referred to the number of trips arrived at and departed from a given zone. Other two parameters were the travel time factors and the total number of zones.

For calculating trip production and attraction the estimating equations, number 2, 4, 5, 7, 10, 11 and 13 (see Appendix A), were used. For using these equations, the following variables were needed.

1. Cars/Zone
2. Cars/Dwelling Unit
3. Persons/Zone
4. Persons/DU
5. Total DU/Zone
6. Travel Time to CBD
7. Wholesale-Retail Jobs
8. Personal Service Jobs

10. Grouped Jobs
11. Jobs
12. LU_1
13. LU_5
14. LU_6
15. LU_9
16. LU_{220}
17. LU_{240}

9. Professional Jobs 18. LU_{250}

19. LU_{280}

For definitions of these variables see Appendix A.

All the information needed for using the estimating equations were gathered by Wilson & Co. The process was divided mainly into five parts.

1. The total population and the dwelling units.
2. The cars per zone.
3. Travel Time to CBD
4. The total jobs and classification into categories.
5. The land use areas.

Further, to calibrate and to test the gravity model a telephone survey was conducted and the travel time factors were determined.

The Total Population and the Dwelling Units

The city was divided into 28 zones. Zonewise population distribution was made from the 100 per cent population survey which was available from the city. The number of students in each zone was obtained from the university data, i.e. from the addresses of the students at the university. Then the total population per zone was obtained by adding the population per zone obtained from the survey and the number of students per zone obtained from the university data.

The original equations were developed from the data obtained in the Hutchinson Metropolitan Area, where there were no university students. Manhattan had about 8,400 university students and in addition to that some few thousands were connected with the university. The influence of the student population on Manhattan was that there were very few single-family units. Generally 5 to 10 students stayed in one house. Some families had rented some of their rooms to the students. Therefore, a house was divided into the number of apartments it had or in the number of rooms in which students were staying independently, and considered these apartments or rooms as separate dwelling units rather than considering the whole house as one dwelling unit. This was done with the aid of a land use map, studying each house in each block. After obtaining the total population per zone and the number of dwelling units per zone, persons per dwelling unit were calculated.

The Cars Per Zone

Because of the university, a considerable number of out-of-county cars were found to be in Manhattan. The total number of cars registered at the university were 8,309. Out of 6,308 students - registered cars at the university, 5,090 cars were out of county cars. There were comparatively fewer out of county cars with the faculty and staff.

The process of estimating the number of cars per zone was divided into three parts.

1. To estimate the number of cars per zone from the Riley

County registered cars in Manhattan.

2. To distribute out-of-county cars which were registered at the university in their respective zones.
3. To estimate out-of-county cars which were not registered at the university but were in Manhattan, for each zone.

To estimate the number of cars per zone from the Riley County registered cars in Manhattan, a random sample was chosen from the Riley County tag registration numbers until a 15 per cent sample of Manhattan cars was obtained. (For the method used in the determination of the sample size see Appendix B). These cars were then distributed in their respective zones and the number of cars per zone were obtained for this 15 per cent sample. Then for each zone the number of cars were calculated for the 100 per cent value and the Riley County registered cars per zone in Manhattan were obtained.

All out-of-county cars which were registered at the university were distributed manually in their respective zones, and the number of cars per zone for this category were obtained.

The out-of-county cars which were not registered at the university but were in Manhattan, were considered to be 5 per cent of the Riley County registered cars in Manhattan. The estimates of the number of cars per zone for this category were calculated by taking the 5 per cent values of the number of cars per zone obtained from the Riley County registered cars in Manhattan.

Finally, the cars per zone were obtained by adding the number of cars per zone obtained from: (i) the Riley County registered cars in Manhattan, (ii) the out-of-county cars which were registered at the university, and (iii) the out-of-county cars which were not registered at the university but were in Manhattan. Further, the number of cars per dwelling unit were calculated from the number of dwelling units per zone.

Travel Time to the CBD

The travel time to the CBD was defined as the driving time from the zone centroid in question to the CBD zone centroid, in minutes. The term "Travel Time to the CBD" was referred to as "CBD Distance" in the Report by Smith. (See Appendix A and Reference 2).

To obtain these times, first the average driving times for every street from intersection to intersection were determined. These times were determined by actually driving every street both ways in the morning, noon, evening, and night periods when volumes were representative of peak-hour canditions. Trial runs were made until the total dispersion of driving time was less than the average time for that particular street. The Floating Car method was used to determine the time. The field procedure for obtaining the travel times can be found in (3).

Finally, the travel time to the CBD for each zone was obtained by taking the driving time from the center of that zone to the nearest intersection and then adding the times determined by above method for the shortest route to the centroid of the CBD zone.

The Total Jobs and Classification into Categories

Nothing helpful was available with the city on employment or jobs. Therefore, a survey of all the businesses was made. This was done by going shop to shop in the downtown area and other shopping centers. To get the locations of spot businesses and services scattered throughout the city the land use map was used.

The information gathered in this survey was the business name, address, type of business, and the number of employees. For a representative data sheet see (Appendix B). From these data the total number of jobs were separated manually into the needed five categories. With the help of the addresses these jobs were further distributed in their respective zones and jobs per zone were obtained. Faculty members of the university were considered in the grouped jobs. Students trips to the university were considered as home-work trips. When work trip attraction was calculated by equation number 7 (see Appendix A), students were considered in the category of 'jobs'. As students do not attract others for their services (except university staff and faculty), they were neither classified in any further job categories nor used in any other equations. See Appendix A for job categories.

The Land Use Areas

In determing the various land use areas some trouble was encountered, because the areas needed were not clearly defined. For example, in LU_9 which calls for recreation and institution, whether to take whole land area or only the building area. A school which has 10 acres of land but a building only on a very small portion of it, should be consider as 10 acres or only the area which was built. In this study it was decided to take the building area plus 50 per cent of the land area.

Again, in LU_{220} which calls for super food market, whether to consider the parking area or not. In this case it was decided to include all the parking area of the super food market, because parking was also considered as attraction.

All the land use areas were obtained from the land use map.

Appendix C shows the zonewise gravity model factors as estimated by the above methods.

The Telephone Survey

In order to calibrate the gravity model the telephone survey was made. Five per cent random sample was selected from the city telephone directory. Business listings were deleted from the telephone book before the selection of the sample. The survey was divided into two categories. One was for the trips made in 24 hours and the second category was for the trips made between 4 P.M. and 7 P.M. Two separate samplings were made for this purpose. If a person was duplicated, he was eliminated from the list of the second category.

The persons were requested at least one day in advance for remembering the trips they made. The trips were recorded on the telephone traffic survey sheet (see Appendix B) and then further classified into three trip purposes. Further the trips were distributed in their respective zones. In all 100 calls were recorded for the trips made in 24 hours and 350 calls for the trips made between 4 P.M. and 7 P.M. This survey along with the traffic counts at screenlines and intersections was useful in checking the estimated trips.

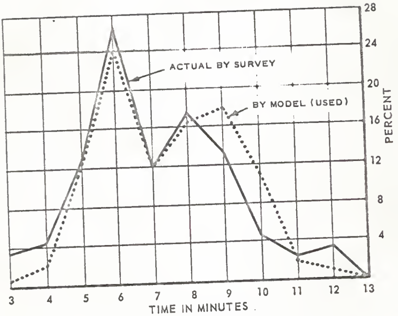
The procedure followed for conducting the O-D survey by telephone can be found in (4).

Development of Travel Time Factors

The calibration of the gravity model (Equation A, page 6) was carried out using the three trip purposes; home-work, home-other, and non-home. The calibration consisted principally of the determination of travel time factors which resulted in a trip travel time frequency distribution which satisfactorily compared to the actual trip travel time frequency distribution.

First the trip travel time frequency curve was drawn from the data obtained in the telephone interview survey. The trip travel time frequency was defined as the percent of total trips falling in each one minute increment of driving time. i.e. the number of 3 minute trips, the number of 4 minute trips, and so on. Then an initial set of travel time factors was assumed and the trip interchanges between all zones were computed. The trip travel time frequency distribution of the trip interchanges was determined by finding the number and the percentage of trips falling in each one minute increment of driving time. The estimated trip travel time frequency was then compared to the actual trip travel time frequency distribution.

If the comparisons were not within the limits desired, an adjustment was made in the initially assumed set of travel time factors for each trip purpose. The travel time factors were adjusted manually to bring the gravity model estimated percentage of trips, in each travel time increment, into closer agreement with the actual trips at each increment. The actual adjustment was made for each travel time increment by multiplying the initial travel time factor by the ratio of the percentage of the actual trips to the percentage of estimated trips for the respective time increments. The adjusted travel time factors (for each one minute of travel time) were then plotted against respective travel time increments on straight-line graph paper. The second set of travel time factors was then determined from a hand-fitted line of best fit to the adjusted factors. The gravity model was then run using the second set of travel time factors, and then the comparisons of trip travel time frequency, etc. were repeated. This process was continued until satisfactory agreement among the comparisons was reached. The set of Iowa travel time factors (5) was also tried for comparisons. Figure 1 shows the comparisons of trip travel time distributions as obtained for home-work trips.



HOME TO WORK TRIPS
FREQUENCY FACTORS

FIGURE 1

TESTING THE MODEL DISTRIBUTION

All the variables needed for estimating trip production and attraction were collected and the productions and attractions were calculated by using the equations developed by Prof. Smith. The equations for estimating productions and attractions in any city are usually developed (by multiple regression analysis techniques) from data collected in a small sample of O-D interviews. However, Wilson & Co. decided to use the "Hutchinson equations" and to develop a correction factor for them rather than to conduct any standard O-D interviews.

The zonal trip interchanges for the entire city were next computed using the gravity model. It was necessary to compare the present-day trip distribution given by the model to the existing trip distribution in the city. Three screenlines as shown in figure 2 were set up to get the actual traffic counts. Traffic counts were also taken at various intersections. The numbers of trips given by the model were too high when compared with the traffic counts at screen lines and intersections. The telephone survey gave an additional evidence against the numbers of trips obtained by the model.

Correction Factor

When zone to zone trip interchange comparisons were made, the variations between the traffic counts and the estimated trips were found to be high in those zones where the students were in great

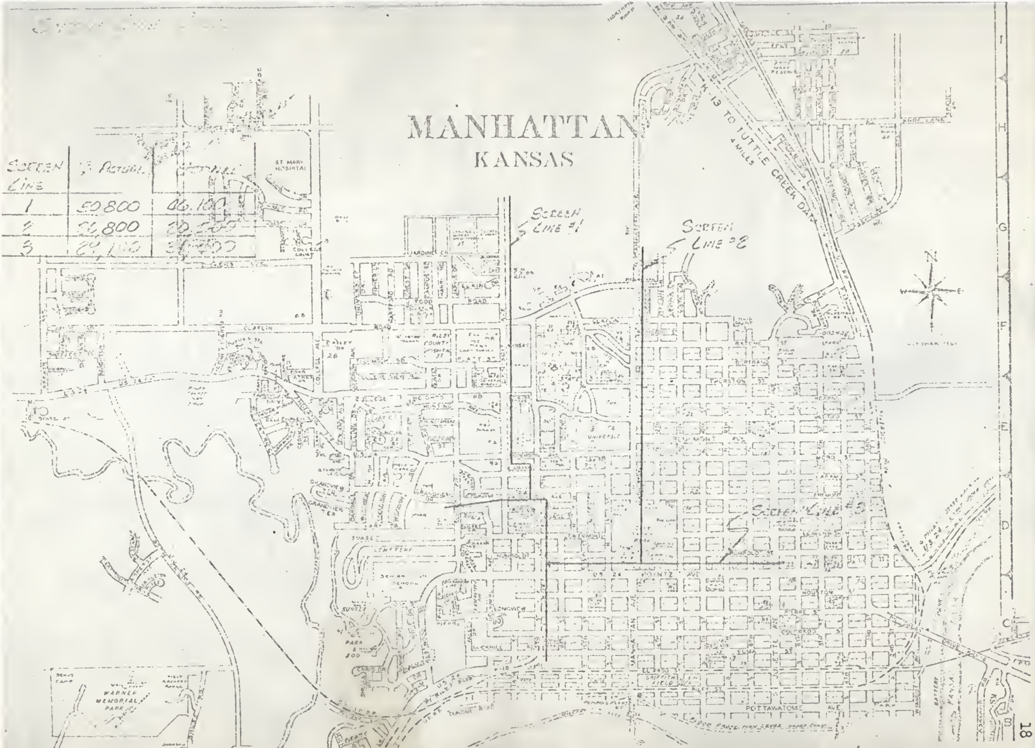


FIGURE 2: LOCATION OF SCREENLINES

number. Therefore, it was apparent to attribute these variations to the student population. One of the reasons for these variations to be present in the student populated zones, was considered to be that students, even though having individual cars when living in the same house, tend to go to school or any other common place in one car. This was brought to notice in the telephone survey.

To correct this situation it was decided to neglect some of the student population, but how much was not known. The main purpose behind all this was to eliminate the variations between the counted trips and the calculated trips for each zone. Therefore, a correction factor was developed by Bendix Computer on purely trial and adjust basis until the estimated and actual trips were balanced. The original form of the equation was as follows:

$$\frac{\text{Total Population} - \text{Students} + 0.75\ \text{Students}}{\text{Total Population}} \times 0.80 \times \text{Estimated Trips}$$

$$= \text{Actual Trips}$$

From this equation the following correction factor was obtained.

$$\frac{\text{Total Population} - 0.25\ \text{Students}}{\text{Total Population}} \times 0.80$$

These factors were calculated for each zone and finally, the trips were corrected as follows:

$$\frac{\text{Total Population} - 0.25\ \text{Students}}{\text{Total Population}} \times 0.80 \times \text{Estimated Trips}$$

$$= \text{Trips (corrected)}$$

Screenline Comparison

Three screenlines were set up for a comparison of screenline crossings (actual traffic count) and the crossings obtained from the gravity model with the various combinations of parameters. The location of the various screenlines is shown in figure 2.

Table 1 gives the actual crossings of screenlines and the crossings obtained from the gravity model. Figure 3 shows a graphical comparison of screenline checks. Crossings of screenlines

TABLE 1

COMPARISON OF SCREENLINE CROSSINGS OF ALL TRIPS USING ACTUAL TRAFFIC COUNT AND MODEL DATA

Screenline	Actual	Model
1	50,800	46,100
2	20,800	20,500
3	29,100	31,400

1 and 3 showed about 9 per cent and 8 per cent differences respectively. This could have been remedied by applying zone to zone adjustment factors, but for planning purposes and in the judgment of the past experiences, these differences were not considered to be significant.

This study procedure pointed out the importance of a comprehensive series of screenlines. Therefore there is a need for a comprehensive series of screenlines in this type of study.

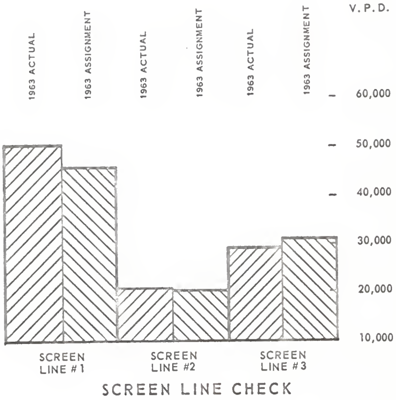

V. P. D.
1963 ACTUAL
1963 ASSIGNMENT
1963 ACTUAL
1963 ASSIGNMENT
1963 ACTUAL
1963 ASSIGNMENT
60,000
50,000
40,000
30,000
20,000
10,000
SCREEN LINE #1
SCREEN LINE #2
SCREEN LINE #3
SCREEN LINE CHECK

FIGURE 3

CONCLUSIONS

It was concluded that:

1. Current zonal trip productions and attractions obtained from the mathematical equations developed by Prof. Bob L. Smith appeared to give a usable first estimate of the Manhattan zonal productions and attractions.

2. Trip productions and attractions seemed to be a function of the type of population (i.e. student population in Manhattan). Some adjustments were required in these equations due to the considerable student population. A series of correction factors were developed to reflect the effect of the student population.

3. Three trip purposes - home-work, home-other, and non-home - appeared to be adequate for prediction of zonal trip productions and attractions.

4. In the estimation of future trip attractions, the square terms used in the equations gave trouble. Therefore it is recommended to avoid square terms in so far as possible in the formulation of mathematical equations.

5. Travel time factors for distribution of trips by the gravity model were satisfactorily estimated by calibrating the gravity model with trip travel time frequency data obtained from the telephone interview survey.

6. The five per cent telephone survey along with screenline and intersection counts appeared to be adequate for checking the model.

It was not discussed in this report but the same equations were used for estimating future (1985) trips. If some standard correction factors or a mathematical method to calculate them is developed for the type of population (e.g. student population in Manhattan), these equations will save considerable time and money in estimating trip interchanges by the gravity model.

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(1) "Calibrating and Testing a Gravity Model for Any Size Urban Area", Office of Planning, U. S. Department of Commerce, Bureau of Public Roads, July 1963.

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(3) "Determining Travel Time", Procedure Manual 3B, National Committee on Urban Transportation, Public Administration Service, Chicago, 1958.

(4) Edens, H.J., "Origin and Destination Surveys by Telephone", Traffic Engineering, April 1963, pp. 11-12.

(5) "Gravity Model Procedures Used by Iowa Planning Survey", U. S. Department of Commerce, Bureau of Public Roads, Division of Planning and Research, Kansas City, Mossouri, July 1962.

APPENDIX A

TABLE 15*

ESTIMATING EQUATIONS FOR TRIP PRODUCTION FROM MULTIPLE REGRESSION ANALYSES **

Equation No. 1 - OSP 22030 - Home-Work - Full Sample

$$Y = -5.78775 + 10.25491(\text{Cars/DU}) + 1.52715(\text{Pers./DU}) - 0.70627(\text{CBD Dist.})$$
$$- 2.66103(\text{Cars/DU})(\text{Pers./DU}) + 0.30996(\text{Pers./DU})(\text{CBD Dist.}) - 0.039634(\text{CBD Dist.})^2$$

Y = Trips/Dwelling Unit

*** Equation No. 2 - RSP 14030 - Home-Work - Reduced Sample

$$Y = -0.54297 - 0.96297(\text{Cars/DU}) + 0.79424(\text{Pers./DU}) + 0.13594(\text{CBD Dist.})$$
$$+ 0.31954(\text{Cars/DU})(\text{Pers./DU}) - 0.10496)(\text{Pers./DU})(\text{CBD Dist.}) + 0.018626(\text{CBD Dist.})^2$$

Y = Trips/Dwelling Unit

Equation No. 3 - OSP 22039 - Home-Other - Full Sample

$$Y = -5.92767 + 11.60937(\text{Cars/DU}) + 1.39224(\text{Pers./DU}) - 1.20225(\text{CBD Dist.})$$
$$- 2.26609(\text{Cars/DU})(\text{Pers./DU}) + 0.29830(\text{Pers./DU})(\text{CBD Dist.}) + 0.007200(\text{CBD Dist.})^2$$

Y = Trips/Dwelling Unit

*See note at end of Table 16.
**Smith, Bob L., "An Application of Gravity Model Theory to a Small City in Kansas Using a Small Sample of Origin-Destination Data", Kansas State University, Manhattan, Kansas, September 1963, pp. 64-69.
***Equations used in the Manhattan, Kansas Transportation Study.

TABLE 15 (Cont.)

*** Equation No. 4 - RSP 14039 - Home-Other - Reduced Sample

$$Y = 4.56907 - 6.09284(\text{Cars/DU}) - 1.69056(\text{Pers./DU}) + 0.58893(\text{CBD Dist.})$$

$$+ 2.98149(\text{Cars/DU})(\text{Pers./DU}) - 0.29073(\text{Pers./DU})(\text{CBD Dist.}) + 0.042162(\text{CBD Dist.})^2$$

Y = Trips/Dwelling Unit

*** Equation No. 5 - NHP 04514 - Non-Home - Full Sample

$$Y = - 2.398094 - 0.0051391(LU_1) - 0.017017(LU_5) + 0.054498(LU_6) + 0.058424(\underline{\text{Jobs}})$$

$$+ 0.048989(\text{Pers./Zone}) - 0.084438(\text{Tot. DU/Zone}) - 0.017802(\text{Cars/Zone})$$

$$+ 0.0000005793(LU_1)^2 + 0.000003317(LU_5)^2 + 0.00052392(LU_6)^2 - 0.000023462(\text{Jobs})^2$$

$$- 0.000023616(\text{Pers./Zone})^2 + 0.000089245(\text{Tot. DU/Zone})^2 + 0.000060598(\text{Cars/Zone})^2$$

Y = Trips/Zone/1000 trips produced in 14 selected zones

Equation No. 6 - NRP 04514 - Non-Home - Reduced Sample

$$Y = - 6.22386 - 0.0046915(LU_1) + 0.043900(LU_5) + 0.045839(LU_6) + 0.070971(\underline{\text{Jobs}})$$

$$+ 0.058497(\text{Pers./Zone}) - 0.15106(\text{Tot. DU/Zone}) + 0.038259(\text{Cars/Zone})$$

$$+ 0.0000005283(LU_1)^2 - 0.00020223(LU_5)^2 + 0.00064132(LU_6)^2 - 0.00002833(\text{Jobs})^2$$

$$- 0.00002883(\text{Pers./Zone})^2 + 0.00013757(\text{Tot. DU/Zone})^2 + 0.00002562(\text{Cars/Zone})^2$$

Y = Trips/Zone/1000 trips produced in 14 selected zones

TABLE 16*

ESTIMATING EQUATIONS FOR TRIP ATTRACTION FROM MULTIPLE REGRESSION ANALYSES

***Equation No. 7 - Work Trip Attr. - Home-Work - Full Sample (Adj. Jobs)

$$Y = 1.109 + 0.0624\,(\text{Jobs})$$

Y = Trips/Zone/1000 trips produced in 14 selected zones

Equation No. 8 - RS 460 - Home-Work - Reduced Sample (Zone 12 Omitted)

$$Y = 1.092802 + 0.058113(\text{Jobs})$$

Y = Trips/Zone/1000 trips produced in 14 selected zones

Equation No. 9 - MRA 51409 - Home-Other - Full Sample

$$\begin{aligned} Y = &- 0.62306 - 0.048951(\text{LU6}) + 0.005561(\text{LU9}) - 0.0052420(\text{Pers./Zone}) + 0.035644(\text{Tot.DU/Zone}) \\ &- 0.050611(\text{Who.-Ret. Jobs}) + 0.06504(\text{Pers. Serv. Jobs}) + 0.064090(\text{Prof. Jobs}) \\ &- 0.012982(\text{Grouped Jobs}) + 0.32256(\text{LU}_{220}) + 1.95827(\text{LU}_{240}) + 1.63904(\text{LU}_{250}) + 0.39525(\text{LU}_{280}) \\ &+ 0.00017289(\text{LU}_6)^2 - 0.00000037908(\text{LU}_9)^2 - 0.0000001466(\text{Pers./Zone})^2 \\ &+ 0.000018689(\text{Tot. DU/Zone})^2 - 0.0000094125(\text{Who.-Ret. Jobs})^2 - 0.00061319(\text{Prof. Jobs})^2 \\ &+ 0.0001369(\text{Grouped Jobs})^2 - 0.0032360(\text{LU}_{220})^2 - 0.054781(\text{LU}_{240})^2 - 0.0055373(\text{LU}_{280})^2 \end{aligned}$$

Y = Trips/Zone/1000 trips produced in 14 selected zones

* See note at end of table.

TABLE 16 (Cont.)

***Equation No. 10 - RSA 51309 - Home-Other - Reduced Sample

$$\begin{aligned}
Y = &- 0.021097 - 0.080372(LU_6) + 0.0045021(LU_9) + 0.0078854(\text{Pers./Zone}) \\
&- 0.013214(\text{Tot. DU/Zone}) - 0.049754(\text{Who.-Ret. Jobs}) + 0.26185(\text{Pers. Serv. Jobs}) \\
&- 0.018923(\text{Prof. Jobs}) - 0.0041486(\text{Grouped Jobs}) + 0.35568(LU_{220}) + 0.88353(LU_{240}) \\
&+ 2.63884(LU_{250}) + 0.35530(LU_{280}) + 0.00017385(LU_6)^2 - 0.0000003212(LU_9)^2 \\
&- 0.000003921(\text{Pers./Zone})^2 + 0.000059441(\text{Tot. DU/Zone})^2 - 0.000024614(\text{Who.-Ret. Jobs})^2 \\
&- 0.00003059(\text{Prof. Jobs})^2 + 0.000078437(\text{Grouped Jobs})^2 - 0.0031158(LU_{220})^2 \\
&- 0.032500(LU_{240})^2 - 0.0043047(LU_{280})^2
\end{aligned}$$

Y = Trips/Zone/1000 trips produced in 14 selected zones

***Equation No. 11 - NHA 04714 - Non-Home - Full Sample

$$\begin{aligned}
Y = &- 0.722068 - 0.004496(LU_1) - 0.055532(LU_5) + 0.052999(LU_6) + 0.045612(\text{Jobs}) \\
&+ 0.02664(\text{Pers./Zone}) - 0.0314071(\text{Tot. DU/Zone}) - 0.009572(\text{Cars/Zone}) + 0.0000005513(LU_1)^2 \\
&+ 0.00012975(LU_5)^2 + 0.00045254(LU_6)^2 - 0.000019178(\text{Jobs})^2 - 0.000016506(\text{Pers./Zone})^2 \\
&+ 0.000061364(\text{Tot. DU/Zone})^2 + 0.000044775(\text{Cars/Zone})^2
\end{aligned}$$

Y = Trips/Zone/1000 trips produced in 14 selected zones

TABLE 16 (Cont.)

Equation No. 12 - NRA 04714 - Non-Home - Reduced Sample

$$Y = -3.03559 - 0.0073974(LU1) - 0.024895(LU_5) - 0.0027639(LU_6) + 0.056735(Jobs)$$
$$+ 0.062327(Pers./Zone) - 0.11725(Tot.\ DU/Zone) - 0.014188(Cars/Zone)$$
$$+ 0.0000014912\,(LU_1)^2 + 0.000048958\,(LU_5)^2 + 0.00063131(LU_6)^2 - 0.00002446(Jobs)^2$$
$$- 0.00002917(Pers./Zone)^2 + 0.00014079(Tot.\ DU/Zone)^2 + 0.000049897(Cars/Zone)^2$$

Y = Trips/Zone/1000 trips produced in 14 selected zones

***Equation No. 13 - OSP 14034 - Non-Home - Full Sample

$$Y = 3.34575 - 6.39670(Cars/DU) - 0.52092(Pers./DU)$$
$$+ 0.000120(CBD\ Dist.) + 2.52203(Cars/DU)(Pers./DU)$$
$$- 0.35194(Pers./DU)(CBD\ Dist.) + 0.13654(CBD\ Dist.)^2$$

Y = Trips/Dwelling Unit

Equation No. 14 - RSP 14034 - Non-Home - Reduced Sample

$$Y = 3.75602 - 6.31798(Cars/DU) - 1.19446(Pers./DU) + 0.46274(CBD\ Dist.)$$
$$+ 2.76797(Cars/DU)(Pers./DU) - 0.45012(Pers./DU)(CBD\ Dist.)$$
$$+ 0.13799(CBD\ Dist.)^2$$

Y = Trips/Dwelling Unit

TABLE 16 (Cont.)

Note: Equations 13 and 14 were used only for the estimation of numbers of non-home productions or attractions.

1. LU_x indicates 1000's of square feet of land use

   x, if single digit, indicates major group land use

   x, if 3 digit, indicates land use categories within major group land uses

   (See page 31 for land use codes)

2. In equations 1, 2, 3, 4, 13, 14:

   DU = dwelling units which responded to the O-D interview

   Pers. = persons

   CBD Dist. = distance from the zone centroid in question to the centroid of zone 12, in minutes.

3. In equations 5, 6, 7, 8, 9, 10, 11, 12:

   Tot. DU/Zone = Total number of dwelling units per zone

   Grouped Jobs = Total jobs in wholesale, retail, finance, personal services, amusement, recreation, professional government, and self-employed.

   Jobs = Total of all jobs

   Who.-Ret. Jobs - Total jobs in wholesale, retail, finance and insurance

   Pers. Serv. Jobs = Total jobs in personal service

   Prof. Jobs = Total jobs in professional area

LAND USE CODES

LU_1 : Manufacturing

LU_5 : Construction

LU_6 : Personal, Business, Repair Services and Office

LU_9 : Recreation and Institution

LU_{220} : Super food markets

LU_{240} : Department store and general merchandise stores

LU_{250} : Apparel and accessories stores

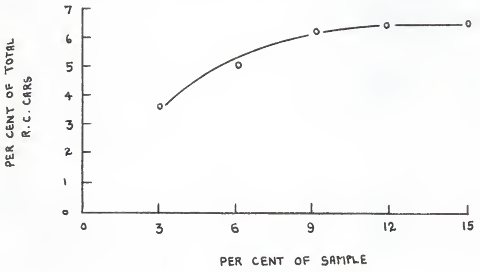
LU_{280} : Gasoline service stations

APPENDIX B

DETERMINATION OF 15 PER CENT SAMPLE SIZE

For the determination of the sample size to estimate the number of cars per zone, five samples each of 3 per cent random sample from the Riley County tag registration numbers were chosen. For each of the five samples the cars were distributed in their respective zones in Manhattan and in the areas outside of Manhattan. Then, the estimates of the per cent of total Riley County cars in each zone in Manhattan and in each area outside of Manhattan were calculated for each of the five samples.

The values of the per cent of total Riley County cars were then plotted against the per cent of sample for each zone. All the graphs showed that by the time the per cent of sample reached to 15 per cent value, the value of the per cent of total cars became approximately constant. Therefore, finally it was decided that 15 per cent sample was adequate to estimate the number of cars per zone.



Interview	Call No.	Date	Time	NA	R.
	1	6/21	AM 10:55		
	2	6/24	AM 9:00		
	3				
	4				
	5				
	6				

Report Complete ______
Coded by ______
Checked by ______

1. How many passenger cars owned at this address? **1**

2. How many company owned or leased passenger cars used by people at this address? **0**

3. How many persons live here? **1**

4. Did any member of this household drive a passenger car between 4-7 p.m. today?

No ___ Yes ___

Telephone No. 9-5596

Name Swiatlicki, Alair

Address 830 Bluemont

Sample No.	2428
Zone	11
Date of Travel	Saturday 6/22

Other employed members of household

Trip No.	Where did this trip begin? 4-7 p.m.	Where did this trip end? 24 Hr.	Time of Starting	From	Purpose	To	Total No. In Car	Sex M 1	Sex F 2	1 M	2 C	3 WT	4 GP	5 H	6 RU	Type of Business (Driver)	Address of Place of Work (Driver)	Zone No. (")
1	Out of Town Ft. Riley	26 Lee St.	9:00 PM	1	1 Work 2 Home 3 Shopping 4 Other	4	2										Ft. Riley	O.T.
2	26 Lee St.	01 Bus station	PM 11:30	4		4	1											
3	01 Bus station	home 11	PM 12:00	2	1 Work 2 Home 3 Shopping 4 Other	4	1											
4	home 11	Lee St 26	AM 10:00	4		2	1											
5	Lee St. 26	home 11	Noon 12:00	2	1 Work 2 Home 3 Shopping 4 Other	4	1											
6	home 11	out of town Clay Center	PM 12:30	4		2	1											
7	Out of town Clay Center	home 11	5:00	2	1 Work 2 Home 3 Shopping 4 Other	2	1											
8	home 11	N. Anderson Sunset Ave 26	6:30	4		4	1											
9	Sunset Ave 26	Holiday Inn. 10		2	1 Work 2 Home 3 Shopping 4 Other	4	2											

M = Manufacturing C = Commercial W.T. = Warehousing & Transportation G.P. = Government & Professional
H = Housewife R.U. = Retired or Unemployed

1/11

Business Name	Address	Type	No. of Employees*	Traffic Area No.
~~Dillon Paint Co.~~	~~State Theatre Bldg.~~	~~VAN~~	—	
Internal Revenue	" " "	Government	39	
T. William Varney (C.P.A)	" " "	Service	16	8
Hunter-Lundberg, Gen. Contr.	" " "	contract const.	391	11
Federal Crop Insurance	" " "	government	12 29	
Chas. E. Crum (Electrologist)	" " "	Service	16	
Northwestern Mutual Life	" " "	fin.ins.real est.	55	
Wadell & Reed-United Fund. Inc.	" " "	Service	25	
WIBW Sales	" " "	"	16	8
Kilmers Cafeteria	212 S 4th	wholesale+retail	144	
Bus Depot	" "	Public Utilities	53	
Railway Express	213 "	Public Utilities	2 3	
Buchanan Liquor Store	215 "	wholesale+retail	44	
Manhattan Typewriter Co.	217 "	wholesale+retail	64	
Sewell Tailors	219 "	wholesale+retail	24	
M & R Cafe	221 "	wholesale+retail	74	
Centennial Bar	301 "	wholesale+retail	74	
Staffel Pawn Shop	303 "	wholesale+retail	24	
C & M Motor Supply	305-311 "	wholesale+retail	44	
City Dairy	313 "	Total Manufacturing	102	
Eagles Club	312 "	Service	46	
Glenn Liquor Store	339 "	wholesale+retail	24	
Manhattan Mattress	414 "	Service	36	6
Rooks Sales Co.	520 "	wholesale+retail	84	10
Majors Produce	4th & El Paso	"	44	10
Texaco Bulk Station	615 S 4th	wholesale+retail	44	5
Manhattan TV & Cable	111 S 5th	Service	VAN 16	4
Remington Plumbing & Heating	105 "	contract construction	71	4
Bell Taxi Co. Inc.	110 "	Public Utilities	123	4
Landon & Landon Prod., Inc.	112 "	Service	36	4
Army Recruiting Service	114 "	Service	29	4
Westgate Wheel Aligning Co.	" "	Service	36	4
Bell Clinic	123 S 5th	Service	96	4
Orkin Exterminator	431 "	Service	26	6

* includes all persons on the payroll

APPENDIX C

Gravity Model Factors

	Total Pop	Total DU	Total Cars	Total Jobs	Cars/DU	Persons/DU	Dist CBD
Zone 01	1514	276 [illegible]	2455	2793	1.67	3.81	–
02	712 939	181 [illegible]	280 355	119	1.80	5.06	2.28
03	[illegible] 533	125	260	97	2.04	4.26	2.73
04	365	106	127	245	1.18	3.38	1.68
05	1079	325	570	1681	1.75	3.82	1.78
06	1732	476	1243	118	2.62	3.64	1.75
07	82	22	33	86	1.50	3.73	2.87
08	1260	327	582	98	1.78	3.65	3.63
09	352	110	225	22	2.04	3.20	4.13
10	1181	301	661	133	1.53	3.94	2.86
11	3473	1285	1847	55	1.43	2.79	3.06
12	837	215	168	511	2.76	4.13	3.63
13	1356	980	135	2805	2.14	1.38	5.35
14	2040	812	969	86	1.19	2.51	4.25
15	1609	926	825	117	0.89	1.76	4.80
16	219	64	89	0	1.39	3.65	4.41
17	306	84	117	39	1.39	3.64	5.08
18	2559	701	1141	60	1.63	3.66	4.61
19	14	4	6	–	1.50	3.50	4.65
20	1680	549	900	8	1.58	2.97	7.58
21	989	329	525	46	1.60	3.01	8.18
22	658	475	551	–	1.46	1.39	6.41
23	596	283	379	52	1.34	2.07	6.50
24	617	213	490	95	2.02	2.54	8.25
25	989	428	705	151	1.65	2.32	8.71
26	1222	367	768	328	2.09	3.33	6.18
27	547	146	305	101	2.09	3.33	6.67
28	535	192	270	4	1.41	3.05	5.50
Sub Totals				7931			
		Students		8400			
Totals	29,569	10,423	14,770	16,331	1.41	2.82	4.92

(cut off)	9	10	11	12	13	14	15	16
							Per 1000 □'	
...os ...'E	Jobs Pers Serv	Jobs Prof	Jobs *	LU1 Manu.	LU5 Const.	LU6	LU9 R&I	LU220
719	880	84	311	9.25	7.75	243.96	74.48	24.40
14	21	–	–	–	30.00	7.90	370.40	–
29	20	–	27	127.50	63.80	–	63.90	–
82	27	–	–	97.90	25.00	37.80	9.00	–
98	43	3	7	9.40	5.60	18.90	26.20	18.80
3	42	–	34	–	–	1.60	33.60	–
7	4	4	71	–	–	0.80	3045.00	–
4	22	–	17	24.00	–	20.00	180.00	66.00
–	4	–	–	59.50	5.60	2.00	210.00	–
35	49	–	9	–	–	8.00	–	5.00
8	6	–	26	–	–	–	92.00	–
157	253	29	26	–	–	27.85	7.20	–
–	–	–	2400	–	–	–	10,000.00	–
5	29	–	–	–	–	10.00	6.90	–
12	13	4	13	–	–	0.40	40.00	–
–	–	–	–	–	–	–	–	–
38	1	–	–	–	–	–	–	–
10	29	–	21	–	–	2.00	85.50	–
–	–	–	–	–	–	–	–	–
–	2	–	–	–	–	–	–	–
17	9	–	–	–	–	–	2.00	–
–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	15.00	–
–	70	–	7	–	–	0.40	76 130.20	–
–	144	–	–	–	–	9.60	100 274.00	50.00
–	240	20	33	–	–	0.40	–	–
–	16	–	61	–	–	[illegible]	62.5 ~~[illegible]~~	–
–	4	–	–	–	–	16.50	200.60	8.00
1432	1930	144	3063	322.55	137.75	460.01	14,83[illegible] .38	192.20

GRAVITY MODEL FACTORS

LU240	LU250	LU280	PERS./CAR	STUDENTS
90.80	72.36	15.60	2.31	92
–	–	–	2.81	25
–	–	–	2.05	4
–	–	–	2.87	6
–	–	44.00	1.89	64
–	–	–	1.39	357
–	–	2.50	2.48	8
–	–	8.00	2.16	78
–	–	–	1.56	13
–	–	28.00	2.57	91
–	–	–	1.88	471
–	5.5 –	8.10	5.44	347
–	–	–	10.00	~~1245~~ 1254
–	–	10.00	2.11	748
–	–	3.20	1.95	786
–	–	–	2.46	24
–	–	4.90	2.62	16
–	–	10.00	2.25	172
–	–	–	2.33	–
–	–	–	1.88	559
–	–	3.50	1.87	151
–	–	–	1.19	631
–	–	–	1.54	312
–	–	–	1.26	31
–	–	25.00	1.35	401
–	–	–	1.59	212
–	–	–	1.79	21
–	–	–	2.17	62
90.80	72.36	162.80	2.00	7616

AN ANALYSIS OF THE PROCEDURES USED IN THE MANHATTAN, KANSAS TRANSPORTATION STUDY

by

PANDURANG R. PATIL

B.S., Michigan State University, 1962

AN ABSTRACT OF A MASTER'S REPORT

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AN ANALYSIS OF THE PROCEDURES USED IN THE
MANHATTAN, KANSAS TRANSPORTATION STUDY

By P. R. Patil

ABSTRACT

This report presents a documentation of the methodology used by Wilson & Co. in the Manhattan, Kansas Transportation Study. It covers the methodology used in estimating 1963 trip productions, attractions, travel time factors for use in the gravity model formula, and the testing of the model against the present-day trip distribution.

Earlier it has been suggested that a basic aim of the transportation planning process is to provide decision makers with quantitative information about the consequences of decisions concerning the type, location, size, and timing of transportation improvements. Recently another aim is considered to be to enable the transportation planner to better understand the underlying factors which influence travel patterns. Traffic distribution models have greatly aided in this respect. If certain characteristics about an urban area are known, it is possible to compute an estimate of its trip distribution patterns by utilizing mathematical model techniques.

To obtain the basic parameters needed, with considerable less

time, money, and efforts, for utilizing these mathematical models, new techniques are developing. The estimating equations for trip production and attraction as developed by Prof. Bob L. Smith for their use in gravity model were used by Wilson & Co. in the Manhattan Transportation Study. But these equations were developed from the Hutchinson, Kansas Metropolitan Area origin-destination (O-D) data, and therefore, to balance the estimated trip distribution to the actual trip distribution in Manhattan, a correction factor was developed.

It was concluded that the current zonal trip productions and attractions obtained from the mathematical equations developed by Prof. Smith appeared to give a usable first estimate of the Manhattan zonal productions and attractions. In this study, trip productions and attractions seemed to be a function of the type of population (i.e. student population in Manhattan). A series of correction factors were developed to reflect the effect of the student population.