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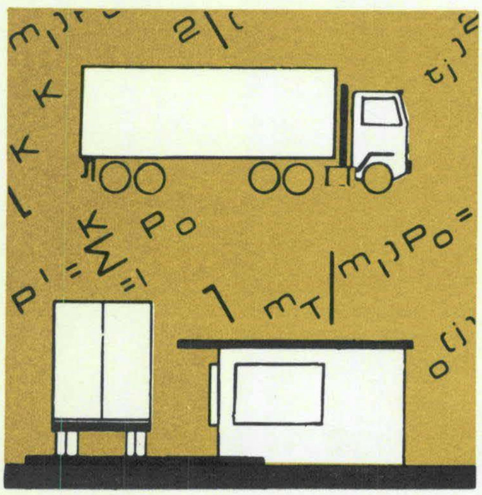
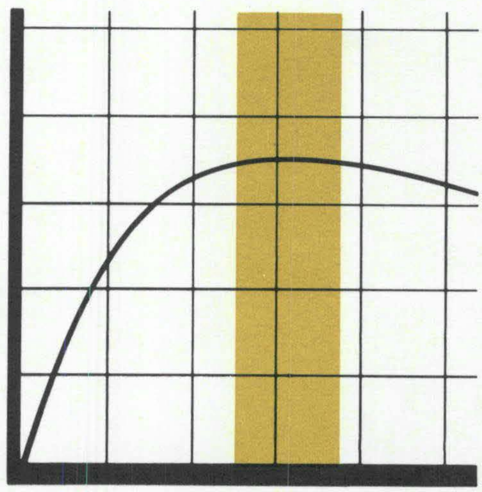
MIDWEST RESEARCH INSTITUTE

OPTIMUM ENFORCEMENT LEVEL FOR TRAFFIC WEIGHT OPERATIONS

MRI REPORT

APPENDICES





IOWA HIGHWAY RESEARCH BOARD PROJECT HR-138
For the
IOWA STATE HIGHWAY COMMISSION, AMES, IOWA

MIDWEST RESEARCH INSTITUTE 425 VOLKER BOULEVARD, KANSAS CITY, MISSOURI 64110 • AREA 816 561-0202

OPTIMUM ENFORCEMENT LEVEL FOR TRAFFIC WEIGHT OPERATIONS

APPENDICES TO FINAL REPORT
October 31, 1968

MRI Project No. 3158-P

Iowa Highway Research Board
Project HR-138

Conducted by the

Midwest Research Institute
Kansas City, Missouri

for the

Iowa State Highway Commission
Ames, Iowa

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APPENDIX 1, TAB A

AVERAGE IOWA MILEAGE PER TRUCK TRIP

Basic Information Source

1963 Iowa State Highway Commission Loadometer Survey Records[1/]

Form of Data

Individual trip distances are recorded in miles. The origin and destination of each trip and the state of registration of the vehicle are recorded in a coded form.

Method of Analyzing Data

The number of vehicles originally surveyed were far more than needed for the purpose of estimating a gross average mileage per trip. The records were therefore sampled systematically using every nineteenth trip. A total of 503 trips were sampled.

For trips within Iowa the trip mileage was simply recorded for each trip record. For trips that originated or terminated out of state, only the estimated portion of the trip that occurred within Iowa was recorded. The estimate of mileage in Iowa was made by examining the probable route taken on a map of Iowa highways.

Results of the Analysis

GENERAL TRUCK POPULATION

Trip Location	No. of Trips	Mileage	Average Mileage
Iowa only	382	27,623	72.3
Partial out of state	121	29,005	240.0
All	503	56,628	112.3

1/ 1963 data was most recent Origin-Destination survey available. It is not believed that average trip mileage would change greatly in a few years.

Estimate For the Violator Population

The above average mileage estimate applies to the general population of trucks. A mileage figure is also needed for weight regulation violators. The Loadometer Survey provides no direct information on mileage of violators. It was not believed that violators travel greater or less distances than non-violators per trip. However, it is possible that violations are more frequent per vehicle on out-of-state trucks than in-state trucks. Hence, the average distance might be shifted towards the 240-mile trip distance of out-of-state vehicles.

A tape record of all 1967 violations was used to determine the fraction of violations committed by in/out-of-state vehicles as follows:1/

VIOLATORS ONLY

Registration	Percent of Violators	Average Mileage
Iowa	78.8	72.3
Other	21.2	240.0
All	100.0	108.0

The density of violations does not seem to depend significantly on state of registration since 108.0 is so close to 112.3. However, out-of-state violators travel about three times farther per violation and thus may cause three times as much road damage per violation.

1/ The program used to process the tape is at Appendix 6.

APPENDIX 1, TAB B

NUMBER OF TRUCK TRIPS PER YEAR IN IOWA

Basic Information Sources

1. ISHC Planning Division: "Estimated Annual Vehicle Miles of Travel in Iowa in 1968 by Road System and Vehicle Type."

2. ISHC Planning Division: W-4 Table All Main Rural Roads 1966.

3. Appendix 1, Tab M of this report.

4. Appendix 1, Tab A of this report (Average Iowa Mileage per Truck Trip).

Method of Processing Data

Item 1 supplied an estimated 1.333 billion truck miles not including pickups and panels for 1968 on the primary and secondary rural roads of Iowa. However, we are also interested in the annual vehicle miles traveled by pickups and panels on these roads. This information could not be directly determined from the available data, so the following method was used to estimate this information:

The ratio of distance traveled by pickups and panels (D_p) to truck mileage (D_t) from item 1 is assumed to be in direct proportion to the number of pickups and panels counted at traffic weight stations (C_p) to trucks counted (C_t). The unknown term, the number of miles traveled by pickups and panels, is equal to:

$$D_p = D_t\left(\frac{C_p}{C_t}\right)$$

The distance traveled by pickups and panels was calculated separately for primary roads and secondary roads.

Distance traveled by pickups and panels on primary roads:

1. D_t = 0.923 million truck miles (excluding pickups and panels) from item 1.

2. Ratio C_p/C_t = 0.423 from item 2.

Therefore:

D_t primary roads = (0.923×10^9) (0.423) = 0.389 billion miles

<u>Distance traveled by pickups and panels on secondary roads</u>:

1. D_t = 0.410 billion truck miles (excluding pickups and panels) from item 1.

2. The fraction of trucks (C_p) observed on secondary roads could not be directly determined from the available data. The fraction of trucks (C_p) was assumed to be the product of the fraction of trucks on primary roads (0.297) times the ratio of single units observed on secondary roads (0.91) to single units observed on primary roads (0.48).1/

   Therefore:

   C_p = 0.297 (0.91/0.48) = 0.561

   and $C_t = 1 - C_p$ = 0.439

3. Ratio C_p/C_t = 1.26

Therefore:

D_t secondary roads = (0.410×10^9) (1.26) = 0.524 billion miles

The total vehicle miles in 1968 for trucks, pickups and panels is the sum of the distances calculated for these vehicles on primary and secondary roads, and is equal to 2.246 billion vehicle miles.

Now

$$T = M/m$$

where: T is the number of annual trips by trucks, pickups, and panels, M is the total annual truck, panel and pickup mileage, and m is the average distance traveled per truck trip, from item 4.

1/ Item 3.

Result of Analyses:

$$M = 2.246\ (10)^9$$

$$m = 112.3$$

$$T = 2.246\ (10)^9/112.3 = 20.0 \text{ million annual trips}$$

APPENDIX 1, TAB C

FRACTION OF TRUCK TRIPS IN VIOLATION

Basic Information Sources

1. ISHC T.W.O. "Summary of Results of Traffic Weight Operations" (Attached).

2. ISHC Planning Department "Analysis of Traffic Volume and Weight Study--1966", Table W-7, p. 67.

3. ISHC T.W.O. Communication to MRI: Number of Traffic Weight Officers by Year.

4. Appendix 1, Tabs A,B of this report.

5. ISHC T.W.O. "Summonses Issued by Traffic Weight Officers July 1, 1966 through June 30, 1967 (Attached).

6. Tape File of 1967 Violation Records.

7. ISHC Planning Department Motor Vehicle Traffic Data.

Method of Processing Data

Item 2 indicated that 6.05 percent of the truck trips in Iowa were made in violation of overweight or oversize regulations. Item 5, attached below, indicated that out of 19,084 summons issued only 7,513 or 39.4 percent were overweight or oversize violation. Hence, a rough estimate of the percent violating would be 6.05 percent/0.394 or 15.5 percent. However, an analysis of item 6 indicated that about 10 percent of these violations belong to both the overweight/oversize category and the registration violation category. Hence, 1.5 percent of the violations would be double counted by the above calculation; the actual percent violating in 1967 was 15.5-1.5 percent or 14.0 percent. This is the percent of traffic violating one or more of the laws enforced by T.W.O.

As explained in Section III A of the report the number of summons in any given year is proportional to the traffic T, the fraction violating V, and the probability of apprehension, P. Hence, the change of V with P can be obtained by scaling from the number of apprehensions and correcting for growth in probability of apprehension, and truck trips (measured by registration R) over a number of years. In other words:

$$V = KA/PR$$

where $$K = (V'P'R'/A')$$

and V', R', T', and A' are the values for 1967. K = 0.0159

Below is a table showing the results of these calculations for Iowa.

	Average Staff	Apprehension[2] Probability (P)	Truck[3] Registration (thousands) (R)	Summonses[4] (thousands) (A)	Fraction Violating (V)
1950	19	0.0021	191	14.9	0.590
1952	28	0.0031	204	18.8	0.472
1954	42	0.0046	216	22.0	0.350
1956	41	0.0045	226	20.4	0.316
1958	46	0.0051	235	16.9	0.225
1960	45	0.0050	248	13.4	0.172
1962	49	0.0054	256	16.2	0.186
1964	57	0.0063	281	18.2	0.163
1966	54	0.0060	335	21.2	0.168
1967	56	0.0062	350	19.1	0.140

1/ Item 3.

2/ 1967 value taken from Appendix 1, Tab D. Other values were taken as linearly proportional to staff. (Apprehension model is linear for small P.)

3/ Item 7.

4/ Item 1 (Attached below). Prior to 1958 improper registration regulations were not too enforced. Summonses issued include estimate of improper registration violations.

SUMMONSES ISSUED BY TRAFFIC WEIGHT OFFICERS

July 1, 1966 through June 30, 1967

Also Completion of Summonses Issued in Prior Period

Type of Violation	No. of Summonses Issued	Fine and Court Costs Paid	Increased Registrations
WEIGHT			
Overload of Registrations	3,498	$ 39,647.29	$ 83,168.44
Single Axle Overloads	2,384	77,425.27	125.00
Two Axle Tandem Overloads	2,263	61,516.85	
Three Axle Tandem Overloads	11	3,390.14	
Gross Overloads	1,339	66,906.27	75.00
Improper Registration	7,897	118,150.51	16,993.95
Other Violations	176	3,567.50	131.25
Subtotal	17,568	$ 370,603.83	$ 100,493.64
DIMENSIONS			
Width	816	$ 13,362.75	
Length	626	14,401.50	
Height	16	245.00	
Front-End Projection	58	1,310.00	
Sub-Total	1,516	$ 29,319.25	
TOTALS	19,084	$ 399,923.08	
Cases prior to July 1, 1966 now complete (454)		$ 15,989.70	$ 8,296.43
Registration increases due to Warnings			5,199.14
GRAND TOTALS	19,084	$ 415,912.78	$ 113,989.21

SUMMARY OF RESULTS OF TRAFFIC WEIGHT OPERATIONS

Fiscal Year	No. of Summonses Issued	Total Paid Fines & Costs	Total Paid Registration	Cost of Operation
1941-42	8,320	$ 70,270.55	$ 173,685.60	$ 61,559.91
1942-43	7,820	49,683.66	186,637.40	70,040.49
1943-44	7,507	54,862.80	157,365.11	72,598.96
1944-45	7,383	64,740.50	154,283.41	83,276.37
1945-46	10,009	87,640.90	183,300.08	81,296.99
1946-47	10,125	104,245.45	174,096.52	82,902.94
1947-48	9,784	128,650.20	212,263.91	85,545.13
1948-49	9,479	130,715.15	267,667.20	80,454.60
1949-50	10,505	109,543.69	310,810.61	80,599.24
1950-51	10,474	151,887.87	268,225.35	86,467.15
1951-52	13,324	221,364.06	268,205.32	156,220.75
1952-53	16,805	272,586.41	341,300.55	197,862.66
1953-54	15,605	241,039.18	314,305.22	221,700.75
1954-55	14,739	259,717.35	439,629.28	225,392.79
1955-56	14,444	263,134.82	402,759.49	229,135.08
1956-57	13,692	256,941.42	336,703.83	236,373.96
1957-58	11,952	279,741.95	235,956.70	234,867.14
1958-59	12,565	294,485.66	247,389.00	249,217.64
1959-60	13,370	340,422.59	136,336.11	228,584.23
1960-61	14,247	356,523.12	134,674.91	332,832.70
1961-62	16,177	416,031.55	177,444.87	342,176.67
1962-63	16,819	406,576.74	238,170.56	360,704.14
1963-64	18,196	433,559.23	214,568.07	387,971.59
1964-65	22,796	525,546.38	183,268.66	433,650.39
1965-66	21,213	481,548.21	168,942.41	477,089.26
1966-67	19,084	415,912.78	113,989.21	485,668.76
TOTAL	346,434	$ 6,417,362.22	$ 5,861,979.38	$ 5,584,190.29

NOTE: Figures shown under "Registration" show only the amount of additional registration fees paid on vehicles actually found to be under registered.

Results of the Analysis

The results of the analysis are shown graphically in Section III, A-5 of the report.

The following function was fitted to the data for calculation purposes:

$$V = 0.02 + 0.98e^{-K_D P}$$

where K_D , the deterrence constant, is determined from 1967 conditions:

$$P = 0.00618, \quad V = 0.140$$

$$K_D = -\frac{1}{P} \text{ logarithm}_e \left((V-0.02)/0.98\right)$$

$$K_D = -\frac{1}{0.00618} \text{ logarithm}_e \left((0.140-0.02/0.98\right)$$

$$K_D = 340.0$$

Therefore, in 1968, $P = 0.0070$

$$V = 0.02 + 0.98e^{-340.(0.0070)}$$

$$V = 0.111$$

APPENDIX 1, TAB D

PROBABILITY OF APPREHENSION

Basic Information Sources

1. ISHC T.W.O.: "Summary of Results of Traffic Weight Operations, July 1, 1966, through June 30, 1967."

2. Appendix 1, Tab B of this report.

3. Appendix 1, Tab C of this report.

4. ISHC Planning Division: "Volume of Traffic on the Primary Road - 1965."

5. Tape File of 1967 violations.

6. Appendix 1, Tab A of this report.

7. ISHC Planning Division: "Highway Mileage in Iowa by Surface Type, January 1, 1967."

8. Page III-67 of this report.

Method of Data Analysis

Apprehension rate method: One method of determining apprehension probability is to determine the number of apprehensions per violating trip.

For example: In year 1968, according to item 2, there will be $20.00(10)^6$ trips with a 3 percent growth rate in traffic, in 1967 there were $19.42(10)^6$ trips of which, according to item 3, 14 percent involved one or more violations. Computer analysis of item 5 indicated there were 0.88 violators per violation (because of multiple violations by one violator on one trip). Item 1 indicated there were 19,084 apprehensions during the same period.

We may assemble these facts as follows:

Probability of apprehension = Apprehensions/violating trips

or

$$P = (19{,}084)(0.88)/(19.42)(10)^6(0.14)$$

Results of the Analysis

$$P = 0.00618 \text{ for } 1967$$

Application of the Results

From Section III-A-4 of the report we know that P can be related to staff level, S, by a relation of the following general form:1/

$$P = 1 - e^{-K_A S}$$

where K_A is a lumped constant depending on such factors as length of trip, number of miles of road being patrolled, etc. We may solve the above equation for K_A :

$$K_A = - \ln(1-P)/S$$

This method was used to find K_A's for conventional fixed sites and for roving patrols using loadometers for the scheduling and other management techniques employed in 1967.

Site Type	Apprehension Constant (1967)
Fixed site	$1.22(10)^{-4}$
Roving patrol	$0.35(10)^{-4}$
Total	$1.577(10)^{-4}$

These K_A values were in turn inserted into the Apprehension Model to obtain P's for a range of new S's. For 1968,

$$\text{Effective Staff} = 64 \times (0.70) = 44.7 \text{ men}$$

$$P = 1.0 - e^{-1.577(10)^{-4} x (44.7)} = 0.0070$$

1/ Assuming that the size of the staff is not sufficient to fully man all available inspection sites.

Theoretical Analysis Method

Another method of estimating P is by theoretically calculating K_A from the factors known to compose it.

Under the assumption of random scale location:

$$P = 1 - e^{-(MHDP_S/168LC)S}$$

Hence,

$$K_A = MHDP_S/168LC$$

where M , etc., are defined in Section III-A-4 of the report as:

M = trip length of vehicles in violation

H = hours worked per day

D = days worked per week

P_S = probability of inspecting vehicles going by site

L = length of road under surveillance

C = crew per site (average)

We estimate these values as follows (for 1967 average):

Parameter	Value	Source or Method
M	108	Item 6
H	8	Nominal
D	5	Nominal
P_S	1	Assumed (true for fixed sites)
L	17,931 1/	Item 7
C	2.58	Item 8

1/ Rural primary and paved secondary only.

Thus $K_A = 108(8)(5)(1)/168(17,931)(2.58) = 4.33(10)^3/7.78(10)^6$.

$$K_A = 5.56(10)^{-4}$$

However, it is known that the inspection sites are not placed randomly, but are placed in regions of high traffic density. This effectively boosts P and K_A by a factor related to the traffic concentration. The more traffic is concentrated on a few miles of roads the better the chance of properly locating a scale, and the better the probability of apprehension.

Figure 1-D-1 shows the traffic concentration of the Primary Road System. This information was processed to produce the graph in Figure 1-D-2 by plotting the fractional cumulative mileage traveled versus the cumulative amount of highway used in traveling.

Figure 1-D-3 shows how the information from Figure 1-D-2 is processed to produce P_j's , probabilities that traffic will be located in regions 1,000 miles in length. The primary road information was combined with information on secondary roads that added to a truck mileage of 1.15 million truck miles per day.

As discussed in Section III-A-4 of the report and displayed on Figure 1-D-3, P_j's can be used to calculate a "boost factor" on the probability of apprehension calculated using the random site location method. This factor for Iowa is 1.41.

Since the single site probability of apprehension is proportional to the apprehension constant K_A we can boost K_A to 1.41 K_A to accommodate this effect.

Results of the Analysis

The theoretical value for P may now be calculated as

$$P = 1 - e^{-1.41\left[(5.56)(10)^{-4}\right]S}$$

where the effective staff size (S) is the product of the average staff for 1967 (56 men) and a (70%) factor to allow for vacations, sick leave, holidays, and escort duty S = 56(0.70) = 39.2 men or

$$P = 1 - e^{-1.41(5.56)(10)^{-4}(39.2)}$$

AVERAGE DAILY TRUCK TRAFFIC COUNT[1/]

Average Daily Truck Traffic Count	Midpoint	Section Length	Total Distance Traveled	Cumulative Distance Traveled
0 - 49.9	25	683.2	17,000	17,000
50 - 99.9	75	929.6	70,000	87,000
100 - 199	150	1,900.6	280,000	367,000
200 - 299	250	2,925.2	733,000	1,100,000
300 - 399	350	1,093.1	382,000	1,482,000
400 - 499	450	724.4	326,000	1,808,000
500 - 699	600	1,491.7	900,000	2,708,000
700 - 899	800	0.0	0	2,708,000
900 - 1,099	1,000	288.9	288,900	2,996,900
	TOTALS	10,036.0	2,996,900	

Miles traveled in a day - 2.997×10^6
Miles traveled in a year - 109.0×10^7

1/ 1965 Iowa Volume of Traffic on Primary Road System.

Figure 1-D-1 - Traffic Concentration on Iowa Primary Road System

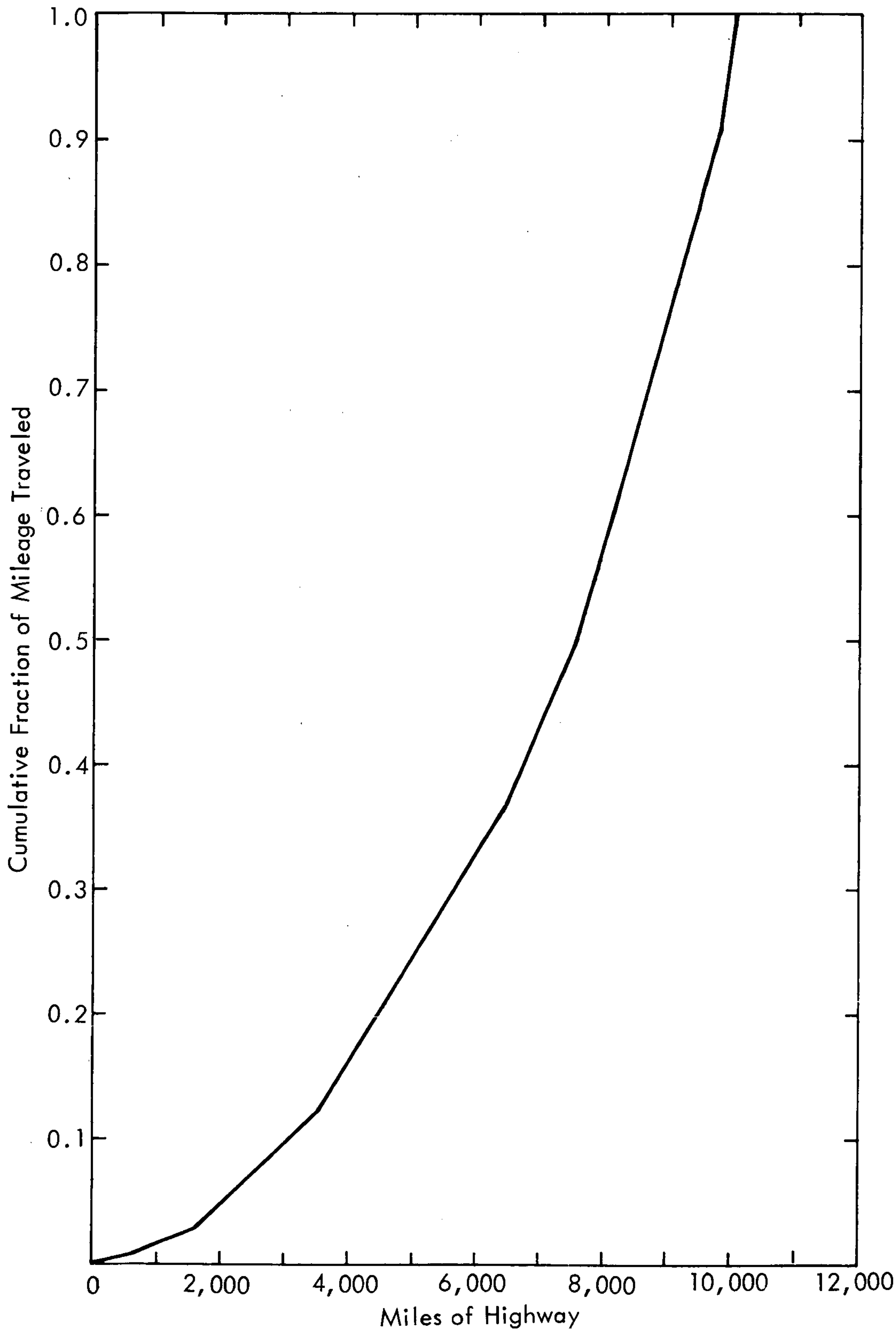

Figure 1-D-2, Cumulative Fraction of Mileage Traveled vs. Miles of Primary Road Used

PRIMARY

Mileage Region (J)	Cumulative Fraction of Miles Traveled	Fractional Increase = P_j	P_j^2
1) 0 - 999.9	0.0067	0.0067	0.000045
2) 1,000 - 1,999.9	0.0343	0.0267	0.001706
3) 2,000 - 2,999.9	0.0705	0.0362	0.001310
4) 3,000 - 3,999.9	0.117	0.0465	0.002162
5) 4,000 - 4,999.9	0.178	0.0610	0.003721
6) 5,000 - 5,999.9	0.239	0.0610	0.003721
7) 6,000 - 6,999.9	0.3110	0.0720	0.005702
8) 7,000 - 7,999.9	0.4160	0.1050	0.011025
9) 8,000 - 8,999.9	0.5530	0.1370	0.018769
10) 9,000 - 9,999.9	0.7230	0.1700	0.028900

PAVED SECONDARY

11) 10,000 - 10,999.9	0.7576	0.0346	0.001197
12) 11,000 - 11,999.9	0.7922	0.0346	0.001197
13) 12,000 - 12,999.9	0.8268	0.0346	0.001197
14) 13,000 - 13,999.9	0.8614	0.0346	0.001197
15) 14,000 - 14,999.9	0.8960	0.0346	0.001197
16) 15,000 - 15,999.9	0.9306	0.0346	0.001197
17) 16,000 - 16,999.9	0.9652	0.0346	0.001197
18) 17,000 - 17,999.9	0.9998	0.0346	0.001197

Cumulative Fraction Mileage	Sum P_j	Sum P_j^2
1.000	1.000	0.078258

Boost Factor = Number of 1,000 mile segments x sum $\left[P_j^2\right]$

Boost Factor = 18 x 0.078258 = 1.41

Figure 1-D-3 - Calculation of Boost Factor on Apprehension Probability Due to Scale Location Along High Traffic Density Roads

$$P = 1 - e^{-0.0550}$$

$$P = 1 - 0.9465$$

$$P = 0.0530$$

It should be noted that the apprehension rate method, which is a more direct method, yielded a value of 0.0062 or about 12 percent of the theoretical value based on the apprehension model.

The difference between the two figures was attributed to the "leakage" of information on scale schedules and other enforcement practices to violators. This leakage was assumed to be independent of slow changes in staff size, so that the apprehension rate calculated value for K_A would be insensitive to staff size. The leakage rate would change if ways could be found to prevent violators from finding out about enforcement practices.

APPENDIX 1, TAB E

AVERAGE FINE PER VIOLATING VEHICLE

Basic Information Sources

1. Tape file of 1967 Violation Records.

2. Sample of 1967 scale operation reports.

3. ISHC Summary of Traffic Weight Operations for the period July 1, 1966, through June 30, 1967.

Method of Analyzing Data

A sample was made of T.W.O.'s own 1967 scale operation reports. The instructions for carrying out the sample are at Appendix 4. The fines and/or registration increases (both referred to as a "fine" herein) for each day's operations in the sample were recorded and a breakdown between fixed and roving violations calculated. The average fine per violation was calculated by simply totaling the dollars collected and dividing by the total violations recorded in item 3.

A computer analysis of Item 1 (simply tabulating the number of violations committed for each violator apprehended)1/ indicated that there are 1.135 violations per violator. This fact can be used to determine the average amount paid by each violator as follows:

Results of Analysis

Mode of Apprehension	Percent of Apprehensions	Average Fine Per Violation	Average Fine Per Violator 2/
Fixed Sites	77.4	23.70	26.95
Roving Patrol	22.6	37.50	42.60
All	100.0	26.80	30.40

1/ The computer program is documented at Appendix 10.
2/ Taken equal to 1.135 times the average fine per violation.

APPENDIX 1, TAB F

DISTRIBUTION OF PAVEMENT TYPES AND COSTS IN IOWA
(Primary System) 1/

Basic Information Sources

The information on pavement types and costs in the Iowa primary road system was obtained from the Iowa State Highway Commission. The information was forwarded by Mr. Stephen E. Roberts, Research Engineer.

In a telephone discussion with Mr. Roberts on May 21, 1968, two pavement properties were confirmed. The bituminous treated soil aggregate is no longer used and current standards provide no structural coefficient. A structural coefficient of 0.20 was chosen based on the similarity to currently employed cold laid bituminous concrete base. Also, it was agreed to treat the asphalt treated crushed stone in pavement class 6 as asphalt treated base class I with a structural coefficient of 0.34.

A majority of the pavement courses are types in current use. The structural coefficients for these courses are obtained from "Guide for Primary and Interstate Road Pavement Design," Design Department, Soils, January 1968.

Data Processing and Application

The calculation of uncompensated pavement costs per violating vehicle mile requires the following inputs discussed here:

1. Pavement structure sufficiently well defined to calculate useful life in terms of reference axle applications.

2. The number of miles of each pavement structure (or the percent of total miles).

3. The cost of the pavement per lane mile.

1/ Distribution of Pavement Types and Costs for paved secondary roads is contained in Appendix 1, Tab M.

The pavement structures are well defined by the information provided by the ISHC. However, for class number 5 two thicknesses are indicated and for class 6 a range of thicknesses is indicated. For the class 6 pavements the extremes are used so that there are in the distributions two type 5 and two type 6 pavements. The percent miles within these classes are presented later in this section.

A range of costs is given for the class 5 and 6 pavements. The extreme values are used. The minimum value is associated with minimum thickness and maximum value is associated with maximum thickness.[1/]

Careful consideration has been given to portland cement concrete slabs covered with an asphalt concrete course. In effect, these pavements have two lives, first as a rigid pavement with pcc surface, and then as a flexible pavement with pcc base course. From this point of view these pavements could be considered as possessing a life which is the sum of the two separate lives and a total cost which is the sum of original pavement plus asphalt surfacing. In the same light one might project current pcc pavements as possessing the potential of second life as a flexible pavement. However, not all pcc pavements will be used since marginal soil support or altered alignment and grade requirements may reduce the desirability of the second life. Thus at any time the primary road system will contain these pavements in their first and second life states. The current state on the Iowa primary system is defined by the supplied data.

It appears that a pcc pavement (in first life) should be evaluated as a rigid pavement with one useful life. The associated pavement cost is for the pcc structure. A pavement which consists of an asphaltic concrete surface course over an old pcc slab should be treated as a single life flexible pavement. However, the cost applied here should cover only the expense of adding the asphaltic concrete surface course. This procedure accounts for the possibility of a second pavement life and proportions first and second lives according to the state of the highway system.

The cost of the asphaltic concrete surface course (over pcc base) is estimated from the data supplied by the ISHC. The current

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1/ It is recognized that factors other than thickness do affect pavement costs. However, for average correlations the chosen assignments seem most logical.

pcc slab pavements cost $100,000 to $120,000 per two lane mile. Currently an 8 in. pcc base with asphalt surface would cost $168,000 per two lane mile. The cost of the asphaltic surface course is taken as $68,000 per two lane mile or $34,000 per lane mile.1/

Results

Two pavement distributions are presented and used in the calculations of uncompensated costs per violation vehicle mile. The first distribution uses equal amounts of the two different pavement thicknesses in class numbers 5 and 6. This distribution emphasizes thick, high capacity pavements and tends to hold uncompensated costs to a minimum. The second distribution contains a higher proportion of the thinner pavements and is used in calculations which attempt to locate an upper bound on uncompensated costs per violating vehicle mile on the primary system. These distributions are given in Table 1-F-1 together with structure and cost values used.

The class 4 pavement with 9 in. pcc is not used in the current system. It has been carried through the calculations to indicate the second life potential of currently employed 9 in. pcc pavements.

1/ The figure used is the largest of the possible differences. However, it is a conservatively low estimate since resurfacing requires shoulder and entrance rework.

TABLE 1-F-1

PAVEMENT CHARACTERISTICS, COST AND DISTRIBUTION IN THE IOWA PRIMARY SYSTEM

Class No.	Structural Elements	Structural Coef.	Structural No.	Pavement Cost per lane mile($)	Decimal Percent of total Primary miles Distribution 1	Decimal Percent of total Primary miles Distribution 2
1	$\frac{1}{4}$ in. invert. penetration	0.20	0.89			
	7 in. rolled stone	0.12	(1.00 used)	17,500	0.03	0.03
2	2 in. asph. concrete	0.44	2.28			
	7 in. bitum. treat. soil aggr.	0.22	(2.3 used)	27,500	0.01	0.01
3	3 in. asph. concrete	0.44				
	8 in. rolled stone	0.12	2.38			
	2 in. soil aggr.	0.05	(2.4 used)	30,000	0.03	0.03
4	4 in. asph. concrete	0.44	4.96	34,000	0.41	0.41
	8 in. pcc	0.40	(5.00 used)	(for asph. resurface)		
4	4 in. asph. concrete	0.44	5.36	34,000	0.00	0.00
	9 in. pcc	0.40	(5.40 used)	(for asph. resurface)		
5	8 in. pcc	NA	NA	50,000	0.21	0.32
5	9 in. pcc	NA	NA	60,000	0.21	0.10
6	3 in. asph. concrete	0.44				
	10 in. asph. treat. crush. stone	0.34	5.02			
	6 in. soil aggregate	0.05	(5.00 used)	50,000	0.05	0.08
6	4.5 in. asph. concrete	0.44				
	14 in. asph. treat. crush stone	0.34	7.04			
	6 in. soil aggregate	0.05	(7.00 used)	60,000	0.05	0.02

APPENDIX 1, TAB G

PAVEMENT MAINTENANCE COST DATA
(Primary Roads)1/

Source of Information

The basic data are obtained from the Statistical and Financial Reference ISHC (66-67) and from the Summary, Maintenance Control Sections, ISHC 1966.

Data Requirements, Processing and Results

The data needed are the annual cost of pavement maintenance per lane mile as a function of pavement type. These specific costs are used in the calculation of uncompensated costs per violating vehicle mile. Since maintenance cost data are recorded per roadway mile, it is necessary to determine the average number of lanes per roadway mile. Then the annual specific cost can be found as

$$\text{Annual pavement maintenance cost per lane mile} = \frac{\text{Annual pavement maintenance cost per mile}}{\text{Average lanes per road mile}}$$

Table 1-G-1 presents the (1966) proportions of two- and four-lane pavements in the Iowa primary system.

Portland cement concrete and asphalt pavements constitute 91.9% of two-lane and 99.8% of four-lane pavements. Table 1-G-2 presents average lanes per road miles. Table 1-G-3 presents maintenance costs per mile.

1/ Pavement Maintenance Cost for Paved Secondary Roads are contained in Appendix 1, Tab M.

TABLE 1-G-1

MILES OF TWO- AND FOUR-LANE PRIMARY HIGHWAYS

Pavement	Miles Two-Lane	Miles Four-Lane
Portland Cement Concrete	4,303	417
Asphalt material over pcc	3,114	32
Asphalt	1,541	70
Other (extensions omitted)	790	1
	9,748	520

TABLE 1-G-2

AVERAGE LANES PER ROAD MILE

Pavement	Lanes Per Mile
Portland cement concrete	2.177
Asphalt material over pcc	2.020
Asphalt over flexible base	2.087
All asphalt	2.043

TABLE 1-G-3

ANNUAL SURFACE MAINTENANCE COSTS PER MILE

Pavement	Costs ($/mile) Routine	Special	Shoulders & Approaches	Total
Portland cement concrete	283	37	391	711
Asphalt material over pcc	171	24	396	591
Asphalt	313	266	226	805
Asphalt surface treated	1,269	272	116	1,657
Gravel or crushed stone	625	322	36	983
Extensions (maintained by cities)	891	44	22	957

Only the routine and special costs are appropriate to the calculation of uncompensated costs per violating vehicle mile. The sum of these two quantities is used together with average lanes per road mile to compute the costs in Table 1-G-4.

TABLE 1-G-4

PRIMARY ROADS ANNUAL SURFACE MAINTENANCE COSTS PER LANE MILE

Pavement	Annual Cost Per Lane Mile (dollars)
Portland cement concrete	147.0
Asphalt material over pcc	97.0
Asphalt over flexible base	277.0

APPENDIX 1, TAB H

DISTRIBUTION OF AXLE WEIGHTS FOR OVER-REGISTRATION AND OVERWEIGHT VEHICLES

Source of Information

Data used in the development of these distributions are taken from tables in the 1966 Iowa Analysis of Traffic Volume and Weight Study. The specific tables used are identified in subsequent descriptions of procedures. The combined distribution of over-registration and overweight vehicles uses the summonses issued by traffic weight officers, July 1, 1966, through June 30, 1967.

Required Data

The data discussed here are used in the calculation of uncompensated cost per violating vehicle mile. For each violating group (over-registration or overweight) the following information on each violating axle is required:

1. The axle configuration (single or tandem)
2. The legal weight
3. The actual weight (or amount over legal)
4. The average number of such violation axles per violating vehicle

Over-Registration Vehicles

The over-registration vehicles are those whose gross weights exceed the weight for which they are registered. They do not include vehicles which are over maximum allowable weight limits on a single axle, more than one axle, or on the entire vehicle.

In order to obtain the four required data items, it is necessary to determine the distribution of axle weights for commercial vehicles and to assign the over legal weight increment to the axles. The data from Table W-4, All Main Rural, are used. Also used are the implications of the "Summonses Issued by Traffic Weight Officers," July 1, 1966, through June 30, 1967.

The data on summonses show that for overload of registrations the increased registration per summons is \$23.78. This implies that the average registration increase is one increment or about 2,000 lb.[1] It follows that the average over legal (registration weight) amount is one-half the weight increment or 1,000 lb. This average is used here and is distributed over the axles of the violating vehicle.

Axle weight distributions are obtained from Table W-4, All Main Rural. Each type of vehicle is treated separately in initial data processing although in some cases similar types are grouped together. Where axle weights are over legal maximums the axles are dropped together with associated weights which constitute the entire vehicle set. (These eliminated axles and vehicles are over maximum weight limits as opposed to over-registration vehicles.) The values in the W-4 table are classified in weight ranges. The central value of the interval is used for all the axles in the indicated range.

The distribution of axle weights for each vehicle type is used as a guide for the distribution of the average 1,000 lb. over-registration load among the vehicle axles. These assignments are shown with other features of the data reduction in Table 1-H-1. Distributions of Legal and Actual Axle Weights for Over-Registration Vehicles by Vehicle Type.

As shown in Table 1-H-1 a large proportion of the panels and pickups are not capable of violating registration weight limits. This situation occurs when both axles are in the 2,000-lb. range.

The last column in Table 1-H-1 provides average numbers of the indicated axle per over-registration vehicle of the type. The next step uses these values to generate a distribution of axle types and weights applicable to the entire population of vehicles which are over their registration weights. The relative frequencies of over-registration violations by vehicle type are obtained from the summonses issued by traffic weight officers, July 1, 1966, through June 30, 1967.

The summarization of summonses by type indicates that approximately 0.218 of the violations are for, or involve, over-registration weight. (The value 0.218 consists of 0.183 for over-registration directly plus 0.035 from other violations which involve added registration fees.)

The distribution of commercial vehicles by type is obtained from the W-4 table, All Main Rural.

1/ At weights less than 24,000 lb. the weight and fee increments are not uniform. However, most weight increments are 2,000 lb. and the average fee increase for 2,000 lb. is approximately \$25.

TABLE 1-H-1

DISTRIBUTIONS OF LEGAL AND ACTUAL AXLE WEIGHTS FOR OVER-REGISTRATION VEHICLES BY VEHICLE TYPE

Vehicle Type	Vehicles Weighed	Axles Over Max. Weights	No. Vehicles Eligible for Over-Reg.	Distribution of Weight Increase	Axle, or Set, Type	Axle Wt. (legal) (lb.)	No. Axles Available for Over-Reg.	Over-Reg. Axle Wt.	Axles per Vehicle of Indicated Type
Panel &	1,306	0	293	300 lb. on front	Single	2,000	293	2,300	1.0
Pickup				700 lb. on rear	Single	5,000	293	5,700	1.0
2 Axle,	1,045	3 Singles	1,037	300 lb. on front	Single	2,000	205	2,300	0.198
4 & 6 Tire				700 lb. on rear	Single	5,000	832	5,300	0.802
					Single	5,000	484	5,700	0.467
					Single	7,500	143	8,200	0.138
					Single	10,000	251	10,700	0.242
					Single	14,000	137	14,700	0.132
					Single	17,000	22	17,700	0.021
3 Axle	390	14 Tandems	376	300 lb. on front single	Single	2,000	5	2,300	0.013
Single Unit				700 lb. on tandem	Single	5,000	180	5,300	0.479
					Single	7,500	42	7,800	0.112
					Single	10,000	107	10,300	0.285
					Single	14,000	42	14,300	0.112
					Tandem	4,000	4	4,700	0.011
					Tandem	9,000	153	9,700	0.407
					Tandem	15,000	70	15,700	0.186
					Tandem	21,000	35	21,700	0.093
					Tandem	27,000	95	27,700	0.253
					Tandem	31,000	19	31,700	0.051
Tractor	169	2 Singles	167	200 lb. on front axle	Single	5,000	165	5,200	0.988
Semitrailer				400 lb. on each of	Single	7,500	2	7,700	0.012
3 Axle				other singles	Single	7,500	55	7,900	0.329
					Single	10,000	150	10,400	0.898
					Single	14,000	102	14,400	0.611
					Single	17,000	27	17,400	0.162
Tractor	647	37 Singles	610	200 lb. on front single	Single	5,000	313	5,200	0.513
Semitrailer		27 Tandems		500 lb. on tandem	Single	7,500	180	7,700	0.295
4 Axle				300 lb. on rear single	Single	10,000	117	10,200	0.192
					Single	10,000	304	10,300	0.498
					Single	14,000	182	14,300	0.298
					Single	17,000	124	17,300	0.203
					Tandem	4,000	1	4,500	0.0016
					Tandem	9,000	170	9,500	0.279
					Tandem	15,000	137	15,500	0.225
					Tandem	21,000	141	21,500	0.231
					Tandem	27,000	124	27,500	0.203
					Tandem	31,000	37	31,500	0.0607

TABLE 1-H-1 (Continued)

Vehicle Type	Vehicles Weighed	Axles Over Max. Weights	No.Vehicles Eligible for Over-Reg.	Distribution of Weight Increase	Axle, or Set, Type	Axle Wt. (legal) (lb.)	No. Axles Available for Over-Reg.	Over-Reg. Axle Wt.	Axles per Vehicle of Indicated Type	
Tractor	2,110	384 Tandems	1,918	200 lb. on front single	Single	5,000	216	5,200	0.1126	
Semitrailer				400 lb. on tridems and	Single	7,500	333	7,700	0.1736	
5 Axle				tandems.(Total 1,000 lb.	Single	10,000	1,372	10,200	0.7153	
				incremental increase	Single	14,000	0		0	
				per vehicle.)	Tridem	17,000	3	17,400	0.0016	
					Tandem	9,000	623	9,400	0.3248	
						15,000	622	15,400	0.3243	
						21,000	609	21,400	0.3175	
						27,000	1,330	27,400	0.6934	
						31,000	649	31,400	0.3384	
Tractor	10	3 Tandems	8	100 lb. on front single	Sgl & Tdm	5,000	2	5,100	0.25	
Semitrailer				200 lb. on tridems	Sgl & Tdm	7,500	4	7,600	0.50	
6 Axle				350 lb. on tandems	Sgl & Tdm	10,000	2	10,100	0.25	
					Sgl & Tdm	10,000	5	10,200	0.625	
					Sgl & Tdm	14,000	3	14,200	0.375	
					Tandem	9,000	1	9,350	0.125	
					Tandem	15,000	4	15,350	0.500	
					Tandem	21,000	4	21,350	0.500	
					Tandem	27,000	7	27,350	0.875	
Truck & Trailer	152	12 Singles	144	For 3 Axle --	Single	2,000	42	2,200	0.2916	0.2884*
Combinations				200 lb. on front	Single	5,000	36	5,100	0.2500	0.2000
(6, 6 Axle Units				400 lb. on each	Single	5,000	59	5,200	0.4097	0.4855
Omitted)				other single.	Single	5,000	11	5,300	0.0764	0.0724
					Single	5,000	46	5,400	0.3194	0.2875
				For 4 Axle --	Single	7,500	9	7,600	0.0625	0.0500
				200 lb. on front	Single	7,500	13	7,700	0.0903	0.1548
				300 lb. on other	Single	7,500	7	7,800	0.0486	0.0461
				single and	Single	7,500	4	7,900	0.0278	0.0250
				500 lb. on tandem.	Single	10,000	110	10,200	0.7638	0.6492
					Single	10,000	18	10,300	0.1250	0.1185
				For 5 Axle --	Single	10,000	12	10,400	0.0833	0.0875
				200 lb. on front	Single	14,000	60	14,200	0.4166	0.3525
				200 lb. on other	Single	14,000	5	14,300	0.0347	0.0329
				singles & tridem	Single	14,000	12	14,400	0.0833	0.0750
				400 lb. on tandems.	Single	17,000	19	17,200	0.1319	0.1055
					Single	17,000	1	17,300	0.0069	0.0066
				For 5 Axle - 2 Trailer	Single	17,000	4	17,400	0.0278	0.0250
				100 lb. on front	Tandem	4,000	1	4,400	0.0069	0.0119
				200 lb. on each	Tandem	4,000	5	4,500	0.0347	0.0329
				other axle.	Tandem	9,000	15	9,400	0.1042	0.1786

TABLE 1-H-1 (Concluded)

Vehicle Type	Vehicles Weighed	Axles Over Max. Weights	No. Vehicles Eligible for Over-Reg.	Distribution of Weight Increase	Axle, or Set, Type	Axle Wt. (legal) (lb.)	No. Axles Available for Over-Reg.	Over-Reg. Axle Wt.	Axles per Vehicle of Indicated Type	
Truck & Trailer	152	12 Singles	144	For 5 Axle - 2 Trailer	Tandem	9,000	17	9,500	0.1180	0.1119
Combinations				100 lb. on front	Tandem	15,000	7	15,400	0.0486	0.0833
(6, 6 Axle Units				200 lb. on each other	Tandem	15,000	7	15,500	0.0486	0.0461
Omitted)				axle.	Tandem	21,000	2	21,400	0.0139	0.0238
(concluded)				(concluded)	Tandem	21,000	6	21,500	0.0417	0.0395
					Tandem	27,000	5	27,400	0.0347	0.0595
					Tandem	27,000	2	27,500	0.0139	0.0132

* In the original reduction the truck trailer units were treated separately according to vehicle configuration and then combined giving equal emphasis to each configuration. This procedure produced these values for number of axles per over-registration vehicles of the truck-trailer types.

Table 1-H-2 presents the factors discussed above and used in developing the weight factor for over-registration vehicles in a sample of 1,000 trucks of all types on primary roads.

The distribution of axle characteristics for over-registration vehicles is obtained by applying the weight factors for specific vehicle types to the over-registration axle characteristics for the vehicle type. This procedure entails multiplying the last columns in Tables 1-H-1 and 1-H-2. The results have been regrouped and several axles with nearly equal characteristics have been combined. The results are presented in Table 1-H-3.

Vehicles Over Maximum Legal Weights

Maximum legal limits can be exceeded on a single axle, a tandem set, an axle group or on the entire vehicle. In order to obtain the four required data items, it is necessary to determine the legal weight and overweight for each axle (or tandem set) which is in violation. The basic data are obtained from the Iowa W-6 tables, 1966. Here the data are given for individual, type identified, vehicles with violations in percent over state law. Violations are recorded for individual axles, axle groups and total weights.

The first step in processing the data is to determine the primary violation type for each vehicle which is indicated with more than one violation. Four overweight violation types are used, (1) single axle, (2) tandem set, (3) axle group (more than tandem), and (4) vehicle gross. In selection of a primary violation type the intent is to describe most accurately the extra legal axles, their legal loads, and their overage. The selection rules use the percent over state law values given in W-6. The rules are:

Single axle of tandem in violation--Treat as a single axle.

Single axle of tandem and tandem set in violation--Treat as tandem if tandem percent violation is largest.

Single(s) in group and group in violation--Use singles if there are two or more. Use the one violation single if it is twice or more in violation compared to group.

Group and gross in violation--Use the gross unless gross violation is one-half or less of group.

TABLE 1-H-2

DEVELOPMENT OF WEIGHT FACTORS FOR OVER-REGISTRATION VEHICLES

(1) Vehicle Type	(2) No. in Sample of 1,000 Trucks	(3) Violations per Vehicle of Specified Type	(4), (2)·(3) Violations in Specified Type per 1,000 Trucks of All Types	(5) Over-Reg. Violations per Total Violations	(6) Other Factor (= 1.0 if not indicated)	(7), (2)·(3)·(5)·(6) Over-Reg. Vehicles of Specified Type per 1,000 Trucks of All Types	(8), (7)/$\sum$(7) Weight Factor for Over-Reg. Vehicles of Specified Type
Panel & pickup	272	0.00261	0.71	0.218	293/1306*	0.0347	0.00790
2 axle	154	0.0238	3.665			0.7990	0.18200
3 axle	54	0.02385	1.288			0.2810	0.06400
2S1	31	0.02666	0.826			0.1512	0.03444
2S2	100	0.02833	2.833			0.6176	0.14068
3S2 & 3	364	0.0300	10.92			2.3806	0.54224
Truck + trailer(s) & others	25	0.02316	0.579			0.1262	0.02874
					$\sum$(7) =	4.3903	1.00000

* The factor 293/1306 accounts for the proportion of these light units which are capable of being over registration by having one axle above the 2,000 lb. classification.

TABLE 1-H-3

AXLE CHARACTERISTICS OF OVER-REGISTRATION VEHICLES ON PRIMARY ROADS

Single Axles			Tandem Sets		
Legal Weight (Kips)	Amount Over Legal Weight (Kips)	Average Number of Axles Per Over-Reg. Vehicle	Legal Weight (Kips)	Amount Over Legal Weight (Kips)	Average Number of Sets Per Over-Reg. Vehicle
2.000	0.200	0.0083	4.000	0.400	0.0003
	0.300	0.0447		0.500	0.0012
5.000	0.100	0.0057		0.700	0.0007
	0.200	0.1877	9.000	0.400	0.1812
	0.300	0.1787		0.500	0.0425
	0.400	0.0083		0.700	0.0261
	0.700	0.0929	15.000	0.400	0.1782
7.500	0.100	0.0014		0.500	0.0330
	0.200	0.1406		0.700	0.0119
	0.300	0.0085	21.000	0.400	0.1728
	0.400	0.0142		0.500	0.0336
	0.700	0.0251		0.700	0.0049
10.000	0.200	0.4335	27.000	0.400	0.3673
	0.300	0.0917		0.500	0.0289
	0.400	0.0390		0.700	0.0162
	0.700	0.0440	31.000	0.400	0.1835
14.000	0.200	0.0101		0.500	0.0085
	0.300	0.0500		0.700	0.0033
	0.400	0.0272			
	0.700	0.0239			
17.000	0.200	0.0030			
	0.300	0.0287			
	0.400	0.0082			
	0.700	0.0039			

Single and gross in violation--Use the gross unless gross violation is one-half or less of single.

Tandem and gross in violation--Use the gross unless gross violation is one-half or less of tandem.

Single, a separate tandem, and gross all in violation--Use the gross unless its percent violation is smaller than the other two taken individually.

After the selection of a primary violation, the primary violation within each vehicle type are listed and grouped in classes of 3 percent violation increments.* The center value of each class increment is assigned for all class members.

All violations are converted to single and tandem axle form. For gross vehicle weight violations the conversion uses the axle weight distributions found for specific vehicle types in the over-registration analysis. The legal weights distributed on the axles are for 3 axle trucks 45,000 lb., and for semi-trailer and trailer units 72,000 lb. The percent violation figures are used with these values to obtain gross overweight in pounds. The gross overweight is then divided among the axles according to the weight distributions previously determined.

The axle group violations are first converted to gross violations by retaining the percent violation but reducing the number of violating axles to one-half the vehicle axles. The conversion to singles and tandems then follows as a conversion from gross load violation.

Overweight data from Table W-6 1966 have been processed as described above. One data set was obtained from the tables for highway system (01) with added data on vehicle types 2D, 3A, 2S2 and truck-trailers from system (03). These data should be representative of weight violations on the heavily traveled, highly enforced part of the primary system. The axle characteristics are given in Table 1-H-4.

The weight factor for each vehicle type is found by procedure similar to that used for the over-registration vehicles. The distribution of types is obtained from the W-4 table, All Main Rural: the summonses issued by traffic weight officers indicate that 0.3143 of the summonses are

* The 3 percent class interval grouping are not used for the three-axle single units where the small sample (9) and distribution of values would be poorly represented by the 3 percent class intervals. Values within 3 percent of one another are grouped and averaged for the three-axle vehicles.

TABLE 1-H-4

DISTRIBUTIONS OF LEGAL AND ACTUAL AXLE WEIGHTS FOR OVER LEGAL WEIGHT VEHICLES BY VEHICLE TYPE
(For Highway Systems 01 and 03)

Vehicle Type	No. Vehicles in Sample	Axle Type	Legal Weight (lb.)	Amount Over Legal (lb.)	Number of Axles Per Overweight Vehicle of Specified Type
2A	4	Single	18,000	900	1.0
3A	9	Single	13,500	500	0.333
		Single	18,000	300	0.111
		Single	18,000	2,600	0.111
		Tandem	31,500	1,200	0.333
		Tandem	32,000	1,400	0.333
		Tandem	32,000	4,600	0.111
2S2 & 1	49	Single	18,000	300	0.3470
		Single	18,000	800	0.1021
		Single	18,000	1,350	0.1633
		Single	18,000	2,400	0.0204
		Tandem	32,000	500	0.1429
				1,450	0.0816
				2,400	0.1021
				3,400	0.0204
				5,300	0.0204
3S2	201	Single	14,000	200	0.1791
				650	0.1692
				1,100	0.0398
				1,500	0.0448
				1,950	0.0100
				2,400	0.0050
				3,200	0.0100

TABLE 1-H-4 (Concluded)

Vehicle Type	No. Vehicles in Sample	Axle Type	Legal Weight (lb.)	Amount Over Legal (lb.)	Number of Axles Per Overweight Vehicle of Specified Type
3S2 (Concluded)	201	Single	18,000	300	0.0945
				800	0.0348
				1,350	0.0299
				2,400	0.0100
				3,000	0.0050
		Tandem	29,000	450	0.3582
				1,300	0.3383
				2,200	0.0796
				3,000	0.0896
				3,900	0.0199
				4,800	0.0100
				6,500	0.0199
			32,000	500	0.1343
				1,450	0.0498
				2,400	0.0149
				3,400	0.0348
				4,300	0.0100
				5,300	0.0100
				6,200	0.0149
				8,200	0.0050*
				10,000	0.0050*
Truck-trailer combinations	8	Single	7,000	100	0.5000
				300	0.2500
				1,000	0.6250
				1,200	0.2500
			18,000	300	0.1250
		Tandem	29,000	400	0.5000
				1,300	0.2500
				3,900	0.6250
				4,800	0.2500

* These two values were omitted in the calculation of the final distribution which was subsequently used to obtain a minimum value for uncompensated life and maintenance use.

for overweight. The overweight violations from highway system 01 show 386 violations by 231 overweight vehicles. These data are dominated by the four-axle and more, semi- and truck-trailer units, and indicate that for these units there are approximately 0.60 weight violating vehicles per weight violation summons. These values are used to calculate weight factors as shown in Table 1-H-5.

The distribution of axle characteristics for overweight vehicles is obtained by applying the weight factors for specific vehicle types to the overweight axle characteristics for the vehicle type. This procedure entails multiplying the last columns in Tables 1-H-4 and 1-H-5. The results have been regrouped and axles with nearly equal characteristics have been combined. The results are presented in Table 1-H-6.

Over-Registration and Overweight Vehicles

A combined distribution of axle characteristics for over-registration and overweight vehicles can be formed from tables prepared separately for these two violation types. The combined distribution is obtained by using revised weight factors for each combination of vehicle type and violation type. The denominator of the revised weight factor is 4.3903 + 3.8112 = 8.2015, the number of violating vehicles, over-registration and overweight, in the sample of 1,000 trucks of all types. The numerators of the weight factors are over-registration or overweight vehicles of the specified type per 1,000 trucks of all types. These latter quantities are listed in column 7 of Tables 1-H-2 and 1-H-5.

Vehicles Over Maximum Legal Weight Limits on System 31

An additional distribution is obtained to be used in setting an upper bound for uncompensated life and maintenance use per overweight violating vehicle. The data in Table W-6 for highway system 31 were chosen. This highway system contains roads which are being replaced by interstates so that current traffic runs partially on older roads which may be under-designed for current usage. In addition, the W-6 data for this system are obtained on a road which currently has no permanent enforcement weight station.

The processing of data from the W-6 table parallels that described previously except that the weight factor for vehicle type is derived directly from the overweight data sample. (There is no attempt or need in this case to obtain violator frequency for a 1,000 truck sample of all types.) The results are presented in Table 1-H-7 and 1-H-8.

TABLE 1-H-5

DEVELOPMENT OF WEIGHT FACTORS FOR OVERWEIGHT VEHICLES

(1) Vehicle Type	(2) No. in 1,000 Truck Sample	(3) Violations Per Vehicle Of Specified Type	(4), (2).(3) Violations (Total) in Specified Type Per 1,000 Trucks of All Types	(5) Overweight Violations Per Total Violations	(6) Weight Violating Vehicle Per Overweight Violation	(7), (2).(3).(5).(6) Overweight Vehicles of Specified Type Per 1,000 Trucks of All Types	(8), $(7)/\sum(7)$ Weight Factor For Overweight Vehicles Of Specified Type
Panel & pickup	272	0.00261	0.71	0.0000 (by inference)		0.0000*	0.0000
2 axle	154	0.02380	3.665	0.1210 (by inference)	1.00	0.4440*	0.1165
3 axle	54	0.02385	1.288	0.3143**	1.00	0.4048	0.1062
2S1	31	0.02666	0.8264		1.00	0.2597	0.0681
2S2	100	0.02833	2.8330		0.60	0.5342	0.1402
3S2 & 3	364	0.0300	10.9200		0.60	2.0593	0.5403
Truck + trailer(s) & others	25	0.02316	0.5790		0.60	0.1092	0.0287
					$\sum(7) =$	3.8112	1.0000

* Indicated by the ratio of overweight to legal weight axles for this type in the W-4 Table, All Main Rural.
** Ratio is overweight to total summonses.

TABLE 1-H-6

AXLE CHARACTERISTICS OF OVERWEIGHT VEHICLES ON PRIMARY ROADS
(Systems 01 and 03)

Single Axles			Tandem Sets		
Legal Weight (Kips)	Amount Over Legal Weight (Kips)	Average Number of Axles Per Overweight Vehicle	Legal Weight (Kips)	Amount Over Legal Weight (Kips)	Average Number of Sets Per Overweight Vehicle
7.000	0.100	0.0143	29.000	0.400	0.2079
	0.300	0.0072		1.300	0.1900
	1.000	0.0179		2.200	0.0430
	1.200	0.0072		3.000	0.0484
13.000	0.500	0.0354		3.900	0.0287
14.000	0.200	0.0968		4.800	0.0126
	0.650	0.0914		6.500	0.0108
	1.100	0.0215	32.000	0.500	0.0926
	1.500	0.0242		1.200	0.0354
	1.950	0.0054		1.400	0.0737
	2.400	0.0027		2.400	0.0224
	3.200	0.0054		3.400	0.0217
18.000	0.300	0.1151		4.300	0.0054
	0.800	0.0162		4.600	0.0118
	0.900	0.1977		5.300	0.0083
	1.300	0.0390		6.200	0.0081
	2.400	0.0083		8.200	0.0027*
	2.600	0.0118		10.000	0.0027*
	3.000	0.0027			

* These two contributions were omitted in calculations designed to provide a minimum value for uncompensated life and maintenance use.

TABLE 1-H-7

DISTRIBUTIONS OF LEGAL AND ACTUAL AXLE WEIGHTS FOR OVER LEGAL WEIGHT VEHICLES BY VEHICLE TYPE
(For Highway System 31)

Vehicle Type	Number of Vehicles	Axle Type	Number of Axles or Sets	Legal Weight (Lb.)	Amount Over Legal (Lb.)	Axles per Violating Vehicle of Specified Type
3A	3	Tandem	2	32,000	2,400	0.6666
			1		5,300	0.3333
2S2 & 1	7	Single	4	18,000	300	0.5714
		Tandem	1	32,000	3,400	0.1429
			1		4,300	0.1429
			1		5,300	0.1429
3S2 & 2-2	73	Single	12	14,000	200	0.1644
			10		600	0.1370
			11		1,100	0.1507
			5		1,500	0.0685
			4		1,900	0.0548
			2		2,400	0.0274
			1		2,800	0.0137
			1		5,400	0.0137
			1	18,000	1,350	0.0137
			1		1,900	0.0137
			1		2,400	0.0137
			1		3,500	0.0137
		Tandem	24	29,000	500	0.3288
			20		1,300	0.2740
			22		2,200	0.3014
			10		3,100	0.1370
			8		3,900	0.1096
			4		4,800	0.0548
			2		5,600	0.0274
			2		10,800	0.0274
			4	32,000	500	0.0548
			2		1,450	0.0274
			2		2,400	0.0274
			2		3,400	0.0274
			3		4,300	0.0411
			2		5,300	0.0274
			2		7,200	0.0274
			2		9,100	0.0274

TABLE 1-H-8

AXLE CHARACTERISTICS OF OVERWEIGHT VEHICLES ON PRIMARY ROADS

(For Highway System 31)

Single Axles			Tandem Sets		
Legal Weight (Kips)	Amount Over Legal Weight (Kips)	Average Number of Axles Per Overweight Vehicle	Legal Weight (Kips)	Amount Over Legal Weight (Kips)	Average Number of Axles per Overweight Vehicle
14.000	0.200	0.1446	29.000	0.500	0.2892
	0.600	0.1205		1.300	0.2410
	1.100	0.1325		2.200	0.2651
	1.500	0.0602		3.100	0.1205
	1.900	0.0482		3.900	0.0964
	2.400	0.0241		4.800	0.0482
	2.800	0.0120		5.600	0.0241
	5.400	0.0120		10.800	0.0241
18.000	0.300	0.0482	32.000	0.500	0.0482
	1.350	0.0120		1.450	0.0241
	1.900	0.0120		2.400	0.0482
	2.400	0.0120		3.400	0.0361
	3.500	0.0120		4.300	0.0482
				5.300	0.0482
				7.200	0.0241
				9.100	0.0241

APPENDIX 1, TAB I

UNCOMPENSATED ROAD LIFE AND MAINTENANCE USAGE

Source of Basic Analytical Relationships

The basic analytical relationships are taken from Highway Research Board Special Report 61E, "The AASHO Road Test, Report 5, Pavement Research," and from two design guides. The design guides, prepared by the AASHO Committee on Design, are: "AASHO Interim Guide for the Design of Rigid Pavement Structures," April, 1962, and "AASHO Interim Guide for the Design of Flexible Pavement Structures," October 12, 1961.

Flexible Pavement Life Use

The relation between pavement condition, pavement structures, and loads carried is given by

$$W = \frac{1}{R}\left(\frac{C_0-p}{C_0-C_1}\right)^{1/\beta}\rho ,$$

where

W = Number of axle applications

R = Regional factor (to account for environment and environment-soil interactions)

C_0 = Initial serviceability index (new pavement value)

= 4.2 in AASHO tests, a value applicable to Iowa pavements

p = Present serviceability index (after the W axle applications)

C_1 = Final serviceability index in AASHO tests

= 1.5

β and ρ are functions which contain the axle configurations, axle weight, and the pavement structural property.

$$\beta = 0.4 + \frac{0.081(L_1+L_2)^{3.23}}{(S_n+1)^{5.19}L_2^{3.23}} \quad , \text{ and}$$

$$\rho = \frac{10^{5.93}(S_n+1)^{9.36}L_2^{4.33}}{(L_1+L_2)^{4.79}} \quad ,$$

where

L_1 = Load carried by a single axle or tandem pair (kips)*

L_2 = 1.0 for single axle; = 2.0 for tandem pair

S_n = Structural number, a property of the pavement given by

$$S_n = A_1D_1 + A_2D_2 + A_3D_3$$

D_1, D_2, D_3 = Thickness in inches of the surface course, base course, and subbase, respectively

A_1, A_2, A_3 = Coefficients of load carrying capacities of the courses.

* 1.0 kip = 1000. pounds.

Total Life

When S_n is given or calculated the total useful life of a pavement is calculated using the equation for W. In this calculation (p) is set equal to 2.5, the final value for primary roads. According to Iowa practice the regional factor R is set equal to 3.0 for Classes I, II and III, and 2.0 for Class IV. (The value $R = 3.0$ has been used in calculations for this report.) The axle configuration and load are set equal to reference values, $L_1 = 18.0$ and $L_2 = 1.0$. The resulting value of W is written W_{tr} and is the number of reference axle load applications which the pavement should sustain during its useful life.

Reference Axle Equivalences

With the total pavement life available in terms of reference axle applications it is necessary to define life usage by every axle in these same units, i.e., reference axle applications. The equivalence value sought is the number of reference axle applications which would use the same amount of pavement life as one application of the nonreference axle. It is given by

$$W_{rx} = \frac{W_{tr}}{W_{xr}} = \frac{\rho_r}{\rho_x}\left(\frac{4.2-2.5}{4.2-1.5}\right)^{\left(\frac{1}{\beta_r} - \frac{1}{\beta_x}\right)}$$

Here the subscripts r and x on ρ and β indicate that they are evaluated with the reference axle values and nonreference values respectively.

The value W_{rx} is a measure of life use by the nonreference axle in terms of reference axle applications. The equation for W_{rx} is applied twice for each violation axle. In one calculation the legal weight of the axle is used; in the second calculation the actual weight is used. The difference of these two values is the uncompensated life use by the violation axle, in units of reference axle applications.

Rigid Pavement Life Use

The relations for the rigid pavement and their applications are similar to the flexible pavement case. The fundamental relation is

$$W = \rho \left(\frac{C_0 - p}{C_0 - C_1} \right)^{1/\beta} \left(\frac{S_c' \sigma}{S_c \sigma'} \right)^{(4.22 - 0.32 p_t)} ,$$

where as before

W = Number of axle applications

C_0 = Initial serviceability index

- (but = 4.5 for rigid pavements)

C_1 = Terminal serviceability index in AASHO tests

= 1.5

p = Present serviceability index (after W applications)

The β and ρ have generally the same forms but different coefficients and exponents.

$$\beta = 1.0 + \frac{3.63(L_1 + L_2)^{5.20}}{(D_2 + 1)^{8.46} L_2^{3.52}}$$

$$\rho = \frac{10^{5.85}(D_2 + 1)^{7.35} L_2^{3.28}}{(L_1 + L_2)^{4.62}}$$

L_1 = Axle load or tandem set load (kips)

L_2 = 1.0 for single axle; = 2.0 tandem set

D_2 = Concrete slab thickness (inches)

The factor with S_c, S_c' σ, and σ' is used to compensate for material and soil differences between the analyzed pavement and the AASHO test pavements.

p_t = Terminal value of serviceability index, = 2.5 for Iowa primary roads

S_c = Modulus of rupture for concrete (28 day) in the AASHO test (psi)

= 690 psi

S_c' = Modulus of rupture for concrete (28 day) in analyzed pavement (psi)

$$\frac{\sigma}{\sigma'} = \frac{\left\{\left[\frac{(E/k)D_2^3}{12(1-\mu^2)}\right]^{1/4} - a_1\right\}(E'/k')^{1/4}}{\left\{\left[\frac{(E'/k')D_2^3}{12(1-\mu^2)}\right]^{1/4} - a_1\right\}(E/k)^{1/4}},$$

where

E = Modulus of elasticity for concrete in AASHO test

= 4.2×10^6 psi

E' = Modulus of elasticity for concrete in analyzed pavement (psi)

μ = Poisson's ratio = 0.2

a_1 = 10.0 inches, a load distribution measure

k = The soil support value in the AASHO test (psi/in)

= 60.0 psi/in

k' = Soil support value for analyzed pavement (psi/in)

Total Life

Total pavement life is calculated using the expression for W with L_1 = 18.0 and L_2 = 1.0, and p = 2.5. The result is denoted as W_{tr} reference axle applications.

Reference Axle Equivalences

As in the case with flexible pavement calculations the life used by a nonreference axle is calculated in terms of equivalent reference axle applications. The life use by axle sub x is

$$W_{rx} = \frac{W_{tr}}{W_{tx}} = \frac{\rho_r}{\rho_x}\left(\frac{4.5-2.5}{4.5-1.5}\right)^{(1/\beta_r - 1/\beta_x)},$$

where the subscripts r and x indicate the use of reference and non-reference axle properties.

The equation for W_{rx} is applied twice for each violation axle. The actual weight is used in one calculation, the legal weight in the other. The difference in W_{rx} values is the uncompensated life use in the units (reference axle applications).

Load - Maintenance Relations

There are no explicit data which identify the relations between loads and pavement maintenance costs. There are, however, some data which provide a basis for estimating these relationships. In the AASHO road tests the pavements were inspected and their states recorded at closely spaced intervals. The history of pavement states and the history of load passages were used to derive relations between cracking and load applications. Cracking is probably the best single measure of pavement maintenance requirements. It is used here to establish the uncompensated maintenance use per lane mile which arises from the passage of an over legal axle load.

Flexible Pavement Cracking

The AASHO road test results indicated that the first appearance of class two cracking was related to pavement design, loads, and load applications. The class two cracking is likely to require patching or sealing and is considered here as an indication of the design-load-maintenance relationship.

The relation has the form

$$W_c = \frac{A_0(a_1D_1+a_2D_2+a_3D_3+a_4)^{A_1} L_2^{A_3}}{(L_1+L_2)^{A_2}} ,$$

where

W_c = Number of load applications to first appearance of class two cracking.

(weighted to smooth seasonal variations)

L_1 = Load carried by single axle or by tandem pair (kips)

L_2 = 1.0 for single axle, = 2.0 for tandem pair

D_1 = Surfacing thickness (inches)

D_2 = Base thickness (inches)

D_3 = Subbase thickness (inches)

The capital and lower case A's were chosen by AASHO investigators to fit the test results.

Table 1-I-1 presents the values of the coefficients.

TABLE 1-I-1

COEFFICIENTS FOR FLEXIBLE PAVEMENT CRACKING

Coefficient	Value
A_0	0.3048×10^5
A_1	7.275
A_2	3.136
A_3	2.947
a_1	0.33
a_2	0.10
a_3	0.08
a_4	1.0

The number of reference load applications to class two cracking forms the basis for calculating maintenance use. This value is obtained using the equation for W_c with $L_1 = 18.0$ and $L_2 = 1.0$. The result is denoted W_{rm}. For a nonreference axle the equivalent use of maintenance is obtained as the ratio W_{rmx}.

$$W_{rmx} = \frac{W_{rm}}{W_{xm}} = \left(\frac{1.0}{L_{2x}}\right)^{2.947}\left(\frac{L_{1x}+L_{2x}}{19.0}\right)^{3.136}$$

where

L_{1x} = Nonreference axle load (kips)

L_{2x} = 1.0 for single nonreference axle

= 2.0 for tandem nonreference axle set,

and the reference values 18.0 and 1.0 have been inserted together with the exponents. W_{rmx} is the maintenance use by the nonreference axle x in terms of equivalent applications of reference axles. (Notice that the parameters relating to the flexible pavement structure cancel out.)

Application to Maintenance Use

The equation for W_{rmx} is applied twice for each violation axle. In one calculation the legal load is used; in the second calculation the actual load is used. The difference of the resulting values is the uncompensated maintenance use in reference axle applications.

Rigid Pavement Cracking

The AASHO road test results provide the following relation between cracking and load applications for rigid pavements.

$$C' = \frac{A_0 L_1^{A_1} W^2}{D_2^{A_2}}$$

where

C' = cracking index, linear feet of cracks per 1000 square feet of pavement.*

L_1 = Axle load or tandem set load (kips)

W = Number of applications

* It was noted by the AASHO investigators that $C' = 100$ constituted a substantial amount of structural deterioration.

D_2 = Pavement thickness (inches)

A_0, A_1, and A_2 = coefficients dependent on the pavement reinforcement and axle configuration.

The relation can be written

$$W = \left[\frac{C' D_2^{A_2}}{A_0 L_1^{A_1}} \right]^{1/2} .$$

We chose a single axle load of 18.0 kips as a reference and any convenient amount of cracking, C' , to form a basis for maintenance use. This basis is a number of reference axle applications given by

$$W_{rm} = \left[\frac{C' D_2^{A_{2r}}}{A_{0r} L_{1r}^{A_{1r}}} \right]^{1/2} ,$$

where the subscript r is used to indicate that the values and exponents are selected for the single axle, reference load.

The application of a nonreference axle will promote cracking equivalent to some applications of the reference axle. We interpret this as equivalent maintenance use. The equivalence is given by

$$W_{rmx} = \frac{W_{rm}}{W_{xm}} = D_2^{\left(\frac{A_{2r} - A_{2x}}{2}\right)} \left(\frac{A_{0x}}{A_{0r}}\right)^{1/2} \frac{L_{1x}^{(A_{1x}/2)}}{L_{1r}^{(A_{1r}/2)}} .$$

This is the maintenance use by nonreference axle x in terms of equivalent reference axle applications. The coefficients and exponents depend on pavement and axle configuration as shown in Table 1-I-2.

TABLE 1-I-2

RIGID PAVEMENT CRACKING COEFFICIENTS AND EXPONENTS

Pavement	Axle Configuration	$A_0^{1/2}$	$\frac{A_1}{2}$	$\frac{A_2}{2}$
nonreinforced	single	1.995×10^{-5}	2.62	4.84
nonreinforced	tandem	2.455×10^{-7}	4.38	6.33
reinforced	single	1.122×10^{-5}	2.30	3.57
reinforced	tandem	4.266×10^{-7}	3.13	3.96

Application to Maintenance Use

The equation for W_{rmx} is applied twice for each violation axle. In one calculation the legal load is used; in the second calculation the actual load is used. The difference of the resulting values is the uncompensated maintenance use in reference axle applications.

APPENDIX 1, TAB J

AVERAGE LOSS PREVENTED FOR DETERRED REGISTRATION VIOLATORS

Basic Information Sources

1. ISHC: "Summary of Traffic Weight Operations for the Period July 1, 1966, through June 30, 1967."

2. ISHC Planning Division: Motor Vehicle Data.

3. Appendix 1, Tab B of this report.

Method of Analyzing Data

Item 3 indicated that $20.00(10)^6$ truck trips occurred in Iowa in 1968. Item 2 indicated that there were 356,000 vehicles registered in Iowa in 1968.

We have estimated that 48,000 panels and pickups only use the municipal system. Therefore, 307,815 vehicles use the rural system.1/ This implies that $20.00(10)^6/307{,}815 = 65.0$ trips per year were taken by the "average" vehicle.2/

Item 1 indicated that registration violations3/ brought in $100,161 for 9,824 violations or $10.20 per violation. Once a violator is apprehended he must pay the registration increase and cannot pay the increase twice. Hence, the most Iowa can lose from such a violation if it goes unapprehended for a full year is $10.20. We prorate this over the 65.0 trips to obtain an average loss per trip of $10.20/65.0 = $0.157 per trip.

Results of Analysis

Average loss for Iowa per trip of a registration violator = $0.157.

1/ This estimate was obtained by dividing the total rural mileage for panels and pickups by the average annual rural mileage per vehicle.
2/ These are 112.3 mile "average" trips. Shorter trips are more frequent.
3/ As measured by apprehended registration violators.

APPENDIX 1, TAB K

FIXED AND VARIABLE COSTS OF ENFORCEMENT

Basic Information Sources

1. ISHC: "Budget Status Report," July 1, 1966 to July 14, 1967.

2. ISHC: "Table of Organization and Manning-Traffic Weight Operation," dated January 11, 1968.

Method of Data Analysis

Item 2 provided information on the number of men on the T.W.O. staff and their salaries. This was developed into an average salary figure.

Item 1 provided information on the other types of expenditures necessary to support T.W.O. These were divided according to whether they would vary with staff, i.e., whether they were fixed or variable.

Some costs were considered semi-fixed, i.e., would increase in steps once manpower passed certain fixed levels. These are associated with hiring more administrative personnel.

The calculations and assumptions are displayed in Figure 1-K-1.

Result of Analysis

Shown in Figure 1-K-1, and in Section III-A-3 of the Report.

VARIABLE OPERATING COSTS (Thousands)

Salary (1967 average salary and benefits for enforcement officers):1/	$6.813
Vehicle Operation ($104,284 per year (1967)); per enforcement officer, $104,284/56):	1.862
Miscellaneous Budget (variable portion):	0.228
Total Variable Operating Cost per Enforcement Officer	$8.903

FIXED OR SEMI-VARIABLE OPERATING COSTS (Thousands)

Enforcement Level		20-49		Current 50-90		91-150		151-210
Administrative Salary:2/								
Director	(1)	$10.70	(1)	$10.70	(1)	$10.70	(1)	$ 10.70
Assistant Director	(1)	11.00	(1)	11.00	(2)	20.60	(2)	20.60
Stenographer	(1)	4.63	(2)	9.26	(2)	9.26	(2)	9.26
Clerk	(2)	8.00	(2)	8.00	(3)	12.00	(4)	16.00
Mechanic	(1)	7.86	(1)	7.86	(1)	7.86	(2)	15.72
Total Administrative Salary		$42.19		$46.82		$60.42		$72.28
Miscellaneous Budget		12.79		12.79		12.79		12.79
Total Fixed and Semi-Variable Operating Costs		$54.98		$59.61		$73.21		$85.07

1/ Average 1967 enforcement level = 56, final staff level 1967 = 64.

2/ Numbers in parentheses indicate number of administrative personnel in each capacity.

Figure 1-K-1 - Variable and Fixed Operating Costs of T.W.O.

APPENDIX 1, TAB L

AVERAGE LOSS PREVENTED FOR DETERRED OVERWEIGHT OR OVERSIZED VIOLATORS

Basic Information Sources

1. Table 1, Section III-B-10 of this report. ?

2. Appendix 1, Tab A of this report.

3. ISHC T.W.O.: "Summonses Issued by Traffic Officers, July 1, 1966,through June 30, 1967."

Method of Data Analysis

Item 1 indicates that overweight violators cause \$0.00809 worth of uncompensated wear per mile of travel. Item 2 indicates that violators travel on the average 108. miles. Hence overweight violators cause 0.00809(108.) = \$0.874 damage per trip in violation.

Item 3 indicates that oversize violators which cause no damage make up 20.2 percent of both oversize and overweight violators taken together.

Hence the weighted average damage for overweight and oversize violators is:

$$0.874(0.798) + 0(0.202) = \$0.697$$

Results of Analysis

Average loss for Iowa per trip of an overweight or oversized violator = \$0.697.

Use of Results

The average dollar value per trip for increased compliance, L_V , can now be calculated as the weighted average of the average dollar value for uncompensated road wear and the average value for increased registration fees collected. L_v may be calculated from the following formula:

$$L_v = f_{vw}L_{vw} + f_{vl}L_{vl}$$

where

f_{vw} = fraction of overweight violators
= 0.394[1/]

f_{vl} = fraction of violators committing registration violations
= 0.606[1/]

L_{vw} = Loss per violator due to uncompensated road wear
= \$0.697[2/]

L_{vl} = Loss per violator due to withheld registration fees
= \$0.157[3/]

therefore

$$L_v = (0.394)(\$0.697) + (0.606)(\$0.157) = \$0.370$$

The average dollar value for increased compliance per trip = \$0.37.

1/ Appendix 1, Tab C.
2/ Appendix 1, Tab L.
3/ Appendix 1, Tab J.

APPENDIX 1, TAB M

CALCULATIONS FOR UNCOMPENSATED COSTS ON SECONDARY ROADS

General

These calculations require the same types of information and computations as are required for the primary roads. The same road life and maintenance use relations are applied here. This Tab M presents the sources, logic and procedures used for the paved secondary roads.

Distribution of Road Types and Costs

A representative sample of secondary road pavements and the general characteristics of the pavements were supplied by Mr. Eugene Mills, ISHC, in telephone calls. General pavement characteristics are shown in Table 1-M-1.

The structural characteristics for the flexible pavements are assigned and calculated as shown in Table 1-M-2. The nearly equal types are combined with rounded structural numbers as will be shown in Table 1-M-3.

Pavement Costs

Guidance in pavement cost is obtained from "Secondary Structures Cost Assignment," Table 1 and 2. These tables refer to

Trunk Class Codes 1, 2, 3, 4, 5, and 6

Feeder Class Codes 1, 2, 3, and 4

Local Class Codes 1, 2, 3, and 4

The average cost for new pavement construction per two-lane mile varies from $37,000 to $42,000. The average for all four cost areas is $39,750. Using comparable primary road pavement costs a range of costs per lane mile is selected as $17,000 to $26,400, as will be shown in Table 1-M-3.

TABLE 1-M-1

SECONDARY ROAD PAVEMENT CHARACTERISTICS

Code	Type	Base + Surface	Surface
44	asphalt	less than 8 in.	road or plant mix $\geq$ 1.0 in.
46	"	"	plant mix asphalt $\geq$ 1.0 in.
47	"	"	plant mix asphalt $<$ 1.0 in.
48	"	"	inverted penetration $\geq$ 1.0 in.
54	"	greater than or equal to 8 in.	road or plant mix $\geq$ 1.0 in.
55	pcc	–	6 in. or 7 in. with no reinforcing or sub base
56	asphalt	greater than or equal to 8 in.	plant mix asphalt $\geq$ 1.0 in.
57	"	"	plant mix asphalt $<$ 1.0 in.
58	"	"	inverted penetration $\geq$ 1.0 in.

TABLE 1-M-2

ESTIMATED TYPICAL STRUCTURAL NUMBERS FOR PAVED, FLEXIBLE SECONDARY ROADS

Code No.	Structure	Coefficient	Contribution to Structural No.	Structural Number
44 & 46	2 in. asph. conc.	0.44	0.88	
	4 in. crushed stone	0.12	0.48	
	3 in. soil aggr.	0.05	0.15	1.51
47	$\frac{1}{2}$ in. asph. conc.	0.44	0.22	
	4 in. crushed stone	0.12	0.48	
	3 in. soil aggr.	0.05	0.15	0.85
48	$1\frac{1}{2}$ in. invert. pene.	0.20	0.30	
	4 in. crushed stone	0.12	0.48	
	3 in. soil aggr.	0.05	0.15	0.93
54	$2\frac{1}{2}$ in. asph. conc.	0.44	1.11	
	6 in. asph. tr. base II	0.23	1.38	
	4 in. soil aggr.	0.05	0.20	2.68
56	$2\frac{1}{2}$ in. asph. conc.	0.44	1.10	
	6 in. crushed stone	0.12	0.72	
	4 in. soil aggr.	0.05	0.20	2.02
57	$\frac{1}{2}$ in. asph. conc.	0.44	0.22	
	8 in. crushed stone	0.12	0.96	
	4 in. soil aggr.	0.05	0.20	1.38
58	$1\frac{1}{2}$ in. invert. pene.	0.20	0.30	
	7 in. crushed stone	0.12	0.84	
	4 in. soil aggr.	0.05	0.20	1.34

Table 7 in the above reference provides estimated annual maintenance costs per mile as follows for Trunk and Feeder secondary roads.

Surface Type	Cost per Mile ($)
1 paved	325
2 paved	660
3 dustless	790

On primary roads over one-half of surface maintenance costs go to pavement surface work. On secondary roads the fraction should be somewhat larger. Seventy-five percent is chosen so that pavement maintenance costs per lane mile year are taken as:

Pavement	Cost per Lane Mile Year
pcc	122
asphalt	247

Table 1-M-3 summarizes the secondary road pavements, extent and costs.

TABLE 1-M-3

PAVED SECONDARY ROAD PAVEMENTS AND COSTS

Code No.	Thickness or Structural No.	Road Miles	Fraction of Miles	Pavement Costs ($) Construction Lane/mile	Maintenance Lane/(Mile Year)
47 & 48	SN = 1.0	678	0.0859	17,000	247
44,46,57, & 58	SN = 1.5	1,355	0.1716	18,000	247
56	SN = 2.0	4,480	0.5674	19,000	247
54	SN = 2.7	35	0.0044	20,000	247
55	T = 6 in.	677	0.0858	25,000	122
55	T = 7 in.	670	0.0849	26,400	122

With the pavement construction costs in Table 1-M-3 the average cost per lane mile is $19,800, in agreement with the data from secondary structures cost assignment.

Distribution of Axle Weights

The axle weight data for the primary roads are modified to account for the different vehicle mix which is observed on the secondary roads. Data from three sources are used to establish the distribution of vehicle types on paved secondary roads. The sources are:

1. "Creston Origin and Destination Traffic Report," Iowa, 1961 (Data from external station on FAS 807 South, for July average weekday traffic, Table 3-1)

2. "Buena Vista Country Paved Secondary Road Origin and Destination Traffic Study," August 1961. (From the table, Vehicle Classification, Traffic passing through Buena Vista County Interview Stations, 1961 August average weekday traffic).

3. Telephone conversations with Mr. Eugene Mills, ISHC (From a traffic survey with two stations in Polk County and one station in Stafford County. These were only counts over a 24-hour period.

Table 1-M-4 presents the data from these three sources. The commercial vehicle counts are extracted and compared with data from the primary system in Table 1-M-5. This latter table shows a substantial difference in the primary and secondary road traffic. On the primary system the single units constitute 48 percent of the total commercial; on the secondary system the single units constitute 91 percent of the total commercial. The distribution (from W-4 table) for primary roads is modified to the secondary distribution as shown in Table 1-M-6. The distribution by type is then used to develop weight factors for overweight vehicles on paved secondary roads as shown in Table 1-M-7. These weight factors are then applied to the overweight axle characteristics for highway systems 01 and 03. The results are presented in Table 1-M-8.

TABLE 1-M-4

VEHICLE TYPE DISTRIBUTION ON PAVED SECONDARY ROADS

	Source 1		Source 2		Source 3	
	No. Vehicles	% of Total	No. Vehicles	% of Total	No. Vehicles	% of Total
Passenger Cars			5,094	78.19	1,009	77.85
Panels & Pickups			690	10.59	176	13.58
Passenger Cars & Panels & Pickups	346	91.05	5,784	88.78	1,185	91.43
2 Axle - 4 Tire					22	1.70
2 Axle - 6 Tire					78	6.02
3 Axle					3	0.23
Total Single Unit Trucks	31	8.16	652	10.01	103	7.95
Buses			3	0.05		
4 Axle Semi					1	0.08
5 Axle Semi					2	0.15
Total Semi's	3	0.79	75	1.15	3	0.23
Double Bottoms					5	0.39
Total Multiple Unit Trucks	3	0.79	75	1.15	8	0.62
Total Commercial	34	8.95	730	11.21	111	8.56
Total	380	100.00	6,514	100.00	1,296	100.00

TABLE 1-M-5

COMPARISON OF TRUCK TYPES ON SECONDARY AND PRIMARY ROADS

	Source							
	1 (secondary)		2 (secondary)		3 (secondary)		4 (primary)*	
	No.	% of Commercial	No.	% of Commercial	No.	% of Commercial	No.	% of Commercial
Total single unit trucks and buses	31	91.18	655	89.73	103	92.79	4,086	48.09
Total semi's and multiple units	3	8.82	75	10.27	8	7.21	4,410	51.91
Total commercial	34	100.00	730	100.00	111	100.00	8,496	100.00

* Source No. 4 is the Table W-4: All Main Rural for 1966.

TABLE 1-M-6

DISTRIBUTION BY TYPE ON SECONDARY ROAD

Vehicle Type	Number in 1000 Truck Sample on Primary Road	Factor for Conversion to Secondary Road	Calculated Number in 1000 Truck Sample on Secondary Road
Panel & pickup	272	91/48	516
2 axle	154	"	292
3 axle	54	"	103
3 axle semi	31	9/52	5
4 axle semi	100	"	17
5 and 6 axle semi	364	"	63
Truck & trailer(s) & others	25	"	4

TABLE 1-M-7

DEVELOPMENT OF WEIGHT FACTORS FOR OVERWEIGHT VEHICLES ON PAVED SECONDARY ROADS

(1) Vehicle Types	(2) Calculated Number in 1000 Truck Sample on Paved Secondary Road	(3) Violations per Vehicle of Specified Type	(4), (2)·(3) Violations (Total) in Specified Type Per Thousand Trucks of All Types	(5) Overweight Violations Per Total Violations	(6) Weight Violating Vehicle Per Over-Weight Violation	(7),(2)·(3)·(5)·(6) Overweight Vehicle of Specified Type Per Thousand Trucks of All Types	(8),(7)/$\sum$(7) Weight Factor for Overweight Vehicles of Specified Types on Secondary Road
Panel & Pickup	516	0.00261	1.34676	0.0000 (by inference)*		0.0	0.0
2 axle	292	0.02380	6.9496	0.1210 (by inference)	1.0	0.84090	0.3967
3 axle	103	0.02385	2.45655	0.3143	1.0	0.77209	0.3643
3 axle semi	5	0.02666	0.13330		1.0	0.04190	0.0198
4 axle semi	17	0.02833	0.48161		0.6	0.09082	0.0428
5 and 6 axle semi	63	0.03000	1.89000		0.6	0.35642	0.1682
Truck + trailer(s) and others	4	0.02316	0.09264		0.6	0.01747	0.0082
						(7) = $\sum$ 2.1196	1.0000

* The inferred values are derived from W-4 data applied to the primary road vehicle distribution.

TABLE 1-M-8

CHARACTERISTICS OF OVERWEIGHT VEHICLES ON SECONDARY PAVED ROADS

Single Axles			Tandem Sets		
Legal Weight (Kips)	Amount Over Legal Weight (Kips)	Average Number of Axles Per Overweight Vehicle	Legal Weight (Kips)	Amount Over Legal Weight (Kips)	Average Number of Sets Per Overweight Vehicle
7.000	0.100	0.004100	29.000	0.400	0.064349
	0.300	0.002050		1.300	0.058952
	1.000	0.005125		2.200	0.013389
	1.200	0.002050		3.000	0.015071
13.500	0.500	0.121312		3.900	0.008472
14.000	0.200	0.030125		4.800	0.003732
	0.650	0.028459		6.500	0.003347
	1.100	0.006694	31.5	1.2	0.121312
	1.500	0.007535	32.0	0.500	0.028705
	1.950	0.001682		1.400	0.133180
	2.400	0.000841		2.400	0.006876
	3.200	0.001682		3.400	0.006726
18.000	0.300	0.072209		4.300	0.001682
	0.800	0.010223		4.600	0.040437
	0.900	0.396700		5.300	0.002555
	1.350	0.012018		6.300	0.005853
	2.400	0.002555		8.200	0.000841
	2.600	0.040437		10.000	0.000841
	3.000	0.000841			

APPENDIX 1, TAB N

AVERAGE UNCOMPENSATED PAVEMENT COSTS PER VIOLATING VEHICLE MILE

The calculated values are summarized in Table 1 below.

TABLE 1-N-1

AVERAGE UNCOMPENSATED PAVEMENT COSTS PER VIOLATING VEHICLE MILE

Uncompensated Costs per Violating Vehicle Mile ($)	Type Violators	Highway System*	Comments
0.002246	Overweight	Primary (01 and 03)	Conservatively low value obtained using high quality pavement emphasis and overload distribution from well policed routes.
0.012531	Overweight	Primary (31)	Upper bound value using pavements with emphasis on lighter structures and overload data from lightly policed routes.
0.021205	Overweight	Secondary (paved)	Average value based on distribution of commercial vehicle types found on secondary roads.
0.001227	Overweight and over-registration taken together	Primary (01 and 03)	Conservatively low value for combined violation types.
0.00809	Overweight	Primary (01 and 03) and secondary (paved)	Average value based on distribution of truck traffic on primary roads (69%) and paved secondary roads (31%).

* Classifications obtained from Analysis of Traffic Volume and Weight Study, Iowa, 1966, Table W-6.

Each entry in Table 1-N-1 is derived through consideration of road pavement types, their costs, and the uncompensated use per violating vehicle. Summary tables which follow indicate the magnitude of these considerations and the manner in which they are combined. The tables contain the major items which are described under Methodology, Road-Damage Submodel. The more detailed considerations and numerics appear in the appendices.

Tables 1-N-2, 1-N-3, and 1-N-4 show the assembly of the conservatively low value for the primary system.1/ Here, in the class 5 and 6 pavements, the mileage (extent factor) is divided equally between the extreme pavement thicknesses.

Tables 1-N-5, 1-N-6, and 1-N-7 show the assembly of the upper bound value for the primary system.2/ Here, added emphasis is given to the thinner pavement structures; the distribution of violations is taken from a highway section with no permanent (enforcement) weight station, and lower physical properties are used for the rigid pavements. The increase in uncompensated costs here is due mainly to the distribution of violations and the emphasis on thinner pavement structures.

Tables 1-N-8, 1-N-9, and 1-N-10 show the assembly of the uncompensated cost value for secondary roads.

The uncompensated cost value for secondary roads is higher than the comparable value for the primary system. This increase arises primarily from the lower structural properties of the secondary pavements. (The low structural property pavements have a higher cost per reference axle served during their useful life.)

The vehicle distribution by type is changed here to reflect the higher proportion of single unit trucks on secondary roads. Associated with this change is a reduction in large overweights applied by heavy vehicles.

The regional factor is reduced here to 1.0. (The value 3.0 is used for all primary roads.) The final serviceability index is left at 2.5 although design practice in Iowa uses 2.0 as a final value for secondary roads.

1/ Rigid pavement calculations here used: modulus of rupture = 650 psi, soil coefficient = 150 psi/in, and modulus of elasticity = 4.2×10^6 psi.

2/ Rigid pavement calculations used: Modulus of rupture = 500 psi, soil coefficient = 100 psi/in, and modulus of elasticity = 4.2×10^6 psi.

For secondary road rigid pavement the physical properties used are: modulus of rupture = 690 psi, soil coefficient = 100 psi/in, and modulus of elasticity = 4.2×10^6 psi. The total rigid pavement life calculated in reference axle applications is reduced by the factor 0.68 to account for the lack of sub-base in pavement construction. The corrected life appears in the tables.

Tables 1-N-11 and 1-N-12 show the assembly of the uncompensated cost value for over-registration and overweight violators taken together. Table 1-N-3 is also applied in this calculation. The overweight values and pavement emphasis correspond to those used for the conservatively low uncompensated costs on primary systems 01 and 03. The over-registration violators contribute less to uncompensated costs than do the overweight violators. As a result, the average uncompensated cost per violator mile is reduced.

TABLE 1-N-2

AVERAGE UNCOMPENSATED COST PER MILE FOR OVERWEIGHT VEHICLES
(Primary System 01 and 03)

Road	Average Cost per Violation Mile ($)	Road Extent & Traffic Dist. Weight Factor	Contribution to State-Wide Average ($)
Class 1	40.020	0.000 000 7	0.000 028 0
2	0.595 6	0.000 020 8	0.000 012 4
3	0.492 7	0.000 081 0	0.000 039 9
4 (8 in. pcc)	0.005 275	0.108 047 6	0.000 570 0
5 (8 in. pcc)	0.002 578	0.234 707 4	0.000 605 1
5 (9 in. pcc)	0.001 568	0.479 735 2	0.000 752 2
6 (SN = 5)	0.008 047	0.013 176 5	0.000 106 0
6 (SN = 7)	0.000 807 0	0.164 230 8	0.000 132 5
			0.002 246 1

TABLE 1-N-3

ROAD EXTENT AND TRAFFIC DISTRIBUTION WEIGHT FACTORS

Road	Extent Factor	Reference Axles $\times 10^{-6}$	Product $\times 10^{-6}$	Weight Factor
Class 1	0.03	0.000 138	0.000 004 1	0.000 000 7
2	0.01	0.012 800	0.000 128 0	0.000 020 8
3	0.03	0.016 600	0.000 498 0	0.000 081 0
4 (8 in. pcc)	0.41	1.619 400	0.663 954 0	0.108 047 6
5 (8 in. pcc)	0.21	6.868 00	1.442 280 0	0.234 707 4
5 (9 in. pcc)	0.21	14.038 000	2.947 980 0	0.479 735 2
6 (SN = 5)	0.05	1.619 400	0.080 970 0	0.013 176 5
6 (SN = 7)	0.05	20.184 000	1.009 200 0	0.164 230 8
			6.145 014 1	

TABLE 1-N-4

PRIMARY ROAD PAVEMENTS, THEIR UNCOMPENSATED USE BY OVERWEIGHT VEHICLES FROM SYSTEMS 01 AND 03

Road Class No.	Pavement	Structural No. Coef.	Structural No.	Reference Axles During Life	Average Uncompensated Ref. Axles per Violating Vehicle (overweight)		Average Uncompensated Fraction Used per Violating Vehicle (overweight)		Pavement Cost per Lane Mile ($)	Maintenance Cost per Lane Mile Year ($)	Average Uncompensated Cost per Mile per Violating Vehicle (overweight)		
					Life	Maintenance	Life	Maintenance			Life ($)	Maintenance ($)	Total ($)
1	$\frac{1}{4}$ in. invert pene. 7 in. rolled stone	0.20 0.12	0.89 (1.00 used)	0.13762×10^{3}	0.259 39	0.174 73	$0.188\ 49 \times 10^{-2}$	$0.126\ 97 \times 10^{-2}$	17,500	277	32.986	7.034 1	40.020
2	2 in. asph. conc. 7 in. bit.tr.soil ag.	0.44 0.22	2.28 (2.3 used)	0.128×10^{5}	0.242 0	0.174 73	1.891×10^{-5}	1.365×10^{-5}	27,500	277	0.520 0	0.075 6	0.595 6
3	3 in. asph. conc. 8 in. rolled stone 2 in. soil - aggr.	0.44 0.12 0.05	2.38 (2.4 used)	0.166×10^{5}	0.240 4	0.174 73	1.448×10^{-5}	1.053×10^{-5}	30,000	277	0.434 4	0.058 3	0.492 7
4	4 in. asph. conc. 8 in. pcc	0.44 0.40	4.96 (5.00 used)	$1.619\ 4 \times 10^{6}$	0.241 27	0.174 73	$0.148\ 99 \times 10^{-6}$	$0.107\ 90 \times 10^{-6}$	34,000 (asph. resurface of pcc)	97	0.005 066	0.000 209 3	0.005 275
4	4 in. asph. conc. 9 in. pcc	0.44 0.40	5.36 (5.4 used)	2.81×10^{6}	0.244 47	0.174 73	0.87×10^{-7}	0.63×10^{-7}	34,000 (asph. resurface of pcc)	97	0.002 958	0.000 012 2	0.002 97
5	8 in. pcc	-	-	6.868×10^{6}	0.342 12	0.204 26	$0.498\ 14 \times 10^{-7}$	$0.297\ 41 \times 10^{-7}$	50,000	147	0.002 491	0.000 087 44	0.002 578
5	9 in. pcc	-	-	14.038×10^{6}	0.357 09	0.197 98	$0.254\ 37 \times 10^{-7}$	$0.141\ 03 \times 10^{-7}$	60,000	147	0.001 526	0.000 041 46	0.001 568
6	3 in. asph. conc. 10 in. asph.tr.c.stone 6 in. soil aggr.	0.44 0.34 0.05	5.02 (5.00 used)	$1.619\ 4 \times 10^{6}$	0.241 27	0.174 73	$0.148\ 99 \times 10^{-6}$	$0.107\ 90 \times 10^{-6}$	50,000	277	0.007 450	0.000 597 8	0.008 047
6	4.5 in. asph.conc. 14 in. asph.tr.c.stone 6 in. soil aggr.	0.44 0.34 0.05	7.04 (7.00 used)	20.184×10^{6}	0.255 35	0.174 73	$0.126\ 51 \times 10^{-7}$	$0.865\ 69 \times 10^{-8}$	60,000	277	0.000 759 1	0.000 047 96	0.000 807 0

TABLE 1-N-5

AVERAGE UNCOMPENSATED COST PER MILE FOR OVERWEIGHT VEHICLES
(Primary System 31)

Road	Average Cost per Violation Mile ($)	Road Extent & Traffic Dist. Weight Factor	Contribution to State-Wide Average ($)
Class 1	70.373 9	0.000 000 8	0.000 056 3
2	1.091 64	0.000 026 7	0.000 029 1
3	0.915 08	0.000 103 8	0.000 095 0
4 (8 in. pcc)	0.010 67	0.138 341 7	0.001 476 1
5 (8 in. pcc)	0.016 23	0.457 926 2	0.007 432 1
5 (9 in. pcc)	0.009 85	0.292 496 4	0.002 881 1
6 (SN = 5)	0.015 73	0.026 993 5	0.000 424 6
6 (SN = 7)	0.001 63	0.084 110 9	0.000 137 1
			0.012 531 4

TABLE 1-N-6

ROAD EXTENT AND TRAFFIC DISTRIBUTION
WEIGHT FACTORS FOR UPPER BOUND ON PRIMARY ROADS

Road	Extent Factor	Reference Axles $\times 10^{-6}$	Product $\times 10^{-6}$	Complete Weight Factor
Class 1	0.03	0.000 138	0.000 004 1	0.000 000 8
2	0.01	0.012 800	0.000 128 0	0.000 026 7
3	0.03	0.016 600	0.000 498 0	0.000 103 8
4 (8 in. pcc)	0.41	1.619 400	0.663 954 0	0.138 341 7
5 (8 in. pcc)	0.32	6.868 00	2.197 760 0	0.457 926 2
5 (9 in. pcc)	0.10	14.038 000	1.403 800 0	0.292 496 4
6 (SN = 5)	0.08	1.619 400	0.129 552 0	0.026 993 5
6 (SN = 7)	0.02	20.184 000	0.403 680 0	0.084 110 9
			4.799 376 1	1.000 000 0

TABLE 1-N-7

PRIMARY ROAD PAVEMENTS, THEIR UNCOMPENSATED USE BY OVERWEIGHT VEHICLE FROM SYSTEM 31

Road Class No.	Pavement	Structural No. Coef.	Structural No.	Reference Axles During Life	Aveg. Uncompensated Ref. Axles per Violating Vehicle (overwt. on System 31. Life	Aveg. Uncompensated Ref. Axles per Violating Vehicle (overwt. on System 31. Maintenance	Average Uncompensated Fraction Used per Violating Vehicle (overwt. on System 31) Life	Average Uncompensated Fraction Used per Violating Vehicle (overwt. on System 31) Maintenance	Pavement Cost per Lane Mile ($)	Maintenance Cost per Lane Mile Year ($)	Average Uncompensated Cost per Mile per Violating Vehicle Life ($)	Average Uncompensated Cost per Mile per Violating Vehicle Maintenance ($)	Average Uncompensated Cost per Mile per Violating Vehicle Total ($)
1	$\frac{1}{4}$ in. invert pene. 7 in. rolled stone	0.20 0.12	0.89 (1.00 used)	$1.376\ 2 \times 10^{2}$	0.537 82	0.358 72	$0.390\ 81 \times 10^{-2}$	$0.260\ 67 \times 10^{-2}$	17,500	277	69.651 8	0.722 1	70.373 9
2	2 in. asph.conc. 7 in. bit.tr.soil ag.	0.44 0.22	2.28 (2.3 used)	$1.271\ 9 \times 10^{4}$	0.501 30		$0.394\ 12 \times 10^{-4}$	$0.282\ 03 \times 10^{-4}$	27,500	277	1.083 83	0.007 81	1.091 64
3	3 in. asph. conc. 8 in. rolled stone 2 in. soil aggr.	0.44 0.12 0.05	2.38 (2.4 used)	$1.641\ 4 \times 10^{4}$	0.497 37		$0.303\ 01 \times 10^{-4}$	$0.218\ 54 \times 10^{-4}$	30,000	277	0.909 03	0.006 05	0.915 08
4	4 in.asph.conc. 8 in. pcc	0.44 0.40	4.96 (5.00 used)	$1.619\ 4 \times 10^{6}$	0.507 43		$0.313\ 35 \times 10^{-6}$	$0.221\ 51 \times 10^{-6}$	34,000	97	0.010 65	0.000 02	0.010 67
4	4 in.asph.conc. 9 in. pcc	0.44 0.40	5.36 (5.40 used)	$2.801\ 8 \times 10^{-6}$	0.514 71		$0.183\ 71 \times 10^{-6}$	$0.128\ 03 \times 10^{-6}$	34,000	97	0.006 25	0.000 01	0.006 26
5	8 in. pcc	–	–	$2.438\ 8 \times 10^{-6}$	0.789 63	0.651 79	$0.323\ 77 \times 10^{-6}$	$0.267\ 25 \times 10^{-6}$	50,000	147	0.016 19	0.000 04	0.016 23
5	9 in. pcc	–	–	$5.064\ 3 \times 10^{-6}$	0.829 53	0.560 25	$0.163\ 80 \times 10^{-6}$	$0.110\ 63 \times 10^{-6}$	60,000	147	0.009 83	0.000 02	0.009 85
6	3 in. asph.conc. 10 in. asph.tr.c.stone 6 in. soil aggr.	0.44 0.34 0.05	5.02 (5.00 used)	$1.619\ 4 \times 10^{6}$	0.507 43	0.358 72	$0.313\ 35 \times 10^{-6}$	$0.221\ 51 \times 10^{-6}$	50,000	277	0.015 67	0.000 06	0.015 73
6	4.5 in. asph.conc. 14 in. asph.tr.c.stone 6 in. soil aggr.	0.44 0.34 0.05	7.04 (7.00 used)	20.184×10^{6}	0.531 75	0.358 72	$0.263\ 45 \times 10^{-7}$	$0.177\ 73 \times 10^{-7}$	60,000	277	0.001 58	0.000 005	0.00163

TABLE 1-N-8

AVERAGE UNCOMPENSATED COST PER MILE FOR OVERWEIGHT VEHICLES ON SECONDARY ROADS

Road	Average Cost per Violation Mile ($)	Road Extent & Traffic Dist. Weight Factor	Contribution to State-Wide Average ($)
47,48	13.081 0	0.000 123 0	0.001 609
44,46,57, & 58	1.727 2	0.001 922	0.003 320
56	0.340 1	0.032 752	0.011 139
54	0.055 55	0.001 526	0.000 085
55 (6 in. pcc)	0.008 54	0.291 928	0.002 493
55 (7 in. pcc)	0.003 81	0.671 749	0.002 559
			0.021 205

TABLE 1-N-9

ROAD EXTENT AND TRAFFIC DISTRIBUTION
WEIGHT FACTORS FOR SECONDARY ROADS

Pavement	Extent Factor	Reference Axles x 10^3	Product x 10^{-3}	Weight Factor
47,48	0.085 9	0.412 85	0.035 46	0.000 123
44,46,57 & 58	0.171 6	3.228 5	0.554 01	0.001 922
56	0.567 4	16.636	9.439 27	0.032 752
54	0.004 4	99.970	0.439 87	0.001 526
55 (6 in. pcc)	0.085 8	980.62	84.137 20	0.291 928
55 (7 in. pcc)	0.084 9	2280.4	193.605 96	0.671 749
			288.211 77	1.000 000

TABLE 1-N-10

SECONDARY ROAD PAVEMENTS, THEIR UNCOMPENSATED USE BY OVERWEIGHT VEHICLES ON SECONDARY ROADS

Pavement Codes	Pavement	Reference Axles During Life	Ave. Uncompensated Ref. Axles per Violating Vehicle (overweight, secondary road) Life	Maintenance	Average Uncompensated Fraction Used per Violating Vehicle (overweight, secondary road) Life	Maintenance	Pavement Cost per Lane Mile ($)	Maintenance Cost per Lane Mile Year ($)	Average Uncompensated Cost per Mile per Violating Vehicle (overweight, secondary road) Life ($)	Maintenance ($)	Total ($)
47,48	Flexible SN = 1.0	$4.128\ 5 \times 10^2$	0.267 61	0.172 29	$0.648\ 20 \times 10^{-3}$	$0.417\ 32 \times 10^{-3}$	17,000	247	11.019 4	2.061 6	13.081 0
44,46 57,58	Flexible SN = 1.5	$3.228\ 5 \times 10^3$	0.262 51		$0.813\ 10 \times 10^{-4}$	$0.533\ 65 \times 10^{-4}$	18,000	247	1.463 6	0.263 6	1.727 2
56	Flexible SN = 2.0	$1.663\ 6 \times 10^4$	0.252 92		$0.152\ 04 \times 10^{-4}$	$0.103\ 57 \times 10^{-4}$	19,000	247	0.288 9	0.051 2	0.340 1
54	Flexible SN = 2.7	$9.997\ 0 \times 10^4$	0.235 14		$0.235\ 20 \times 10^{-5}$	$0.172\ 34 \times 10^{-5}$	20,000	237	0.047 04	0.008 51	0.055 55
55	pcc 6 in.	$0.980\ 62 \times 10^6$	0.304 00	0.316 15	$0.310\ 00 \times 10^{-6}$	$0.322\ 40 \times 10^{-6}$	25,000	122	0.007 75	0.000 79	0.008 54
		$\frac{1.442\ 1 \times 10^6}{0.68}$			$\frac{0.210\ 80 \times 10^{-6}}{0.68}$	$\frac{0.219\ 23 \times 10^{-6}}{0.68}$					
55	pcc 7 in.	$2.280\ 4 \times 10^6$	0.303 65	0.269 99	$0.133\ 16 \times 10^{-6}$	$0.118\ 40 \times 10^{-6}$	26,400	122	0.003 52	0.000 29	0.003 81
		$\frac{3.353\ 5 \times 10^6}{0.68}$			$\frac{0.905\ 47 \times 10^{-7}}{0.68}$	$\frac{0.805\ 09 \times 10^{-7}}{0.68}$					

TABLE 1-N-11

AVERAGE UNCOMPENSATED COST PER MILE
FOR OVER-REGISTRATION AND OVERWEIGHT VEHICLES
(Primary Systems 01 and 03)

Road	Average Cost per Violation Mile ($)	Road Extent & Traffic Dist. Weight Factor	Contribution to State-Wide Average ($)
Class 1	22.02	0.000 000 7	0.000 015 4
2	0.3315	0.000 020 8	0.000 006 9
3	0.274 2	0.000 081 0	0.000 022 2
4 (8 in. pcc)	0.002 802	0.108 047 6	0.000 302 7
5 (8 in. pcc)	0.001 426	0.234 707 4	0.000 334 7
5 (9 in. pcc)	0.000 863	0.479 735 2	0.000 414 0
6 (SN = 5)	0.004 463	0.013 176 5	0.000 058 8
6 (SN = 7)	0.000 441	0.164 230 8	0.000 072 4
			0.001 227 1

TABLE 1-N-12

PRIMARY ROAD PAVEMENTS, THEIR UNCOMPENSATED USE BY OVER-REGISTRATION AND OVERWEIGHT VEHICLES

Road Class No.	Pavement	Structural No. Coef.	Structural No.	Reference Axles During Life	Avg. Uncompensated Ref. Axles per Violating Vehicle (overwt. & over-reg.) Life	Maintenance	Average Uncompensated Fraction Used per Violating Vehicle (overwt. and over-registration) Life	Maintenance	Pavement Cost per Lane Mile ($)	Maintenance Cost per Lane Mile Year ($)	Average Uncompensated Cost per Mile per Violating Vehicle (Both overweight and over-reg.) Life ($)	Maintenance ($)	Total ($)
1	$\frac{1}{4}$ in. invert.pene.	0.20											
FLEXM FLEXL	7 in.rolled stone	0.12	0.89 (1.00 used)	$0.137\ 62 \times 10^3$	0.140 68	0.102 48	$0.102\ 23 \times 10^{-2}$	$0.744\ 68 \times 10^{-3}$	17,500	277	17.89	4.13	22.02
2	2 in.asph.conc.	0.44											
	7 in. bit.tr.soil ag.	0.20	2.28 (2.3 used)	0.128×10^5	0.133 6	0.102 48	1.044×10^{-5}	$0.800\ 6 \times 10^{-5}$	27,500	277	0.287 1	0.044 4	0.331 5
3	3 in.asph.conc.	0.44											
	8 in.rolled stone	0.12											
	2 in.soil aggr.	0.05	2.38 (2.4 used)	0.166×10^5	0.132 8	0.102 48	$0.800\ 0 \times 10^{-5}$	$0.617\ 3 \times 10^{-5}$	30,000	277	0.240 0	0.034 2	0.274 2
4	4 in.asph. conc.	0.44											
	8 in.pcc	0.40	4.96 (5.00 used)	$1.619\ 4 \times 10^6$	0.133 18	0.102 48	$0.822\ 40 \times 10^{-7}$	$0.632\ 82 \times 10^{-7}$	34,000 (asph.re-surface of pcc)	97	0.002 796	0.000 006	0.002 802
4	4 in.asph.conc.	0.44											
	9 in.pcc	0.40	5.36 (5.4 used)	2.81×10^6	0.132 1	0.102 48	0.470×10^{-7}	0.365×10^{-7}	34,000 (asph.re-surface of pcc)	97	0.001 598	0.000 004	0.001 602
RIGDM RIGDL 5	8 in.pcc	--	--	6.868×10^6	0.188 79	0.122 28	$0.274\ 88 \times 10^{-7}$	$0.178\ 04 \times 10^{-7}$	50,000	147	0.001 374	0.000 052	0.001 426
	9 in.pcc	--	--	14.038×10^6	0.196 14	0.118 67	$0.139\ 72 \times 10^{-7}$	$0.845\ 34 \times 10^{-8}$	60,000	147	0.000 838	0.000 025	0.000 863
FLEXM FLEXL 6	3 in.asph conc.	0.44											
	10 in. asph.tr.c. stone	0.34											
	6 in. soil aggr.	0.05	5.02 (5.00 used)	$1.619\ 4 \times 10^6$	0.133 18	0.102 48	$0.822\ 40 \times 10^{-7}$	$0.632\ 82 \times 10^{-7}$	50,000	277	0.004 112	0.000 351	0.004 463
6	4.5 in.asph.conc.	0.44											
	14 in. asph.tr.c. stone	0.34											
	6 in. soil aggr.	0.05	7.04 (7.00 used)	20.184×10^6	0.138 99	0.102 48	$0.688\ 64 \times 10^{-8}$	$0.507\ 73 \times 10^{-8}$	60,000	277	0.000 413	0.000 028	0.000 441

APPENDIX 2

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APPENDIX 3

SAMPLE VIOLATION RECORDS AND CODING INSTRUCTIONS

This appendix contains a brief outline of the summons data coding format used by the ISHC to compile the violations tape for 1967. A page of sample violation records is included as Table 3-1. Each record represents 80 columns of data from an IBM card, divided as follows:

Item 1 Columns 1-5, Date summons was issued - day, month, and year.

Item 2 Columns 6-7, Code number of officer issuing summons.

Item 3 Columns 8-12, The last five digits of the summons number.

Item 4 Columns 13-32, Name of the owner of the vehicle in violation.

Item 5 Columns 32-34, Number of the county in which the violation was acted upon.

Item 6 Columns 35-44, Address of the owner of the vehicle.

Item 7 Column 45, Code number of the violating vehicle type.

Item 8 Columns 46-47, Code number of the scale at which violation was apprehended.

Item 9 Columns 48-49, Code number of county of origin for Iowa registered vehicles, or of state of origin for out of state registrations.

Item 10 Columns 50-54, License number of the violating vehicle.

Item 11 Columns 55-56, Code number of type of violation.

Item 12 Columns 57-66, Amount of fines assessed and fines paid.

Item 13 Columns 67-70, Amount of costs paid.

Item 14 Columns 71-77, License class required, and amount paid for license change.

Item 15 Columns 78-80, Type of completion and date of completion.

The computer program, Violation Tape Analysis, documented in Appendix 6, analyzed the data on the violation tape to produce information on the numbers and fractions of violations that were:

1. in state and out of state;

2. overweight and not overweight;

3. apprehended during the day versus apprehended during the night; and

4. the fraction of violators that received more than one summons.

It is recommended that an owner code be added to the record of each violator, so that a file of multiple violators can be maintained by the computer.

TABLE 3-1

SAMPLE VIOLATION RECORDS

```
087672747195AMER BUS             09LINCOLN   1C82000C762C01200012000400          173
207676649919AMER BUS LINES       78LINCCLN   12040BC4358201000010000400          173
077677346588AMER CHIEF VAN LINES75MEMPHIS    3114JT0034820100001000040 0         173
112666622221AMER COLEMAN         78LITTLETON 3060NTE7669201CC0010000500          161
J4-676150357AMER COLLUIC         78SCOTT BLF 3200NOTEMP3001300013000400          174
03-666636716AMER CYANAMID        78JACKSON   3062LP73823CC10CC010000500          164
273678440558AMER CYANAMIC CO     75ALTON     211840123620037CC037000400          472
03-6773552CCAMER CYANOMIC        11LCHRV     4  1K1387291030000300 00500         174
18067C651541AMER EQUIP           77SX C      322YYA613550057520575 20400         174
034677343579AMER FARM LINE       11CKLA C    3183N012278201000010000400          172
056676247494AMER FARM LINES      78CKLA C    3063N023288201000010000500          172
300673353505AMER FOOD            27K C       3  2M0975682010000100004CC          174
235677148176AMER FOODS           17ST PAUL   2122K24767200064000840040 0         172
222673142414AMER FUEL & SUP      77MILWAUKEE 2094Q5E81C8201000010000400          171
130673353487AMER HOMES           77D M       323YYA022530137301373005 00         174
066671347438AMER HOMES INC       06C M       305YYA828920057800578004 00         172
311672739846AMER LBR             C9MPLS      2082K277168201C00010000400          171
158668230070AMER LSNG            94D M       3  77003488401C0001000040 0         163
J9-67535472CAMER MILLING         78RALSTCN   321YYA2690300110001100040 0         174
254666225222AMER MVG & STG       65COL       2101&PE1158201000010000400          162
023676442905AMER OIL             78CASPER    3064RT1411820100C010000500          171
179678451134AMER RED BALL TRS    75INDPLS    2112J3632C830100001000040 0         173
031676624152AMER ROAD EQUIP      78OMAHA     2062616286910040C004000500          171
317676649969AMER SHUFFLE BOARDS  78UNION C   3202RP9782920140001400040 0         173
J3-671556095AMER SYNTHETIC       16LCUISV    32810813785009251092510400          174
172678240870AMER T & T           08K C       2172M2354481C10000100004CC          171
06-678253639AMER TEL & TEG       08K C       2172M69503870050000500050005007C0174
248666133137AMER TENT & CAN      65LA FCLL   3104K044PX500717907179040 0         163
158666437991AMER TENT & CANVAS   78LAFOLLETTE3204J433PX8201C0001000040 0         164
153665825166AMER TK REN          78FT WORTH  3064K178938201000010000400          161
236668630408AMER TRF & STG       17MLTN      212       8301C00010000400          162
198678156823AMER TRS             75CHI       3111L3691L8201C00010000400          174
093676641675AMER TRS LINES       78CHI       3201K676778201000010000400          171
076667728231AMER UNIFORM         75BENTON    3114JX02C282C050C005000400          162
158671551010AMER VALVE           16INDPLS    2281L1327F8201000010000400          173
06267C6B5810AMERICAN OIL         77SCARSB    222790066786                        871
060666632950AMERICAN VAN LINES   78FT WAYNE  3061L9335L99C1C00010000500          164
68-673153817AMES & BASS          77MARCUS    323YYA4682500298802988040 0         174
017661827640AMES R D             22MC GREGOR 2  220C30C86C0500005000400          471
31167C641105AMF W TCOL INC       77C M       3  YYA00732016660166600500          171
195678246943AMMONS B R           85ROGERS    2140LC1976820050000500040 0         172
166665830040AMR TK LEASE         78FAIRF     30600M8364820100001000050 0         162
230671154373AMSDEN C D           06VINTCN    2  060294150036820388 2             174
266672447773AMUNELSON H          45CRESCC    2  960133510005000050004000501500373
048665832563AMWAY CORP           78ADA       3062J276218301500C15000500          163
C86672247C94ANAMOSA CONC PROD    16ANAMOSA   41353003991000500000500040082007 50172
08-665837399ANASTASI F           78HARLAN    20683017292000750007500500          164
118675449C77ANCHOR LSNG          97CMAHA     22620097C53C0230C023000400          173
264676642967ANCHOR MTR FRT       78WARREN    3202J324CN82010000100004 00         172
225665628941ANCO MFG SUP         78TULSA     2063N4577782C10000100005 00         162
3C1672739840ANDERSEN E H         38CDR FALLS 2  380187220027000270004 00         171
159671452339ANDERSON & MANDLE    16MILAN     3291K0P1343003885038850400          173
310678352716ANDERSON BROS        75AKRON     2117503079860050000500040 0         174
236667825978ANDERSON C           71SUTHERLAND2  71002242001540015400400          363
039667730366ANDERSON C B         75WAGNER    311407115Y8101000010000400          163
091668218810ANDERSON C L         08GOWRIE    217940304610005000050004000709500161
284666626297ANDERSON C TKG       78AMARILLO  3064K382148201000010000500          162
128668335702ANDERSON CHEM        75LITTCHF   3112KC7633820100001000040 0         164
PAGE   6
```

APPENDIX 4

SAMPLING INSTRUCTIONS FOR OPERATIONAL RECORD SAMPLE

T.W.O. Cost/Effectiveness Data Collection

Sampling Instructions

1. Purpose of Sample: To compare the cost/effectiveness of current fixed scale and roving patrol T.W.O. work parties.

2. Frame or File to be Sampled: Calendar year 1967 file of Form 771 "Scale Station Record - Daily Report."

3. Information to be Recorded from Records: As on enclosed sample information sheets. There should be one sheet filled out for each party's 8-hour period of operation. (There may be several Form 771's covering one such period for busy parties.) Most of the information will come from the Form 771's, but it may be necessary to obtain some corresponding data from accounting or other records.

4. Size of the Sample: Approximately 5 percent (1 out of 19 operating periods for every party).

5. Method of Sampling: Systematic sample of every 19th work period with a new random starting point for each work party.

6. Details of Sampling Procedure:

   A. The records for each party are bound together in a few volumes. The procedure below is repeated for each work party.

   B. Pick a random starting point for the work party from the attached table of random numbers. (Cross off each random number as it is used and do not use any number more than once.)

   C. Count down to the starting point in the first volume for the work party. For example, the first random point is 03; therefore, the first party's starting point is 03, i.e., the first work period (not Form 771) to be sampled is the 3rd.

D. Record all data on the starting point work record (1 or more Form 771's) onto a sample data sheet.

E. Count down 19 more work periods and copy the data on that record. Count down 19 more, copy and so on until all records for the work party have been counted, e.g., the first party will be represented by the 3rd, 22nd, 41st, etc., records, yielding approximately a 5 percent sample for the calendar year 1967.

F. Repeat procedures B through F for all other work parties.

G. If the data on a record are unusable for any reason, simply reject the record, count down 19 more and continue. Keep two tallies on the number of such rejections, one for fixed sites and one for roving patrols.

H. As of now the only known reason for a large number of rejections would be due to unclosed cases which should not be included in the sample. If some other major reason for rejections appears, or if the rejection rate exceeds 10 percent, please advise MRI.

7. Also, if for any reason, you do not consider 1967 sufficiently representative of current methods of operation, please advise MRI.

TABLE OF RANDOM STARTING POINTS

03	17	13	12	09	03	04	05	17	05
19	15	04	18	12	11	17	19	18	11
05	10	11	16	06	15	10	16	01	12
02	14	07	08	01	08	18	02	09	10
09	02	06	07	14	02	13	06	08	16

NOTES:
1. Use in any order.
2. Cross off as used.
3. Do not use any number more than once.
4. Use as many as needed, extras are supplied.

Work Party No. 19 Scale No. ________

T.W.O. SAMPLE OF DAILY OPERATIONS REPORTS

1. Mode of Operation: A. Fixed Station B. Roving Patrol (Circle A or B)

2. A. Date 5-1-68

   B. Hours of Operation 7AM to 3 PM

   C. Inactive Periods: a. Lunch ________ to ________

   b. Administrative ________ to ________

   c. Other ________ to ________

3. A. Number of Personnel on Duty: a. Capt. _____ b. Sgt. 1 c. Officer 1

   B. Number of Man-Hours Charged: a. Capt. _____ b. Sgt. 8 c. Officer 8

4. A. Number of Summons Issued 1 Later opp.

   B. Fines Paid ________

   C. Court Costs Paid ________

   D. Registration Increases Paid to Iowa ________

5. Out-of-Pocket Expenses:

   A. Mileage at 4-1/2¢ per mile 136

   B. Subsistence 3.80

   C. Public Scale Payment ________

   D. Other ________

Comments (weather, etc.)

clear
road dry
Traffic subnormal

Sample Information Sheet, Operational Record Sample

APPENDIX 5

OPERATIONAL EXPERIMENT SAMPLE DATA SHEET

Background

Current weight scale traffic count records do not include recording traffic flow rate by time of the date, but only record total traffic by truck type for the entire day of operation.

The attached form was used to gather information on the rate of traffic flow so that an evaluation could be made of the daily manpower scheduling practices now used. The data were also used to analyze the possible "decay" in truck traffic following the opening of a scale. The data were processed by the computer program documented in Appendix 7.

WEIGHT SCALE TRUCK TRAFFIC COUNT

Scale Location 10 Mile South of Tylon Scale Number 16 - 246 North Hour Period 8AM - 4PM Date 3-5-68

TRUCK TYPE	8 0-15 min Count	Viol	16-30 min Count	Viol	31-45 min Count	Viol	9AM 46-60 min Count	Viol	19-10 2 hour Count	Viol	10-11 3 hour Count	Viol	11-12 4 hour Count	Viol	12-1 5 hour Count	Viol	1-2 6 hour Count	Viol	2-3 7 hour Count	Viol	3-4 8 hour Count	Viol	TOTAL Count	TOTAL Viol
TRK	-	-	1	-	5	-	-	-	7	-	2	-	3	-	3	-	2	-	6	-	7	-	36	-
TK	2	-	2	-	3	-	2	-	6	-	7	-	6	-	7	1	4	1	3	-	2	-	44	2
TK 2	-	-	-	-	1	-	-	-	4	-	4	-	1	-	3	-	4	-	2	-	-	-	19	-
TT - ST	-	-	-	-	-	-	2	-	-	-	2	-	-	-	1	-	4	-	1	-	4	-	14	-
TT - ST 2	3	-	3	-	3	-	3	-	10	2	6	1	7	1	3	-	3	-	5	-	-	-	46	4
TT2 - ST2	4	-	10	-	6	-	6	-	17	3	20	1	28	1	25	1	33	-	15	-	6	1	170	7
TT2 - ST3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-
TK - Pup	-	-	1	-	-	-	-	-	2	-	1	-	1	-	-	-	-	-	1	-	1	-	7	-
Double Bottoms	-	-	-	-	1	-	1	-	4	-	4	-	-	-	2	-	1	-	-	-	3	-	16	-
All Others	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	2	-	1	-	-	-	4	-
All Busses	1	-	-	-	-		-	-	1	-	-	-	-	-	-	-	-	-	-	-	2	-	4	-
																							361	13

TRK - Pickups, Campers, etc.

TK - 2 Axle Truck

TK2 - 3 Axle Truck

TT-ST - 2 Axle tractor 1 Axle Trailer

TT-ST2 - 2 Axle Tractor 2 Axle Trailer

TT2-ST2 - 3 Axle Tractor 2 Axle Trailer

TT2-ST3 - 3 Axle Tractor 3 Axle Trailer

TK - Pup - Tk and any Pup Trailer

APPENDIX 6

COMPUTER PROGRAM DOCUMENTATION: VIOLATION TAPE ANALYSIS

The program IOWA TAPE is written in COBOL and 360 Basic Assembly Language and is presented here. The program computes the numbers and fractions of violations that are: (1) in state and out of state; (2) overweight and not overweight; (3) apprehended during the day versus apprehended during the night, and (4) the fraction of violators that received more than one summons. Input to this program is the T.W.O. violation tape.

```
000010 IDENTIFICATION DIVISION.
000020 PROGRAM-ID. 'IOWATAPE'.
000040 ENVIRONMENT DIVISION.
000050 CONFIGURATION SECTION.
000060 SOURCE-COMPUTER.    IBM-360 F30.
000070 OBJECT-COMPUTER.    IBM-360 F30.
000080 INPUT-OUTPUT SECTION.
000090 FILE-CONTROL.
000100     SELECT INPUT-TAPE ASSIGN TO 'SYS001' UTILITY 2400 UNITS.
000110     SELECT PRINTER ASSIGN TO 'SYS002' UNIT-RECORD 1403 UNIT.
001010 DATA DIVISION.
001020 FILE SECTION.
001030 FD  INPUT-TAPE
001040                 RECORDING MODE IS F
001050                 BLOCK CONTAINS 20 RECORDS
001060                 RECORD CONTAINS 80 CHARACTERS
001070                 LABEL RECORDS ARE OMITTED
001080                 DATA RECORD IS INPUT-X.
002010 01  INPUT-X.
002020     03  DATE                        PICTURE X(5).
002030     03  DATE-X REDEFINES DATE.
002040         05  DAY                     PICTURE X.
002050         05  FILLER                  PICTURE X(4).
002060     03  FILLER                      PICTURE X(40).
002070     03  VEHICLE                     PICTURE X(9).
002080     03  VEHICLE-X REDEFINES VEHICLE.
002090         05  FILLER                  PICTURE X(2).
002100         05  STATE                   PICTURE XX.
002110         05  FILLER                  PICTURE X(5).
```

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```
002120      03  VIOLATION                 PICTURE XX.
002130      03  FILLER                    PICTURE X(5).
002140      03  FINE                      PICTURE X(5).
002150      03  FILLER                    PICTURE X(6).
002160      03  COST                      PICTURE X(5).
002170      03  FILLER                    PICTURE X(3).
003010 FD   PRINTER
003020              RECORDING MODE IS F
003030              RECORD CONTAINS 133 CHARACTERS
003040              LABEL RECORDS ARE OMITTED
003050              DATA RECORD IS LINE.
003060 01   LINE.
003070      03  FILLER   PICTURE X.
003080      03  L        PICTURE X(132).
004010 WORKING-STORAGE SECTION.
004020 77   NIGHT-REV    PICTURE S9(13)V99   COMPUTATIONAL-3.
004030 77   DAY-REV      PICTURE S9(13)V99   COMPUTATIONAL-3          .
004040 77   BOTH         PICTURE S9(7)       COMPUTATIONAL-3 .
004050 77   WEIGHT       PICTURE S9(7)       COMPUTATIONAL-3    .
004060 77   OTHER        PICTURE S9(7)       COMPUTATIONAL-3        .
004070 77   NVIOL        PICTURE S9(7)       COMPUTATIONAL-3      .
004080 77   INSTATE      PICTURE S9(7)       COMPUTATIONAL-3         .
004090 77   OUTSTATE     PICTURE S9(7)       COMPUTATIONAL-3         .
004100 77   NIGHT-NO     PICTURE S9(7)       COMPUTATIONAL-3    .
004110 77   DAY-NO       PICTURE S9(7)       COMPUTATIONAL-3        .
004120 77   TOTAL-VIOL   PICTURE S9(7)       COMPUTATIONAL-3        .
004130 77   S1           PICTURE X.
004140 77   S2           PICTURE X.
004150 77   S3           PICTURE X.
```

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```
005010 01  RECORD-IDENTIFICATION.
005020     03 OLD-RECORD.
005030         05  FILLER  PICTURE X(14) VALUE 'XXXXXXXXXXXXXX'.
005040     03 NEW-RECORD.
005050         05 DATE-NEW PICTURE X(5).
005060         05 VEHICLE-NEW PICTURE X(9).
005070 01  DISTX-2 COMPUTATIONAL-3.
005080     03  DISTX PICTURE S9(7) OCCURS 100 TIMES.
006020 01  LINKAGE-DATA     .
006030     03 REVENUE-OUT      PICTURE S9(5)V99 COMPUTATIONAL-3.
006040     03 FINE-IN          PICTURE X(5).
006050     03 COST-IN          PICTURE X(5).
007010 01  DETAIL  .
007020     03 DESX-01                          PICTURE X(50).
007030     03 FILLER                           PICTURE X(5).
007040     03 DESX-02                          PICTURE Z(9)9.
007050     03 DESX-03 REDEFINES DESX-02        PICTURE Z(7).99.
007060     03 DESX-04 REDEFINES DESX-03        PICTURE Z(3)9.9(5).
007080 01  LINEX.
007090     03  FILLER  PICTURE X(5) .
007100     03  I       PICTURE ZZ9.
007110     03  FILLER  PICTURE X(5).
007120     03  J       PICTURE Z(7)9.
008010 PROCEDURE DIVISION.
008020     OPEN INPUT INPUT-TAPE, OUTPUT PRINTER.
008070     MOVE ALL ' ' TO LINE.
008030     MOVE 'X' TO S1.
008040     MOVE 'X' TO S2.
008060     MOVE 'X' TO S3.
```

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008050      MOVE ZERO TO NVIOL.
008080      MOVE ZERO TO BOTH.
008090      MOVE ZERO TO WEIGHT.
008100      MOVE ZERO TO OTHER.
008110      MOVE ZERO TO INSTATE.
008120      MOVE ZERO TO OUTSTATE.
008130      MOVE ZERO TO NIGHT-REV.
008140      MOVE ZERO TO DAY-REV.
008150      MOVE ZERO TO NIGHT-NO.
008160      MOVE ZERO TO DAY-NO.
008170      MOVE ZERO TO TOTAL-VIOL.
            PERFORM ZAP VARYING NVIOL FROM 1 BY 1 UNTIL NVIOL > 100.
            MOVE ZERO TO NVIOL.
            GO TO LOOP.
        ZAP.
            MOVE ZERO TO DISTX (NVIOL).
009010  LOOP.
            READ INPUT-TAPE AT END PERFORM BREAK-VIOLATION GO TO STOP.
009030      MOVE DATE TO DATE-NEW.
009040      MOVE VEHICLE TO VEHICLE-NEW.
009050      IF NEW-RECORD NOT = OLD-RECORD PERFORM BREAK-VIOLATION.
009060      ADD 1 TO NVIOL.
009070      IF STATE  )  '01'
009080                          MOVE '0' TO S3
009090              ELSE        MOVE 'I' TO S3.
009100      IF VIOLATION = '20' OR VIOLATION = '30' OR VIOLATION = '40'
009110                                  OR VIOLATION = '50'
009120                          ADD 1 TO WEIGHT
009130                          MOVE 'Y' TO S1
```

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009140               ELSE    ADD 1 TO OTHER
009150                       MOVE 'Y' TO S2.
009160      MOVE FINE TO FINE-IN.
009170      MOVE COST TO COST-IN.
009180      ENTER LINKAGE.
009190      CALL 'TOTALREV' USING LINKAGE-DATA.
009200      ENTER COBOL.
010010      IF DAY ) '0' ADD REVENUE-OUT TO NIGHT-REV ADD 1 TO NIGHT-NO
010020               ELSE ADD REVENUE-OUT TO DAY-REV ADD 1 TO DAY-NO.
010030      ADD 1 TO TOTAL-VIOL.
010060      GO TO LOOP.
011010 BREAK-VIOLATION.
011020      IF S3 = 'I' ADD 1 TO INSTATE.
011030      IF S3 = 'O' ADD 1 TO OUTSTATE.
011040      MOVE 'X' TO S3.
011050      IF S1 = 'Y' AND S2 = 'Y' ADD 1 TO BOTH.
011060      MOVE 'X' TO S1.
011070      MOVE 'X' TO S2.
011080      IF NVIOL > 100 MOVE 100 TO NVIOL.
011090      IF NVIOL > ZERO ADD 1 TO DISTX (NVIOL).
011100      MOVE ZERO TO NVIOL.
            MOVE NEW-RECORD TO OLD-RECORD.
012010 STOP.
012020      MOVE ALL ' ' TO DETAIL.
012030      MOVE 'TOTAL NUMBER OF VIOLATIONS' TO DESX-01.
012040      MOVE TOTAL-VIOL TO DESX-02.
012050      MOVE DETAIL TO L.
012060      WRITE LINE AFTER 0.
012070      MOVE 'NUMBER OF INSTATE VIOLATORS' TO DESX-01.
```

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012080      MOVE INSTATE TO DESX-02.
012090      MOVE DETAIL TO L.
012100      WRITE LINE AFTER 2.
012110      MOVE 'FRACTION OF INSTATE VIOLATORS' TO DESX-01.
012120      ADD INSTATE, OUTSTATE GIVING NVIOL.
012130      DIVIDE NVIOL INTO INSTATE GIVING DESX-04.
012140      MOVE DETAIL TO L.
012150      WRITE LINE AFTER 1.
012160      MOVE 'NUMBER OF OUT STATE VIOLATORS' TO DESX-01.
012170      MOVE OUTSTATE TO DESX-02.
012180      MOVE DETAIL TO L.
012190      WRITE LINE AFTER 1.
013010      DIVIDE NVIOL INTO OUTSTATE GIVING DESX-04.
013020      MOVE 'FRACTION OF OUT STATE VIOLATORS' TO DESX-01.
013030      MOVE DETAIL TO L.
013040      WRITE LINE AFTER 1.
013050      MOVE 'TOTAL NUMBER OF VIOLATORS' TO DESX-01.
013060      MOVE NVIOL TO DESX-02.
013070      MOVE DETAIL TO L.
013080      WRITE LINE AFTER 1.
013090      MOVE 'TOTAL NUMBER OF VIOLATIONS' TO DESX-01.
013100      MOVE TOTAL-VIOL TO DESX-02.
013110      MOVE DETAIL TO L.
013120      WRITE LINE AFTER 3.
013130      MOVE 'TOTAL NUMBER OVERWEIGHT VIOLATIONS'TO DESX-01.
013140      MOVE WEIGHT TO DESX-02.
013150      MOVE DETAIL TO L.
013160      WRITE LINE AFTER 1.
013170      MOVE 'TOTAL NUMBER NON-OVERWEIGHT VIOLATIONS' TO DESX-01.
```

```
MOVE OTHER TO DESX-02.
MOVE DETAIL TO L.
WRITE LINE AFTER 1.
MOVE 'NUMBER OF VIOLATORS COMMITTING BOTH' TO DESX-01.
MOVE BOTH TO DESX-02.
MOVE DETAIL TO L.
WRITE LINE AFTER 1
SUBTRACT BOTH FROM NVIOL GIVING DESX-02.
MOVE 'NUMBER OF VIOLATORS COMMITTING ONE TYPE' TO DESX-01.
MOVE DETAIL TO L.
WRITE LINE AFTER 1.
MOVE 'NUMBER OF DAY VIOLATIONS' TO DESX-01.
MOVE DAY-NO TO DESX-02.
MOVE DETAIL TO L.
WRITE LINE AFTER 3.
MOVE 'NUMBER OF NIGHT VIOLATIONS' TO DESX-01.
MOVE NIGHT-NO TO DESX-02.
MOVE DETAIL TO L.
WRITE LINE AFTER 1.
MOVE 'AVERAGE DAY REVENUE ' TO DESX-01.
DIVIDE DAY-NO INTO DAY-REV GIVING DESX-03
MOVE DETAIL TO L.
WRITE LINE AFTER 1.
MOVE 'AVERAGE NIGHT REVENGE' TO DESX-01.
DIVIDE NIGHT-NO INTO NIGHT-REV GIVING DESX-03.
MOVE DETAIL TO L.
WRITE LINE AFTER 1.
MOVE 'NO OF TICKETS, NO. OF OCCURANCES' TO L.
WRITE LINE AFTER 0.
```

```
015050     PERFORM DUMP VARYING NVIOL FROM 1 BY 1 UNTIL NVIOL > 100.
015060     CLOSE INPUT-TAPE, PRINTER.
015070     STOP RUN.
015090 DUMP.
015100     MOVE ALL ' ' TO LINEX.
015110     MOVE NVIOL TO I.
015120     MOVE DISTX (NVIOL) TO J.
015130     MOVE LINEX TO L.
015140     WRITE LINE AFTER 1.


// EXEC ASSEMBLY
TOTALREV START 0
         USING *,15
         STM   14,12,12(13)    SAVE GENERAL REGISTERS
         L     2,0(1)          LOAD ADDRESS OF LINKAGE DATA
         MVC   FININ(5),4(2)   BRING IN THE AMOUNT OF THE FINE
         MVC   FINOT(5),9(2)   BRING IN THE AMOUNT OF LICENSE INCREACE
         MVC   BYTE(1),FININ   MOVE 1ST BYTE INTO WORK AREA
         NI    BYTE,X'F0'      AND OUT THE ZONE
         CLI   BYTE,X'D0'      11 OVER PUNCH = FINE PAID BY JAIL
         BE    ZEROFINE
         CLI   BYTE,X'60'      11 PUNCH ONLY = FINE PAID BY JAIL
         BE    ZEROFINE
         CLI   BYTE,X'F0'      CHECK FOR NUMBER = FINE PAID
         BE    FINEPAID
         CLI   BYTE,X'40'      CHECK FOR BLANK = FINE PAID,
         BNE   ZEROFINE             ELSE FINE DISMISSED
FINEPAID CLC   FININ(5),=C'     '
```

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```
         BE    ZEROFINE         IF THE FIELD = BLANK, NO FINE
         MVC   BYTE(1),FININ+4
         NI    BYTE,X'F0'       RECOVER ZONE OF LAST DIGIT
         CLI   BYTE,X'F0'       F ZONE = 0 ) FINE ) 999.99
         BE    FINEZERO
         CLI   BYTE,X'40'       BLANK = F ZONE
         BE    FINEZERO
         CLI   BYTE,X'D0'       11 PUNCH = 1000.00 ) FINE ) 1999.99
         BE    FINE1000
         CLI   BYTE,X'60'
         BE    FINE1000
         CLI   BYTE,X'C0'       12 PUNCH = 2000.00 ) FINE ) 2999.99
         BE    FINE2000
         CLI   BYTE,X'50'
         BE    FINE2000
         CLI   BYTE,X'E0'       0  PUNCH = 3000.00 ) FINE ) 3999.99
         BE    FINE3000
         CLI   BYTE,X'61'
         BE    FINE3000
ZEROFINE ZAP   TOTAL,=P'0'      ZERO THE TOTAL
         B     CHCKCOST
FINEZERO ZAP   TOTAL,=P'0'
         B     ADDFINE
FINE1000 ZAP   TOTAL,=P'100000'
         B     ADDFINE
FINE2000 ZAP   TOTAL,=P'200000'
         B     ADDFINE
FINE3000 ZAP   TOTAL,=P'300000'
ADDFINE  MVZ   FININ(5),=X'C0C0C0C0C0'  SET ALL ZONES TO C
```

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```
         LA    3,5
         LA    4,FININ+4        CHECK FOR NUMERIC FIELD,
FINELOOP CLI   0(4),X'C0'             IF NOT NUMERIC, SET FINE = ZERO
         BL    ZEROFINE
         CLI   0(4),X'C9'
         BH    ZEROFINE
         BCTR  4,0
         BCT   3,FINELOOP
         PACK  WORK,FININ
         AP    TOTAL,WORK
CHCKCOST CLC   FINOT,=C'
         BE    RETURN
         MVC   BYTE(1),FINOT+4
         NI    BYTE,X'F0'
         CLI   BYTE,X'F0'
         BE    COSTZERO
         CLI   BYTE,X'40'
         BE    COSTZERO
         CLI   BYTE,X'D0'
         BE    COST1000
         CLI   BYTE,X'60'
         BE    COST1000
         CLI   BYTE,X'C0'
         BE    COST2000
         CLI   BYTE,X'50'
         BE    COST2000
         B     RETURN
COSTZERO ZAP   AREA,=P'0'
         B     ADDCOST
```

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```
COST1000 ZAP   AREA,=P'100000'
         B     ADDCOST
COST2000 ZAP   AREA,=P'200000'
ADDCOST  MVZ   FINOT(5),=X'C0C0C0C0C0'
         LA    3,5
         LA    4,FINOT+4
COSTLOOP CLI   0(4),X'C0'
         BL    RETURN
         CLI   0(4),X'C9'
         BH    RETURN
         BCTR  4,0
         BCT   3,COSTLOOP
         PACK  WORK,FINOT
         AP    TOTAL,WORK
         AP    TOTAL,AREA
RETURN   MVC   0(4,2),TOTAL
         LM    14,12,12(13)
         BR    14
         SPACE
FININ    DS    CL5
FINOT    DS    CL5
BYTE     DS    CL1
TOTAL    DS    CL4
WORK     DS    CL4
AREA     DS    CL4
         END
```

END OF DATA

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APPENDIX 7

COMPUTER PROGRAM DOCUMENTATION: FRACTION VIOLATING VS. TIME ANALYSES

This program, written in FORTRAN IV, provides a distribution of truck traffic, summonses issued, and fraction of traffic in violation with respect to time of day and as a decay function from the time a station is opened. The output is normalized to truck traffic per operation hour, summonses issued per operations hour, and fraction of truck traffic in violation per operations hour. Input to this program is a tape with data that come from Weight Scale Traffic Count. An example of a data sheet is shown in Appendix 5.

```
C JOB TITLE TRAFFIC DECAY AND TIME OF DAY MODEL
C
C
C THIS PROGRAM PROVIDES DATA FOR ANALYZING TRAFFIC, SUMMONSES ISSUED,
C AND FRACTION OF TRAFFIC IN VIOLATION. THE DATA IS PRESENTED WITH RESPECT
C TO TIME OF DAY AND AS A DECAY FUNCTION FROM TIME A STATION IS OPENED.
C THE OUTPUT IS NORMALIZED TO TRAFFIC PER OPERATING HOUR, SUMMONSES ISSUED
C PER OPERATING HOUR, AND FRACTION OF TRAFFIC IN VIOLATION PER OPERATING HOUR
C
C INPUT TO THIS PROGRAM IS A TAPE OF WEIGHT SCALE TRAFFIC COUNT
C
C     INPUT-DATA
C     SC = SCALE NUMBER                                     COL  1- 8
C     IHOUR = MILITARY TIME OF OPENING                      COL  9-10
C     IDUR  = HOURS STATION IS OPEN NOT GREATER THAN 8      COL 11-12
C     IPARTY= NUMBER OF CREW PARTY OPERATING SCALE          COL 13-14
C     DATE  = DATE OF OBSERVATION                           COL 15-18
C     ICHECK = LAST DATA CARD
C
C     A(I,J) = TRAFFIC COUNT I TRUCK TYPE J TIME CELL
C     B(I,J) = SUMMONSES ISSUED I TRUCK TYPE J TIME CELL
C VARIABLE DEFINITIONS
C ASUM(J) = TOTAL TRAFFIC J TIME CELL
C BSUM(J) = TOTAL SUMMONSES ISSUED J TIME CELL
C
C TIME OF DAY MODEL
C ITIME = MILITARY TIME OF DAY
C TRAF1(ITIME) = TOTAL TRAFFIC FOR ITIME
C VLT1(ITIME)  = TOTAL SUMMONSES ISSUED FOR ITIME
PAGE  1
```

```
C ISAMP(ITIME) = TOTAL OPERATING HOURS ITIME
C
C DECAY MODEL
C TRAF2(J) = TOTAL TRAFFIC J HOUR FROM OPENING
C VLT2     = TOTAL SUMMONSES ISSUED FOR J HOUR FROM OPENING
C ISAMP2(J) = TOTAL OPERATING HOURS FOR J HOUR FROM OPENING
C
C
      DIMENSION TRAF1(24), TRAF2(11), VLT1(24), VLT2(11), ISAMP(24),
     1ASUM(11), BSUM(11), A(11,11), B(11,11)
      DIMENSION SC(2)
      DIMENSION ISAMP2(11)
C
      DO 10 J = 1,24
      ISTOP = 0
      TRAF1(J) = 0.0
      ISAMP(J) = 0
   10 VLT1(J) = 0.0
      DO 15 J = 1,11
      TRAF2(J) = 0.
      ISAMP2(J) = 0
   15 VLT2(J) = 0.0
   20 READ(12) SC,IHOUR,IDUR,IPARTY,DATE,ICHECK
      IF (ICHECK) 25,25,500
   25 READ(12) ((A(I,J),B(I,J),J=1,11),I=1,11)
      TRFFC = 0.
      VLTNS = 0.
      IX = IDUR + 3
      IF (11-IX) 70,80,80
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```

```
   70 IX=11
      WRITE(3,770) SC
   80 CONTINUE
C CALCULATE TRAFFIC, SUMMONSES ISSUED,AND OPERATING HOURS FOR DECAY-MODEL
      DO 30 J = 1,IX
      ASUM(J) = 0.0
      BSUM(J) = 0.
      ISAMP2(J) = ISAMP2(J) + 1
      DO 30 I = 1,11
      ASUM(J) = ASUM(J) + A(I,J)
      BSUM(J) = BSUM(J) + B(I,J)
      TRFFC = TRFFC + A(I,J)
      VLTNS = VLTNS + B(I,J)
      TRAF2(J) = TRAF2(J) + A(I,J)
   30 VLT2(J) = VLT2(J) + B(I,J)
      ITIME = IHOUR + 1
C CALCULATE TRAFFIC, SUMMONSES ISSUED, AND OPERATING HOURS FOR TIME-OF-DAY-MODEL
      ISAMP(ITIME) = ISAMP(ITIME) + 1
      DO 40 J = 1,4
      TRAF1(ITIME) = TRAF1(ITIME) + ASUM(J)
   40 VLT1(ITIME) = VLT1(ITIME) + BSUM(J)
      DO 50 J=5,IX
      ITIME = ITIME + 1
      IF(24-ITIME) 41,42,42
 41   ITIME=1
   42 TRAF1(ITIME) = TRAF1(ITIME) + ASUM(J)
      VLT1(ITIME) = VLT1(ITIME) + BSUM(J)
   50 ISAMP(ITIME) = ISAMP(ITIME) + 1
C WRITE EXCEPTION STATEMENT IF MORE THAN 5 SUMMONSES ARE ISSUED
PAGE   3
```

```
C WITHIN ANY DATA CELL
      TRADG = VLTNS/TRFFC
      WRITE (3,750) SC,IHOUR,IDUR,IPARTY, DATE, TRADG
      DO 60 J=1,11
      DO 60 I=1,11
      IF (B(I,J)-5) 60,60,66
   66 WRITE(3,761) ((A(I,J),B(I,J),K=1,11))
   60 CONTINUE
      ISTOP = ISTOP + 1
      IF(ISTOP - 183)20,500,500
C PERFORM SUMMARY CALCULATIONS AND WRITE ROUTINE FOR TIME-OF-DAY-MODEL
  500 WRITE(3,730)
      DO 510 I=1,24
      IF (VLT1(I)) 502,503,502
  502 VIOL = VLT1(I)/TRAF1(I)
      GO TO 505
  503 VIOL = 0.
  505 TRAFN1 = TRAF1(I)/ISAMP(I)
      VIOLN1 = VLT1(I)/ISAMP(I)
  510 WRITE(3,735) I, TRAFN1,VIOLN1, VIOL,ISAMP(I)
  520 WRITE(3,740)
C PERFORM SUMMARY CALCULATIONS AND WRITE ROUTINE FOR DECAY-MODEL
      DO 530 I=1,11
      IF (VLT2(I)) 522,523,522
  522 VIOL2 = VLT2(I)/TRAF2(I)
      GO TO 525
  523 VIOL2 = 0.
  525 TRAFN2 = TRAF2(I)/ISAMP2(I)
      VIOLN2 = VLT2(I)/ISAMP2(I)
PAGE  4
```

```
 530 WRITE(3,745) I, TRAFN2,VIOLN2,VIOL2
     CALL EXIT
 700 FORMAT(22F3.0)
701  FORMAT(2A4,3I2,A4,I1)
 730 FORMAT(1H1,T31,'NORMALIZED TIME OF DAY MODEL '///,1H ,T10,'TIME',
    1T22,'TRAFFIC',T43,'VIOLATIONS',T58,'% VIOLATIONS',T83,'SAMPLE'/)
 735 FORMAT(1H ,T11,I2,T22,F10.2,T40,F10.3,T60,F8.4,T80,I5)
 740 FORMAT(1H1,T35,'NORMALIZED DECAY MODEL'///,1H ,T10,'TIME',T20,'TRA
    1FFIC',T43,'VIOLATIONS',T58,'% VIOLATIONS'/)
 745 FORMAT(1H ,T11,I2,T22,F10.2,T40,F10.3,T60,F8.4)
 750 FORMAT(1H0,2A4,3I5,A4,F10.4/)
 761 FORMAT(1H ,22F5.0)
 770 FORMAT(1H ,'DURATION ERROR ',2A4/)
     END
END OF DATA
```

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NORMALIZED TIME OF DAY MODEL

TIME	TRAFFIC	VIOLATIONS	% VIOLATIONS	SAMPLE
1	25.24	0.471	0.0186	34
2	18.91	0.625	0.0331	32
3	18.78	0.889	0.0473	27
4	18.50	0.464	0.0251	28
5	20.23	0.767	0.0379	30
6	25.08	0.632	0.0252	38
7	30.62	0.851	0.0278	47
8	36.91	0.631	0.0171	65
9	42.53	0.714	0.0168	77
10	42.85	1.024	0.0239	85
11	42.85	0.929	0.0217	98
12	38.64	0.790	0.0204	100
13	39.07	0.721	0.0185	104
14	38.66	0.680	0.0176	97
15	39.65	0.710	0.0179	100
16	39.46	0.869	0.0220	84
17	42.32	0.631	0.0149	65
18	36.92	0.600	0.0163	60
19	35.13	0.538	0.0153	52
20	29.43	0.792	0.0269	53
21	30.15	0.348	0.0115	46
22	28.16	0.419	0.0149	43
23	26.26	0.677	0.0258	31
24	23.69	0.538	0.0227	26

NORMALIZED DECAY MODEL

TIME	TRAFFIC	VIOLATIONS	% VIOLATIONS
1	10.78	0.208	0.0193
2	9.37	0.197	0.0210
3	9.96	0.180	0.0181
4	10.67	0.191	0.0179
5	36.49	0.858	0.0235
6	35.76	0.841	0.0235
7	34.30	0.639	0.0186
8	35.28	0.774	0.0219
9	35.25	0.811	0.0230
10	35.06	0.494	0.0141
11	29.80	0.488	0.0164

APPENDIX 8

COMPUTER PROGRAM DOCUMENTATION: COST/BENEFIT ANALYSES

The program, Cost/Benefit Analysis, written in FORTRAN IV is presented here. The program determines the net contribution (benefit less cost), the fraction of trips in violation, and the probability of apprehension for a range of enforcement levels. The program uses as input a card deck that describes the initial operating characteristics of the system. These include: (1) traffic level; (2) initial probability of apprehension; (3) operating cost data; (4) allocation of manpower to fixed site operation, roving patrol, and other activity; and (5) fraction of violators that are overweight, fraction of violators under-registered, and their associated damage costs.1/

1/ The program in its present form applies only when the apprehension effectiveness is manpower limited as discussed in the Apprehension Submodel, Section III-A-4, of this report.

```
C     THIS PROGRAM IS A COST - BENEFIT MODEL FOR THE IOWA TRAFFIC WEIGHT
C     OPERATIONS STUDY. THE PURPOSE OF THIS MODEL IS TO DETERMINE
C     THE NET CONTRIBUTION (REVENUE LESS COST) AND LEVEL OF COMPLIANCE
C     TO THE LAW FOR A RANGE OF STAFF SIZE.
C     TRAFFC - ANNUAL TRUCK TRIPS
C     NACT - NUMBER OF ACTIVITIES (FIXED, ROVING, OTHER)
C     VCOST - VARIABLE OPERATIONS COST PER
C      VCOST - VARIABLE OPERATIONS COST PER MAN
C     VIOLN - INITIAL PROBABILITY OF APPREHENSION
C     STAFFP(I) - ALLOCATION OF MANPOWER TO EACH ACTIVITY
C     FINE(I) - AVERAGE REVENUE PER SUMMONS FOR EACH ACTIVITY
C     STAFFI(I) - INITIAL MANPOWER FOR ITH ACTIVITY
C     PAPPI(I) - INITIAL PROBABILITY OF APPREHENSION FOR ITH ACTIVITY
C     VIOL(I) - FRACTION TRUCK TRAFFIC IN VIOLATION AS FUNCTION OF PAPP(I).
C     VIOLF(J) - FRACTION OF VIOLATORS WITH JTH TYPE VIOLATION
C     DAMAGE(J) - LOSS OR REVENUE PER VIOLATOR WITH JTH TYPE VIOLATION
C     VIOL(I)-FRACTION TRUCK TRAFFIC IN VIOLATION AS FUNCTION OF PAPP(I)
C     PAPPO - INITIAL PROBABILITY APPREHENSION
C     NSITES - NUMBER OF SITES
      DIMENSION STAFFP(10) , FINE(10), XLNGTH(10), XMILES(10),ICREW(10),
     X  APPK(10), FVIOL(10), VIOLFY(10), DAMAGE(10),
     X STAFFI(10), PAPPI(10 ),ISTAFF(10),FIXEDC(10)
      DIMENSION VIOL(50)
      DIMENSION STAFFS(10), PAPP(10)
      INTEGER STAFFN
      PAPP(2) = 0.
      FINE(2) = 0.
      STAFFP(2) = 0.
      READ(1,704) IPASS
PAGE  1
```

```
      DO 2020 ITIMES = 1,IPASS
   10 READ(1,700) TRAFFC, PAPPO, NSITES, NACT, VCOST,VIOLN
   20 READ(1,701) (STAFFP(I), FINE(I), STAFFI(I), PAPPI(I), I =1,NACT)
   22 READ(1,705) (VIOLFY(I), DAMAGE(I), I = 1,2)
   24 READ(1,706) (ISTAFF(K), FIXEDC(K), K = 1, 5)
      OTHER = 1.0 - STAFFP(1) - STAFFP(2)
      VIOL(1) = 1.00
      DETK =-ALOG((VIOLN - 0.02)/0.98)/PAPPO
      DO 2020 IYEAR = 1, 1
      KYEAR = IYEAR - 1
      WRITE(3,802) TRAFFC,VIOLN,PAPPO,STAFFP(1),STAFFP(2), OTHER
      WRITE(3,800)
C     INCREASE LEVEL OF ENFORCEMENT STAFFN
      DO 2000 STAFFN = 15,400,5
      PAPPT = 0.0
      SBENFT= 0.0
      BENFT1 = 0.
      BENFT2 = 0.
      DEPR = 0.
      IF (STAFFN - 205) 901,900,901
  900 WRITE(3,802) TRAFFC,VIOLN,PAPPO,STAFFP(1),STAFFP(2), OTHER
      WRITE(3,800)
  901 CONTINUE
C     COMPUTE PROBABILITY OF APPREHENDING A VIOLATOR PAPP(I) FOR I ACTIVITY
      DO 1210 I = 1, NACT
      PAPPZ = PAPPI(I)
      APPK(I) = -(ALOG(1.0 - PAPPZ))/STAFFI(I)
      STAFFS(I) = STAFFP(I) * FLOAT(STAFFN)
 1210 PAPP(I) = 1.0 - EXP(-APPK(I) * STAFFS(I))
```

PAGE 2

```
C
C     COMPUTE FRACTION OF TRAFFIC IN VIOLATION AS FUNCTION OF PAPP(I).
      DO 1310 I = 1, NACT
 1310 PAPPT = PAPPT + PAPP(I)
      VIOLN = 0.02 + 0.98 * EXP(-DETK * PAPPT)
C
C     COMPUTE TOTAL OPERATING COST AS FUNCTION OF STAFF LEVEL.
C     FIXED COST BFIXED DETERMINED FROM TABLE LOOK UP.
C     VARIABLE COST VCOST IS VARCOST * STAFF LEVEL
      DO 1420 K = 1, 5
      IF (STAFFN -ISTAFF(K)) 1410,1410,1420
 1410 SFIXED = FIXEDC(K)
      GO TO 1430
 1420 CONTINUE
 1430 COST = VCOST * FLOAT(STAFFN) + SFIXED + DEPR
C
C     COMPUTE TOTAL SYSTEM BENEFITS
C
C     BENFT1  REVENUE FROM FINES FOR I ACTIVITY.
C     BENFT2  REVENUE FROM INCREASED REGISTRATION AND PREVENTED ROAD DAMAGE
      DO 1610 I = 1, NACT
 1610 BENFT1 = BENFT1 + TRAFFC * VIOLN * PAPP(I) * FINE(I)
      DO 1620 J = 1,2
 1620 BENFT2 = BENFT2 + TRAFFC*DAMAGE(J)*(VIOL(1) - VIOLN)*VIOLFY(J)
      SBENFT = BENFT1 + BENFT2
C     COMPUTE PROFIT
      PROFIT = SBENFT - COST
C
      SBENFT = SBENFT/1000.
PAGE  3
```

```
      COST    = COST/1000.
      PROFIT = PROFIT/1000.
      FIXED = TRAFFC * VIOLN * PAPP(1) * FINE(1)/1000.
      ROVING = TRAFFC * VIOLN * PAPP(2) * FINE(2)/1000.
      DMAGE = TRAFFC * DAMAGE(1) * (VIOL(1) - VIOLN) * VIOLFY(1)/1000.
      RGTRE = TRAFFC * DAMAGE(2) * (VIOL(1) - VIOLN) * VIOLFY(2)/1000.
      WRITE(3,801) STAFFN, PROFIT,RGTRE, FIXED, ROVING, DMAGE,SBENFT,
     X COST, PAPPT, VIOLN
 2000 CONTINUE
 2020 CONTINUE
      CALL EXIT
  700 FORMAT(E10.0,F10.0,I10,I10,E10.0,F6.3)
  701 FORMAT(4F10.0)
  702 FORMAT(11F7.0)
  704 FORMAT( I2)
  705 FORMAT(4F10.0)
  706 FORMAT(5(I8,F8.0))
  800 FORMAT(1H ,'STAFF',T17,'NET',T29,'REVENUE',T46,'REVENUE',T60,
     X'REVENUE',T76,'REVENUE',T96,'TOTAL',T109,'OPERATING',T122,
     X'P        V'/,1H ,T15,'REVENUE',T27,'REGISTRATION',T44,
     X'FIXED SITES',T58,'ROVING PATROL',T74,'DAMAGE PREVEN.',T95,
     X'REVENUE',T111,'COST'//)
  801 FORMAT (1H ,I4,T15,F7.0,T29,F7.0,T45,F7.0,T60,F7.0,T75,F7.0,T95,
     X F7.0,T111,F7.0,T120,F5.4,T129,F5.4)
  802 FORMAT(1H1,T50,'SYSTEM INPUT DATA'/,1H ,T30,'TRAFFIC ',F10.0,
     XT50,'FRACTION VIOLATING ',F5.3,T77,'PROBABILITY OF APPREHENSION',
     X F5.3/,1H ,T30,'ALLOCATION OF MANPOWER: FIXED ',F5.3,', ROVING '
     X,F5.3, ', OTHER 'F5.3//)
      END
PAGE   4
```

APPENDIX 9

COMPUTER PROGRAM DOCUMENTATION: UNCOMPENSATED ROAD MAINTENANCE USE PER VIOLATING VEHICLE

Two programs, written in FORTRAN, are presented here, FLEXM, and RIGDM. Both programs calculate average uncompensated maintenance use per violating vehicle. The equations used are presented in Appendix 1, Tab I. The computation results are given in average equivalent reference axles per violating vehicle. FLEXM is used for flexible pavements, RIGDM is used for rigid pavements.

Both of these programs (and the programs for life use in the next appendix) use as part of input the axle characteristics of violating vehicles. The programs accept any number of these characteristics up to and including 100. Each card in the axle deck contains

NAXE, LØK, LØVER, AXLES

Format I1, 9X, 3F10.0

Where NAXE = 1 for single axle, = 2 for tandem set

LØK = Legal axle load (Kips)

LØVER = Amount axle load is over legal value (Kips)

AXLES = Average number of axles with these characteristics per violating vehicle

Input for FLEXM

The axle defining deck as described above followed by a card with 3 in position 1.

Output from FLEXM

The contribution from each axle in the deck is printed separately. This output appears in six columns.

Column No.	Value Printed
1	Axle type, 1 = single, 2 = tandem set
2	Axle legal weight (Kips)
3	Amount over legal weight (Kips)
4	Number of reference axles equivalent to legal weight
5	(Number of reference axles equivalent to actual weight) - (number equivalent to legal weight)
6	Contribution to average uncompensated maintenance per violating vehicle in reference axles

Column 6 is summed and printed as the average uncompensated maintenance per violating vehicle in the units reference axles.

The program listing follows:

```
C      FLEXM PROGRAM, MRI PROJECT 3158-P
       REAL LOK,LOVER
       CTAN=.5**2.947
       SUMUN=0.0
       WRITE(3,101)
  101  FORMAT('1','UNCOMPENSATED MAINTENANCE, FLEXIBLE PAVEMENT' ,/)
  201  READ(1,102)NAXE,LOK,LOVER,AXLES
  102  FORMAT(I1,9X,3F10.0)
       GO TO (1,2,3),NAXE
    3  WRITE(3,103) SUMUN
  103  FORMAT(1H0,44HAVE UNCOMPENSATED REF AXLES PER WT VIOL VEH=,E12.5)
       CALL EXIT
    1  C=1.0
       AXE=1.0
       GO TO 4
    2  C=CTAN
       AXE=2.0
    4  ROK=C*((LOK+AXE)/19.0)**3.136
       ROVER=C*((LOK+LOVER+AXE)/19.0)**3.136
       RUN=ROVER-ROK
       RAXUN=RUN*AXLES
       SUMUN=SUMUN+RAXUN
       WRITE(3,104)NAXE,LOK,LOVER,ROK,RUN,RAXUN
  104  FORMAT(1H ,I1,5X,2F12.3,3(5X,E12.5))
       GO TO 201
       END
```

PAGE 1

Input for RIGDM

NTYPE (format I1) (1 for unreinforced pcc, 2 for reinforced)

Axle deck (as defined previously)

Card with 3 in position 1.

Output from RIGDM

The contribution from each axle in the deck is printed separately. This output appears in six columns.

Column No.	Value Printed
1	Type of axle (1 = single, 2 = tandem set)
2	Legal weight for axle (Kips)
3	Amount over legal weight (Kips)
4	For single axle: the equivalent number of reference axles for legal weight For tandem sets: (equivalent reference axles). $D_2^{1.49}$ where D_2 is the as yet unspecified pavement thickness
5	For single axles: (reference axles for actual weight) - (axles for legal weight) For tandem sets: (reference axles for actual weight) - (axles for legal weight) $D_2^{1.49}$
6	(Column 5 value)·(Number of axles of this type, legal weight and overweight per violating vehicle)

The entries in Column 6 are summed separately for single and tandem axles.

The output is

Avg. uncompensated ref. axles per violating vehicle = $SUM1 + (SUM2)/D_2^{1.49}$.

A table of values is printed for slabs from 4 in. to 12 in. The program listing follows:

```
C     RIGDM PROGRAM, MRI PROJECT 3158-P
      REAL LUK,LOVER
      READ(1,101)NTYPE
  101 FORMAT(I1,9X,3F10.0)
      SUM1=0.0
      SUM2=0.0
      GO TO (1,2),NTYPE
    1 WRITE(3,102)
  102 FORMAT('1','UNCOMPENSATED MAINTENANCE, UNREINFORCED RIGID PAVE.')
      COEF1=1./18.0**2.62
      COEF2=1.23058E-02*COEF1
      XPON1=2.62
      XPON2=4.38
      XPON3=1.49
      GO TO 3
    2 WRITE(3,103)
  103 FORMAT('1','UNCOMPENSATED MAINTENANCE, REINFORCED RIGID PAVE.')
      XPON1=2.30
      XPON2=3.13
      XPON3=0.39
      COEF1=1./18.0**XPON1
      COEF2=3.80214E-02*COEF1
    3 READ(1,101)NAXE,LUK,LOVER,AXLES
      GO TO(201,202,203),NAXE
  203 WRITE(3,104)SUM1,SUM2,XPON3
  104 FORMAT(1H0, 45HAVE. UNCOMPENSATED REF AXLES PER WT VIOL VEH=,E12.
     15, 5HPLUS ,E12.5,34HDIVIDED BY D2 RAISED TO THE POWER ,F6.3)
      WRITE(3,105)
  105 FORMAT('0','SLAB THICK      UNCOMP REF AXLES/WT VIOL VEH.')
```

PAGE 1

```
      DO 204 I=4,12
      D2=I
      SUMUN=SUM1+SUM2/D2**XPON3
  204 WRITE(3,106)D2,SUMUN
  106 FORMAT(1H ,3X,F4.1,15X,E12.5)
      CALL EXIT
  201 ROK=COEF1*LOK**XPON1
      ROVER=COEF1*(LOK+LOVER)**XPON1
      RUN=ROVER-ROK
      RAXUN=RUN*AXLES
      SUM1=SUM1+RAXUN
  210 WRITE(3,107)NAXE,LOK,LOVER,ROK,RUN,RAXUN
  107 FORMAT(' ',I1,5X,2F12.3,3(5X,E12.5))
      GO TO 3
  202 ROK=COEF2*LOK**XPON2
      ROVER=COEF2*(LOK+LOVER)**XPON2
      RUN=ROVER-ROK
      RAXUN=RUN*AXLES
      SUM2=SUM2+RAXUN
      GO TO 210
      END
```

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APPENDIX 10

COMPUTER PROGRAM DOCUMENTATION: UNCOMPENSATED PAVEMENT LIFE USE PER VIOLATING VEHICLE

The two programs, FLEXL and RIGDL, written in FORTRAN, are presented here. Both programs calculate average uncompensated pavement life use per violating vehicle. They also calculate useful life and apply it as a basis for calculating average uncompensated life fractions and uncompensated maintenance fractions. FLEXL is used for flexible pavement calculations; RIGDL is used for rigid pavements.

Both programs use as part of input a deck describing the violating axles of violating vehicles. The programs accept any number of these axle descriptor cards up to and including 100. Each card in the deck contains

NAXE, LØK, LØVER, AXLES

Format I1, 9X, 3F10.0

Where NAXE = 1 for single axle, = 2 for tandem set

LØK = Legal axle load (Kips)

LØVER = Amount over legal axle load (Kips)

AXLES = Average number of axles with these characteristics per violating vehicle

Input for FLEXL

The first version of this program performs the calculations for a sequence of pavements with structural numbers separated by uniform increments. The second version calculates for structural numbers which are separately listed in input. The second version simply requires additional input as indicated in the input list below:

SNLO, SNHI, SNINC, RFACT

Format 4 F10.0

FMUN

Format F10.0

(Axle descriptor deck as defined)

Card with 3 in position 1.

SN (Second version only)

Format F10.0

ICON (Second version only)

Format I1

Where

SNLO = Minimum structural number of calculation in first version

SNHI = Largest structural number of calculation in first version

SNINC = Increment for advancing structural number in first version

RFACT = Regional factor (used in both versions)

FMUN = Reference axles equivalent to average uncompensated maintenance use per violating vehicle (from program FLEXM)

SN = Structural number for calculation in second version

ICON = A control number, = 1 causes program to return to read another SN value, = 2 causes program exit (second version).

Output from FLEXL

All the output applicable to one value of structural number is printed in sequence. The output is

Structural number

Pavement life in reference axle applications

β_r and ρ_r values in the life calculation

The contribution of each axle in descriptor deck

Average uncompensated life use per violating vehicle (in units of reference axle applications)

Average uncompensated life fraction per violating vehicle

Average uncompensated fraction of maintenance life used per violating vehicle

The contribution of each axle in the description deck is listed in six columns with the following meanings.

Column No.	Value Printed
1	1 = single axle, 2 = tandem set
2	Axle legal weight (Kips)
3	Amount over legal weight (Kips)
4	Reference axles equivalent to legal weight
5	(Reference axles equivalent to actual weight) - (reference axles equivalent to legal weight)
6	Contribution to average uncompensated life use per violating vehicle

The regional factor was omitted in output. It would be a desirable addition to the program.

The program listings follow:

```
C     FLEXL PROGRAM, MRI PROJECT 3158-P, ORIGINAL VERSION
      REAL LOK(100),LOVER(100)
      DIMENSION NAXE(100),AXLES(100)
      BETA(ODE1,ODE2)=0.4+CD*((ODE1+ODE2)/ODE2)**3.23
      RHOCUT(OAD1,OAD2)=OAD2**4.33/(OAD1+OAD2)**4.79
      READ(1,101)SNLO,SNHI,SNINC,REACT
  101 FORMAT(4F10.0)
      READ(1,101)FMUN
      DO 200 I=1,100
      READ(1,102)NAXE(I),LOK(I),LOVER(I),AXLES(I)
      N=NAXE(I)
      GO TO (200,200,202),N
  102 FORMAT(I1,9X,3F10.0)
  202 NDATA=I-1
      GO TO 203
CDATA READ IN COMPLETE, NDATA SET EQUAL TO NO. OF ITEMS
  200 CONTINUE
CBEGIN OUTER LOOP WITH SN VALUE FOR EACH PASS
  203 SN=SNLO
    1 SUM=0.0
      WRITE(3,103)SN
  103 FORMAT(1H1,45HLIFE USEAGE FLEXIBLE PAVEMENT, STRUCTUAL NO.=,F7.2)
      CD=0.081/(SN+1.0)**5.19
      OAD1=18.0
      OAD2=1.0
      BETAR=BETA(OAD1,OAD2)
      RHOCR=RHOCUT(OAD1,OAD2)
      RHOR=10.0**5.93*(SN+1.0)**9.36*RHOCR
      BETINV=1.0/BETAR
PAGE  1
```

```
      WTR=0.62963**BETINV*RHOR/REACT
      WRITE(3,104)WTR,BETAR,RHOR
  104 FORMAT(1H0,22HTOTAL LIFE REF.AXLES= ,E12.5,6HBETAR=,E12.5,5HRHOR=,
     2E12.5,/)
CNOW ENTER INNER LOOP WITH ONE AXLE DATA SET PER PASS
      DO 400 J=1,NDATA
      AXE=NAXE(J)
      OADOK=LOK(J)
      OADACT=OADOK+LOVER(J)
      WRATOK=0.62963**(BETINV-1.0/BETA(OADOK,AXE))*RHOCR/RHOCUT(OADOK,AX
     2E)
      WRATOV=0.62963**(BETINV-1.0/BETA(OADACT,AXE))*RHOCR/RHOCUT(OADACT,
     2AXE)
      RUN=WRATOV-WRATOK
      RAXUN=RUN*AXLES(J)
      SUM=SUM+RAXUN
      WRITE(3,105)NAXE(J),OADOK,LOVER(J),WRATOK,RUN,RAXUN
  105 FORMAT(' ',I1,5X,2F12.3,3(5X,E12.5))
  400 CONTINUE
      WRITE(3,106)SUM
  106 FORMAT(1H0,47HAVE. UNCOMPENSATED LIFE USE PER WT. VIOL VEH.= ,E12.
     25,16HREFERENCE AXLES.)
      SUM=SUM/WTR
      WRITE(3,107)SUM
  107 FORMAT(1H0,52HAVE. UNCOMPENSATED LIFE FRACTION PER WT. VIOL VEH.=
     2,E12.5)
      SUM=FMUN/WTR
      WRITE(3,108)SUM
  108 FORMAT(1H0,63HAVE. UNCOMPENSATED FRACTION OF MAINT. LIFE PER WT. V
PAGE  2
```

```
     1IOL. VEH.= ,F12.5)
C INCREMENT STRUCTURAL NO. AND TEST FOR CONTINUE OF OUTER LOOP.
      SN=SN+SNINC
      IF (SNHI-SN) 500,1,1
  500 CALL EXIT
      END
```

PAGE 3

```
C      FLEXL PROGRAM, MRI PROJECT 3158-P
       REAL LOK(100),LOVER(100)
       DIMENSION NAXE(100),AXLES(100)
       BETA(ODE1,ODE2)=0.4+CD*((ODE1+ODE2)/ODE2)**3.23
       RHOCUT(OAD1,OAD2)=OAD2**4.33/(OAD1+OAD2)**4.79
       READ(1,101)SNLO,SNHI,SNINC,RFACT
  101  FORMAT(4F10.0)
       READ(1,101)FMUN
       DO 200 I=1,100
       READ(1,102)NAXE(I),LOK(I),LOVER(I),AXLES(I)
       N=NAXE(I)
       GO TO (200,200,202),N
  102  FORMAT(I1,9X,3F10.0)
  202  NDATA=I-1
       GO TO 1
CDATA READ IN COMPLETE, NDATA SET EQUAL TO NO. OF ITEMS
  200  CONTINUE
CBEGIN OUTER LOOP WITH SN VALUE FOR EACH PASS
    1  SUM=0.0
       READ(1,101)SN
       WRITE(3,103)SN
  103  FORMAT(1H1,45HLIFE USEAGE FLEXIBLE PAVEMENT, STRUCTUAL NO.=,F7.2)
       CD=0.081/(SN+1.0)**5.19
       OAD1=18.0
       OAD2=1.0
       BETAR=BETA(OAD1,OAD2)
       RHOCR=RHOCUT(OAD1,OAD2)
       RHOR=10.0**5.93*(SN+1.0)**9.36*RHOCR
       BETINV=1.0/BETAR
PAGE   1
```

```
      WTR=0.62963**BETINV*RHOR/RFACT
      WRITE(3,104)WTR,BETAR,RHOR
  104 FORMAT(1H0,22HTOTAL LIFE REF.AXLES= ,E12.5,6HBETAR=,E12.5,5HRHOR=,
     2E12.5,/)
CNOW ENTER INNER LOOP WITH ONE AXLE DATA SET PER PASS
      DO 400 J=1,NDATA
      AXE=NAXE(J)
      OADOK=LOK(J)
      OADACT=OADOK+LOVER(J)
      WRATOK=0.62963**(BETINV-1.0/BETA(OADOK,AXE))*RHOCR/RHOCUT(OADOK,AX
     2E)
      WRATOV=0.62963**(BETINV-1.0/BETA(OADACT,AXE))*RHOCR/RHOCUT(OADACT,
     2AXE)
      RUN=WRATOV-WRATOK
      RAXUN=RUN*AXLES(J)
      SUM=SUM+RAXUN
      WRITE(3,105)NAXE(J),OADOK,LOVER(J),WRATOK,RUN,RAXUN
  105 FORMAT(' ',I1,5X,2F12.3,3(5X,E12.5))
  400 CONTINUE
      WRITE(3,106)SUM
  106 FORMAT(1H0,47HAVE. UNCOMPENSATED LIFE USE PER WT. VIOL VEH.= ,E12.
     25,16HREFERENCE AXLES.)
      SUM=SUM/WTR
      WRITE(3,107)SUM
  107 FORMAT(1H0,52HAVE. UNCOMPENSATED LIFE FRACTION PER WT. VIOL VEH.=
     2,E12.5)
      SUM=FMUN/WTR
      WRITE(3,108)SUM
  108 FORMAT(1H0,63HAVE. UNCOMPENSATED FRACTION OF MAINT. LIFE PER WT. V
PAGE   2
```

```
     1IUL. VEH.= ,E12.5)
CREAD CONTROL NO. FOR NEXT SN OR EXIT
      READ(1,102)ICON
      GO TO (1,500),ICON
  500 CALL EXIT
      END
```

PAGE 3

Input for RIGDL

Axle descriptor deck (not over 100)

3 in position 1

EP, SOILKP, SCP

Format E10.3, 2F10.0

D2, RMUN, CON

Format F10.0, 8X, E12.5, F10.0

Where EP = Modulus of elasticity for concrete (psi)

SOILKP = Soil support value (psi/in)

SCP = Concrete rupture modulus (psi)

D2 = Slab thickness (in.)

RMUN = Number of reference axles equivalent to average uncompensated maintenance use per violating vehicle (from program RIGDM)

CON = A control number, = 0. on all cards containing D2 and RMUN to be calculated, = 1.0 on otherwise blank card to call program exit.

Output from RIGDL

All output for a slab thickness is printed consecutively. The output items are

Thickness

Modulus of elasticity (fails to print because of format error)*

Modulus of rupture for concrete

---

* A simple correction is required. The program is reported here with the error since it is desirable to provide documentation on programs used, not on revised programs.

Soil support value

Total pavement life in reference axle applications

The β_r and ρ_r used in life calculation

RMATL, the factor compensating for current material properties over AASHO test properties

The individual contributions of violation axles

The average uncompensated life use per violating vehicle (in equivalent reference axles)

The average uncompensated life fraction per violating vehicle

The average uncompensated fraction of maintenance life per violating vehicle, and the RMUN value on which it is based

The list of individual axle contributions appears in six columns which have the same meanings as in the FLEXL output.

The program listing follows:

```
C     RIGDL PROGRAM, MRI PROJECT 3158-P
      REAL LOK(100),LOVER(100)
      DIMENSION NAXE(100),AXLES(100)
      BETA(OAD1,OAD2)=1.0+CD*(OAD1+OAD2)**5.20/OAD2**3.52
      RHOCUT(OAD1,OAD2)=OAD2**3.28/(OAD1+OAD2)**4.62
      DO 200 I=1,100
      READ(1,102)NAXE(I),LOK(I),LOVER(I),AXLES(I)
  102 FORMAT(I1,9X,3F10.0)
      N=NAXE(I)
      GO TO (200,200,202),N
  202 NDATA=I-1
      GO TO 203
CAXLE WT DATA READ IN, NDATA EQUAL NO. OF DATA ITEMS
  200 CONTINUE
  203 READ(1,103)EP,SOILKP,SCP
  103 FORMAT( E10.3,2F10.0)
      DUM1=EP/SOILKP
      DUM2=(DUM1/7.0E+04)**0.25
      DUM1=DUM1/11.52
CNOW ENTER OUTER LOOP WHERE EACH PASS USES A VALUE OF PAVEMENT THICKNESS
  600 READ(1,104)D2,RMUN,CON
  104 FORMAT(F10.0,8X,E12.5,F10.0)
      IF (CON)300,300,500
  300 SUM=0.0
      WRITE(3,105)D2,EP,SCP,SOILKP
  105 FORMAT(1H1,35HLIFE USEAGE, RIGID PAVE. THICKNESS=,F7.2,3HE= ,F12.5
     2/7HSSUBC= ,F8.2/7HSOILK= ,F8.2)
      RMATL=(.607638E04*D2*D2*D2)**0.25-10.0
      RMATL=RMATL/((DUM1*D2*D2*D2)**0.25-10.0)
PAGE  1
```

```
      RMATL=(RMATL*DUM2*SCP/690.)**3.42
      CD=3.63/(D2+1.0)**8.46
      OAD1=18.
      OAD2=1.
      RHOCR=RHOCUT(OAD1,OAD2)
      RHOR=10.0**5.85*(D2+1.0)**7.35*RHOCUT(OAD1,OAD2)
      BETAR=BETA(OAD1,OAD2)
      BETINV=1.0/BETAR
      WTR=.666667**BETINV*RHOR*RMATL
      WRITE(3,106)WTR,BETAR,RHOR,RMATL
  106 FORMAT(1H0,12HTOTAL LIFE= ,E12.5,11H REF. AXLES,/,7HBETAR= ,E12.5,
     28H  RHOR= ,E12.5,9H  RMATL= ,E12.5,/)
CNOW ENTER INNER LOOP WITH ONE AXLE DATA SET PER PASS.
      DO 400 J=1,NDATA
      AXE=NAXE(J)
      OADOK=LOK(J)
      OADACT=OADOK+LOVER(J)
      WRATOK=.666667**(BETINV-1.0/BETA(OADOK,AXE))*RHOCR/RHOCUT(OADOK,AX
     2E)
      WRATOV=.666667**(BETINV-1.0/BETA(OADACT,AXE))*RHOCR/RHOCUT (OADACT
     2,AXE)
      RUN=WRATOV-WRATOK
      RAXUN=RUN*AXLES(J)
      SUM=SUM+RAXUN
      WRITE(3,107)NAXE(J),OADOK,LOVER(J),WRATOK,RUN,RAXUN
  107 FORMAT(' ',I1,5X,2F12.3,3(5X,E12.5))
  400 CONTINUE
      WRITE(3,108)SUM
  108 FORMAT(1H0,47HAVE. UNCOMPENSATED LIFE USE PER WT. VIOL VEH.= ,E12.
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```

```
   25,18H   REFERENCE AXLES.)
      SUM=SUM/WTR
      WRITE(3,109)SUM
  109 FORMAT(1H0,53HAVE. UNCOMPENSATED LIFE FRACTION PER WT. VIOL. VEH.=
   2 ,E12.5)
      SUM=RMUN/WTR
      WRITE(3,110)SUM,RMUN
  110 FORMAT(1H0,53HAVE. UNCOMPENSATED FRACTION OF MAINT. LIFE PER WT. V
   2IOL. VEH.= ,E12.5,17H   BASED ON RMUN= ,E12.5)
      GO TO 600
  500 CALL EXIT
      END
```

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APPENDIX 11

IOWA PUBLIC SCALES AVAILABLE FOR USE BY T.W.O. OFFICERS

Background

Recommendations concerning possible construction of new scales should take into account the fact that there are public scales available for use by T.W.O. officers.

MRI requested that a survey be made of public scales with a capacity of 40,000 lb. and over to determine their number and geographic distribution.

The attached information indicates that there are over 1,500 public scales compared to the Highway Commission's 31 and that some are available in every county.

T.W.O. officers currently use some of these scales routinely. Increased reliance on them is certainly feasible, but not without cost. The average charge to Iowa for use of a public scale is approximately $1-$2.

The effective volume handling capacity of public scales is less than state scales because officers generally have to escort each vehicle to the public scale location.

One major possible use for public scales would be for night time roving patrols as discussed in the Results Section of the report.

NUMBER OF SCALES IN EACH COUNTY
40,000 POUNDS AND OVER

Adair
Adams } - No scales listed in these two counties, but we know there are scales in these counties.

Allamakee - 4
Appanoose - 9
Audubon - 7
Benton - 22
Black Hawk - 33
Boone - 15
Bremer - 11
Buchanan - 20
Buena Vista - 23
Butler - 1
Calhoun - 21
Carroll - 23
Cass - 2
Cedar - 20
Cerro Gordo - 44
Cherokee - 18
Chickasaw - 18
Clarke - 2
Clay - 22
Clayton - 10
Clinton - 25
Crawford - 13
Dallas - 12
Davis - 6
Decatur - 8
Delaware - 10
Des Moines - 14
Dickinson - 12
Dubuque - 25
Emmet - 16
Fayette - 22
Floyd - 11

Franklin - 8
Fremont - 5
Greene - 18
Grundy -3
Guthrie - 1
Hamilton - 10
Hancock - 21
Hardin - 19
Harrison - 27
Henry - 20
Howard - 11
Humboldt - 22
Ida - 8
Iowa - 7
Jackson - 11
Jasper - 18
Jefferson - 8
Johnson - 19
Jones - 8
Keokuk - 8
Kossuth - 24
Lee - 19
Linn - 42
Louisa - 8
Lucas - 7
Lyon - 16
Madison - 10
Mahaska - 2
Marion - 3
Marshall - 23
Mills - 9
Mitchell - 13

Monona - 9
Monroe - 2
Montgomery - 12
Muscatine - 24
O'Brien - 20
Osceola - 14
Page - 15
Palo Alto - 15
Plymouth - 14
Pocahontas - 13
Polk - 48
Pottawattamie - 22
Poweshiek - 22
Ringgold - 2
Sac - 24
Scott - 36
Shelby - 17
Sioux - 20
Story - 31
Tama - 30
Taylor - 3
Union - 9
Van Buren - 11
Wapello - 13
Warren - 12
Washington - 21
Wayne - 8
Webster - 35
Winnebago - 11
Winneshiek - 7
Woodbury - 29
Worth - 9
Wright - 20

TOTAL 1,505