Task B2: Analytic Assumptions

Traffic Load Monitoring and Projections

submitted to

Federal Highway Administration

DTFH61-95-C-00060

submitted by

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October 30, 1998

This paper presents proposed values for most of the variables required for performing the Task C1 analyses. In that task, as described in our Detailed Work Plan, we will perform analyses of the effects of individual variables on accumulated ESALs, pavement design, pavement life, and life-cycle costs for pavement. Our analyses will be for rigid pavement on a four-lane road in the rural other principal arterial (ROPA) functional system (Functional System 2). Values of additional variables required for the more extensive analyses to be performed in Task C2 will be developed in the course of Task C1.

Traffic Variables

Table 1 presents a summary of analyses, most or all of which will be performed in Task C1. The most significant difference[1] between this table and Table 1 of our Detailed Work Plan is the addition of an explicit analysis (A2) of the effects of typical factoring errors resulting from the use of Procedure 5 in our Task B1 report. As stated in our Detailed Work Plan, each analysis will estimate the effects of a potential source of error on pavement design thickness and on pavement life-cycle costs. All analyses will be performed for a "typical" four-lane road in the ROPA functional system.

Table 2 presents proposed values for most of the traffic variables required for the Task C1 analyses outlined in Table 1. Values shown in parentheses are not required for any of the analyses but are shown because they may be of some interest. Most of the values in Table 2 were obtained from sources specified in the table or were based on judgmental interpretation of data in those services. Although not explicitly stated in the footnotes, most of the values also incorporate some judgmental rounding.

In general, the effects on life-cycle costs estimated in Task C1 are likely to be fairly sensitive to the values used for these traffic variables, so we have take care to propose realistic values for all variables. Of particular interest is the degree of error likely in estimates of AADT by VC produced when Procedure 5 is used. As shown in Table 2, we propose assuming typical errors of ± 10 percent for this purpose. The following two paragraphs present the reasoning that resulted in this proposed assumption.

An analysis of data from continuous monitoring sites in four states (Cambridge Systematics, 1994) found that, for rural non-Interstate factor groups, with one exception, standard factoring procedures were able to estimate *total* AADT with mean absolute errors (MAEs) of 5.9 - 10.2 percent. The exception was a group of low volume roads in Nebraska, which had an average AADT of 186 and a MAE of 12.0 percent. In general, factoring errors increase as AADT declines. Hence, it is

[1] Minor differences are: the interchanging of Groups D and E (for consistency with the discussion sequence in our Task B1 Report); and a more specific description of (new) Item E3.

reasonable to assume that MAEs of total truck AADT will be near or above the high end of the 5.9 - 10.2 percent range. On the other hand, on roads with total truck AADT of 1700, MAEs are likely to be lower than 12 percent.

Table 1. Potential Alternatives to be Analyzed

A. Seasonal and Day-of-Week Factors for Combination Trucks:

1. A typical AADT/weekday-count ratio for a typical state.
2. Typical factoring errors.
3. A typical AADT/weekday-count ratio for a road with relatively high weekend truck volumes.
4. A typical ratio of AADT to harvest-season weekday counts.
5. A typical ratio of AADT to harvest-season weekday counts for a road with little or no harvest-season traffic.
6. The ratio of AADT to peak-season weekday counts for a road with atypical seasonal peaking.

B. Percentages of Trucks Factors:

1. Typical percentages for a typical state, obtained from a 365-day AVC count.
2. Percentages obtained at this site using a 48-hour weekday AVC count.

C. Truck Lane Distribution Factors:

1. Typical lane distribution factors.
2. High lane distribution factors.
3. Low lane distribution factors (trucks uniformly distributed across lanes).

D. ESAL Factors by Vehicle Type:

1. Annual average values for typical road.
2. Values for road for which values are at high end of range.
3. Values for road for which values are at low end of range.
4. Values obtained for typical road when values tend to be seasonally high.
5. Values obtained for typical road when values tend to be seasonally low.
6. For road for which values vary by direction, values by direction.

E. Growth Rates:

1. Typical exponential growth rates for heavy trucks and for other vehicles.
2. A single typical exponential growth rate for all traffic.
3. Linear growth for heavy trucks and other vehicles.
4. Exponential growth rates for heavy trucks and other vehicles in a high-growth area.
5. A single exponential growth rate for all traffic in such an area (evaluated relative to D4).
6. Exponential growth rates for heavy trucks and other vehicles in a low-growth area.
7. A single exponential growth rate for all traffic in such an area (evaluated relative to D6).

Table 2. Proposed Values to be Used for Traffic Variables

	Mean	Standard [2]Deviation
Total Volume		
AADT	15,000[a]	(10,000[a])
Single-Unit Trucks		
AADT	500[b]	(600[c])
Percent of total AADT	3.3%[d]	
AAWDT	600[d]	
Combination Trucks		
AADT	1,200[b]	(1,200[c])
Percent of total AADT	8%[d]	
AAWDT	1,500[d]	
Harvest season AAWDT	2,000[e]	
Effect of Typical Factoring Errors on Truck AADT	10%[f]	
Truck Lane Distribution Factor	0.95[g]	
Alternative values	0.5[h]	
	1.0[h]	
Growth Rates		
4-tire vehicles	3.09%[i]	0.9%[c]
Single-unit trucks	3.25%[i]	1.5%[c]
Combination trucks	3.67%[i]	1.5%[c]
Overall	3.12%[i]	0.9%[j]
ESAL Factors		
Single-unit trucks	0.4[k]	(0.1[k])
Range	0.2 - 0.6[k]	
During heavy season	0.75[k]	
During light season	0.2[k]	
For road on which factors vary by direction		
Loaded direction	0.55[j]	
Unloaded direction	0.25[j]	
Combination trucks	1.15[k]	(0.3[k])
Range	0.7 - 1.6[k]	
During heavy season	2.2[k]	
During light season	0.5[k]	
For road on which factors vary by direction		
Loaded direction	1.5[j]	
Unloaded direction	0.8[j]	

Sources on next page.

Table 2. Proposed Values to be Used for Traffic Variables (Continued)

Sources:
a. 1996 Highway Performance Monitoring System data for rural other principal arterials with four lanes (mean rounded up from 13,900).
b. Derived from other values in table.
c. Judgment and other values in table.
d. Hallenbeck, 1997.
e. Stein, 1998.
f. Judgmentally derived from Cambridge Systematics, 1994.
g. AASHTO, 1993.
h. Assumed.
i. Derived from FHWA, 1997a, and FHWA, 1997b.
j. Vlatas and Dresser, 1991.
k. Based on data in Hallenbeck and Kim, 1993.

The above information *suggests* that 10 or 11 percent are likely values for MAEs for total truck AADT on our "typical" four-lane ROPA. For individual VCs, MAEs would likely be higher (and much higher for the less common VCs). However, on an overall basis, the errors obtained for individual VCs usually will partly cancel each other. For the purpose of estimating the typical effect of these errors on estimates of total ESALs, a 10 or 11 percent error appears to be appropriate. Since 10 is a round number, we propose to analyze the effects of +10 and -10 percent errors in the estimates of truck AADT.

Pavement Variables

Table 3 shows values we propose to use for the variables used by the AASHTO design equation for rigid pavements, along with the source of each variable. These values will be used without change in all analyses. Hence, they are likely to have fairly similar effects on pavement design thicknesses and life-cycle costs estimated in all our analyses, and they are unlikely to have any significant effect on our estimates of the relative quality of alternative traffic-analysis assumptions.

Table 3 Proposed Values for Pavement Design Variables

Variable		Value	Source
p_1	Serviceability after reconstruction	4.5	1
p_t	Terminal serviceability	2.5	2
R	Reliability	85%	3
S_o	Standard deviation of logarithm of pavement life	0.3	2
J	Surface load transfer factor	2.8	4
C_d	Drainage factor	1.15	4
k	Effective subgrade reaction modulus	150	4
S_c'	Concrete rupture modulus	650	2
E_c	Concrete elastic modulus	70,000,000	2

Sources:
1. AASHTO, 1993, p. I-8.
2. AASHTO, 1993, pp. II-45 and II-46.
3. AASHTO, 1993, pp. II-9.
4. Jiang, Darter and Owusu-Antwi, 1996.

Life-Cycle Cost Analyses

On the basis of information contained in Cole (1995), we propose to assume a 40-year period for all analyses, with design lives of 28 years for reconstructed Portland cement concrete (PCC) pavement and 12 years for asphalt overlays. As stated in our Task B1 Report, we propose to perform all analyses with a four percent discount rate and to repeat them with a seven percent discount rate. The presentation of our results will focus on the results obtained with one of these discount rates (probably four percent), with a much more cursory discussion of the results obtained with the other rate.

As stated in Section 4 of our Task B1 Report, our estimates of life-cycle costs will include:

- Agency costs for pavement reconstruction and resurfacing;
- Agency costs for contracted and in-house maintenance activities;
- Increased vehicle operating costs and travel-time costs resulting from operation on roads with deteriorated pavements; and
- User delay resulting from pavement reconstruction or resurfacing.

In addition, our estimates will incorporate a simple estimate of the last pavement improvement's residual value at the end of the analysis period. For this purpose, we propose to prorate the cost of the last pavement improvement on the basis of the fraction of its life remaining at the end of the analysis period, where fraction of life remaining may be specified on the basis of either time or pavement condition. If pavement condition is used, the formula for residual value is:

$$V_R = \frac{p - p_f}{p_1 - p_f} \; C_1 \quad (1)$$

Where:

V_R = the residual value at the end of the analysis period;

C_1 = total cost of the last improvement (to the highway agency and to users);

` p = pavement condition (PSI) at the end of the analysis period;

p_1 = pavement condition when pavement was last improved; and

p_f = pavement condition when next improvement will be required.

With two exceptions, procedures and equations for obtaining estimates of the other components of life-cycle costs were presented in Section 4 of our Task B1 Report. One of the exceptions is the cost of pavement maintenance activities; we

will develop procedures for estimating these costs after receipt of a recent study by Michigan State University (1998). The other exception is the cost of user delay due to reconstruction of PCC pavement. We expect to derive an equation for estimating this cost by incorporating the difference in time required for asphalt overlays and PCC pavement reconstruction into our existing equation for estimating the cost of user delay due to an asphalt overlay.

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