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CIVIL ENGINEERING

COURSE NAME:
(BACHELOR'S IN CIVIL ENGINEERING)

Assignment Title:
(Highway engineering 1.)

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Question one

The ministry of works and transport has proposed an upgrade of the rusorera – kakindo to a dual carriageway and to improve some of its junctions. The time for construction of the scheme has been set at two years, with the benefit of the scheme accruing to the road users at the start of the third year. The three main benefits considered are time savings, accident costs, saving and vehicle operating cost reduction. Construction costs are incurred mainly during the two years of construction. But on going annual maintenance cost must be allowed for throughout the economic life of the project which is expected to be 10 years after the load has been commissioned. The following basic data has already been ascertained by experts in highway economics for this analysis:

Accident rate: 0.85 per million vehicle- kilometers (Existing road)
0.25 Per million vehicle-kilometers (Upgraded road)
Average Accident Cost: Us $10,000
Average vehicle time saving; us$ 2.00 per hour
Average vehicle speeds ; 40km/hr. (Existing road)
85km/hr. (Uganda road)
Average vehicle opening cost 0.01 [2+($\frac{35}{v}$) +$0.00005v^2$] in us $ per km
V is the Average vehicle speed
Discount rate 6%
Predicted flow in year 3, f 250 mil. Veh – km/hr.

The traffic flows and the construction / maintenance costs from the highway proposal are shown in the table below.

Traffic flows and costs throughout the economic life highway proposal

year	Predicted flow (10^6Veh – km/yr)	Construction costs (in us $)	Operation cost (in us $)
1	-	150,000,000	-
2	-	10,000,000	-
3	250	-	500,000
4	260	-	500,000
5	270	-	500,000
6	280	-	500,000
7	290	-	500,000
8	300	-	500,000
9	310	-	500,000
10	320	-	500,000
11	330	-	500,000
12	340	-	500,000

As an consultant engineer to the ministry of works and transport, you have been assigned the task of ascertaining whether the project is economically justified. Or not, using both the NPV and b/s ratio techniques for economic evaluation. Briefly comment on your results.

Solution
The extracted data,
Accident rate: R_e = 0.85 per million vehicle- kilometers (Existing road)
R_U = 0.25 per million vehicle-kilometers (Upgraded road)
Average Accident Cost: C_a = Us $10,000
Average vehicle time saving; $s_t =$ us$ 2.00 per hour
Average vehicle speeds ; $v_e =$ 40km/hr. (Existing road)
V_U = 85km/hr. (Uganda road)
Average vehicle opening cost 0.01 $C_{O=}$ = 0.01 [2+($\frac{35}{v}$) +$0.00005v^2$]

Discount rate r = 6%

Required computations
Total benefit, B = $B_a + B_t + B_o$
Where the above terms are defined as below for the third year. F being the predicted flow;
Accident savings
$B_a = (R_e - R_U).C_a.F$ = (0.85 – 0.25) (10000)(250) = us $ 1500000/yr
Operating cost savings
$B_o = 0.01[35\,(\frac{1}{v_e} - \frac{1}{v_u})$ + 0.00005()$v_E^2 \quad - v_u^2$]. F

= 0.01[35($\frac{1}{40}$ - $\frac{1}{85}$) + 0.00005 (40^2 - 85^2)] (250)(10^6) = US $ 454,963/ yr

Time savings

$B_o = (\frac{1}{v_e} - \frac{1}{v_u})$. s_t.F = ($\frac{1}{40}$ - $\frac{1}{85}$) (2.00) (250)(10^6) = us $ 6,617,647 /yr

Therefore the total benefit is given by ;
B = 1500000 + 454963 + 6,617,647 = US $7,197,729

Computation of discounted benefits and costs

		Benefits					costs	
Year	Flow F mil.veh-km/yr	Accident cost savings us $ year	Operating cost savings us$/yr	Travel time savings us $/yr	Total user benefits , B us $/yr	Discounted benefits (PVB) us $/yr	Construction and maintenance costs (us $/yr)	Discounted cost (PVC) us $/yr
1							15,000,000	14,150,943
2							10,000,000	8,899,964
3	250	1,500,000	454963	6,617,647	8,572,610	7,197,729	500,000	419,810
4	260	1,560,000	473162	6,882,353	8,915,515	7,061,923	500,000	396,047
5	270	1,620,000	491360	7,147,059	9,258,419	6,918,429	500,000	373,629
6	280	1,680,000	509559	7,411,765	9,601,324	6,768,555	500,000	352,480
7	290	1,740,000	527757	7,676,471	9,944,228	6,613,480	500,000	332,529
8	300	1,800,000	545956	7,941,176	10,287,132	6,454,274	500,000	313,706
9	310	1,860,000	564154	8,205,882	10,630,036	6,291,902	500,000	295,949
10	320	1,920,000	582353	8,470,588	10,972,941	6,127,233	500,000	279,197
11	330	1,980,000	600551	8,735,294	11,315,845	5,961,046	500,000	263,394
12	340	2,040,000	618750	9,000,000	11,658,750	5,794,042	500,000	248,485
					$\sum \boldsymbol{PVB}$	65,188,613	$\sum \boldsymbol{PVB}$	26,326,133

Computation of NPV &B/C ratio

NPV = $\sum \boldsymbol{PVB}$ **-** $\sum \boldsymbol{PVC}$ **= 65,188,613 – 26,326,133 = US$ 38,862,480**

B/C ratio = $\sum \boldsymbol{PVB}$ **/** $\sum \boldsymbol{PVC}$ **=** $\frac{\mathbf{65{,}188{,}613}}{\mathbf{26{,}326{,}133}}$ **= 2.476**

On conclusion, all the above indicators point to the economic strength of the project under examination.

Question two

The table below shows measured turning movements in the AM peak period as recorded in a traffic survey at a four arm roundabout. The survey was carried out in 2005. The expected rete of traffic growth is 2% it is assumed, that findings will be ready available and that if any redesigns and reconstruction is needed, the roundabout will be reopened to traffic in the same year the survey was carried out. The roundabout is being assessed for capacity to curry peak flows in 2019. The geometric parameters for arms A and B are as shown below.

geometric parameters	Symbols	Units	Arm A	Arm B
Entry width	e	m	14.0	9.0
Approach half width	v	m	8.0	4.5
Average effective flare length	ɤ	m	40.0	40.0
Sharpness of flare	s	-	-	-
Inscribed circle diameter	D	m	30.0	30.0
Entry angle	Φ	deg	30.0	40.0
Entry radius	r	m	40.0	30.0

The base year traffic survey carried out in 2005 reviled the following traffic flows in pcu/hr

	To (destination				
		A	B	C	D
From origin	A	-	220	450	210
	B	200	-	320	450
	C	550	250	-	320
	D	100	420	220	50

The general layout of the roundabout is shown above

Determine the following;

- Design flows for the year 2019

- The approach capacity of arms A and B of the roundabout.
- Establish which of the two arms still has capacity and which one does not.

Solution

Design data

Traffic growth rate r = 2%

Design life, [y (2019 - 2005) + 1] = 15 yrs.

Geometric parameter of the arm A and B is shown in the table below

<u>Traffic assessment</u>

Design flow, DF

DF = 1.125DRF = 1.125P $(1 + r)^y$

Whereby; p = present flow (in pcu/hr)

R = Traffic growth rate (in %)

Y = design life in years

DF = design flow (a modification of the future traffic flow)

DRF = design reference flow

The table of DF of the year 2019

This is from the formula (1.125P $(1 + r)^y$)

		To (destination			
		A	B	C	D
From origin	A	0	333	681	318
	B	303	0	485	681
	C	833	379	0	485
	D	151	636	333	76

3.2 Entry Capacity, Q_e

$$Q_e = k(F - f_c Q_c) \quad where\ f_c Q_c \le F$$
$$= 0 \quad where\ f_c Q_c > F$$

The parameters k, F, f_c, and Q_c are determined as follows

a) Values of k

$$k = 1 - 0.00347(\emptyset - 30) - 0.978\left(\frac{1}{r} - 0.05\right)$$

$$Arm\ A{:}\ k = 1 - 0.00347(30 - 30) - 0.978\left(\frac{1}{40} - 0.05\right) = 1.0245$$

$$Arm\ B{:}\ k = 1 - 0.00347(40 - 30) - 0.978\left(\frac{1}{30} - 0.05\right) = 0.9816$$

b) Values of F

$$F = 303x_2$$

Where;

$$S = \frac{1.6(e - v)}{l'} \Rightarrow S_{Arm\ A} = \frac{1.6(14 - 8)}{40} = 0.240,\ \ S_{Arm\ B} = \frac{1.6(9 - 4.5)}{40} = 0.180$$

$$x_2 = v + \frac{(e - v)}{(1 + 2S)} \Rightarrow x_{2\ Arm\ A} = 8 + \frac{(14 - 8)}{[1 + 2(0.24)]} = 12.054$$

$$\Rightarrow x_{2\ \mathrm{Arm\ B}} = 4.5 + \frac{(9-4.5)}{[1+2(0.180)]} = 7.809$$

$Arm\ A: F = 303(12.054) = 3652.362$
$Arm\ B: F = 303(7.809) \quad = 2366.127$

c) Values of f_c
$f_c = 0.210t_D(1 + 0.2x_2)$

Where;

$$M = \exp\left[\frac{(D-60)}{10}\right] \Rightarrow M_{\mathrm{Arm\ A}} = e^{\left[\frac{(30-60)}{10}\right]} = 0.0498,\ M_{\mathrm{Arm\ B}} = e^{\left[\frac{(40-60)}{10}\right]} = 0.0498$$

And;

$$t_D = \left[1 + \frac{0.5}{(1+M)}\right] \Rightarrow t_{D\ \mathrm{Arm\ A}} = \left[1 + \frac{0.5}{(1+0.0498)}\right] = 1.476,\ t_{D\ \mathrm{Arm\ B}} = 1.476$$

Therefore;

$Arm\ A: fc = 0.210(1.476)[1 + 0.2(12.054)] = 1.057$
$Arm\ B: fc = 0.210(1.476)[1 + 0.2(7.809)] = 0.794$

d) Circulating Capacity Q_c

Arm A: Q_c = $Q_{BB} + Q_{CC} + Q_{DD} + Q_{CB} + Q_{DB} + Q_{DC}$
= $0 + 0 + 76 + 379 + 636 + 333$
= $1424\ pcu/hr$

Arm B: Q_c = $Q_{AA} + Q_{CC} + Q_{DD} + Q_{DC} + Q_{AC} + Q_{AD}$
= $0 + 0 + 76 + 333 + 681 + 318$
= $1408\ pcu/hr$

Finally, the entry capacity, Q_e for;

$Arm\ A: Q_e = 1.0245[3652.362 - 1.057(1424)] = 2200$pcu/hr

$Arm\ B: Q_e = 0.9816[2366.127 - 0.794(1408)] = 1225$ pcu/hr

3.3 Approach Capacity, Q

Arm A: Q = $Q_{AA} + Q_{AB} + Q_{AC} + Q_{AD}$
= $0 + 333 + 681 + 318$
= $1332 pcu/$hr

Arm B: Q = $Q_{BA} + Q_{BB} + Q_{BC} + Q_{BD}$
= $303 + 0 + 485 + 681$
= $1469 pcu/$hr

3.4 Capacity Check, RFC

For sufficient capacity;

RFC = $\frac{Q}{Q_e}$ < or = 0.85

Arm A RFC = $(\frac{Q}{Q_e})_C = \frac{1332}{2200} = 0.61 < 0.85$ …arm still has sufficient capacity.

Arm B RFC = $(\frac{Q}{Q_e})_D = \frac{1469}{1225} = 1.20 < 0.85$ …arms capacity has been exceeded.

Arm c has a RFC ratio of 61% which is less than 70% implying that queuing on this arm will be avoided for 39 out of 40 peak hours.

Arm D on the other hand, has a RFC ratio of 120% which is far greater than 85%, implying that queuing will occur on this arm of the roundabout in all the peak hours

Question three,

The gayaza – kakindo road is in a state of failure and is due for reconstruction. The following facts have already been gathered about the project road.

a) The road is located in a region that has a rainy season with the total span of five months.
b) The subgrade soil is a good quality gravel with socked CBR in the range of 20% to 30 % ;
c) The sub-base material will be cement treated type C ;
d) The most economical material for the road base will be crushed stone ;
e) The most settable surfacing material will be asphalt concrete (AC)

Traffic counts and axle load surveys have shown that the initial (un directional) dairy number of commercial vehicles will be as follows

a. 2– axle and tandem trucks …………..140veh per day
b. Trucks with draw bar trailer ………….. 30veh per day
c. Articulated units ………………….16veh per day
d. busses …………………40veh per day

The economic study has recommended a 15 year design life and forecasts a constant annual traffic growth rate of 2.5%. Design the flexible pavement using the AASHTO approach

Extracted data.

Number of wet months in the region, n_w = 5
Subgrade CBR = 20-30%
Traffic growth rate , r = 2.5 %
Design life y = 15 years
Construction material;

Surfacing material	asphalt concrete (AC)
Road base material	crushed stone stabilized
Sub-base	
Sub-base material	cement treated type C

Determination of subgrade strength, s

From the table of subgrade class in AASHTO approach, CBR range of (20 – 30%) falls in the range 18 %< CBR< 30% implying that the subgrade strength class is s4 .

Determination of cumulative design traffic, T

$D_T = \sum_i^n ti$
Where;
$t_i = 365.V.C.G.Y \times 10^{-6}$ in msa
Unidirectional traffic flow v
The directional split is 100% . F = 100% of traffic volume for each vehicle slass for example 2-axle and tandem trucks
F = 100% x 140 = 140 veh per day .

Wear factor, w

From the table of average equivalence factors, c_i in AASHTO approach,

$C = (\frac{axle\ load, kN}{80})^{4.0}$.
That is to say, since there is no axle loads, the actual tandem trucks; = 2.0

Growth factor, G
According to AASHTO growth factor equation

$$G = [\frac{(1+r)^{y}-1}{y.r}]$$

$$G = [\frac{(1+0.025)^{15}-1}{15(0.025)}] = 1.1955$$

Vehicle class	V (veh/day)	C (esa)	G	Y (years)	Dr (msa)
2-axle and tender trucks	140	2	1.1955	15	1.833
Trucks with drawbar trailer	30	6	1.1955	15	1.178
Articulated units	16	6	1.1955	15	0.628
buses	40	1	1.1955	15	0.262
Cumulative design traffic, Dr (in msa)					***3.901***

From the table of **Cumulative design traffic** in AASHTO approach, **3.901** msa corresponds to a traffic class of T2 where by **2.5 < (in msa) < 8.3**

Required design structural number, DSN.

$$DSN = \frac{(SN_D)(SN_W)}{[\left(\frac{(N_W)}{12}\right)(SN_D)^{2.8} + \left(\frac{(N_D)}{12}\right)(SN_W)^{2.8}]^{\frac{1}{2.8}}}$$

$$DSN = \frac{(59)(82)}{[\left(\frac{(5)}{12}\right)(59)^{2.8} + \left(\frac{(7)}{12}\right)(82)^{2.8}]^{\frac{1}{2.8}}} = 65.4$$

Layer Thicknesses based on the actual design structural number, DSN
The actual design structural number **DSN** $_a$ is given by;

$$DSN_a = a_1h_1 + a_2h_2 + a_3h_3$$

From the design chart for a subgrade strength class in AASHTO approach , s4 and traffic class T2 corresponds to an asphalt surfacing thickness , $\mathbf{h}_1$ of 50mm. and from the table of layer coefficients, $\mathbf{a}_1 = 0.35$, $\mathbf{a}_2 = 0.81$ *and* $\mathbf{a}_3 = 0.12$ therefore ;

$\mathbf{DSN}_a = 0.35(50) + 0.18\mathbf{h}_2 + 0.12\mathbf{h}_3$

By trial and error with guidance from the compacted thickness ranges in AASHTO approach, let's try, $\mathbf{h}_2 = 200mm$ and $\mathbf{h}_3 = 200mm$ for which;

$\mathbf{DSN}_a = 0.35(50) + 0.18 \times (200) + 0.12 \times (200) = 77.5$
Since $\mathbf{DSN}_a$ = 77.5 > DSN = **65.4 , it** implies that design thickness for the layers are capable.

In conclusion, the pavement should therefore be composed of the following layer thickness.

a. surfacing layer : 50mm
b. road base : 200mm
c. sub base : 200mm

Bibliography

Resuch

Number	**Souse**	**Title**	**author**	**year**
1	Journal	Cost benefit analysis ; applications and future opportunities	B Gibson	2016
	Journal	Transportation benefit- cost analysis	Williges chris and Mahmoud mahdavi	2008
2	book	Calculation of roundabouts ;capacity ,waiting phenomena and reliability	Raffaele mauro	2010
3	book	Pavement design and materials .	A.T Papagiannakis, E.A masad	2008
		AASHTO guide for design of pavement structures	American association of state highway and transportation officials , national cooperative highway research program	1993