NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF ENGINEERING

DEPARTMENT OF CIVIL AND WATER ENGINEERING

TRANSPORTATION ENGINEERING I

ECW 3109

Main Examination Paper

December 2024

This examination paper consists of 7 printed pages.

Time Allowed: **3 Hours**

Total Marks: **100**

Examiner's Name: **M. ZHOU**

INSTRUCTIONS

1. Answer any **FOUR** Questions. All questions carry equal marks.
2. Use of calculators is permissible.
3. Supplementary information is provided at the end of the Examination Paper. Candidates are advised to make reasonable assumptions where the given information appears inadequate.
4. Illustrate your answers with clearly well labelled sketches where applicable.

MARK ALLOCATION

QUESTION	MARKS
1.	25
2.	25
3.	25
4.	25
5.	25
TOTAL POSSIBLE MARKS	100

QUESTION 1

a) Define Transportation Engineering and the roles of a Civil Engineer in relation to the following:

i. Geometric design of roads,

ii. Pavement design,

iii. Traffic flow theory,

iv. Roadway capacity analysis and

v. Traffic Management and Control at Intersections. **[10marks]**

b) Define the Level of Serve (LOS) and describe its categories in terms of roadway capacity and average delay. Describe traffic conditions in detail per each category. **[15marks]**

QUESTION 2

a) List 4 factors that influence the geometric design of highways. **[4marks]**

b) Provide a clearly labelled sketch of the cross-section of a two-lane highway. **[4marks]**

c) Provide clearly labelled sketches to show elements and properties of:

i. Horizontal and

ii. Vertical curves. **[8marks]**

d) A 150-m-long equal-tangent crest vertical curve connects tangents that intersect at station 10+360 [m] and elevation 400m AMSL. The initial grade is +4.0% and the final grade is -2.5%. Sketch the curve and determine the elevation and stationing of the high point, PVC and PVT. **[9marks]**

QUESTION 3

a) Define the term pavement and describe its functions. **[4marks]**

b) Draw typical *flexible* and *rigid* pavement structures and identify each layer which plays a role in carrying the traffic loads. **[8marks]**

c) A proposed four-lane major rural highway (2 lanes in each direction) has an estimated Annual Average Daily Traffic (AADT) of 5800 veh/day. This volume is expected to grow at a rate of 6% per annum over the pavement construction period of 5years. Upon opening of the road to traffic at the beginning of the 6th year, annual growth rate of traffic is expected to increase to 8% per annum over the 30-year design life of the pavement. The traffic mix and axle loads are given below:

70% Passenger cars @ 4.5kN per axle

20% 2-Axle trucks @ 28kN per axle

10% 3-Axle trucks @ 40kN per axle

i. Determine the total number of ESALs (or E80s) for the 30-year design life of the pavement if 80% of the directional traffic is considered to be on the design lane. **[6marks]**

ii. What *pavement class* and *road category* should be designed for, according to the Zimbabwean design recommendations? **[2marks]**

iii. By how much will the ESAL value change if the percentage of 3-axle trucks increases to 20% while that of 2-axle trucks reduces to 10%? **[5marks]**

QUESTION 4

a) What do you understand by Traffic Engineering? **[2marks]**

b) 20 vehicles pass a given observation spot x_0 in 1 minute and collectively move a length of 1.6km on the road. For this scenario, establish the following:

i. Flow rate q
ii. Density k
iii. Space mean speed
iv. Average space headway
v. Average time headway **[10marks]**

c) In a traffic observation for a section of highway that has a free-flow speed of 120km/hr and capacity of 3600veh/hr, about 2400 vehicles were counted passing through the observation spot in an hour. If the speed-flow-density relationship according to Greenshield applies for this situation, estimate the space-mean speed of the surveyed vehicles. **[4marks]**

d) A section of a highway has the following flow-density relationship: $q = 80k - 0.4k^2$

What is,

i. the capacity of the highway section
ii. the speed at capacity
iii. the density when the highway is at one-quarter of its capacity? **[9marks]**

QUESTION 5

a) Briefly describe the following in relation to traffic flow theory

i. Level of service (LOS)

ii. Shockwave analysis

iii. Queuing theory

iv. Continuum law of Traffic **[8marks]**

b) The traffic volume q [veh/h] on an urban freeway can be described with the following equation for $q(k)$:

$q = 240k - 50k \ln k$

where k is the density in [veh/km].

i. Calculate the *density at capacity* k_C *[veh/km]* and *capacity* q_C *[veh/h]* of the freeway. **[6marks]**

ii. Calculate the *jam density kjam [veh/km]* of the freeway. **[3marks]**

The freeway is operating at capacity conditions when a motor club decides to block the entire freeway for 10 minutes.

iii. Calculate the *speed and direction* of the shockwave and determine the *number of vehicles* that have been affected by the protest by the time the block is being removed. **[8marks]**

Additional Information

$$ESAL_l = f_d \times G_{rn} \times AADT_l \times 365 \times N_l \times F_{El}$$

$$\text{Traffic}_{\text{nth year}} = 365 \times A(1 + r)^n$$

TABLE 8 80 kN single-axle load equivalency factors, derived from $F = (\frac{P}{80})^4$

SINGLE-AXLE LOAD, P kN	80 kN AXLE EQUIVALENCY FACTOR, F
Less than 15	0,000
15 - 24	0,004
25 - 34	0,019
35 - 44	0,062
45 - 54	0,15
55 - 64	0,32
65 - 74	0,59
75 - 84	1,00
85 - 94	1,6
95 - 104	2,4
105 - 114	3,6
115 - 124	5,1
125 - 134	7,0
145 - 154	9,4
155 - 164	12
165 - 174	16
175 - 184	20
185 - 194	26
195 - 204	32
	39

TRAFFIC CLASS	CUMULATIVE EQUIVALENT TRAFFIC (E80/lane)	DESCRIPTION
E_R	< 0,05 million	Residential access roads; very lightly trafficked, very few heavy vehicles
E0	< 0,2 million	Very lightly trafficked roads, very few heavy vehicles
E1	0,2 - 0,8 million	Lightly trafficked roads, mainly cars, light delivery vehicles and agricultural vehicles, very few heavy vehicles
E2	0,8 - 3 million	Medium volume of traffic; few heavy vehicles
E3*	3 - 12 million	High volume of traffic and/or many heavy vehicles
E4*	12 - 50 million	Very high volume of traffic and/or high proportion of fully laden heavy vehicles
E5*	50 - 200 million	Exceptionally heavily trafficked roads

* For design purposes actual cumulative E80s would be required.

Classification of pavements and traffic for structural design purposes

Pavement class*	Pavement design bearing capacity (million 80 kN axles/lane)	Volume and type of traffic**	
		Approximate v.p.d. per lane***	Description
ES0.003	< 0,003	< 3	Very lightly trafficked roads; very few heavy vehicles. These roads could include the transition from gravel to paved roads and may incorporate semi-permanent and / or all weather surfacings.
ES0.01	0,003 - 0,01	3 - 10	
ES0.03	0,01 - 0,03	10 - 20	
ES0.1	0,03 - 0,10	20 - 75	
ES0.3	0,10 - 0,30	75 - 220	
ES1	0,3 - 1	220 - 700	Lightly trafficked roads, mainly cars, light delivery and agriculture vehicles; very few heavy vehicles.
ES3	1 - 3	> 700	Medium volume of traffic; few heavy vehicles.
ES10	3 - 10	> 700****	High volume of traffic and / or many heavy vehicles.
ES30	10 - 30	> 2200****	Very high volume of traffic and / or a high proportion of fully laden heavy vehicles.
ES100	30 - 100	> 6500****	