FE Review
CE CBT ~ Transportation
spring 2016
some advice

1. watch youtube videos
2. searchable ref mats
   A. Not all underTp.
   B. No index
3. queueing case (demo)

NCEES

A list of Tp Engre' questions
≠ equations in ref mats

* email to/from NCEES
Subject: RE: FW: Questions and concerns about the Transportation portion of the CE CBT FE Exam
From: Cheryl Warren <cwarren@ncees.org>
Date: 3/15/2016 8:41 AM
To: Jon Fricker <fricker@ecn.purdue.edu>

Jon —

Please encourage your students to get familiar with the FE Reference Handbook. Remind them that all 7 FE tests are only using one Handbook so they need to know where to find each of the topics in the text specification for the specific FE test they are taking. I've suggested lookup races during review sessions to several folks as well as reviewing PDF search strategies. Note NCEES does not publish the index with the exams because the index just comes up with numerous electronic search results – the index is published in the hard copy books though. The FE exam specifications are on the NCEES website: http://ncees.org/exams/fe-exam/

I would also encourage you to watch the various videos on the NCEES website about the exam day experience and perhaps show them during the review session as they are quite short: https://www.youtube.com/playlist?list=PLiZohjHNiqzR8RW69ndkJjGh8Bzjoew-

Thanks for supporting licensure.

Sincerely,

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From: Jon Fricker [mailto:fricker@ecn.purdue.edu]
Sent: Monday, March 14, 2016 5:44 PM
To: Cheryl Warren <cwarren@ncees.org>
Cc: Drneovich, Vincent P <drneovich@purdue.edu>
Subject: Re: FW: Questions and concerns about the Transportation portion of the CE CBT FE Exam

Dear Dr. Warren---

Thank you for your reply.

I hope that I did not act unethically (or cause my student to do so) when I asked her whether any questions asked on the FE exam did not have the necessary equations provided in the reference materials. I did not ask for the content of the questions.

I now know that a taker of the FE exam has access to all 240 pages of the reference
15A. Geometric Design

eqns on p. 168-171 of ref. maths
p. 168 SSD
p. 169 length of vert. curves
super elev. on horiz. curves
spiral transition
sight dist. around obstruct.
p. 170 H.C. geom. relationships
p. 171 V.C. " " " 
49.1 HC w/ PC @ Sta 10 + 46

$LC = 820\text{ ft}$, $I = \Delta = 104^\circ 36'$

Find $R$.

\[ R = \frac{LC}{2 \times \sin \left( \frac{\Delta}{2} \right)} = \frac{820\text{ ft}}{2 \times \sin (52^\circ 18')} \]

\[ \sin 52.3^\circ = 0.791 \]

\[ R = \frac{820}{2 \times 0.791} = 518\text{ ft} \]
49.3 sag V.C.

L = 800 ft, \( G_1 = -2.07 \%
\)

\( G_2 = +1.67 \%
\)

PVI @ sta 87+00

" elev = 2438 ft

Find flow
49.3 sag v.c.

\[ L = 800 \text{ ft}, \quad G_1 = -2.070 \]
\[ G_2 = +1.670 \]

PVI @ Sta 87+00

" elev = 2438 ft

Find \( y_{_{f20}} \)

\[ x_{_{f20}} = \frac{G_1 L}{G_1 - G_2} = \frac{-0.02 \times 800}{2.16} \]
\[ = \frac{-0.02 - 0.016}{-0.02 - 0.016} \]

\[ x_{_{f20}} = 444.44 \text{ ft} \]
49.3 cont'd

\[(171.3) \quad \frac{y_{do}}{y_{do}} = \frac{y_{vpc}}{y_{vpc}} + 0.1 \times 10\]

VPI @ elev 2438 ft and sta 87+00

VPC elev = 2438 + (0.02 \times 400)
= 2446 ft

\[\frac{y_{do}}{y_{do}} = 2446 + \frac{(-0.02 \times 444.44) + y_{f}}{-8.89}\]
= 2437 ft. + y_{f}
49.3 cont'd

\[ \frac{g_2 - g_1}{2L} \times \gamma = \frac{+0.016 - (0.02)}{2 \times 800} (444.44)^2 \]

effact = 4.44 ft

\[ \frac{y}{d_0} = 2446 - 8.89 + 4.44 \]

= 2441.6 ft
SSD on crest V.C.

\[ v = 60 \text{ mph} \rightarrow \text{SSD} = 570 \text{ ft (table)} \]

\[ A = |G_2 - G_1| = 5\% \]

At what \( L \) is V.C. long enough?
SSD & V.C. length (cont'd)

\[(169.2) \quad L_{\text{min}} = \frac{AS^2}{2158} \quad \text{if} \quad s \leq L\]

\[L_{\text{min}} = \frac{5 \times (570)^2}{2158} = 752.8 \text{ ft}\]

\[(169.4) \quad L_{\text{min}} = 2s - \frac{2158}{5} \quad \text{if} \quad s > L\]

\[L_{\text{min}} = (2 \times 570) - 431.6 = 708.4 \text{ ft}\]

\[s \leq L_{\text{min}} \quad \text{?} \quad 570 \leq 752.8 \quad \text{?} \quad \text{TRUE}\]

\[s > L_{\text{min}} \quad \text{?} \quad 570 > 708.4 \quad \text{?} \quad \text{FALSE}\]

\[\text{min length of V.C. must be } 752.8 \text{ ft}\]
SSD on H.C. around obstruction
hwy w/ 4 12-ft lanes & 6-ft shoulders
H.C. w/ R = 1200 ft. V = 45 mph

\[
\text{(169.12) } HSO = M_s = R \left[ 1 - \frac{28.65 \times S}{R} \right]
\]

5? \ SSD = (1.47 \times V \times t) + \frac{V^2}{\left[ 30 \frac{\text{a}}{32.2} \right] \pm \phi}

using (168.3) w/ 

V = 45 \text{ mph, } t_{\text{rcn}} = 2.5 \text{ sec, } 
\text{a} = 10 \text{ ft/sec}^2 \text{ decel.}

SSD = 165.4 + 217.35 = 382.75 \text{ ft}
[SSD = 360 \text{ ft in table not avail.}]

* assumed values
SSD on H.C. around obstruction

\[ R_v = 1200 - 12 - 6 = 1182 \text{ ft} \]

\[ H_{SO} = M_S = 1182 \times \left[ 1 - \cot \frac{22.65 \times 382.75}{1182} \right] \]

\[ = 9.28 \]

\[ = 0.987 \]

\[ = 0.0131 \]

\[ H_{SO} = M_S = 15.5 \text{ ft, middle of inner lane to obstruction} \]

\[ [H_{SO} = M_S = 13.7 \text{ ft w/ table}] \]
15C. Pavement Design

A standard 3-52 truck is loaded so that...

- 12k is on the single steering axle
- 36k is on the tandem drive axle
- 32k is on the tandem semi-trailer axle

What is the truck's impact on the pavement?
Use LEFs on p. 172 (table)

Note: 18K on single axle → LEF = 1.00
12K on single → LEF = 0.189
36K on tandem → LEF = 1.38
32K on tandem → LEF = 0.857

Truck's total LEF = 2.426 ESALs

\[
2.426 \text{ ESALs/truck} \times 350 \text{ such trucks/day} \times 6 \text{ da/wk} \times 52 \text{ wk/yr} = 264,919 \text{ ESALs}
\]

Repeat for all vehicles & axle loadings.

ESALs/yr, that segment.

Apply Growth Factor(s) over design life.

* w/ the axle loads specified
15c. Pavement design

Flexible pavement

$SN_3 = 5.0$, $SN_2 = 3.8$, $SN_1 = 2.8$ and

$a_1 = 0.41$, $a_2 = 0.12$, $a_3 = 0.08$

Find initial values for $D_1$, $D_2$, $D_3$ in (172.1).

$SN_1 = a_1 \times D_1$; $D_1 = \frac{SN_1}{a_1} = \frac{2.8}{0.41} = 6.8$

Round up to 7.0" (next 1/2 inch).
\[ SN_2 = (a_1 \times D_1) + (a_2 \times D_2) \]
\[ 3.8 = (0.41 \times 7.0) + (0.12 \times D_2) \]
\[ D_2 = 7.75 \rightarrow 8.0 \]
\[ SN_3 = a_1 D_1 + a_2 D_2 + a_3 D_3 \]
\[ 5.0 = (0.41 \times 7.0) + (0.12 \times 8.0) \]
\[ + (0.08 \times D_3) \]
\[ D_3 = 14.6 \rightarrow 15.0 \]

[Check min \( D_i \) as calcos are done.]
15 H. TP. Planning

(17.1) Gravity Model

distributes trips from zone \( i \) to any (or all) zone \( j \).

\[
T_{ij} = P_i \frac{A_j F_{ij} K_{ij}}{\sum_j A_j F_{ij} K_{ij}}
\]

\( K_{ij} \) usually \( \neq 1.0 \)

\( F_{ij} \) is an inverse function \( = \frac{1}{t_{ij}} \)
15 H. Gravity Model

4 cities in region

\[
\begin{align*}
1 & \quad 2 \quad 3 \quad 4 \\
P & \quad 4724 \quad 901 \quad 193 \quad 108 \\
A & \quad 4909 \quad 774 \quad 174 \quad 69
\end{align*}
\]

travel time between zones

\[
\begin{align*}
1 & \quad 2 \quad 3 \quad 4 \\
t_{2j} & \quad 35 \quad 5 \quad 20 \quad 12
\end{align*}
\]

Find \( T_{2j} \)

First calc. \( F_{2j} \)

\[
F_{21} = \frac{1}{35^2} = 0.0000816
\]

OK to scale up by 1000: \( F_{21} = 0.816 \)

continue \( \rightarrow \)
Gravity Model (cont'd)

\[ F_{22} = \frac{1}{5^2} \times 1000 = 40.00 \]
\[ F_{23} = \frac{1}{20^2} \times 1000 = 2.50 \]
\[ F_{24} = \frac{1}{12^2} \times 1000 = 6.944 \]

(174.1)

\[ T_{21} = 901 \times \frac{4909 \times 0.816}{35,881.5} = 101 \]

\[ A_4 \times F_{21} = 4909 \times 0.816 = 4007.3 \]
\[ A_2 \times F_{22} = 774 \times 40.0 = 30,960.0 \]
\[ A_3 \times F_{23} = 174 \times 2.5 = 435.0 \]
\[ A_4 \times F_{24} = 69 \times 6.944 = 479.2 \]

\[ \sum A_j F_{2j} = 35,881.5 \]
Gravity Model (cont'd)

\[ T_{22} = 777 \]
\[ T_{23} = 11 \]
\[ T_{24} = 12 \]
\[ \sum_{j} T_{2j} = 901 \]
15H. TP. Planning

Logit Models \( a_0, x \)?

(174.2) \( U_x = a_1 x_1 + a_2 x_2 + \ldots \)

modes A and B have attributes

\( c_A = \phi \), \( c_B = \$0.75 \)

\( t_A = 10.5 \text{ min.} \), \( t_B = 18 \text{ min.} \)

If utility function is

\( U_x = a_0 x - (0.47 * c_x) - (0.22 * t_x) \)

find mode shares \( P_A \) & \( P_B \).

Note: \( a_0, A = 0.73 \)
Logit Model

\[ U_A = 0.73 - (0.47 \times 0) - (0.22 \times 10.5) \]
\[ = -1.58 \]
\[ U_B = 0 - (0.47 \times 0.75) - (0.22 \times 18) \]
\[ = -4.31 \]

\[ (174.3) \quad P_A = \frac{e^{U_A}}{e^{U_A} + e^{U_B}} \]
\[ = \frac{0.2060}{0.2060 + 0.0134} = 0.939 \]

\[ \frac{e^{U_B}}{e^{U_A} + e^{U_B}} = \frac{0.0134}{0.2060 + 0.0134} = 0.061 \]

\[ P_A + P_B = 1.000 \checkmark \]
15 D. Traffic Safety

Crash rates at Intersections

\[ (175.1) \quad RMEV = \frac{A \times 10^6}{V} \]

\[ w7 \ V = 365 \times ADT \text{ entering} \]

If 6449 vehs/day enter intersection, and 5 crashes occurred last year, what was crash rate?

\[ RMEV = \frac{5 \times 10^6}{6449 \times 365} = 2.12 \]

Note: ADT is usually a 2-way count.

\[ 3028 \]

\[ 5304 \]

\[ 3519 \]

\[ 1570 \]

\[ A_{\text{entering}} = \frac{2 \times 1570}{2} = 6710.5 \]
15D. Traffic Safety

(175.2) Crash rates on roadway segments

$$RHMVM = \frac{A \times 10^8}{VMT}$$

If a 2.9-mi segment had ADT of 56,690 veh/day and 4 crashes last yr, calc. RHMVM.

$$A = 4, \quad VMT = \frac{56,690 \text{ veh/day} \times 365 \text{ day}}{\text{last yr}} \times 2.9 \text{ mi} = 6,001 \times 10^6 \text{ veh-mi/yr}$$

$$RHMVM = \frac{4 \times 10^8}{6 \times 10^6} = 66.66$$
15D. Crash Reduction

(175.3) crashes prevented

\[ N \times CR \times \frac{ADT_{after \ atrmeas}}{ADT_{before \ atrmeas}} \]

If \( N = 42 \) crashes per HVMV w/0 atrmeas at same ADT,
\( c_1 = 0.14, c_2 = 0.34, \) and
\( ADT_{after} = 11,821 \) and \( ADT_{before} = 9369, \)
how many crashes will be prevented?
crashes prevented

\[(175.3)\]

\[A_2 \times 0.4524 \times \frac{11,821}{9,369} = 22.9\]

\[CR = 0.14 + \left[ (1 - 0.14) \times 0.34 \right] = 0.4524\]

\[\frac{0.2924}{0.2924}\]
15F. TRAFFIC FLOW THEORY


No equations, but...

1) Note linear plot between $S_f$ and $D_j$.

2) Note $D_0$ & $v_m$ occur at $s_0 = S_f/2$, $D_0 = D_j/2$. 
15G. TRAFFIC CONTROL DEVICES

(168.1) Veh signal change interval:

\[ t = \frac{r}{2a \pm 64.4 G} \]

\[ r = \frac{w + d}{v} \]

If driver reaction time is 1.5 sec, veh approaches intersection at 50 fps, veh can decelerate at 10 ft/sec\(^2\) on level terrain, what should be the length of the yellow interval?
Length of yellow

\[(168.1) \quad t = 1.5 \text{ sec} + \frac{50 \text{ ft/sec}}{2 \times 10 \text{ ft/sec}^2} \pm \delta \]

\[= 1.5 + 2.5 = 4.0 \text{ sec.} \]

If the intersection is 60 ft wide and the average veh length is 15 ft, how long should the all-red clearance interval be?

\[(168.2) \quad r = \frac{W + L}{V} \]

\[r = \frac{60 \text{ ft} + 15 \text{ ft}}{50 \text{ ft/sec}} = 1.5 \text{ sec.} \]