APPENDIX K

FLOW CHARTS ILLUSTRATING DECISION RULES
Decision Rules for the Expert System

This document contains flow charts describing the decision rules for the expert system for recommending speed limits in speed zones that was developed as a part of NCHRP Project 3-67.

Terms:

Closest 85th
This is the 5 mph increment that is closest to the 85th percentile speed (e.g., if the 85th percentile speed is 63 mph, the Closest_85th will be 65 mph)

Rounded-down 85th
This is the 5 mph increment obtained by rounding down the 85th percentile to the nearest 5 mph increment (e.g., if the 85th percentile speed is 63 mph, the Rounded-down_85th will be 60 mph)

Closest 50th
This is the 5 mph increment that is closest to the 50th percentile speed (e.g., if the 50th percentile speed is 58 mph, the Closest_50th will be 60 mph)

SL_1
Speed limit calculated using safety surrogates

SL_2
Speed limit calculated using crash data from the crash module

SL
Recommended speed limit

L.A.F.
Limited Access Freeway

R.S.I.U.A.
Road Sections in Undeveloped Areas

R.S.I.D.A.
Road Sections in Developed Areas

Key:

Input or Output
Computation or Process
Decision and Branching
Off-page Connector
Connector
Display
Start

Login

Input Project Info

Select Roadway Type

- Limited Access Freeway (K-4)
- Road Section in Undeveloped Areas (K-13)
- Road Section in Developed Areas (K-22)
Limited Access Freeway (L.A.F.)

User Input

Speed Limit Calculation Without Crash Data - Freeways (K-5)

Have Crash Data?

Yes

Crash Module (K-6)

Calculate SL_2

SL = Lower of SL_1, SL_2

No

SL = SL_1

* 85th percentile speed
* 50th percentile speed
* Section length (in miles)
* Statutory Limit (Statutory_SL)
* Is there Adverse Alignment (Yes or No)
* Is this a Transition Zone? (Yes or No)
* Current AADT
* Roadway Type:
  Undivided (two-lane or multilane)
  Divided or TWLTL (multilane)
* Number of Interchanges

Limited Access Freeway L.A.F. (K-10)
Speed Limit Calculation Without Crash Data (to calculate SL_1) (Limited Access Freeway)

\[
\text{Inter}\_\text{spac} = \frac{\text{Length}}{\text{Number of Interchanges}}
\]

If AADT $\geq 180,000$ and $0.5 < \text{Inter}\_\text{spac} \leq 1$, then SL_1 is higher of \text{Rounded-down_85th} and \text{closest_50th}.

If AADT $\geq 180,000$ and $\text{Inter}\_\text{spac} \leq 0.5$, then SL_1 is lower of \text{Rounded-down_85th} and \text{closest_50th}.

All other cases: SL_1 is closest_85th.

Output SL_1
Crash Module for Freeways (to calculate SL_2)

User Input

Is Years >= 1

Yes

M = 100 Million VMT on this section
Crash_rate = crash rate per M
Injury_rate = Injury rate per M

Do you have data on average crash rates (per 100 million VMT) and average injury rates for similar sections during the same time period?

Average crash rate = Ca
Average injury rate = la

Crash_rate - Ca = crash_diff
Injury_rate - la = injury_diff

Crash Module for Freeways C.M.F.F. (K-7)

No

Since you have less than 1 year of crash data, we suggest that you collect additional data and repeat this process.

If YES, user is asked to enter that number. If NO, average crash and injury rates from HSIS will be used.
C.M.F.F.

Is crash_diff < 0

Yes

Is injury_diff < 0

Yes

Program Calculates Critical Crash_rate (Cc)

Is crash_rate > Cc

Yes

C_level = High

C.M.F.F (K-8)

Is crash_rate > 1.3Ca

Yes

C_level = Low

No

Is crash_rate > Cc

No

C_level = Med

No

The crash_rate in the section is \{crash_diff\}\% higher than the average rate of similar sections.

The rate of injury and fatal crashes in the section is \{injury_diff\}\% higher than the average.
Program Calculates Critical Injury Rate (Ic)

If injury_rate > Cc
- Yes: I_level = High
- No: Is injury_rate > 1.3Ca
  - Yes: I_level = Med
  - No: I_level = Low

Crash_level_1 = Higher of C_level and I_level

If crash_level_1 is High/Med
- Yes: Can traffic control and/or geometric treatments reduce crash/injury rate in this section?
  - Yes: Crash_level = Crash_level_1
  - No: C.M.F.F. (K-9)
- No: Crash_level = Low

C.M.F.F.
Crash Module for Freeways

Is Crash_level Low, Med, or High?

Output: SL_2

If Crash Level = Low
SL_2 = Closest_85th

If Crash Level = Med
SL_2 = Higher of Rounded-down_85th and Closest_50th

If Crash Level = High
SL_2 = Lower of Rounded-down_85th and Closest_50th
L.A.F.

Is SL < 35 mph or > 75 mph?

SL < 35

SL = 35 mph

SL > 75

SL = 75 mph

35 <= SL <= 75

SL is unchanged

Is Terrain = Mountainous and SL > 70 mph

Yes

SL = 70 mph

No

SL is unchanged

The recommended speed limit is SL mph.

Limited Access Freeway (K-11)
L.A.F.

Is SL > Statutory_SL

Yes: The final recommended speed limit is higher than the statutory speed limit for this section.

No

Is there adverse alignment?

Yes: Sections with adverse alignments may need specific maximum safe speed warnings which may be different from the general speed limit for the section. This program does not provide maximum safe speed warnings for adverse alignments.

No

Is 85th > 77mph

Yes: Based on the information gathered from experts in the U.S., this program does not recommend speed limits higher than 75 mph.

No

L.A.F. (K-12)
Is Crash_level_1 is High or Med

Yes

The crash rate of the section is $<\text{crash\_rate}>$ per 100 MVMT. The average rate for similar sections is $<\text{Ca}>$ per 100 MVMT, and the critical rate is $<\text{Cc}>$ per 100 MVMT. The crash rate of the section is $<\text{crash\_diff}>$% higher (or lower) than the average crash rate for similar sections. The rate of injury crashes for the section is $<\text{injury\_rate}>$ per 100 MVMT. The average rate for similar locations is $<\text{la}>$ per 100 MVMT, and the critical rate is $<\text{lc}>$ per 100 MVMT. The rate of injury crashes for this section is $<\text{injury\_diff}>$% higher (or lower) than the average rate for similar sections.

A comprehensive crash study should be undertaken to identify engineering and traffic control deficiencies and appropriate corrective actions. The speed limit should only be reduced as a last measure after all other treatments have either been tried or ruled out.

No

Is Length $<$ Minimum_Section_Length

Yes

A section length of $<\text{Length}>$ miles is too short for speed zoning on public streets and roads for the recommended speed limit. You may consider lengthening the speed zone (if that is possible) or using the speed limits from adjacent sections (if they are appropriate for this section). If 85th percentile speeds and other data you provided are representative of conditions for this short section, then the speed limit noted above should be considered. If the data were taken in a road section with adverse horizontal and vertical alignment, in a construction zone, or in an area with unique geometric and/or traffic control features, then the above noted speed limit may not be appropriate because this expert system is not designed to recommend speed limits for sharp horizontal curves, within the limits of construction zones, or in other special traffic situations.

No

L.A.F.

END
Road Sections In Undeveloped Areas (R.S.I.U.A.)

User Input

Speed Limit Calculation Without Crash Data - Undeveloped Areas (K-14)

Have Crash Data?

- 85th percentile speed
- 50th percentile speed
- Section length (in miles)
- Statutory Limit (Statutory_SL)
- Is there Adverse Alignment (Yes or No)
- Is this a Transition Zone? (Yes or No)
- Current AADT
- Roadside Hazard Rating (RHR)
- Roadway Type:
  - Undivided (two-lane or multilane)
  - Divided or TWLTL (multilane)

Yes

Crash Module (K-15)

Calculate SL_2

SL = Lower of SL_1, SL_2

Road Sections In Undeveloped Areas R.S.I.U.A. (K-19)

SL = SL_1

No
Speed Limit Calculation Without Crash Data (to calculate SL_1) (Roadway Section In Undeveloped Areas)

If RHR = 1, 2, or 3
SL_1 = Closest_85th

If RHR = 4 or 5
SL_1 = Higher of Rounded-down_85th and Closest_50th.

If RHR = 6 or 7
SL_1 = Lower of Rounded-down_85th and Closest_50th.

Output SL_1
Crash Module for Roads in Undeveloped Areas (to calculate SL_2)

User Input

Is Years >= 1

Yes

M = 100 Million VMT on this section
Crash_rate = crash rate per M
Injury_rate = Injury rate per M

Do you have data on average crash rates (per 100 million VMT) and average injury rates for similar sections during the same time period?

Average crash rate = Ca
Average injury rate = la

Crash_rate - Ca = crash_diff
Injury_rate - la = injury_diff

Road Sections In Undeveloped Areas (K-16)

Since you have less than 1 year of crash data, we suggest that you collect additional data and repeat this process.

If YES, user is asked to enter that number. If NO, average crash and injury rates from HSIS will be used.
The crash rate in the section is \(\text{crash}\_\text{diff}\)% higher than the average rate of similar sections.

The rate of injury and fatal crashes in the section is \(\text{injury}\_\text{diff}\)% higher than the average.

Program Calculates Critical Crash rate (Cc)

Is \(\text{crash}\_\text{rate} > Cc\) Yes

\(C\_\text{level} = \text{High}\)

R.S.I.U.A. (K-17)

Is \(\text{crash}\_\text{rate} > 1.3Ca\) Yes

\(C\_\text{level} = \text{Low}\)

\(C\_\text{level} = \text{Med}\)
R.S.I.U.A. → Program Calculates Critical Injury Rate (Ic)

- **Is injury_rate > Cc?**
  - No → Is injury_rate > 1.3Ca?
  - Yes → I_level = Low
  - Yes → I_level = Med

- **I_level = High** → Crash_level_1 = Higher of C_level and I_level

- **Is crash_level_1 High/Med?**
  - Yes → Can traffic control and/or geometric treatments reduce crash/injury rate in this section?
    - No → Crash_level = Low
    - Yes → Crash_level = Crash_level_1

- **Crash_level = Low** → R.S.I.U.A. (K-18)
Road Sections in Undeveloped Areas

Crash Level and Roadway Type

If Crash Level = Low
    SL_2 = Closest_85th

If Crash Level = Med
    SL_2 = Higher of Rounded-down_85th and Closest_50th

If Crash Level = High
    SL_2 = Lower of Rounded-down_85th and Closest_50th

Output: SL_2
R.S.I.U.A.

Is SL < 25 mph or > 65 mph?

SL < 25

SL = 25 mph

SL > 65

SL = 65 mph

15 <= SL <= 65

SL is unchanged

The recommended speed limit is SL mph.

Road Sections In Undeveloped Areas (K-20)
R.S.I.U.A.

Is SL > Statutory_SL

Yes

The final recommended speed limit is higher than the statutory speed limit for this section.

No

Is there adverse alignment?

Yes

Sections with adverse alignments may need specific maximum safe speed warnings which may be different from the general speed limit for the section. This program does not provide maximum safe speed warnings for adverse alignments.

No

R.S.I.U.A. (K-21)
Is Crash level 1 High or Med?

No

The crash rate of the section is <crash_rate> per 100 MVMT. The average rate for similar sections is <Ca> per 100 MVMT, and the critical rate is <Cc> per 100 MVMT. The crash rate of this section is <crash_diff> % higher (or lower) than the average crash rate for similar sections. The rate of injury crashes for the section is <injury_rate> per 100 MVMT. The average rate for similar sections is <la> per 100 MVMT, and the critical rate is <lc> per 100 MVMT. The rate of injury crashes for this section is <injury_diff> % higher (or lower) than the average rate for similar sections. A comprehensive crash study should be undertaken to identify engineering and traffic control deficiencies and appropriate corrective actions. The speed limit should only be reduced as a last measure after all other treatments have either been tried or ruled out.

Yes

Is 85th > 67 mph?

No

Based on the information gathered from experts in the U.S., this program does not recommend speed limits higher than 65 mph for non-limited access road sections in undeveloped areas.

Yes

Is Length < Minimum Section Length

No

A section of <Length> miles is too short for speed zoning on public streets and roads for the recommended speed limit. You may consider lengthening the speed zone (if that is possible) or using the speed limits from adjacent sections (if they are appropriate for this section). If the 85th percentile speeds and other data you provided are representative of conditions for this short section, then the speed limit noted above should be considered. If the data were taken in a road section with adverse horizontal and vertical alignment, in a construction zone, or in an area with unique geometric and/or traffic control features, then the above noted speed limit may not be appropriate because this expert system is not designed to recommend speed limits for sharp horizontal curves, within the limits of construction zones, or in other special traffic situations.

Yes

END
Road Sections In Developed Areas (R.S.I.D.A.)

User input

Speed Limit Calculation Without Crash Data - Developed Areas (K-23)

Have Crash Data?

No

SL = SL_1

Yes

Crash Module (K-24)

Calculate SL_2

SL = Lower of SL_1, SL_2

Road Sections In Developed Areas R.S.I.D.A. (K-28)

* 85th percentile speed
* 50th percentile speed
* Section length (in miles)
* Statutory Limit (Statutory_SL)
* Is there Adverse Alignment (Yes or No)
* Current AADT
* Area-type (Residential-Collector, Residential Subdivision, Commercial, Large Complexes)
* Number of driveways in the section (Driveways)
* Number of Signals (Signals)
* On-street parking and usage (High or Not High)
* Ped/Bike activity (High or Not High)
Speed Limit Calculation Without Crash Data (to calculate SL-1) (Roadway Section In Developed Areas)

Signals_per_mile = Signals / Section Length
Driveways_per_mile = Driveways / Section Length

Are any of the following true?
* Signals_per_mile > 4
* Ped_bike activity = High
* Parking activity = High
* Driveways_per_mile > 60

Is Driveways_per_mile > 40 and <= 60, Signals per mile > 3, and Area Type is (commercial or residential-collector)?

No

Yes

SL_1 = Rounded-down-85th

SL_1 = Closest_85th

SL_1 = Closest_50th

Output SL_1
Crash Module for Roads in Developed Areas (to calculate SL_2)

User Input

* Number of years of crash data (Years)
* Average AADT (AADT)
* Number of crashes during this period (Crashes)
* Number of injury and fatal crashes during this period (Injury_Crashes)

Is Years >= 1

No

Since you have less than 1 year of crash data, we suggest that you collect additional data and repeat this process.

Yes

M = 100 Million VMT on this section
Crash_rate = crash rate per M
Injury_rate = Injury rate per M

Do you have data on average crash rates (per 100 million VMT) and average injury rates for similar sections during the same time period?

Average crash rate = Ca
Average injury rate = la

If YES, user is asked to enter that number. If NO, average crash and injury rates from HSIS will be used.

Crash_rate - Ca = crash_diff
Injury_rate - la = injury_diff

Road Sections In Developed Areas (K-25)
R.S.I.D.A.

Is crash_diff < 0

No

Yes

The crash_rate in the section is \{crash_diff\}% higher than the average rate of similar sections.

Is injury_diff < 0

No

Yes

The rate of injury and fatal crashes in the section is \{injury_diff\}% higher than the average.

Program Calculates Critical Crash_rate (Cc)

Is crash_rate > Cc

No

Is crash_rate > 1.3Ca

No

Yes

C_level = Low

C_level = Med

R.S.I.D.A. (K-26)
R.S.I.D.A. → Program Calculates Critical Injury_Rate (Ic)

Is injury_rate > Cc

Yes → I_level = High

No → Is injury_rate > 1.3Ca

Yes → I_level = Low

No → I_level = Med

Crash_level_1 = Higher of C_Level and I_level

Is crash_level_1 High/Med

Yes → Can traffic control and/or geometric treatments reduce crash/injury rate in this section?

No → R.S.I.D.A. (K-27)

Yes → Crash_level = Crash_level_1

Crash_level = Low
Road Sections In Developed Areas

Crash Level

If Crash Level = Low
   SL_2 = Closest_85th

If Crash Level = Med
   SL_2 = Higher of
       Rounded-down_85th
   and Closest_50th

If Crash Level = High
   SL_2 = Lower of
       Rounded-down_85th
   and Closest_50th

Output: SL_2
R.S.I.D.A.

Is SL < 20 mph or > 50 mph?

SL < 20

SL = 20 mph

SL > 50

15 ≤ SL ≤ 50

SL = 50 mph

SL is unchanged

The recommended speed limit is SL mph.

Road Sections In Developed Areas (K-29)
R.S.I.D.A.

Is SL > Statutory_SL

Yes

The final recommended speed limit is higher than the statutory speed limit for this section.

No

Is there adverse alignment?

Yes

Sections with adverse alignments may need specific maximum safe speed warnings which may be different from the general speed limit for the section. This program does not provide maximum safe speed warnings for adverse alignments.

No

Is 85th > 52 mph?

Yes

Based on the information gathered from experts in the U.S., this program does not recommend speed limits higher than 50 mph for non-limited access road sections in Developed areas.

No

R.S.I.D.A. (K-30)
Is Crash_level_1 High or Med

No

The crash rate of this section is \(<\text{crash\_rate}>\) per 100 MVMT. The average rate for similar sections is \(<\text{Ca}>\) per 100 MVMT, and the critical rate is \(<\text{Cc}>\) per 100 MVMT. The crash rate of this section is \(<\text{crash\_diff}>\)% higher (or lower) than the average crash rate for similar sections. The rate of injury crashes for this section is \(<\text{injury\_rate}>\) per 100 MVMT, and the critical rate is \(<\text{Ic}>\) per 100 MVMT. The rate of injury crashes for this section is \(<\text{injury\_diff}>\)% higher (or lower) than the average rate for similar sections. A comprehensive crash study should be undertaken to identify engineering and traffic control deficiencies and appropriate corrective actions. The speed limit should only be reduced as a last measure after all other treatments have either been tried or ruled out.

Yes

Is Length < Minimum_ Section_Length

No

A section of \(<\text{Length}>\) miles is too short for speed zoning on public streets and roads for the recommended speed limit. You may consider lengthening the speed zone (if that is possible) or using the speed limits from adjacent sections (if they are appropriate for this section). If 65th percentile speeds and other data you provided are representative of conditions for this short section, then the speed limit noted above should be considered. If the data were taken in a road section with adverse horizontal and vertical alignment, in a construction zone, or in an area with unique geometric and/or traffic control features, then the above noted speed limit may not be appropriate because this expert system is not designed to recommend speed limits for sharp horizontal curves, within the limits of construction zones, or in other special traffic situations.

Yes

END