The Highway Safety Manual: A New Tool for Safety Analysis

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Presentation Overview

- **Introduce the HSM - A resource for safety analysis**
- **Highlight useful methods and resources**
- **Provide application examples**

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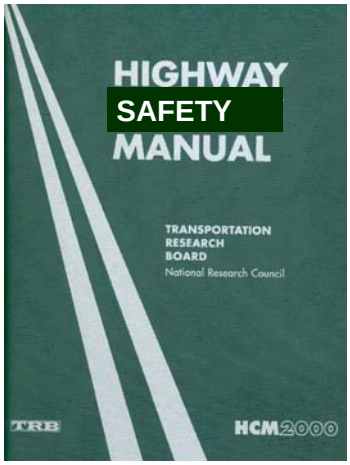
What is the HSM? How will the HSM be useful?

- **Akin to the HCM:**
  - **Definitive**
  - **Widely-accepted**
  - **Science-based**
- **From qualitative descriptive-based analysis to quantitative prediction**
- **Safety focused and those not exclusively focused on safety**



In the beginning…

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HSM – A Tool for Safety Analysis

- **Part A: Introduction, Human Factors, and Fundamentals**
- **Part B: Roadway Safety Management Process**
- **Part C: Predictive Methods**
  - Rural two-lane roads
  - Rural multi-lane highways
  - Urban and Suburban Arterials
- **Part D: Accident Modification Factors**
  - Roadway segments
  - Intersections
  - Road networks
  - Interchanges
  - Special facilities and geometric situations

Anticipated Applications of the HSM

- **Identify**
  - Sites for improvements
  - Contributing factors and potential countermeasures
- **Conduct**
  - Economic appraisals that incorporate safety benefits and prioritize based on estimated safety benefit
  - Safety effectiveness evaluations of implemented treatments
- **Calculate**
  - Anticipated safety benefits associated with various design alternatives
- **Incorporate**
  - Quantitative safety estimates in all alternative improvement evaluations

Part A – Introduction and Overview, Human Factors and Fundamentals

- **Part A provides the context for effectively applying the material in parts B, C, and D of the HSM**
- **Introduction and Overview**
  - Introduces the content and format of the HSM. Explains how the HSM relates to planning, design, and operations activities.
- **Human Factors**
  - Presents the relationship between driver, vehicle, and environment.
- **Fundamentals**
  - Introduce the fundamental concepts for applying methods and tools presented in subsequent chapters of the HSM.

HSM - Fundamental Concepts

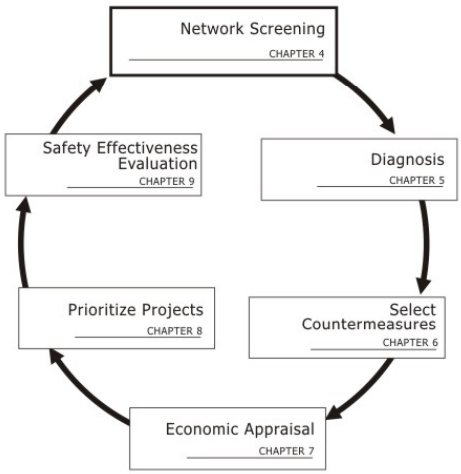
- **Evolving from…**
  - Qualitative to Quantitative
  - Descriptive to Predictive Methods
  - Historical Crash Data to Expected Crashes
- **Reasons for the Evolution**
  - Stability and reliability in results
  - Increase likelihood of effective solutions; effective and efficient expenditure of “safety” dollars
  - Opportunity to explicitly consider quantitative safety in multiple projects and within different stages of the same project

Applying the HSM – Real World Case Study

- **Setting:**

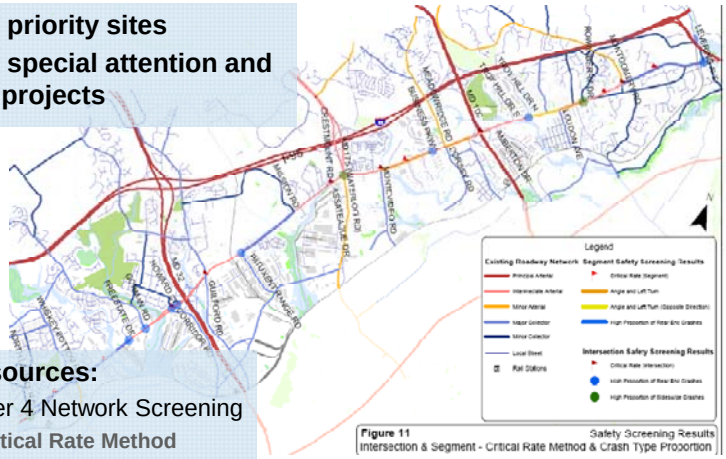
Part B – Roadway Safety Management Process

- Collectively Part B provides tools to implement and maintain a quantitative, systematic, process for studying roadway safety



Part B – Case Study Application

- **Identified priority sites**
- **Identified special attention and breakout projects**



- **HSM Resources:**
  - Chapter 4 Network Screening
    - **Critical Rate Method**
    - **High Proportions Method**

Chapter 4 Network Screening
Critical Rate Method

- **Case Study Application: Identify Priority Sites**
- **A critical crash rate was developed for each site and compared to the observed crash rate**

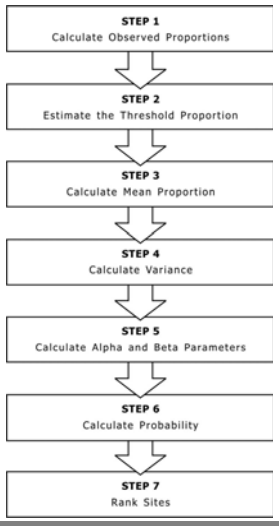
Ranking of Sites According to Critical Rate Method

Sites	Total Crashes for Study Period	Study Period (years)	TEV	TMEV per Study Period	Observed Crash Rate R_i	Average Crash Rate, R_A	Critical Crash Rate, R_C	$R_i > R_C$?
Intersection A	80	4	34,500	50.36	1.59	1.30	1.57	Yes
Intersection B	141	4	65,000	94.92	1.49	1.30	1.50	No
Intersection C	78	4	37,500	54.76	1.42	1.30	1.56	No
Intersection D	62	5	30,000	54.75	1.13	1.30	1.56	No
Intersection E	32	5	20,000	36.50	0.88	1.30	1.62	No

Notes:
All crashes rate units are crashes/TMEV
TEV = Total Entering Vehicles/Average Annual Day for the Study Period
TMEV = Total Million Entering Vehicles/Average Annual Day for the Study Period
Calculations assume 95% confidence level
Calculations assume all five intersections have similar characteristics

$$R_{Ci} = R_a + K_c\sqrt{\frac{R_a}{TMEV_i} + \frac{1}{(2)(TMEV_i)}}$$

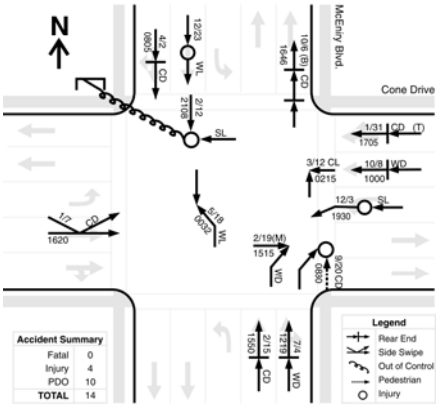
Chapter 4 Network Screening
High Proportions Method



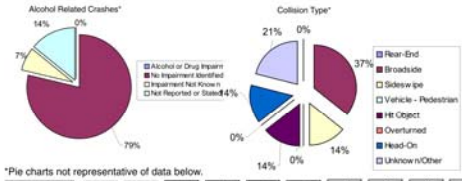
- **Case Study Application: Identify Special Attention and Breakout Projects**
- **Purpose: Identify sites most likely to benefit from improved access management**
- **Target Crash Types:**
  - Angle Crashes and Left-Turn Crashes
  - Rear End Crashes
  - Opposite Direction

Chapter 5 Diagnosis

- **Identifying crash trends and patterns**



Source: *Manual of Transportation Engineering Studies*, ITE 2000



*Pie charts not representative of data below.

Accident Number	1	2	3	4	5	6	7	8	9	10
Date	1/3/92	2/5/92	8/11/92	12/1/93	21/7/93	11/9/93	9/4/94	12/5/94	4/7/94	11/9/94
Day of Week	SU	SA	SU	TU	WE	TH	SA	TH	MO	SU
Time of Day	2115	2010	1925	750	1310	950	1115	1500	1710	2220
Severity	A	A	B	B	K	K	B	B	A	B
Accident Type										
Road Condition	WET	DRY	DRY	DRY	WET	DRY	DRY	DRY	WET	WET
Light Condition	DARK	DARK	DARK	DUSK	LIGHT	LIGHT	LIGHT	LIGHT	DUSK	DARK
Direction	N	N	SU	W	S	W	N	S	N	N
Alcohol (BAC)	0.05	0.08	0	0.05	0	0	0.07	0	0	0.15

Source: *Safer Roads: A Guide to Road Safety Engineering*. K.W. Ogden. P.37

Chapter 6 Select Countermeasures

- **Identify contributing factors**

Crash Type	Possible Contributory Factor(s)
Right – angle	Poor visibility of signals
	Inadequate signal timing
	Excessive speed
	Wet pavement surface
	Inadequate sight distance
	Drivers running red light
Rear - end or Sideswipe	Inappropriate approach speeds
	Poor visibility of signals
	Unexpected lane changes on approach
	Narrow lanes
	Unexpected stops on approach
	Wet pavement surface
	Excessive Speed

Chapter 7 Economic Appraisal

- **Purpose**
  - Determine if a project is economically justifiable
    - **Benefits > Cost = Economically Justifiable**
    - **Benefits < Cost = Not Economically Justifiable**
  - Compare individual projects based on economic evaluations

- **Overview of Chapter Content**
  - Calculate crash reduction (i.e. safety benefits)
  - Convert safety benefits to monetary values
  - Economic Evaluation Methods
    - **Cost/Benefit Evaluations**
      - Benefit Cost-Ratio
      - Net Present Value
  - Cost Effectiveness Evaluations
    - **Cost Effectiveness Index**

Chapter 8 Prioritize Projects

- **Purpose**
  - Identify a group of projects that offer the most safety benefits for a given budget
- **Overview of Chapter Content**
  - Introduction to system prioritization
  - Methods for prioritizing projects across a system
    - **Ranking by Safety Related Measures**
    - **Incremental Benefit-Cost Ratio**
    - **Linear Programming**
    - **Integer Programming**
    - **Dynamic Programming**
    - **Multi-Objective Resource Allocation Optimization**

Chapter 9 Safety Effectiveness Evaluation

- **Approach**

The safety of a roadway element or facility with implemented treatment	↔	The safety of a roadway element or facility without implemented treatment
Estimate		**Prediction**

- **Determine safety effectiveness for:**
  - A single project
  - Group of similar projects
  - Group of similar projects with the intent of quantifying an AMF
  - Specific types of projects or treatments to compare to safety effectiveness to costs

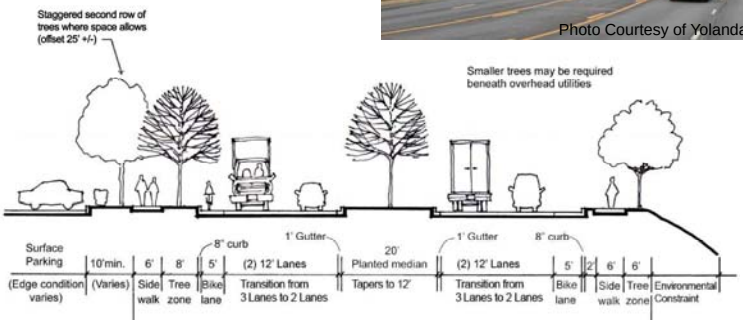
Part C – Predictive Methods

- Part C can be used to predict the safety performance of a roadway or intersection based on physical characteristics.
- Most applicable for a new facility or as part of an extensive re-design of an existing facility.
- Possible to quantify the safety effects of alternatives for comparison with other project-specific measures (community needs, network capacity, operational delay, cost, and right-of-way implications).

Part C – Case Study Application

- **Evaluate Alternative Cross Sections**

Photo Courtesy of Yolanda Takesian



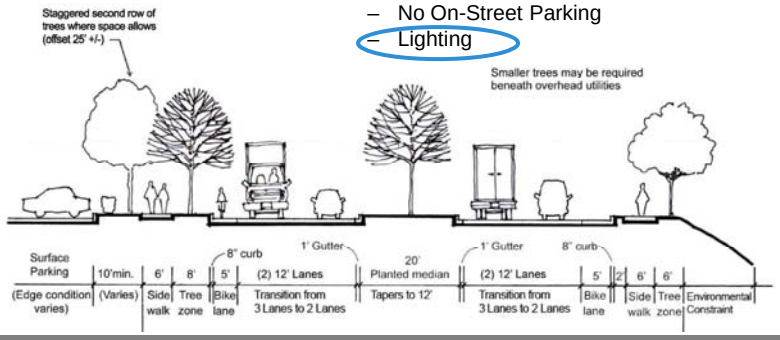
Part C – Case Study Application

Photo Courtesy of Yolanda Takesian

- **Future No Build Condition**
  - 5-Lane Cross Section
    - **4 Lanes with TWLTL**
  - 12 foot lanes
  - No Median
  - No Sidewalks
  - Utility poles on offset at 2 feet at a density of 70 poles/mile
  - 6 Minor Commercial Driveways
  - Roadway segment length = 2 miles
  - AADT = 35000
  - No Automated Speed Enforcement
  - No Lighting
  - No On-Street Parking

Part C – Case Study

- **Future (Alternative) Condition**
  - 4-Lane Cross Section
  - 12 foot lanes
  - Median: Raised, 20 feet in width
  - Sidewalks
  - 6 Minor Commercial Driveways
  - Trees at 70 trees per mile offset 10 feet from travel way
  - Roadway segment length = 2 miles
  - AADT = 35000
  - No Automated Speed Enforcement
  - No On-Street Parking
  - Lighting



Method to Predict Safety Performance of Alternative Designs

1. **Estimate base conditions**
2. **Modify base conditions to site specific conditions**
3. **Predict future conditions**
   - Calculate future base conditions
   - Adjust base conditions for future site specific conditions
4. **Compare results**

$$N_i = N_{bi} * C_i *(AMF_{1i} *AMF_{2i})$$

Part C – Case Study Application Step 1: Estimate Base Conditions

- **Compute Base Condition**
  - $N_{brbase}=N_{brmv}+N_{brsv}+N_{brdwy}$
  - N_{brbase}= total crashes/year
  - N_{brmv}= multiple vehicle crashes/year
  - N_{brsv}= single vehicle crashes/year
  - N_{brdwy}=driveway related crashes/year

Photo Courtesy of Yolanda Takesian

  - N_{brmv}=exp(-9.93+1.17*ln(35000)+ln(2)) = 20.18 crashes/year
  - N_{brsv}=exp(-5.05+0.54*ln(35000)+ln(2)) =3.64 crashes/year
  - N_{brdwy}= 6*0.042(35000/15000)$^{1.172}$ = 0.68 crashes/year
  - N_{brbase}=24.5 crashes/year for base condition

Part C – Case Study Application
Step 2: Modify Base Conditions

- **Apply Appropriate AMFs**
  - Roadside Fixed Objects
  - AMF_{1r}=0.232*70*0.016+(1-0.016)
  - AMF_{1r}= 1.24

Photo Courtesy of Yolanda Takesian

- **Calculate base without pedestrian and bicyclist adjustments**
  - $N_{br}=N_{brbase}(AMF_{1r})$ = 24.5*1.24
  - N_{br}=30.47 crashes/year

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Part C – Case Study Application
Step 2: Modify Base Conditions (con't.)

- **Calculate Pedestrian and Bicyclist Adjustments**
  - $N_{pedr}=N_{br}f_{pedr}$=30.47*0.004
  - N_{pedr}=0.12 crashes/year
  - $N_{biker}=N_{br}f_{biker}$=30.47*0.004
  - N_{biker}=0.12 crashes/year

Photo Courtesy of Yolanda Takesian

- **Apply Pedestrian and Bicyclist Adjustments and Calibration Factor (given as 1.3)**
- **Calculate Predicted Crashes for Existing Conditions**
  - $N_{rs}= (N_{br}+N_{pedr}+N_{biker})C_r$=(30.47+0.12+0.12)*1.3
  - N_{rs}= 39.92 crashes/year

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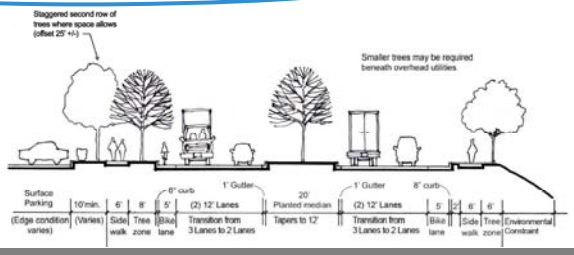
Part C – Case Study
Step 3a: Predict Future Conditions

- **Calculate Base Condition for Alternative**
  - $N_{brbase}=N_{brmv}+N_{brsv}+N_{brdwy}$
  - N_{brmv}=exp(-11.88+1.36*ln(35000)+ln(2)) = 20.96 crashes/year
  - N_{brsv}=exp(-4.59+0.47*ln(35000)+ln(2)) =2.78 crashes/year
  - N_{brdwy}= 6*0.017(35000/15000)$^{1.106}$ = 0.26 crashes/year
  - N_{brbase}=24 crashes/year for alternative base condition



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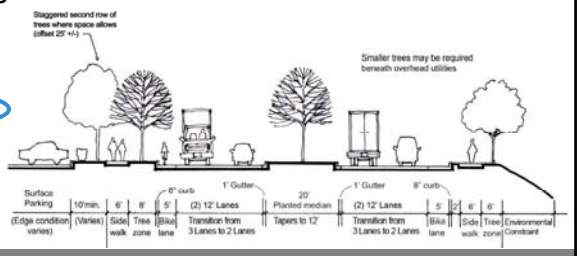
Part C – Case Study
Step 3b: Predict Future Conditions

- **Apply Appropriate AMFs**
  - Roadside Fixed Objects
    - **AMF_{1r}=0.087*70*0.036+(1-0.036)=1.18**
  - Lighting
    - **AMF_{3r} = 1-[(1-0.36*0.004-0.72*0.281-0.83*0.715)*0.203]=0.96**
- **Calculate base without pedestrian and bicyclist adjustments**
  - $N_{br}=N_{brbase}(AMF_{1r}AMF_{3r})$
  - N_{br}= 24*1.18*0.96
  - N_{br}=27.19 crashes/year



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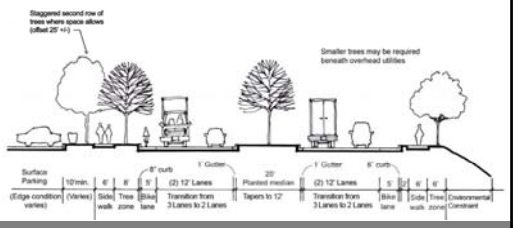
Part C – Case Study
Step 3b: Predict Future Conditions (con't.)

- **Calculate Pedestrian and Bicyclist Adjustments**
  - $N_{pedr}=N_{br}f_{pedr}$=27.19*0.006=0.16 crashes/year
  - $N_{biker}=N_{br}f_{biker}$=27.19*0.006=0.16 crashes/year
- **Apply Pedestrian and Bicyclist Adjustments and Calibration Factor (given as 1.3)**
- **Calculate Predicted Crashes for Future Conditions**
  - $N_{rs}= (N_{br}+N_{pedr}+N_{biker})C_r$
  - N_{rs} =(27.19+0.16+0.16)*1.3
  - N_{rs}= 35.76 crashes/year

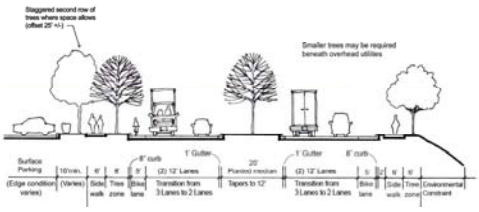


Part C – Case Study
Step 4: Compare Results

Future No Build Condition

N_{rs} = 39.9 crashes/year

Future Alternative Condition



N_{rs} = 35.8 crashes/year

Part D – Accident Modification Factors

- Part D presents accident modification factors (AMFs)
  - Roadway Segments
  - Intersections
  - Interchanges
  - Special Facilities and Geometric Situations
  - Road Networks
- Accident Modification Factors
  - Express the expected change in the number of crashes attributed to a particular countermeasure.
  - Defined as:

$$AMF = \frac{\text{Expected Crash Frequency with Countermeasure}}{\text{Expected Crash Frequency without Countermeasure}}$$

Part D Type of Information

- AMF Available
- Some evidence of safety effects available
- No quantitative information is available

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Estimating Crash Occurrence – Part D AMFs

- Applying the AMF to an expected number of crashes calculated using a calibrated safety performance function and empirical Bayes to account for regression-to-the-mean
- Applying the AMF to an expected number of crashes calculated using a calibrated safety performance function
- Applying the AMF to historic crash count data

Part D – Case Study

- **Question: What are the safety effects of reducing access point density to 5 access points per mile?**
- **Given:**
  - Current spacing is 18 access points/mile on a roadway segment length of 1.6 miles.
  - Setting and Facility: Urban/Suburban Arterial

Exhibit 13-65 Safety Effects of Reducing Access Point Density on Urban and Suburban Arterials

Access Point Density	Severity	AMF	Std. Error
48 pts/mile reduce to 26-48 pts/mile	All	0.71	0.04
26-48 pts/mile reduce to 9-25 pts/mile	All	0.69	0.02
9-25 pts/mile reduce to less than 9pt/mile	All	0.75	0.03

Part D – Case Study

Exhibit 13-65 Safety Effects of Reducing Access Point Density on Urban and Suburban Arterials

Access Point Density	Severity	AMF	Std. Error
48 pts/mile reduce to 26-48 pts/mile	All	0.71	0.04
26-48 pts/mile reduce to 9-25 pts/mile	All	0.69	0.02
9-25 pts/mile reduce to less than 9pt/mile	All	0.75	0.03

- Applicable AMF = 0. 75 with standard error of 0.03
- Current Expected Total Crashes = 15 crashes per year
- Expected Crashes with Reduced Access Density**:**
  - **15*(0.75) = 11 crashes per year**
  - **+/- 15*(0.03) = 0.5 crashes per year**
  - Expect between 10.5 and 11.5 crashes per year
  - Approximately a 25% reduction in crashes/year

Summary

- **HSM is a resource for safety analysis**
  - **Part A:**
    Fundamental knowledge to incorporate safety considerations into any project.
  - **Part B:**
    Tools to implement and maintain a quantitative, systematic, process for studying roadway safety.
  - **Part C:**
    Estimate and predict the safety of roadway design on rural two-lane roads, rural multi-lane highways, and urban and suburban arterial highways.
  - **Part D:**
    Apply accident modification factors to evaluate safety on roadway segments, at intersections, at interchanges, given special facilities and geometric situations, and within road networks.

Anticipated Schedule for HSM

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2007						Submit Prototype Chapter, Revised Annotated Outline	Panel Meeting #2	Mid-Year Meeting				Submit HSM Draft 1
2008	Annual Meeting, Submit Phase 2 Scope of Work	Review Comments HSM Draft 1 Due	Receive Confirmation on Phase 2 Scope of Work	Ongoing Phone Conferences		Submit HSM Draft 2	Receive Comments to HSM Draft 2	Mid-Year Meeting	Ongoing Phone Conferences			Submit HSM Draft 3 Final
2009	Annual Meeting, Review HSM Draft 3 - FINAL					First Edition Containing Interim Materials for the HSM Published						

What can you do now?

- **Explore the HSM website**
  - www.highwaysafetymanual.org
- **Provide Feedback and Concerns**
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  - John Zegeer
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