A Methodology for Predicting Rollover Risk

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Objective

Transportation Recall, Enhancement and Documentation (TREAD) Act of 2000 directed NHTSA to:

- Develop a rating system to assess risk of rollover of light passenger vehicles

- Disseminate information to consumers (★Ratings)

Passenger Vehicle Rollovers

Complex events that reflect the interaction of

- Driver

- Road

- Vehicle

- Environmental Factors (Road conditions, Geometry, Weather, etc.)

Safety Problem

Passenger Vehicle Occupant Fatalities in the U.S., 2001

Other 2%

NCAP Rollover Ratings System [2001]

Rollovers 31%

Frontal Crashes 39%

NCAP Frontal Crashworthiness Ratings System [1979]

Side-Impact 25%

Rear-end Crashes 3%

NCAP Side Impact Ratings System [1997]

NCAP = New Car Assessment Program

Metric to Assess Rollover Risk

Probability of Rollover per Single Vehicle Crash

- Single vehicle crash leading to rollover is indicative of propensity to roll over.

- Use vehicle, driver and environmental characteristics to develop risk model to predict rollover rate for vehicles.

- Disseminate rollover risk in a consumer-friendly manner

Existing Risk Model

Linear Regression Model predicting binary outcome (Rollover / No Rollover)

- Vehicle : Static Stability Factor (SSF)

- Environmental: Storm, Fast (Speed), Road Characteristics (Hilly, Curve, Bad Surface, etc.)

- Driver: Age, Impaired Driving (DRINK), Male

Data: Census of all crashes from Six States.

Static Stability Factor (SSF) - t/2h

First order estimate of steady state lateral acceleration at wheel lift

Center of Gravity Height, *H*
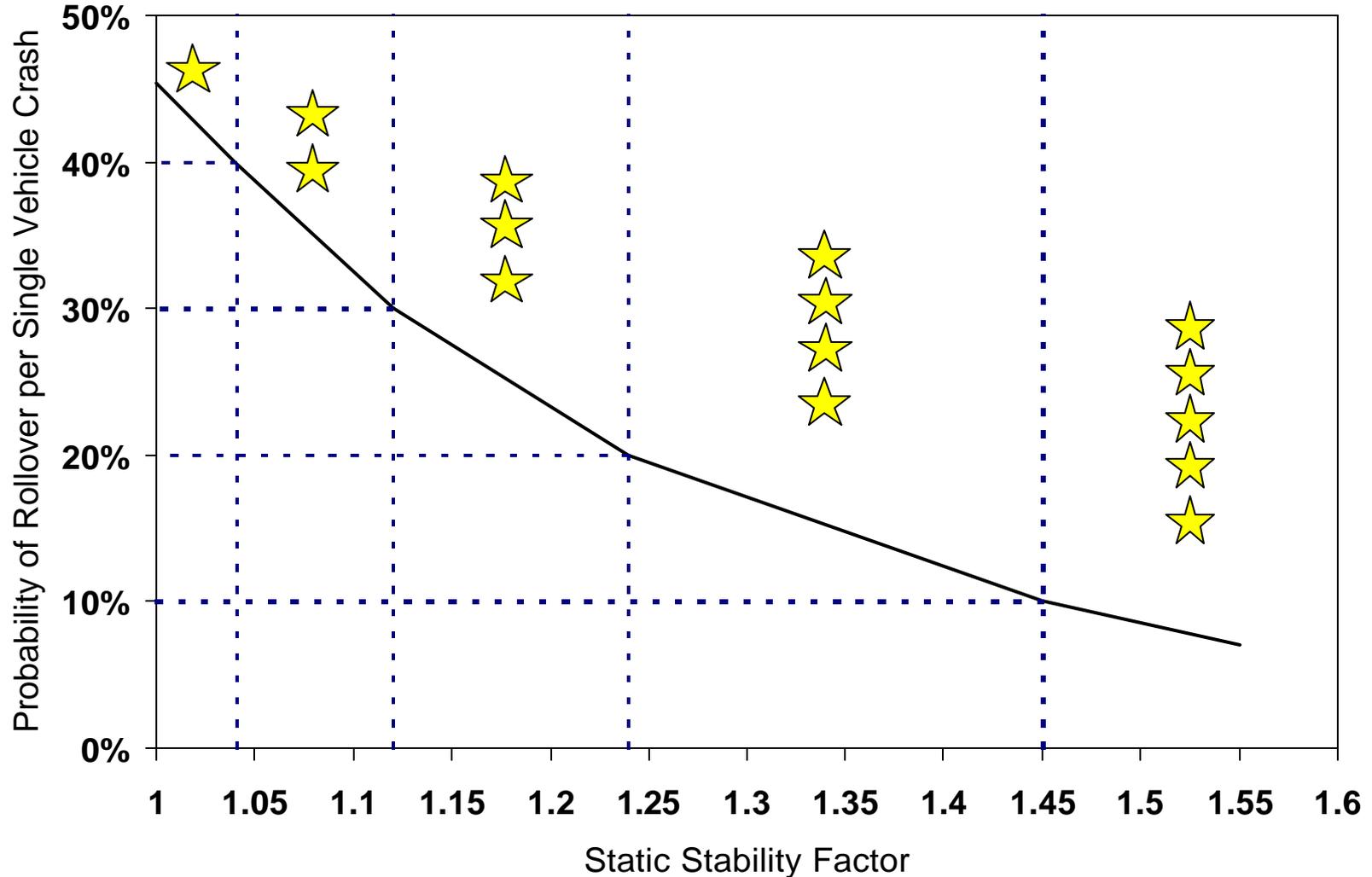
←Track Width, *T*→
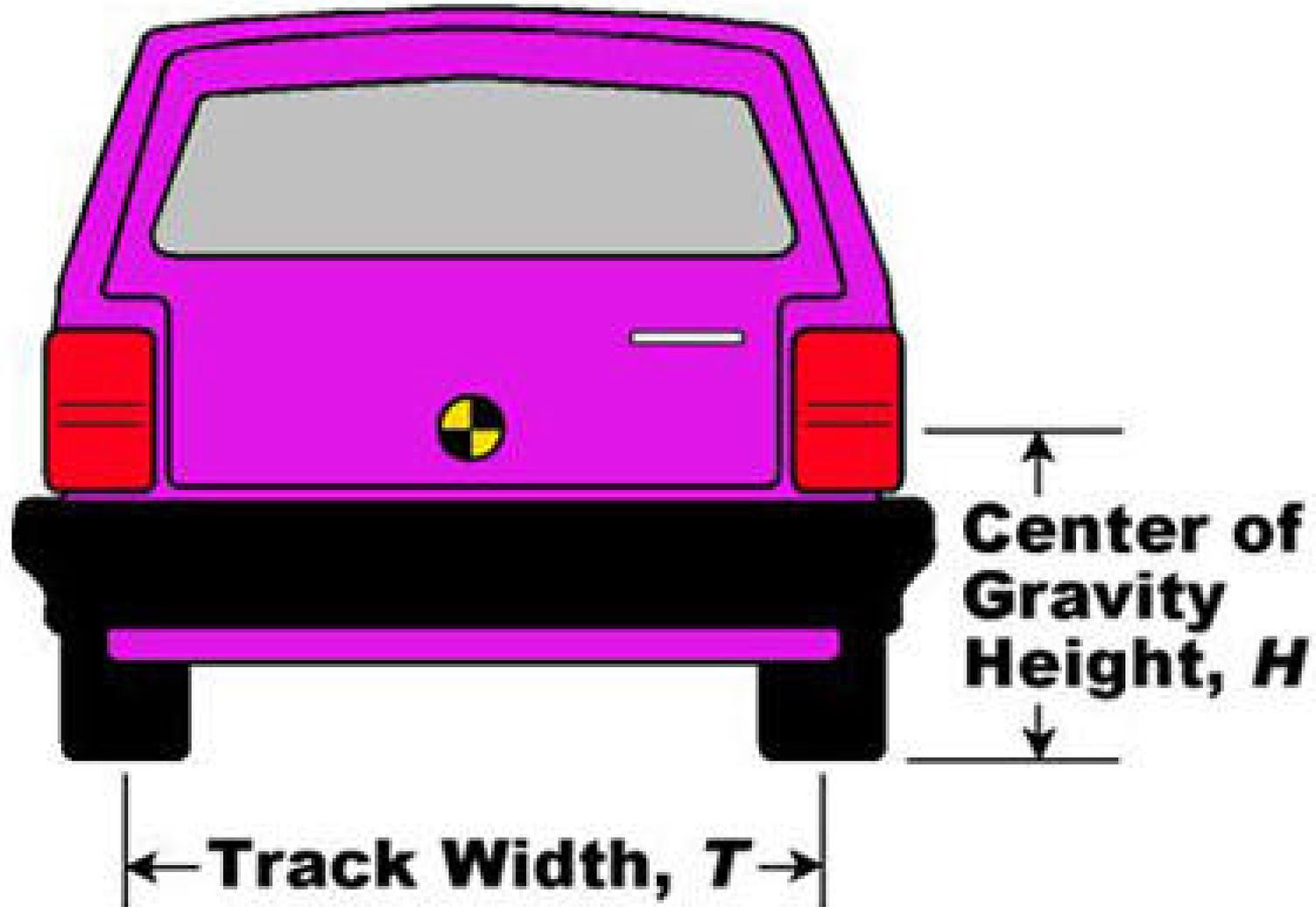
Rollovers per Single Vehicle Crash vs Vehicle SSF Based on data for 100 vehicle models in 220,000 SV Crashes adjusted to avg. crash demographics - Correlation Coefficient: $R^2 = 0.88$
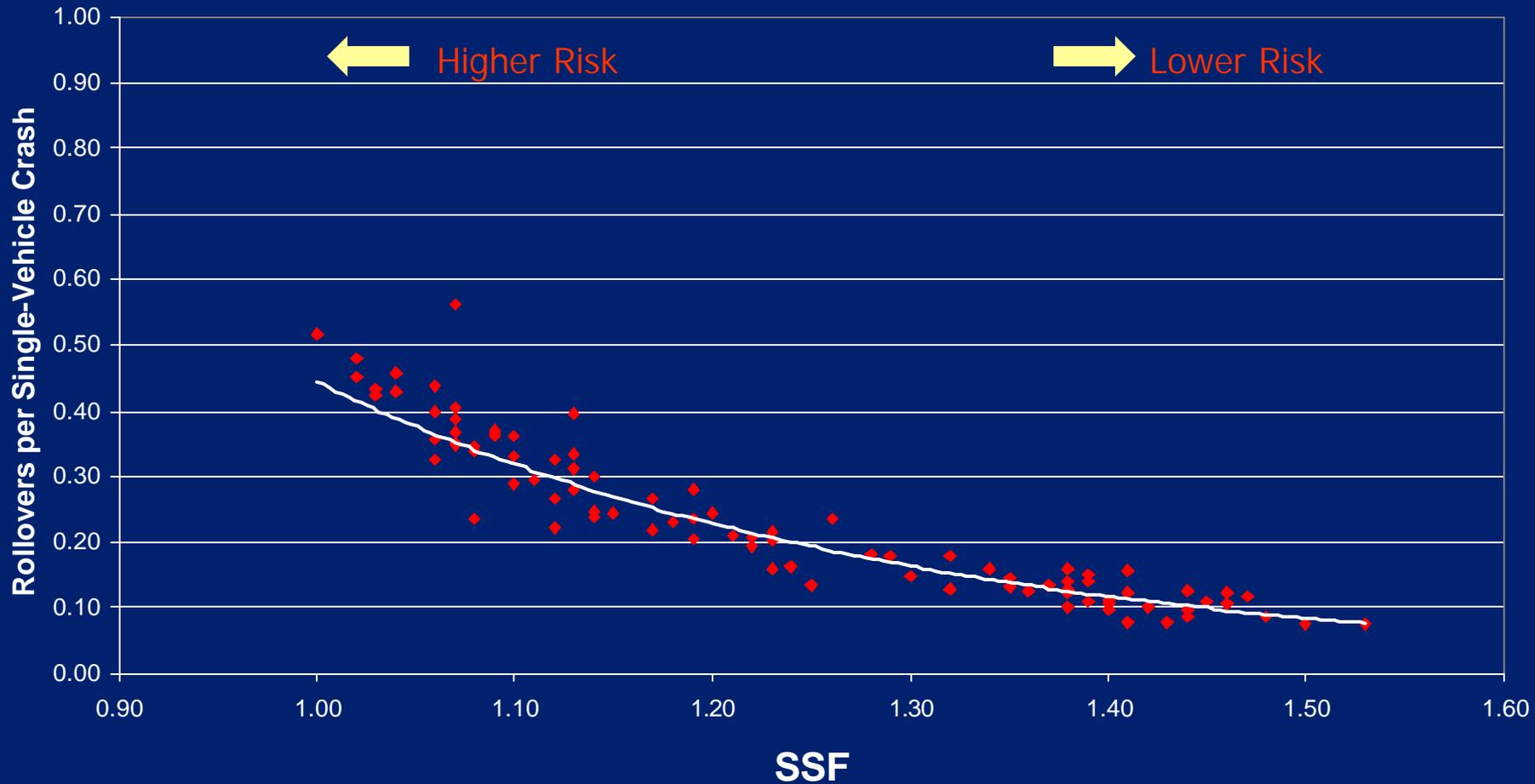
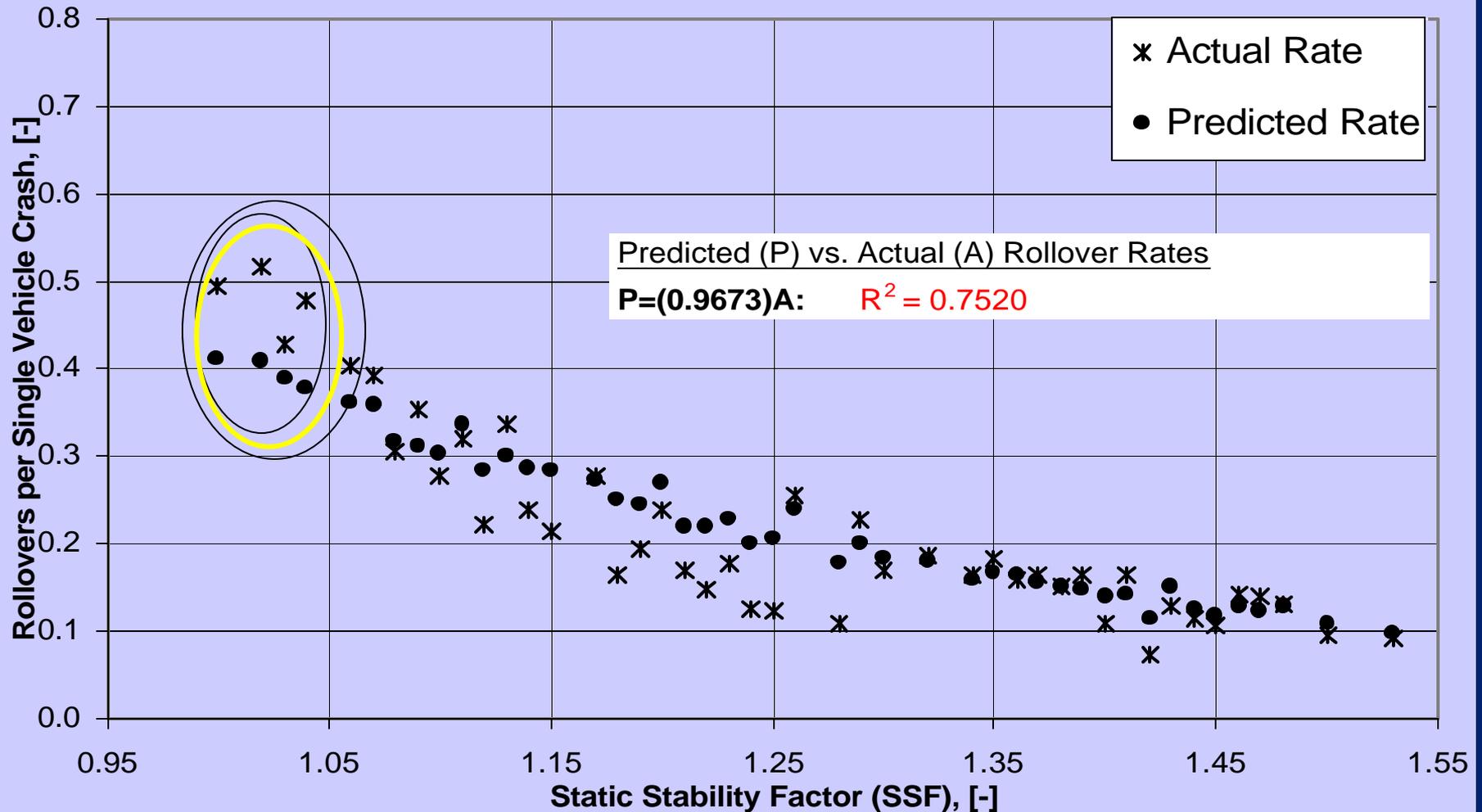# Star Rating Intervals - Summary (Linear) Approach

Proposed Changes

- Logistic Regression Model predicting binary outcome (Rollover / No Rollover)

- Include results of Dynamic Vehicle Testing

  - Fishhook Test indicating Tip-up or No Tip-up of vehicle.

  - J-Turn Test (Light [JL] and Heavy [JH]).

- Disseminate Star Ratings similar to prior approach using results from expanded model.

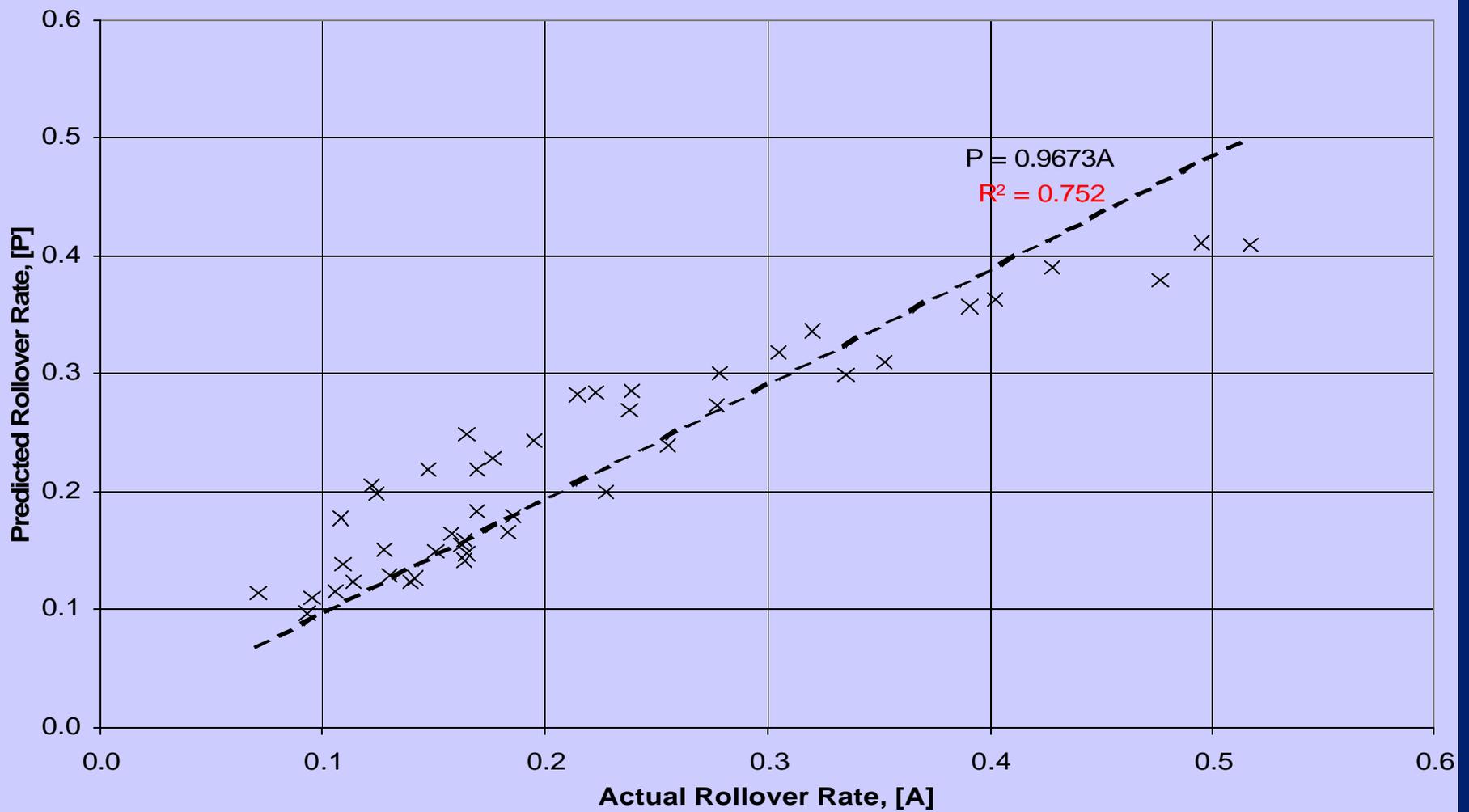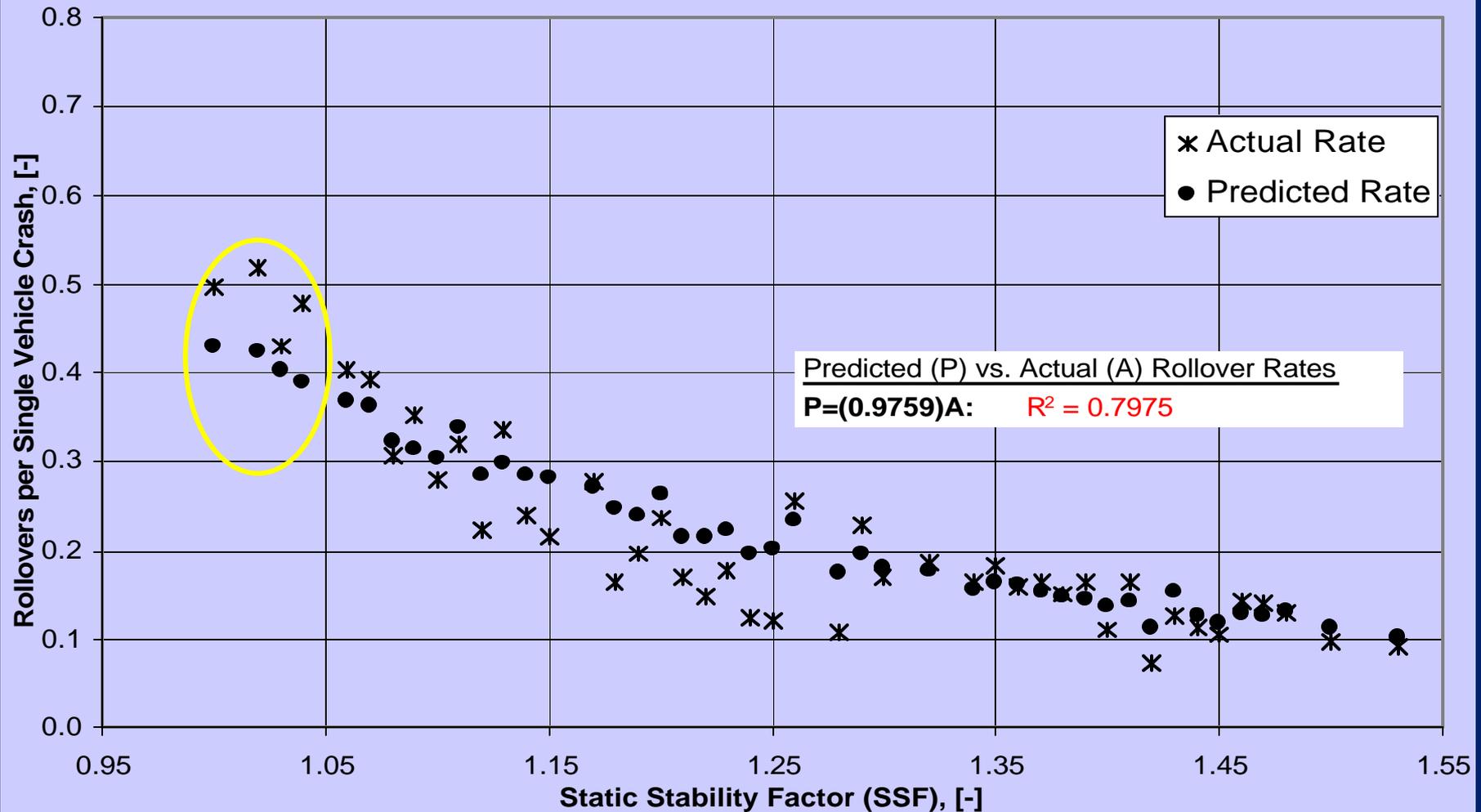# Model 1: Logistic Regression – SSF only
No Transformation

Predicted (P) vs. Actual (A) Rollover Rates

P=(0.9673)A: $R^2 = 0.7520$

Legend:
- ✕ Actual Rate
- ● Predicted Rate

Y-axis: Rollovers per Single Vehicle Crash, [-]

X-axis: Static Stability Factor (SSF), [-]

Logit (Pr(Rollover))=SSF STORM FAST HILL CURVE BADSURF MALE YOUNG OLD DRINK DUMMYFL DUMMYMD DUMMYNC DUMMYPA DUMMYUT

Logistic Regression – SSF only
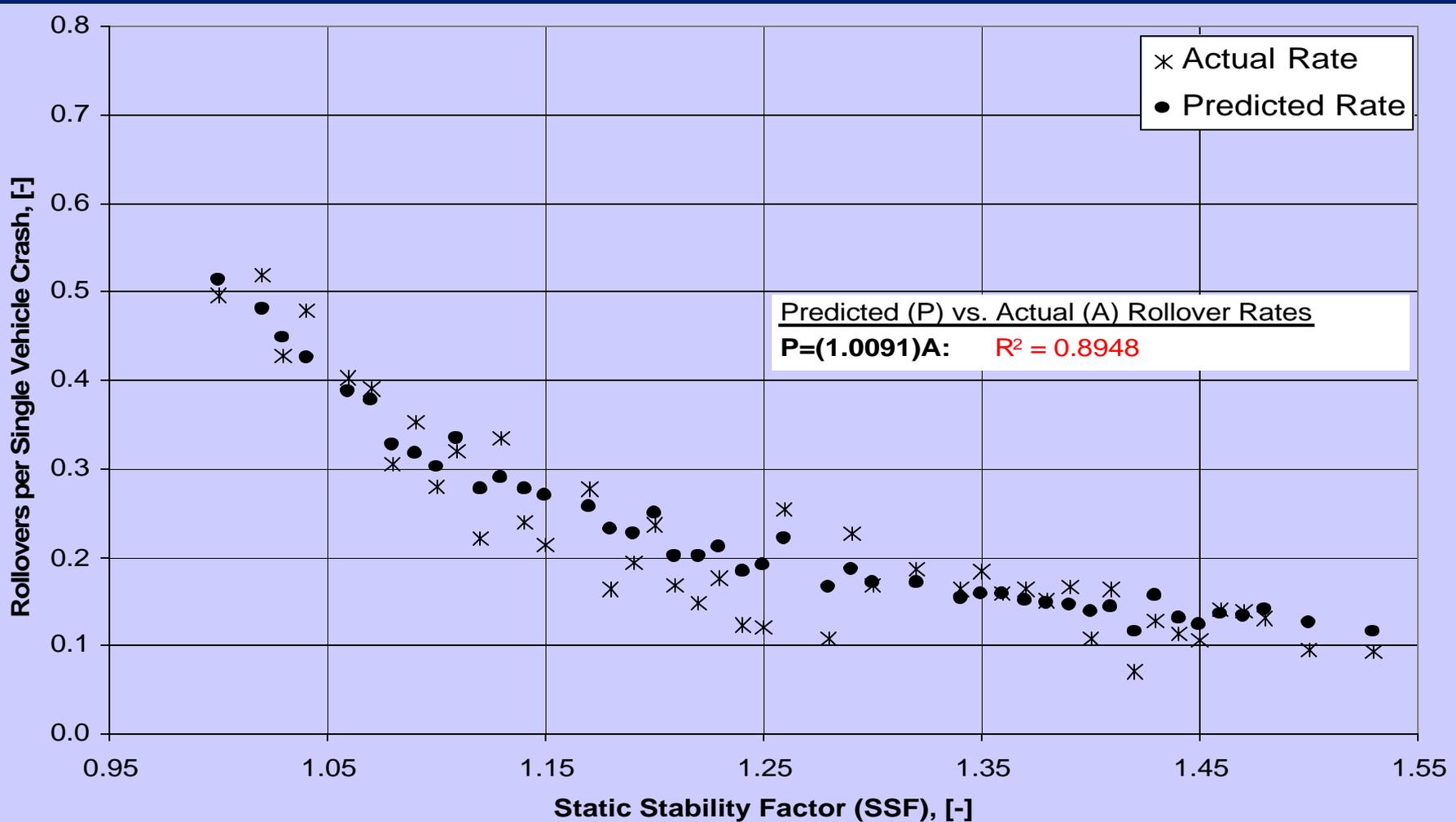## Actual vs. Predicted Rollover Rates

$P = 0.9673A$
$R^2 = 0.752$

Model 2: Logistic Regression – LOG(SSF)

Logit (Pr(Rollover))=Log(SSF) STORM FAST HILL CURVE BADSURF MALE YOUNG OLD DRINK DUMMYFL DUMMYMD DUMMYNC DUMMYPA DUMMYUT
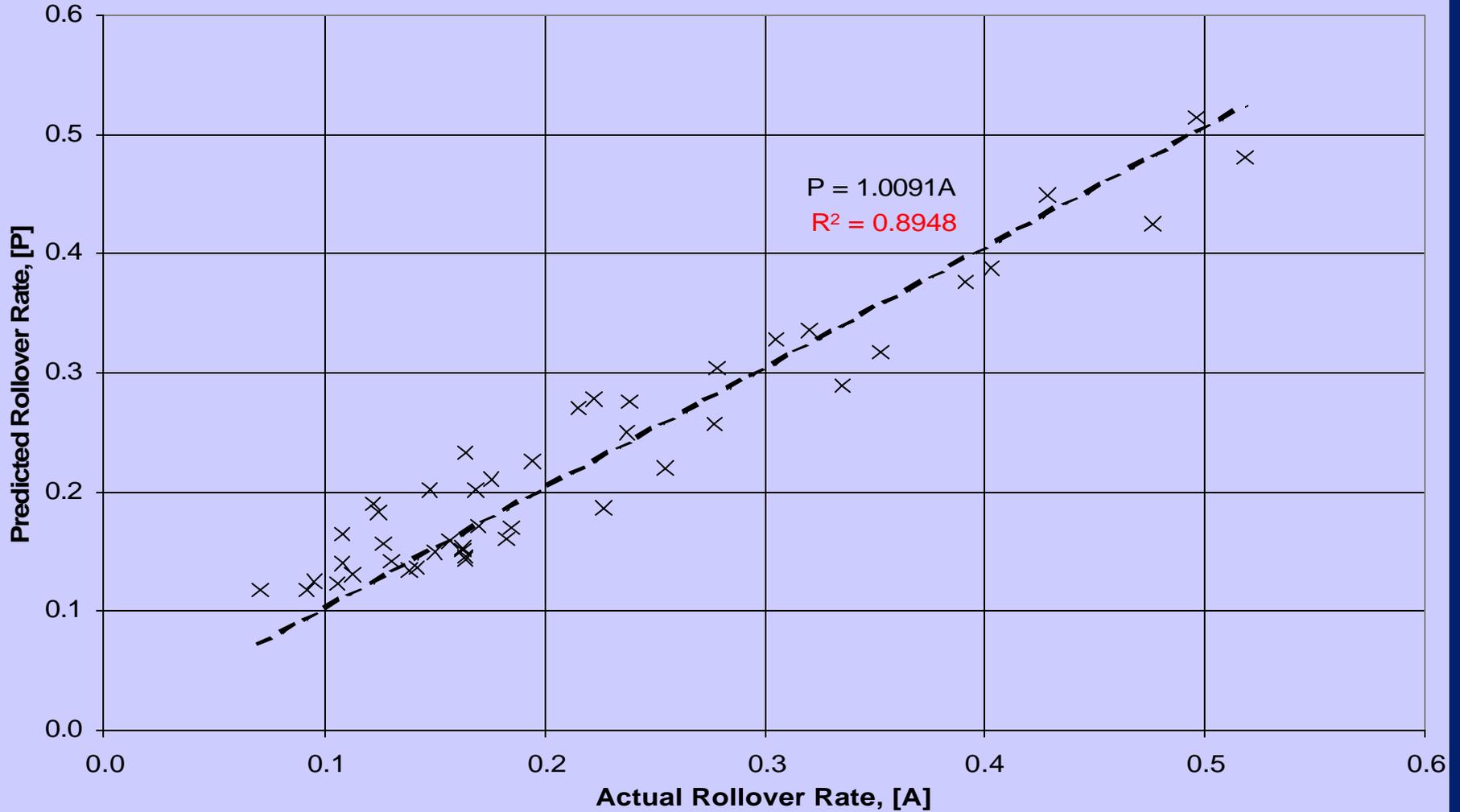
Model 3: Logistic Regression – LOG(SSF-0.90)

Predicted (P) vs. Actual (A) Rollover Rates
P=(1.0091)A: $R^2 = 0.8948$

Logit (Pr(Rollover))=Log(SSF-0.9) STORM FAST HILL CURVE BADSURF MALE YOUNG OLD DRINK DUMMYFL DUMMYMD DUMMYNC DUMMYPA DUMMYUT

Logistic Regression – LOG(SSF-0.90)
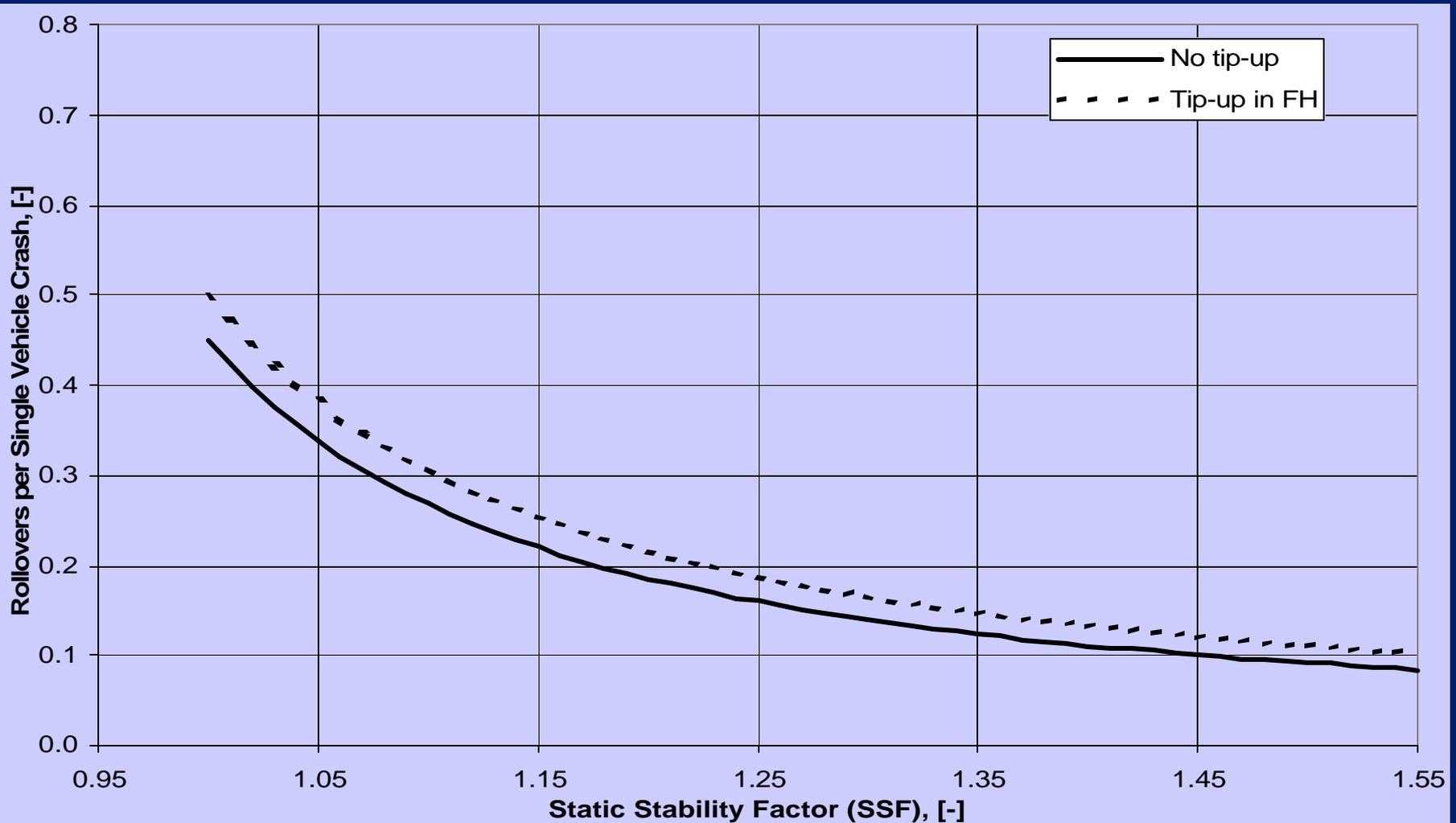## Actual vs. Predicted Rollover Rates

Introduce Dynamic Tests in Model

- J-Turn Test (Light 'JL' and Heavy 'JH')

- Fishhook Test (Light 'FL' and Heavy 'FH')

- Four '0/1' Scores to indicate Wheel Lift during Test.

- Heavy (5 Occupants) more stringent than Light (2 Occupants).

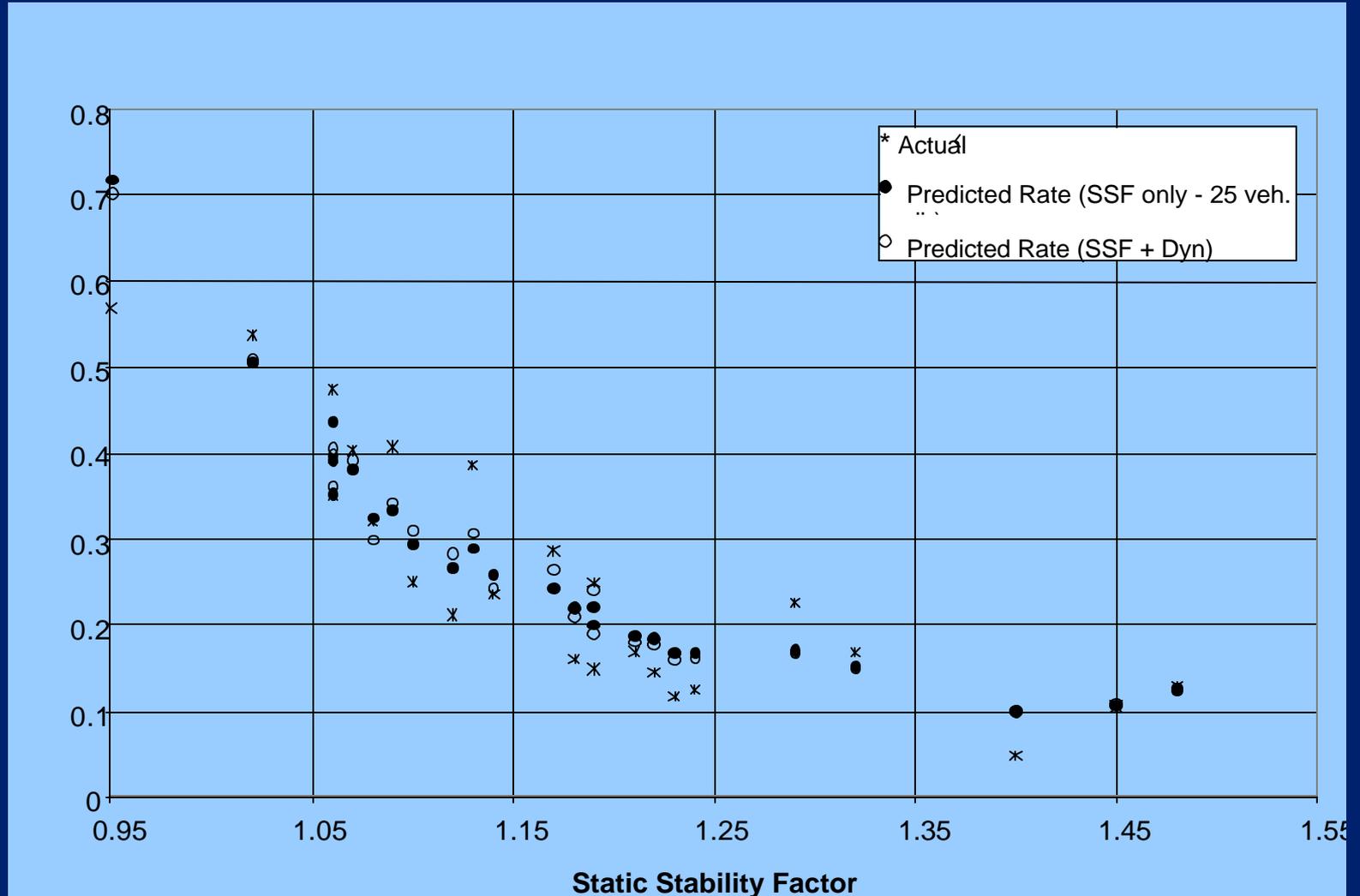- Fishhook more stringent than J-Turn.

Logistic Regression Model
Single Dynamic Variable – Fishhook, Heavy

Logit (Pr(Rollover))=Log(SSF-0.9) FH STORM FAST HILL CURVE BADSURF MALE YOUNG OLD DRINK DUMMYFL
DUMMYMD DUMMYNC DUMMYPA DUMMYUT

Logistic Regression Model
Single Dynamic Variable – Fishhook, Heavy

Logit (Pr(Rollover))=Log(SSF-0.9) FH STORM FAST HILL CURVE BADSURF MALE YOUNG OLD DRINK DUMMYFL DUMMYMD DUMMYNC DUMMYPA DUMMYUT

# Comparison of Combined and SSF only Models
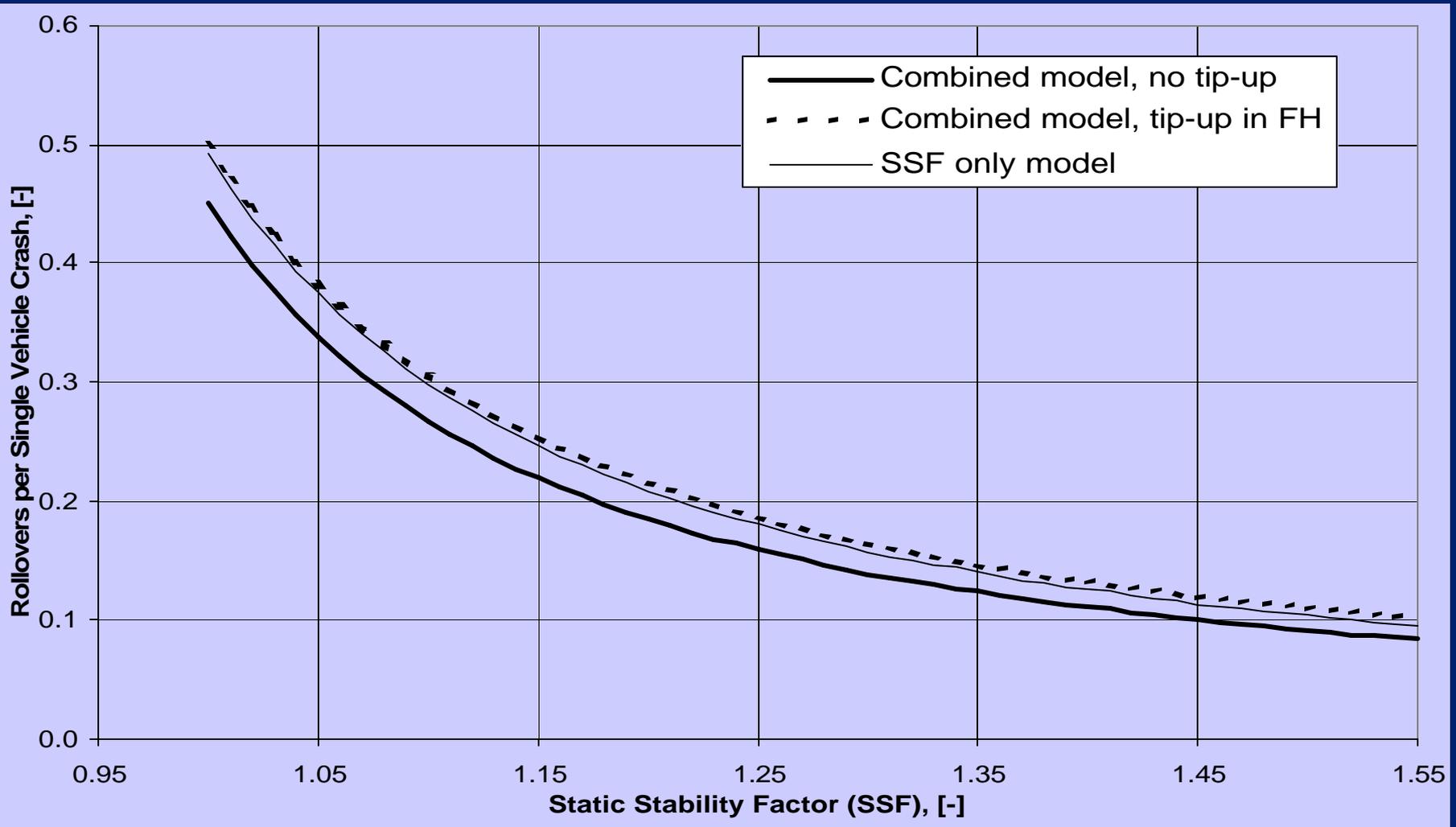
Other Observations

- Only models with FH and JH had positive coefficients

- Possibly few vehicles tipped-up on the other tests.

- Results are driven by very few test results.

- Only results of the FH test included as it is the more stringent test.

Conclusions

- SSF is by far the single best predictor of propensity to roll over.

- Model with SSF and FH have the best predictive power although improvement in predictive power is modest.

- SSF accounts for vehicle dynamics that come into play when tripped up (curb, guard rail)

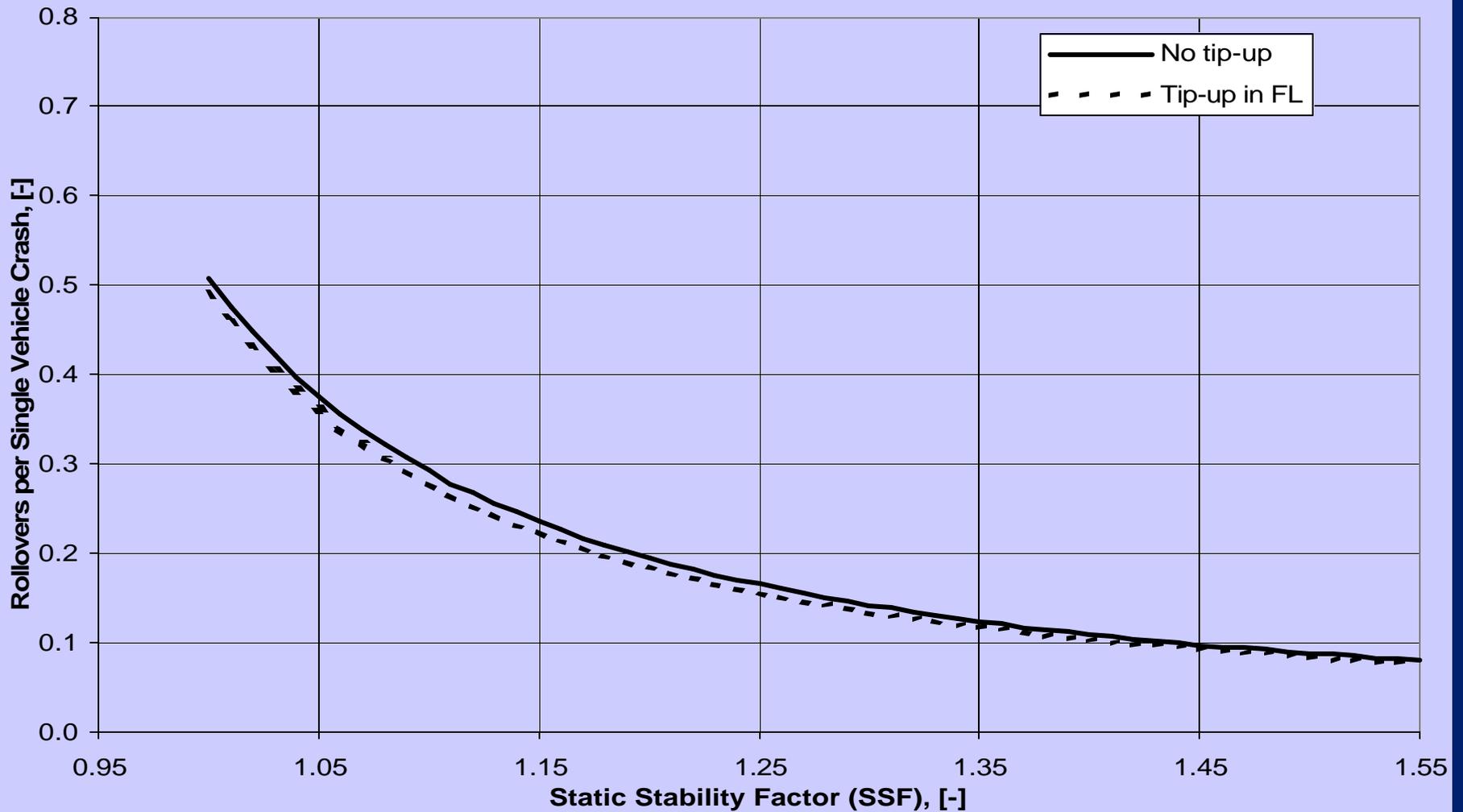- Dynamic tests account for surface forces that contribute to untripped rollovers.

Logistic Regression Model
Single Dynamic Variable – J-turn, Heavy
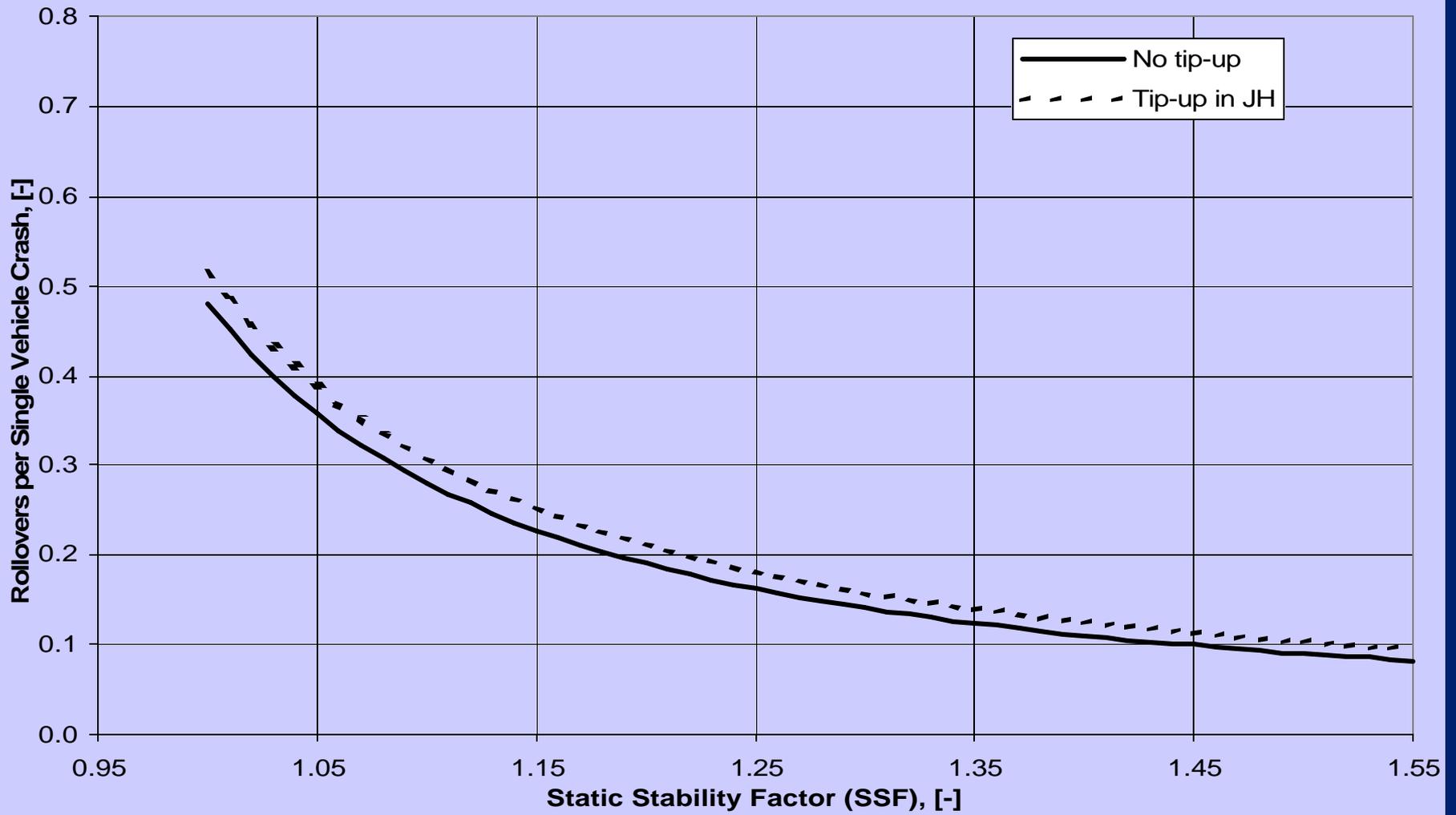
Logistic Regression Model
Single Dynamic Variable – Fishhook, Light

Logistic Regression Model
Single Dynamic Variable – J-turn, Light