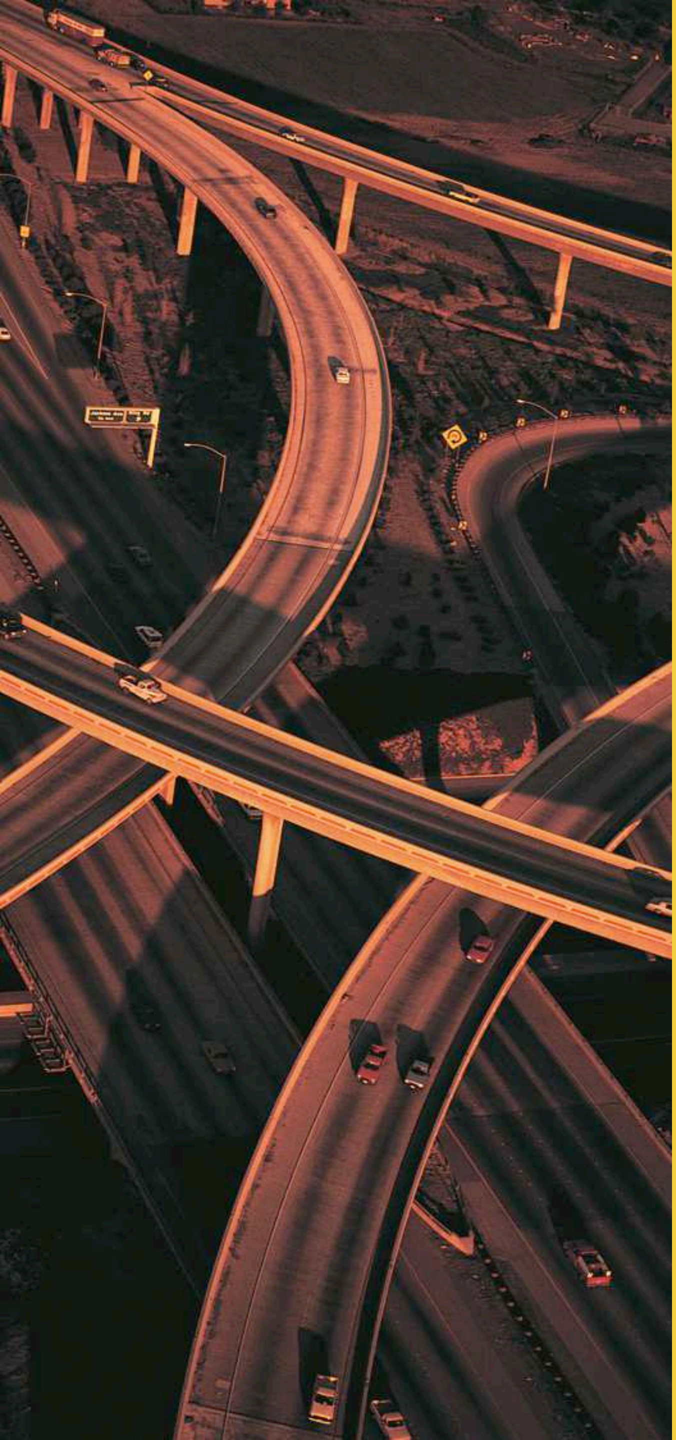

RUTGERS

Center for Advanced Infrastructure and Transportation

Innovations in Traffic Safety and Mobility

Risk Based Traffic Safety Research

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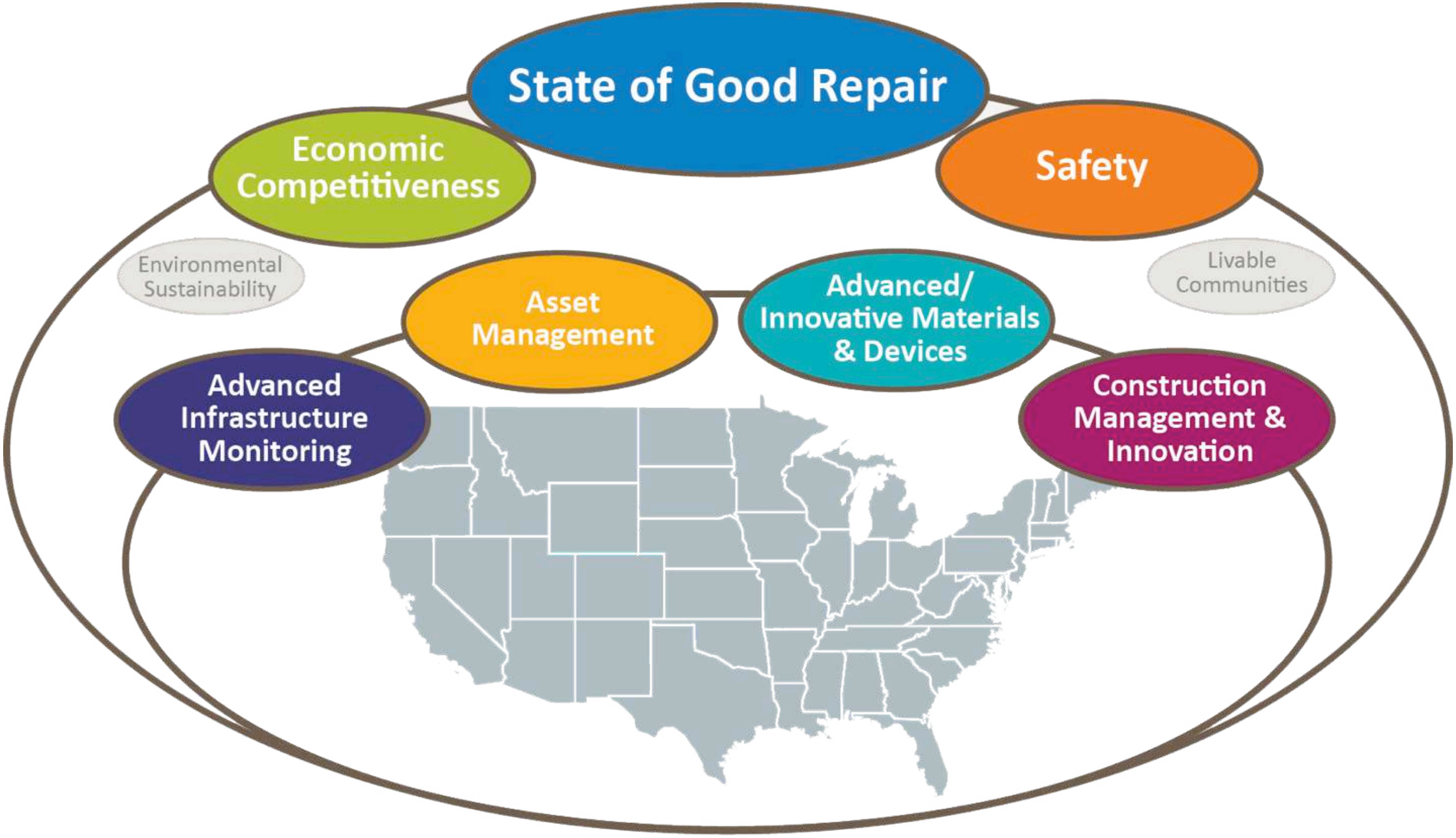
Department of Industrial & Systems Engineering

- CAIT Focus: USDOT Strategic Areas **>>**



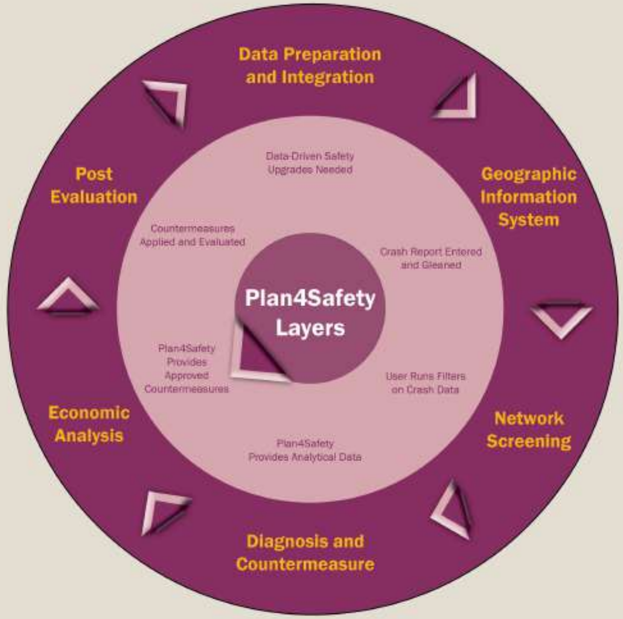
Questions

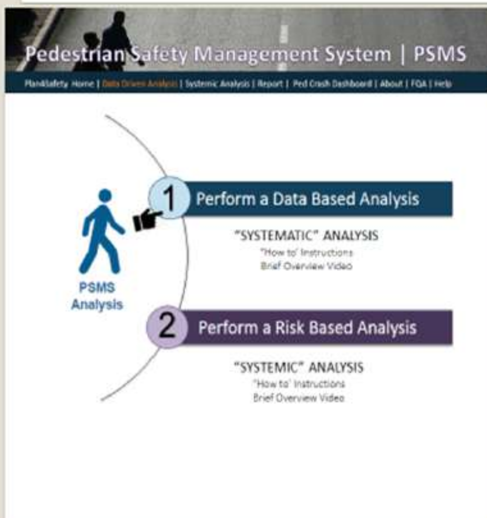
- Why do traffic accidents happen?
    - Driver behavior?
    - Road?
    - Vehicle?
    - Traffic flow, weather, etc.?
    - Traffic signals and law enforcement?
    - All of the above?
- How to mitigate traffic safety risks?
    - Traditional reactive & systematic approach to safety planning and engineering
    - Proactive safety measures – systemic approach
    - Near real-time situational awareness for drivers
    - Near real time situational awareness for law enforcement
    - Smart and connected cars & smart roadways
    - Self-regulating smart cars – advanced cruise control/drive by-wire
    - Near real-time and dynamic insurance pricing

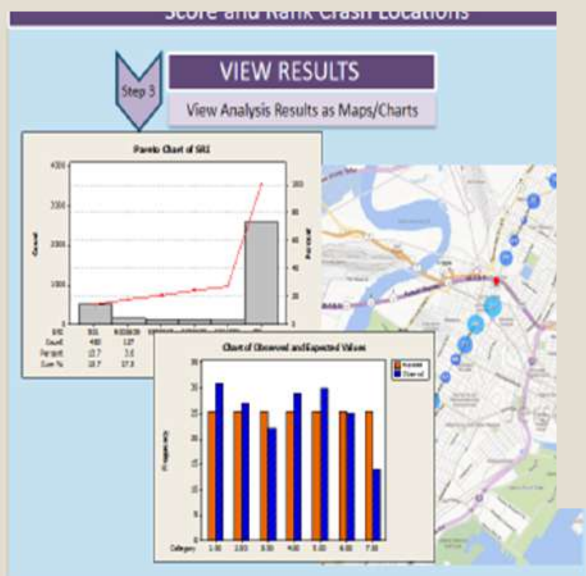
Safety & Mobility @ Rutgers CAIT - TSRC

- Inception 2006
- Safety/mobility resource center funded by FHWA and NJ DOT
- Development of new technologies (e.g., Plan4Safety or P4S)
- Services to NJ DOT/ FHWA/ municipalities/counties/law enforcement
- TSRC has been a major force in effectively improving traffic safety in New Jersey.

Rutgers Plan4Saefty (P4S)







Plan4Saefty Functional Architecture

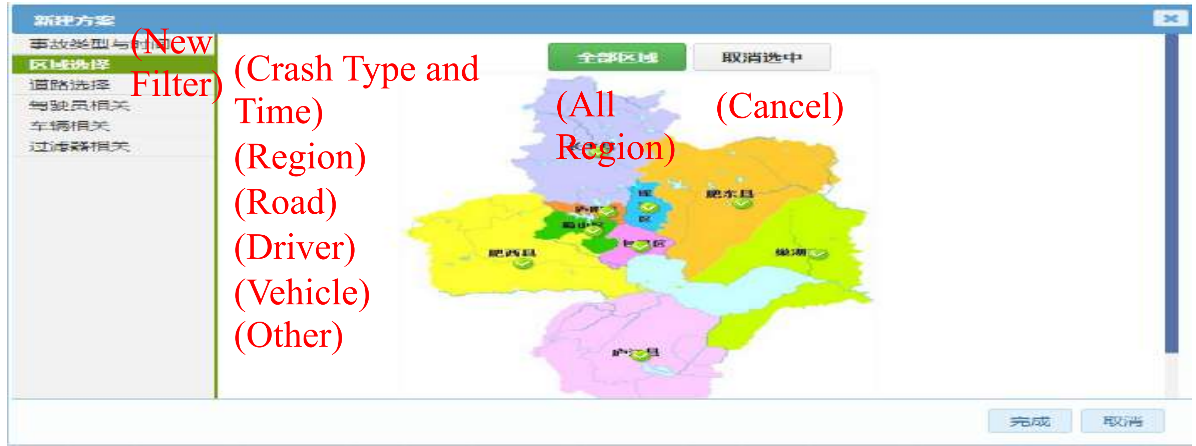
Ring 5 – Presentation	Ring 4 – Connection to other management systems	Ring 3 – Applications	Ring 2 - Advanced Functions	Ring 1 – Core & Basic functions
• Engineers • Planners • Officers • General Public • Public Officials	• Road pavement Management • ITS management • Bridge • Law Enforcement • Traffic Control Center • Emergency Management • Capital Planning • Public Transit • Asset Management • Risk Management • Public Information Portal • Insurance Management	**Safety Analysis** **Safety Planning** **Safety Engineering** **Safety Evaluation** **Law enforcement** **Peds and bikes** **Commercial vehicles** **Safe Navigation** **Situational Awareness** **Safety Training**	Using historical crash data • Safety Performance Function • Crash Modification Factor (CMF) • Scenario generation & diagnosis analysis • Cost & benefit analytics • Advanced Filtering • Extended GIS mapping • Routing & Navigation • Crash prediction Using near miss data • Data fusion • Crash prediction • Hot spots • Near Crash Analysis Using hybrid data • Crash forecasting • Driver violation check • Safety and Mobility Analysis • Post-Crash Health Economics • Safety Grant Eligibility • Crash Impact Simulation • Crime Hot Spots • Enforcement Dispatch Routing • Real Time Monitoring • Post evaluation • Driver licensing	Using historical crash data • Trend Line • Hot spot analytics with different crash types • Cluster finder • High Risk Road Segments • Crash Rates • Critical Crash Rate • Severity Rate • Critical Severity Rate • Basic filtering • Basic GIS mapping • Crash summary • Road Histogram • Basic reporting Using hybrid data • High Risk rural Roads • Intersection Analysis • Intersection ranking • High Risk Urban Roads

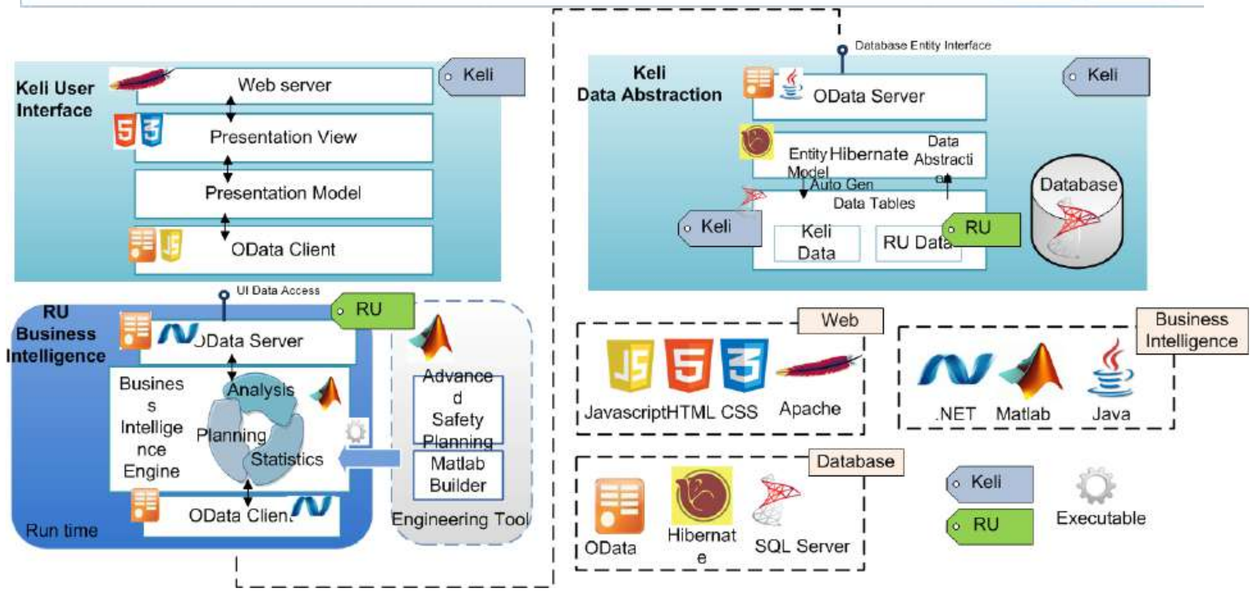
P4S Recognition

- Plan4Safety has won many awards, including the *USDOT Best Practice Award for the 2009 National Roadway Safety Awards,*
- Plan4Safety has been recognized internationally in the Annual Showcase of 2013 in the *Intertraffic World* Magazine, published in Britain,
- Among the top three safety systems recognized in the USA,
- P4S is in China.

Plan4Safety (P4S) is in China

- Collaboration with Anhui Kelli on traffic safety and mobility started in 2012.
- A two phase project was already completed (11/2013).
- A joint program between Anhui Keli and Rutgers on ITS will start in May 2014.
- Anhui Keli is designated as one of the main ITS companies in China by the Chinese government.





Current Technology

Historical Crash data

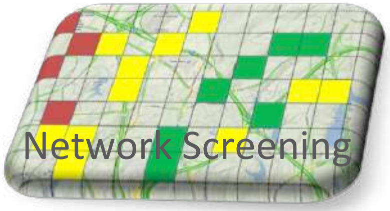
Static Roadway Characteristics

Historical Weather data

Traditional Safety Prediction Models

- Non-individualized
- Passive

#{Crashes} = *f*(Some Driving Features, Static Roadway Features,...)



Crashes are Rare Events!

Safety Predictive Analytics – Historical data

Historical Database

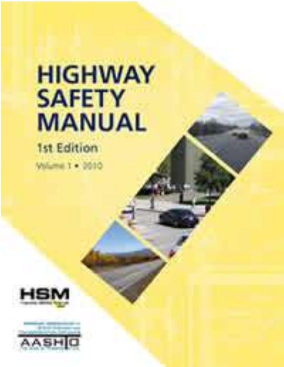
- Crash Records
- Traffic Volume Data

$X_1(t)$ $X_2(t)$ …. $X_k(t)$

Predictive Model

Z_1 Z_2 …. Z_n

$Y_i(t)$ = Average Crash Frequency
For site *i* at time t



Roadway (Engineering) Database:

- length of segment, *l*ane width, shoulder width, shoulder type, roadside hazard rating, presence or absence of horizontal curve, curve characteristics, Lighting, Speed Limit and ….

How to find a good model?

- **Based on AADT and Roadway Length**
- **Models were developed by data from specific states**

Adjust the calculated SPF predicted value for base conditions to actual or proposed conditions

Adjust SPF to reflect local conditions: Climate , Driver populations , Animal populations , Crash Reporting System.

Improve crash estimations by combining predicted data with historical data

Inputs → SPF → Crash Modification Factor → Calibration Factor → Empirical Bayesian Method → **Average Crash Frequency**

$$N_{predicted} = SPF \times (CMF1 \times CMF2 \times \ldots) \times C$$

$$N_{expected} = w \times N_{predicted} + (1-w) \times N_{observed}$$

Safety Predictive Analytics – Historical data

Poisson Model (popular model)

$N_i(t)$: # of crashes in site i and year t

$$f(N_i(t),\lambda_i) = e^{-\lambda t}\frac{(\lambda_i t)^{N_i(t)}}{N_i(t)!}$$

$$E(N_i(t)) = \exp(\sum_{j=0}^{p}\beta_j x_j)$$

Average crash at site *i* and year *t*

Roadway characteristics and traffic information

Negative binomial model

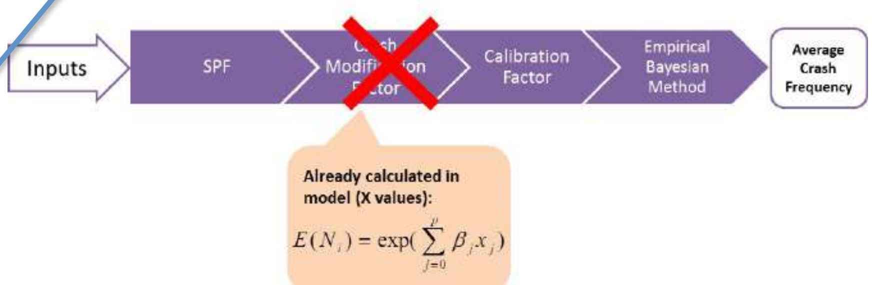
Assume that the Poisson parameter is random variable (with gamma distribution)

$$f(N_i(t)\,|\,x_i,\lambda_i,\nu,\delta) = \int_0^{\infty} e^{-\lambda_i}\frac{(\lambda_i)^{N_i}}{N_i!}.G(\lambda_i\,|\,\nu,\delta).d\lambda_i$$

$$f(N_i\,|\,x_i,\nu,\delta) = \frac{\Gamma(\nu+N_i)}{\Gamma(\nu)\Gamma(N_i+1)}\left(\frac{\delta}{1+\delta}\right)^{\nu}\left(\frac{1}{1+\delta}\right)^{N_i}$$

$$f(N_i\,|\,x_i,\alpha,\delta) = \frac{\Gamma(N_i+1/\alpha)}{\Gamma(1/\alpha)\Gamma(N_i+1)}\left(\frac{1}{1+\alpha\mu_i}\right)^{1/\alpha}\left(1-\frac{1}{1+\alpha\mu_i}\right)^{N_i}$$

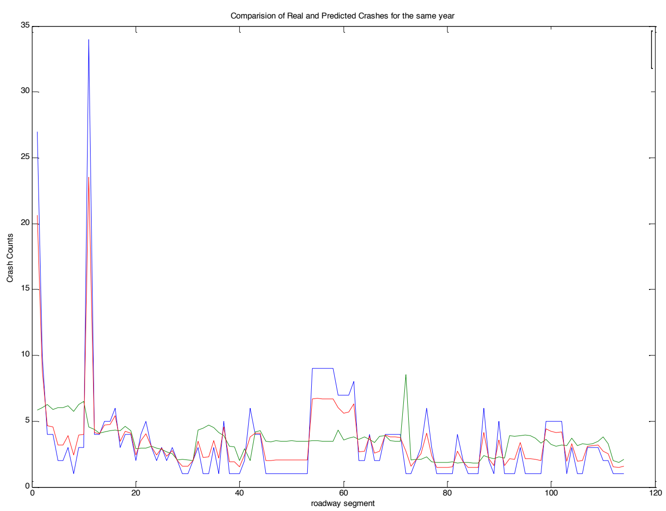
$$E(N_i) = \mu_i = \exp(\sum_{j=0}^{p}\beta_j x_j)$$



Safety Predictive Analytics – Historical data

Input features and response variables used for building the proposed crash prediction model:

	Feature	Data Type	Base Condition
Input Features			
x_1	Road Segment ID	Number	-
x_2	SRI	Text	-
x_3	Location Type	Categorical	-
x_4	Facility type	Categorical	-
x_5	Road Segment Length	Real	-
x_6	Start-Point	Real	-
x_7	End-Point	Real	-
x_8	Number of Lane	Integer	-
x_9	Road Total Width	Real	-
x_{10}	Speed Limit	Integer	-
x_{11}	AADT	Real	-
x_{12}	Lane Width	Real	3.75m
x_{13}	Shoulder Width	Real	2.5m
x_{14}	Shoulder Type	Categorical	Paved
x_{15}	Presence of Median	Binary	absence of a lane
x_{16}	Median Width	Real	4.5m urban, 9.0m Rural
x_{17}	Median Barrier	Binary	absence of a lane
x_{18}	Passing lane	Number	absence of a lane
x_{19}	2-way left-turn	Binary	absence of 2-way left-turn
x_{20}	Lighting	Binary	absence of Lighting
x_{21}	Presence of on-street parking	Binary	absence of on-street parking
x_{22}	Type of on-street parking	Binary	absence of on-street parking
Response Variables			
Y	Total Crashes	Integer	-
Y_1	Fatal Crashes	Integer	-
Y_2	Major Injuries Crashes	Integer	-
Y_3	Minor Injuries Crashes	Integer	-
Y_4	Property-Only-Damage Crashes	Integer	-



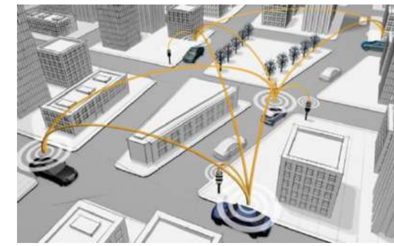
Evolution of Traffic Safety Prediction Models

Historical Crash data

Static Roadway Characteristics

Crowdsourcing

V2V, V2I



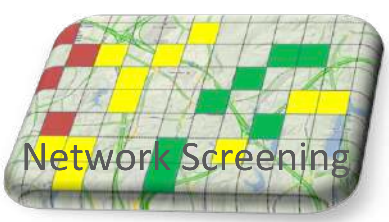
Weather data

NDD

Traditional Safety Prediction Models

- Non-individualized
- Passive

#{Crashes} = *f*(Some Driving Features, Static Roadway Features,…)



Advanced Technologies => New Data Streams

Crashes are Rare Events!

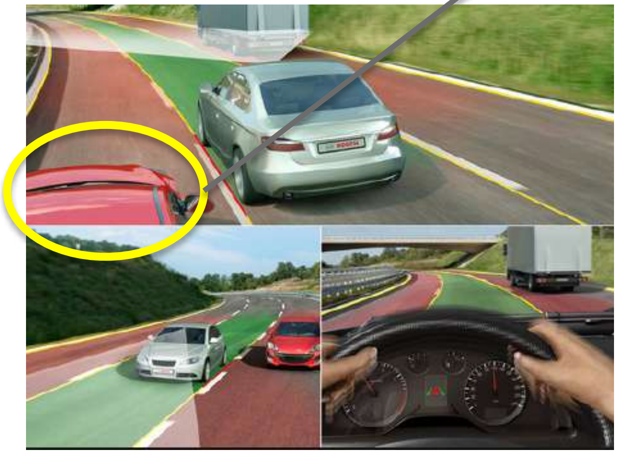
Real-time Safety Prediction Model

- Individualized
- Active

Pr{Crash, Near-Crash, Baseline} = *f*(Historical Crashes, Real-time Roadway, & Drivers Features, Incidents, …)

Smart and connected vehicle technology

Single crash cause
at a time



Smart car Example: Blind Spot Warning

Samrt phone Example: Forward Collision Warning

These new safety technologies are very helpful but they miss the interrelationship among

multiple causes of risky situations!

Multiple Data Streams

Static Data
Roadway conditions, traffic signals, etc.

Dynamic data

Weather & roadway conditions real time

Near miss, IOT & roadway sensors

Traffic flow data V2V,V2I & crowdsourcing

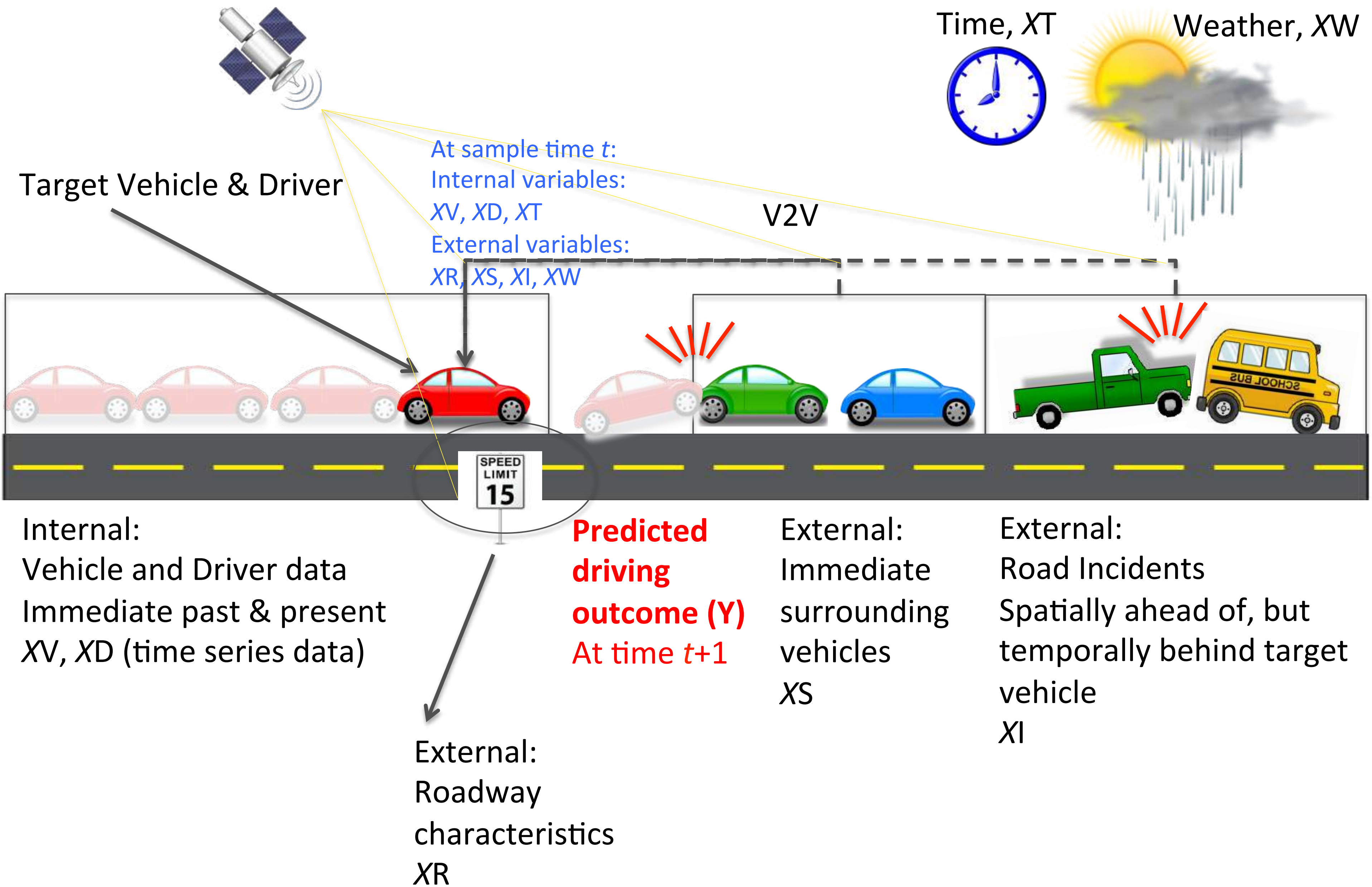
Weather data and roadway condition
can be reported near real time by sensors, vehicles, and roadway sensors.

Crashes are rare events and crash based safety solutions are reactive; Near real time near miss data and unsafe driving conditions can protect vulnerable users, e.g., pedestrians and bicycles.

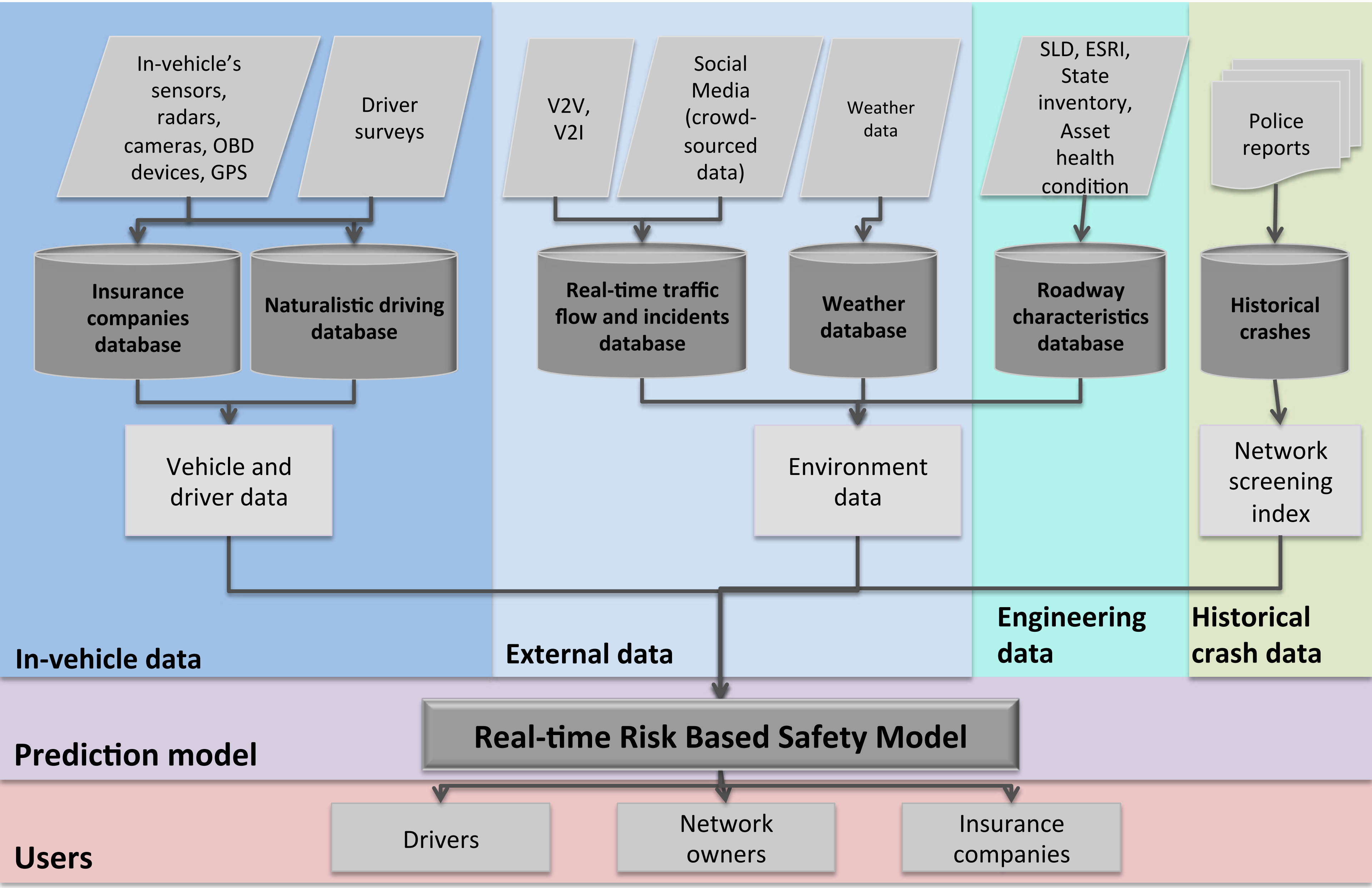
Warnings & real time unsafe driving conditions generated between vehicles and between vehicles and infrastructure;

Naturalistic Driving Data

Illustration of Traffic Safety Risk Factors



Real-Time Risk Based Safety Model



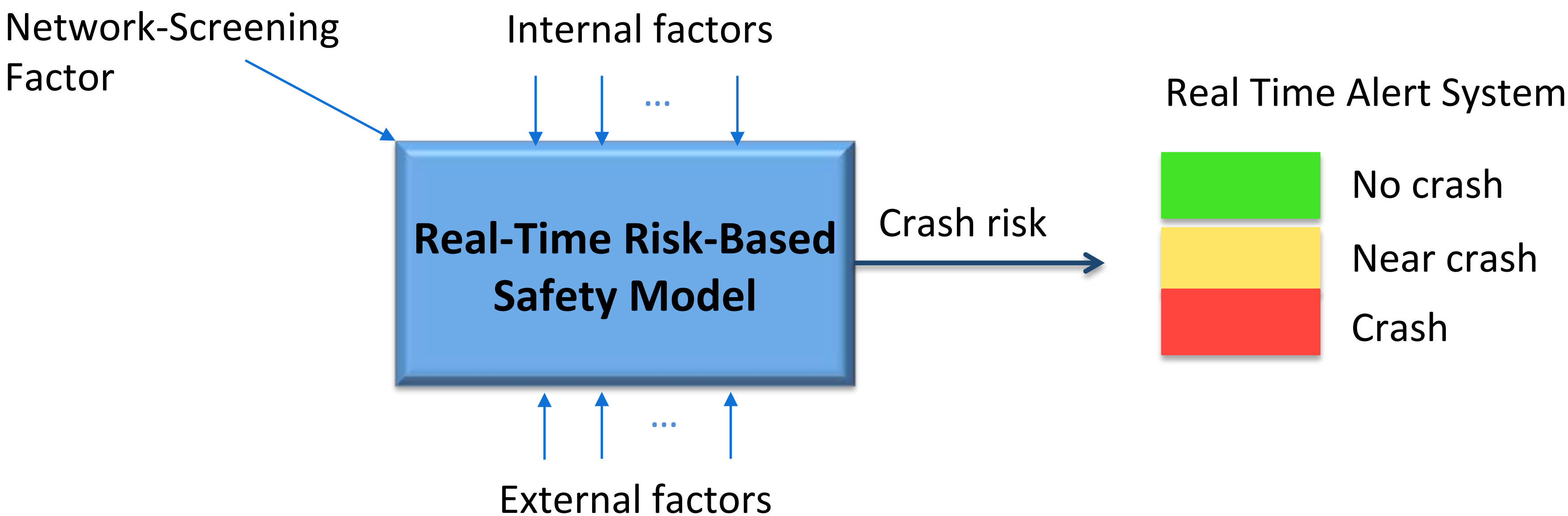
Real-Time Risk Based Safety Model (cont.)

Classification model's input/output

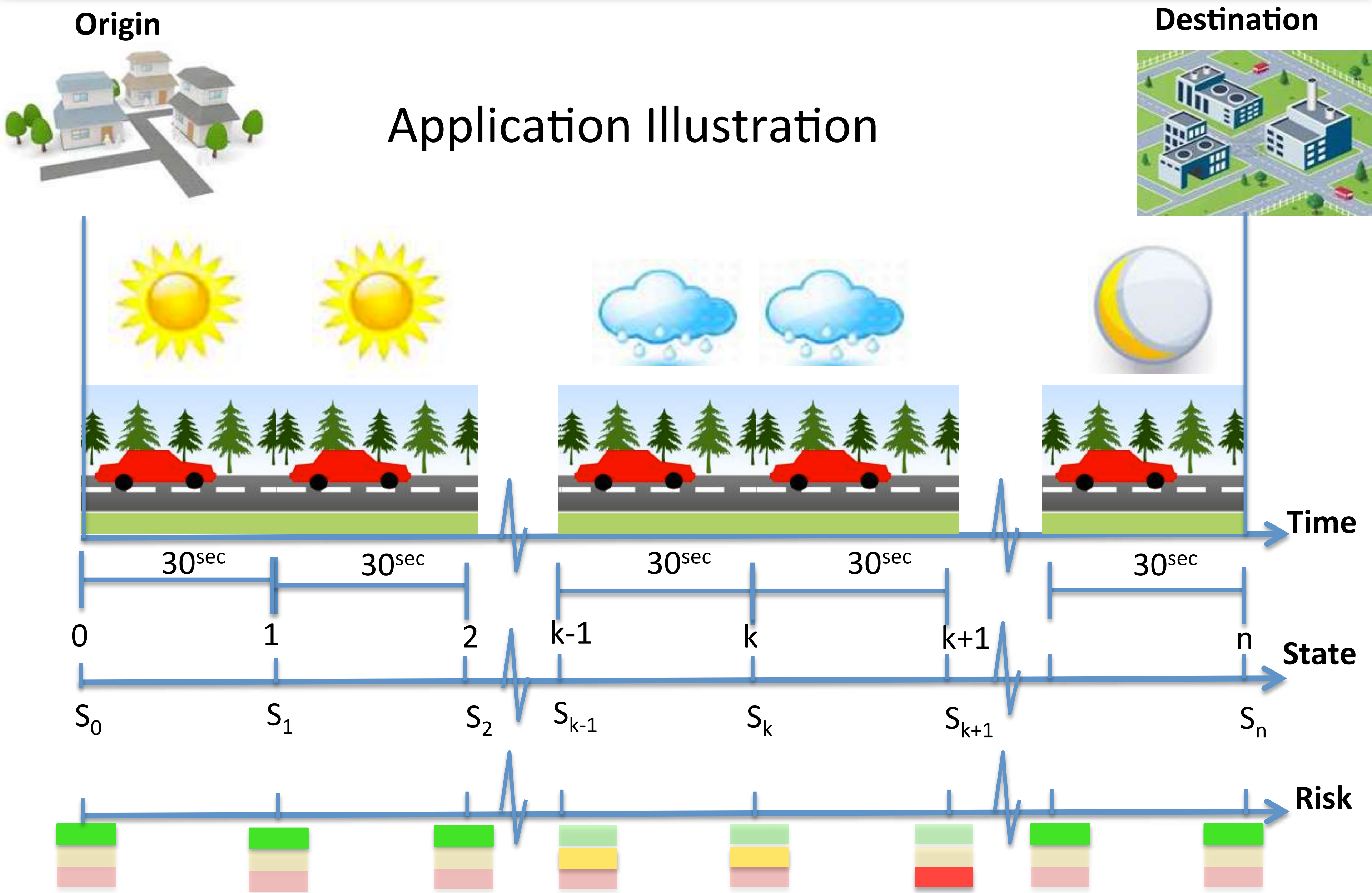
State Vector at time t:

X^n = [Driver, Vehicle, Road, Weather, Time, Network-Screening Factor]

- Driver, Vehicle: Internal factors
- Road, Weather, Time: External factors
- Network-Screening Factor: Historical Crash Data



Near Real-Time Risk Based Safety Model (cont.)



Overall Framework