# Fundamental probabilistic analysis on effectiveness of safety-presentation type on safe driving support system

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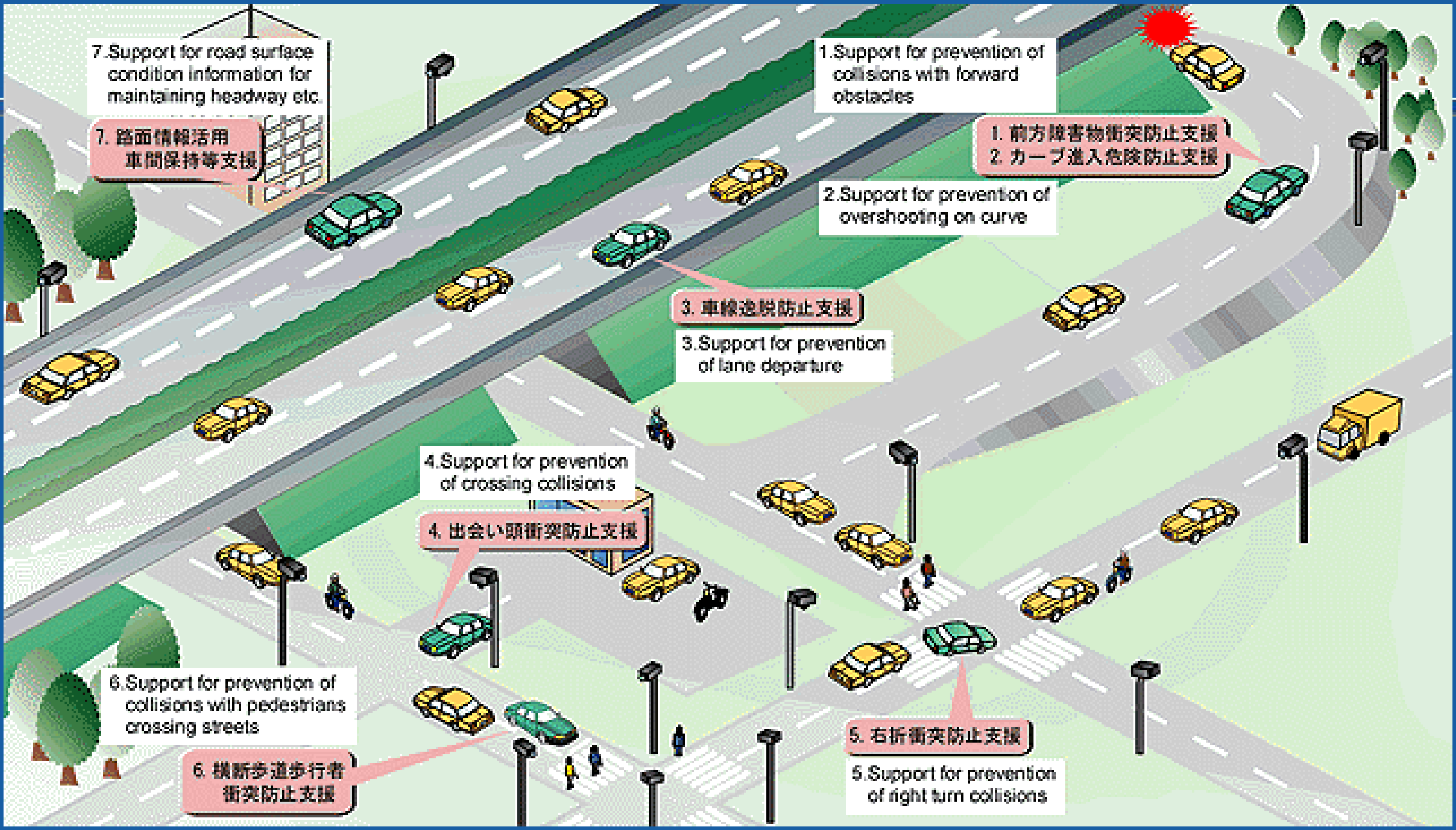
# Current Situation

- Traffic road accidents in Japan
  - About 10,000 people are killed (decreasing)
  - About 1,000,000 people are injured (increasing)

⇒AHS(Advanced Cruise-Assist Highway System)

- Seven support services
  - Necessity of quantitative assessments



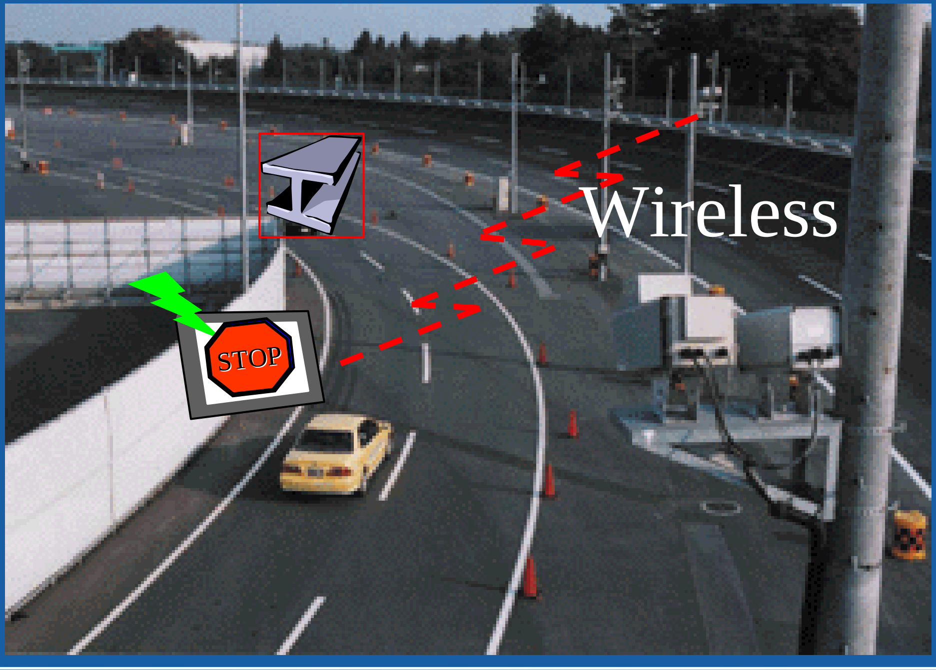

Source: Ministry of Land, Infrastructure and Transport

# Seven Services of AHS

- **Prevention of collision with forward obstacles**
- Prevention of overshooting on curve
- Prevention of lane departure
- Prevention of crossing collisions
- Prevention of right turn collisions
- Prevention of collisions with pedestrians crossing streets
- Road surface condition information for maintaining headway,etc

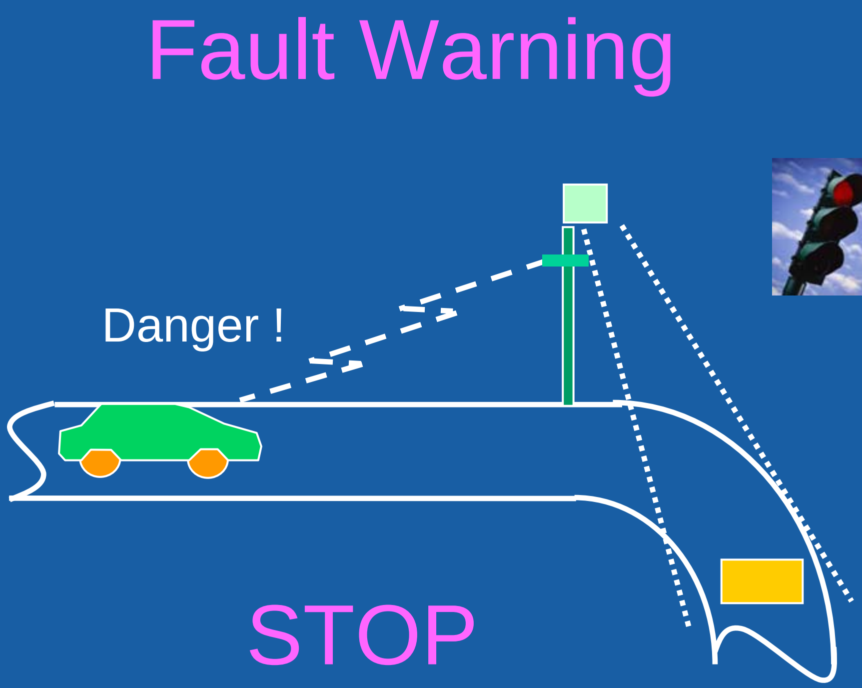
# Safety Analysis

- Safety alarm for forward obstacle curve collision
  - Road-Vehicle communication system



# Discussion Point

- Configuration of safety monitoring system
  - Fault warning type & Safety presentation type



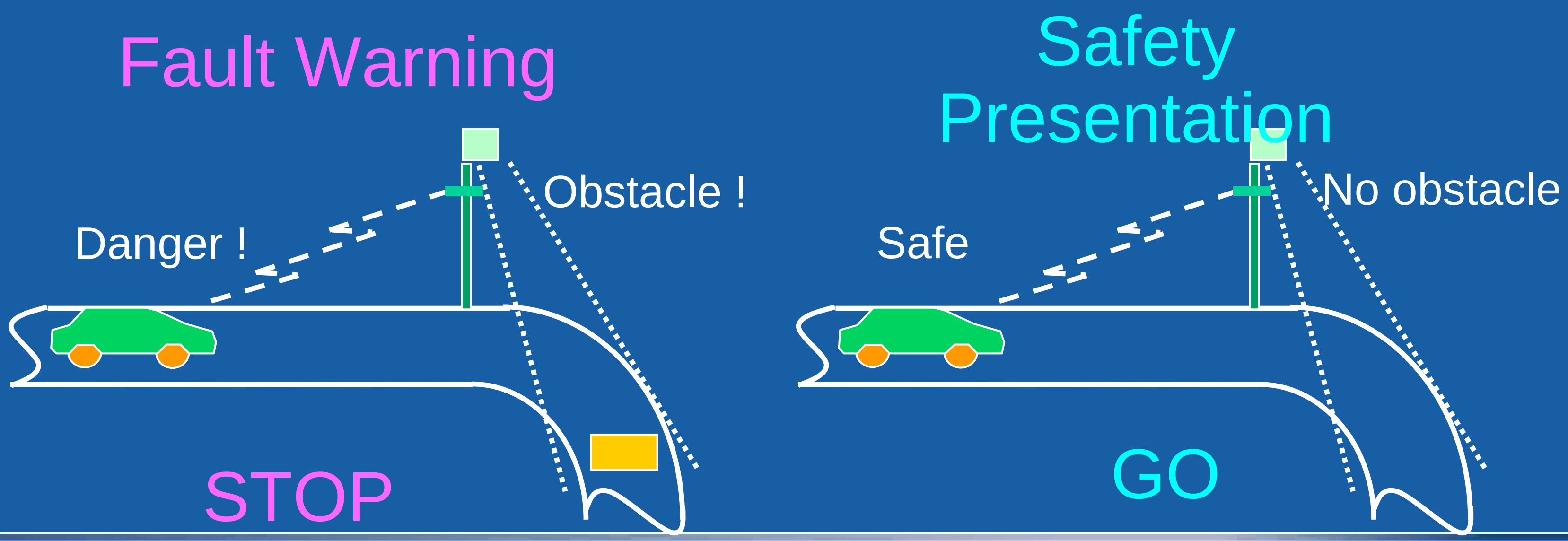


Which is more appropriate?

# Comparative Study

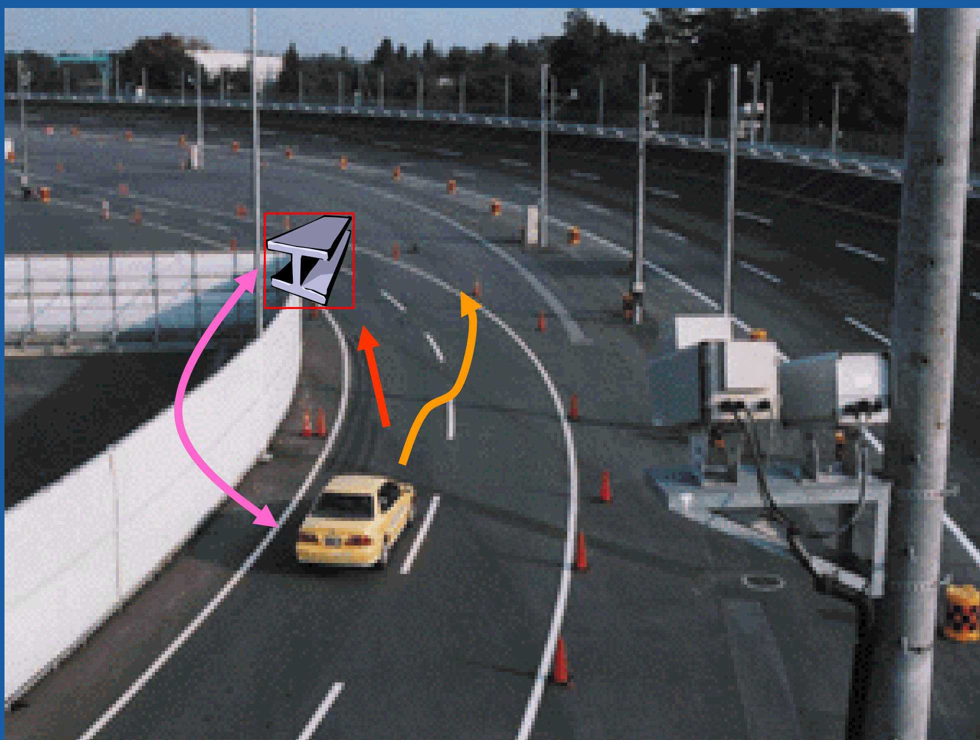
- Evaluation of implementation effect
  - Possibility of decreasing accidents (normal operation)
  - Scarcity of increasing accidents (abnormal operation)

    => Probabilities of fail dangerous failure



# Accident Outbreak

- Definition of the process



***A***: Avoidance Action

Ex. stopping, changing lane

$\bar{A}$: No Avoidance Action

Ex. keeping on driving

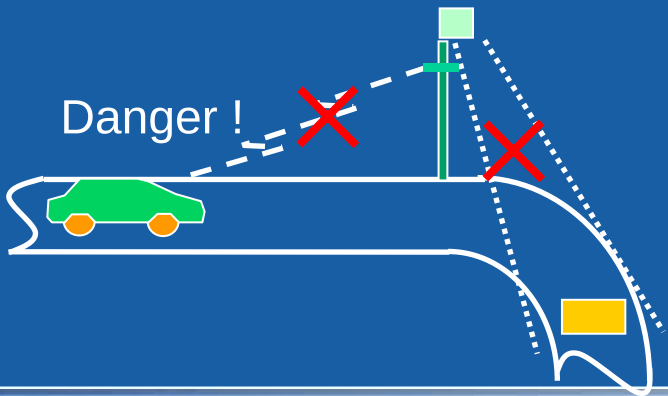
***D***: Presence of Dangerous Relation

Def. situation where $\bar{A}$ surly cause accident

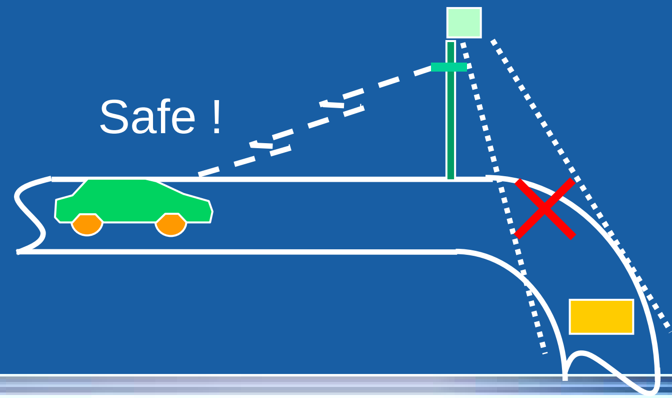
# Fail Dangerous Failure

- Fault warning
  - Sensor fails to detect a danger relation *D*
  - Sensor succeeds in detecting *D* but fails to send a message
- Safety presentation
  - Sensor fails to detect *D* and sends false message

Fault Warning

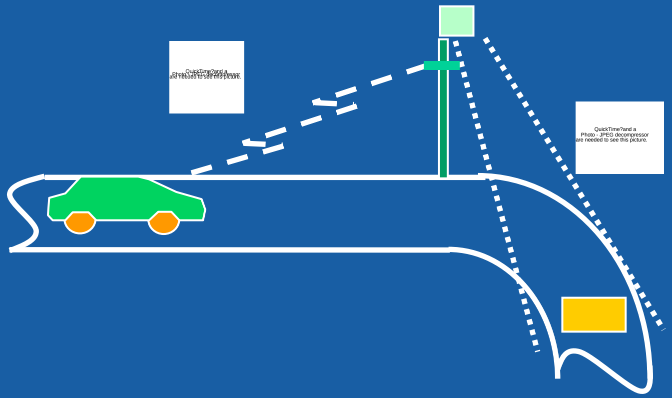



Safety Presentation



# Fail Dangerous Probability

- Reliabilities
  - Sensor detection
  - Communication



- Fault warning
  - Sensor fails to detect a danger relation *D*

QuickTime?and a Photo - JPEG decompressor are needed to see this picture.

  - Sensor succeeds in detecting *D* but fails to send a message

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- Safety presentation
  - Sensor fails to detect *D* and sends false message

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# Study Result #1

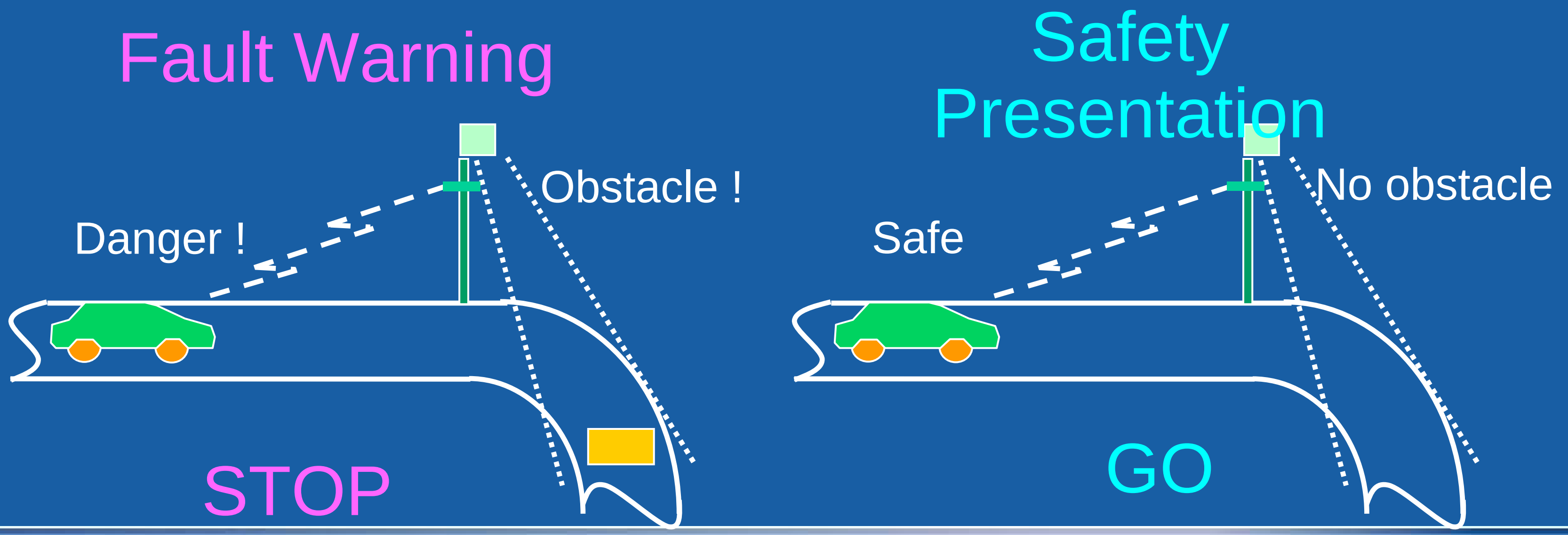
- Evaluation of implementation effect
  - Possibility of decreasing accidents (normal operation)
  - Scarcity of increasing accidents (abnormal operation)

=> Probabilities of fail dangerous failure

# Comparative Study

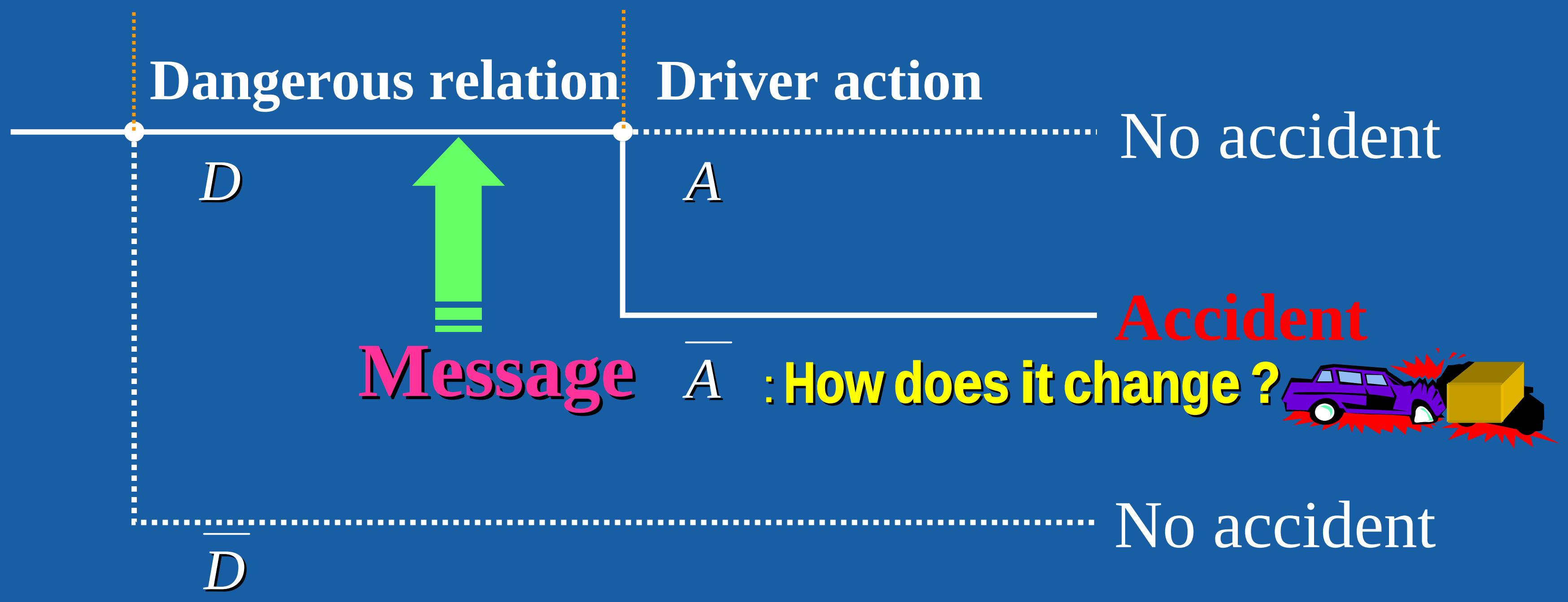
- Evaluation of implementation effect
  - Possibility of decreasing accidents (normal operation)
  - Scarcity of increasing accidents (abnormal operation)

    =>Estimated Accident Probability after Implementation



# Accident process

- Event Tree



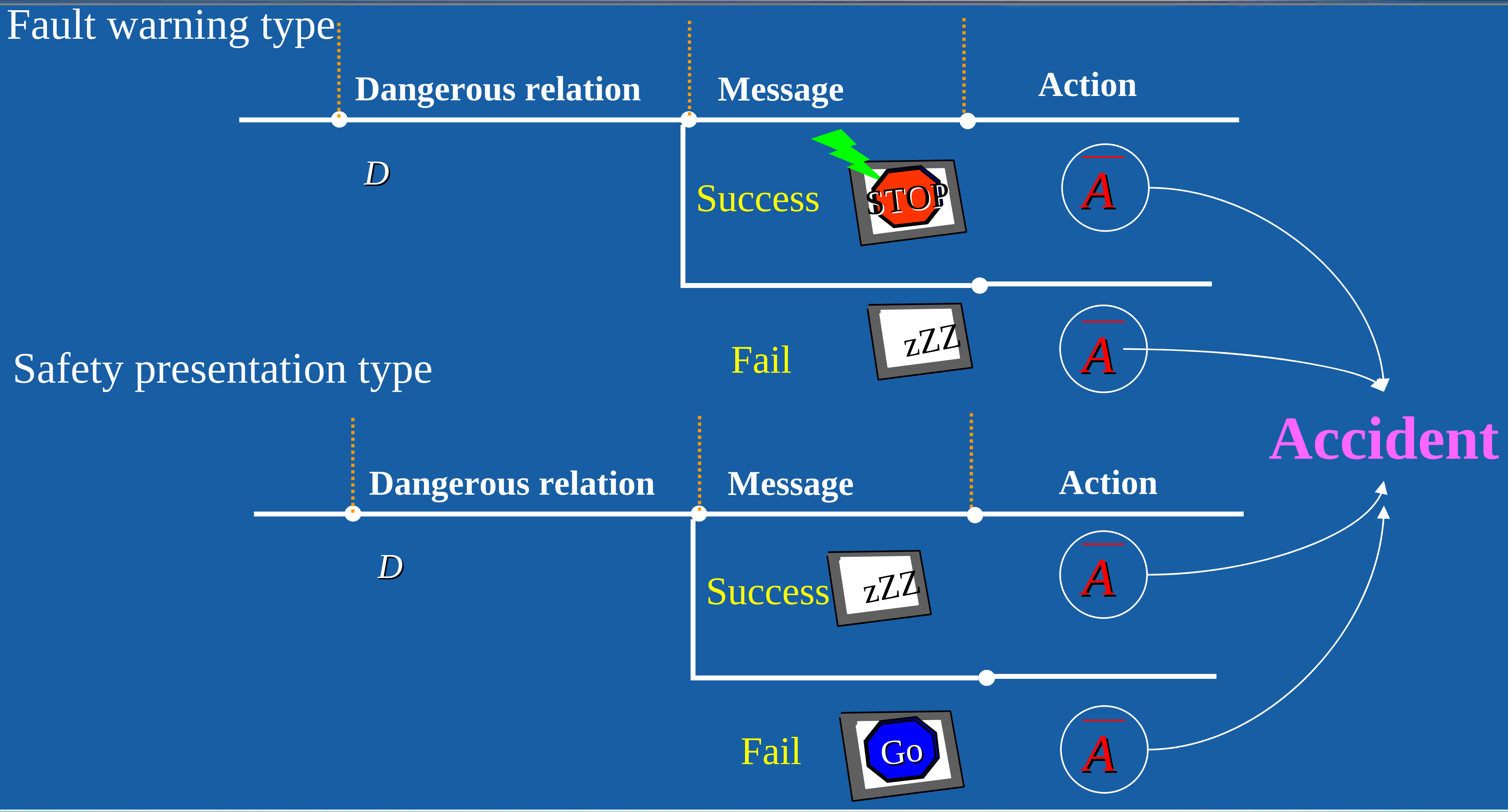

$D$: Presence of Dangerous Relation

$A$: Avoidance Action

$\overline{D}$: Non-Presence of Dangerous Relation

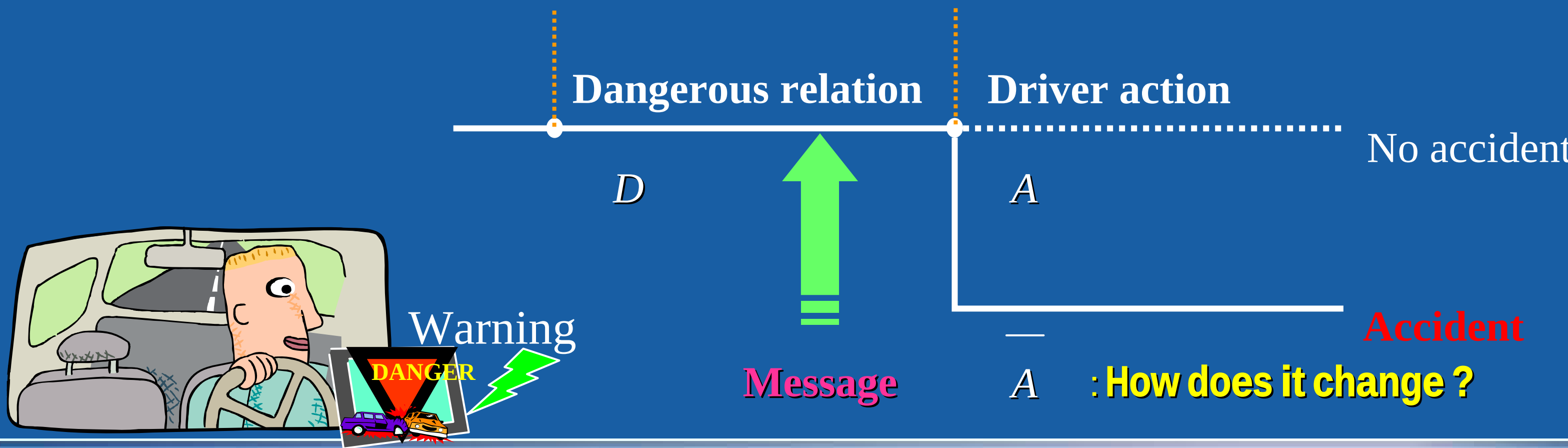
$\overline{A}$: No Avoidance Action

# Effect of Message



# Effect of safety device

- Evaluation method
  - Experimental approach (case by case: bottom up)
    - e.g. driving simulator base
  - Theoretical approach (general purpose: top down)
    - e.g. concept base



# *Topics*

- Theoretical Approach: Cognitive Driver Model
  - Concept: risk homeostasis hypothesis
  - Our proposed model: maximum acceptable risk model

# Risk Homeostasis Theory

- Outline of the risk homeostasis theory
  - A driver behaves based on a target level of risk

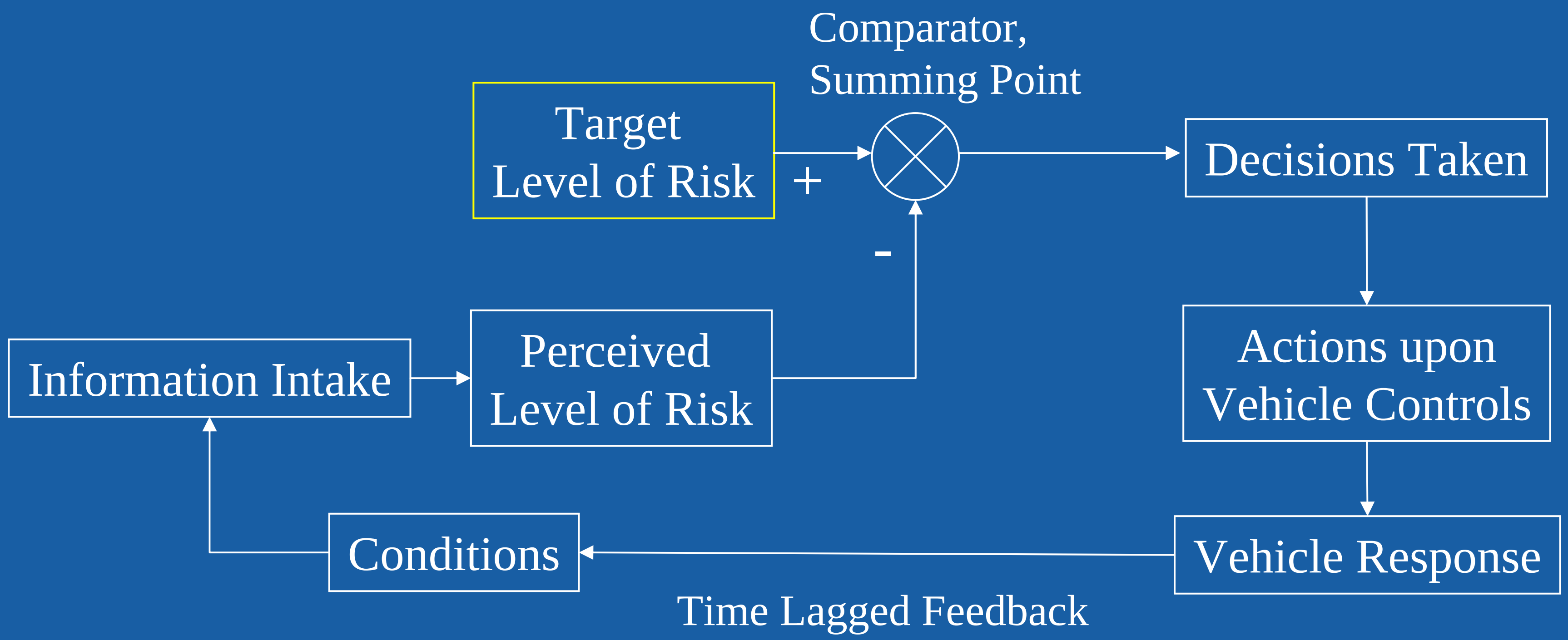
    ⇓

  - An accident rate fluctuates around a stable mean
    => Risk Homeostasis

Wild, G. J. S: *Target Risk*, PDE Publications, 1994

# Task Model (Target Risk Model)

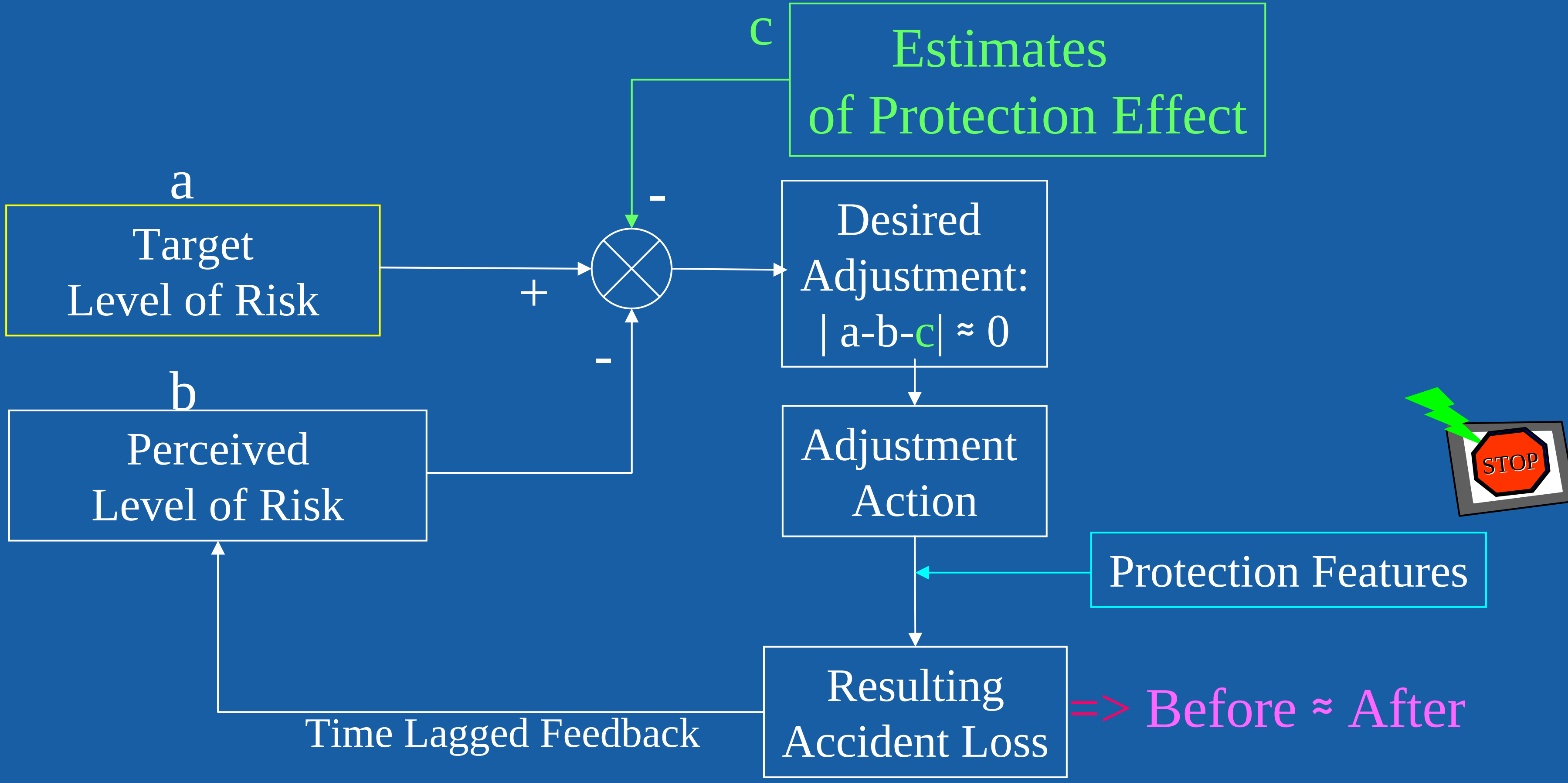
- A driver behaves based on a target level of risk



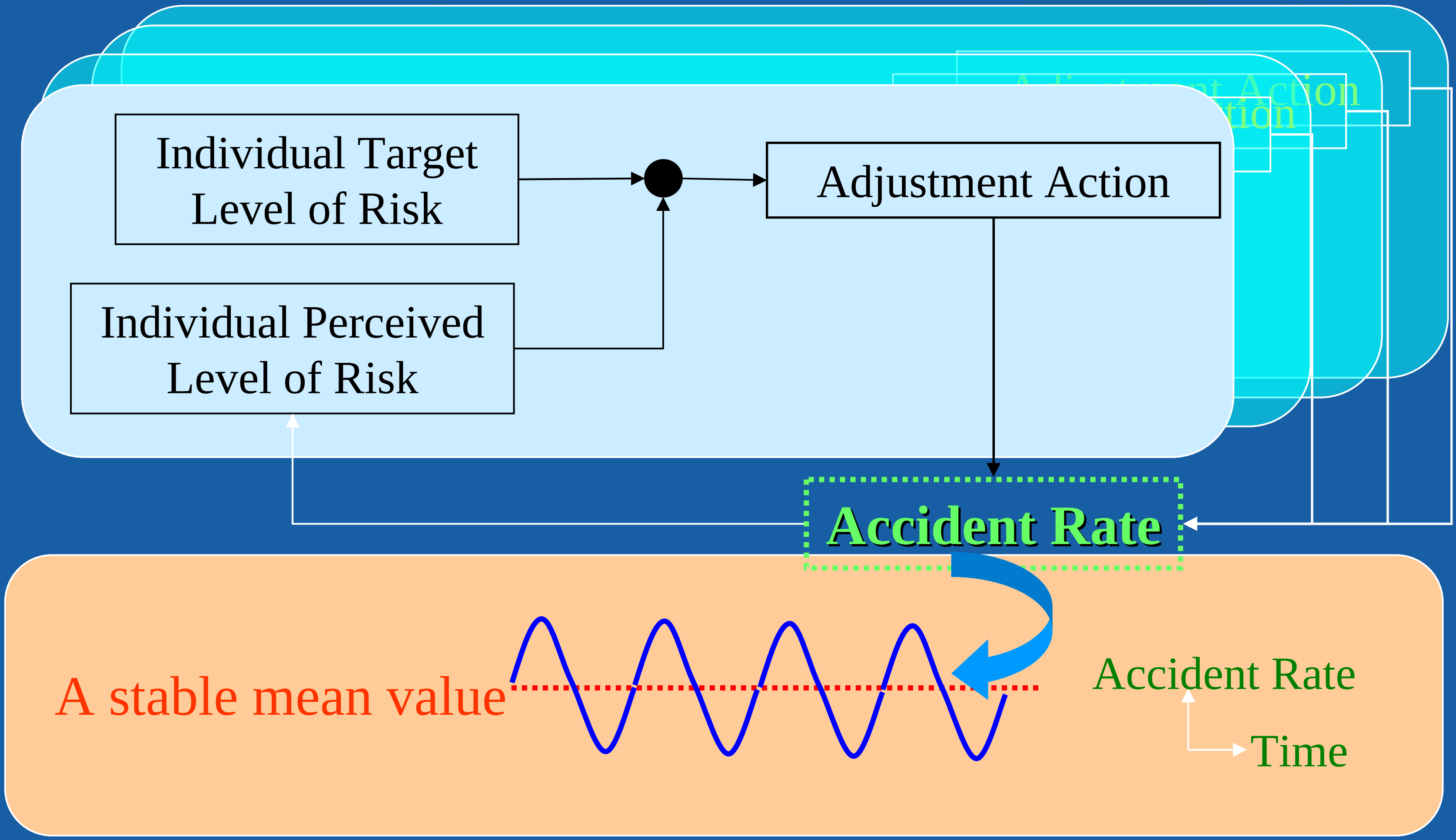

Reference: Wild, G. J. S, *The theory of Risk Homeostasis: Implications for Safety and Health*, Risk Analysis, 1982

# Risk Homeostasis Model

- An accident rate fluctuates around a stable mean



# Accident Rate



# Argument for more than a decade

- Fruitless argument
  - Adams, 1981: The efficacy of seat belt legislation --- is one of evidence (by Wilde: the author)
  - Grime, 1979: A review of research on the protection --- is one of contrary evidence (by MacKenna, 1982)

=> Wiled, 1984; MacKenna, 1982 is not sufficient analysis

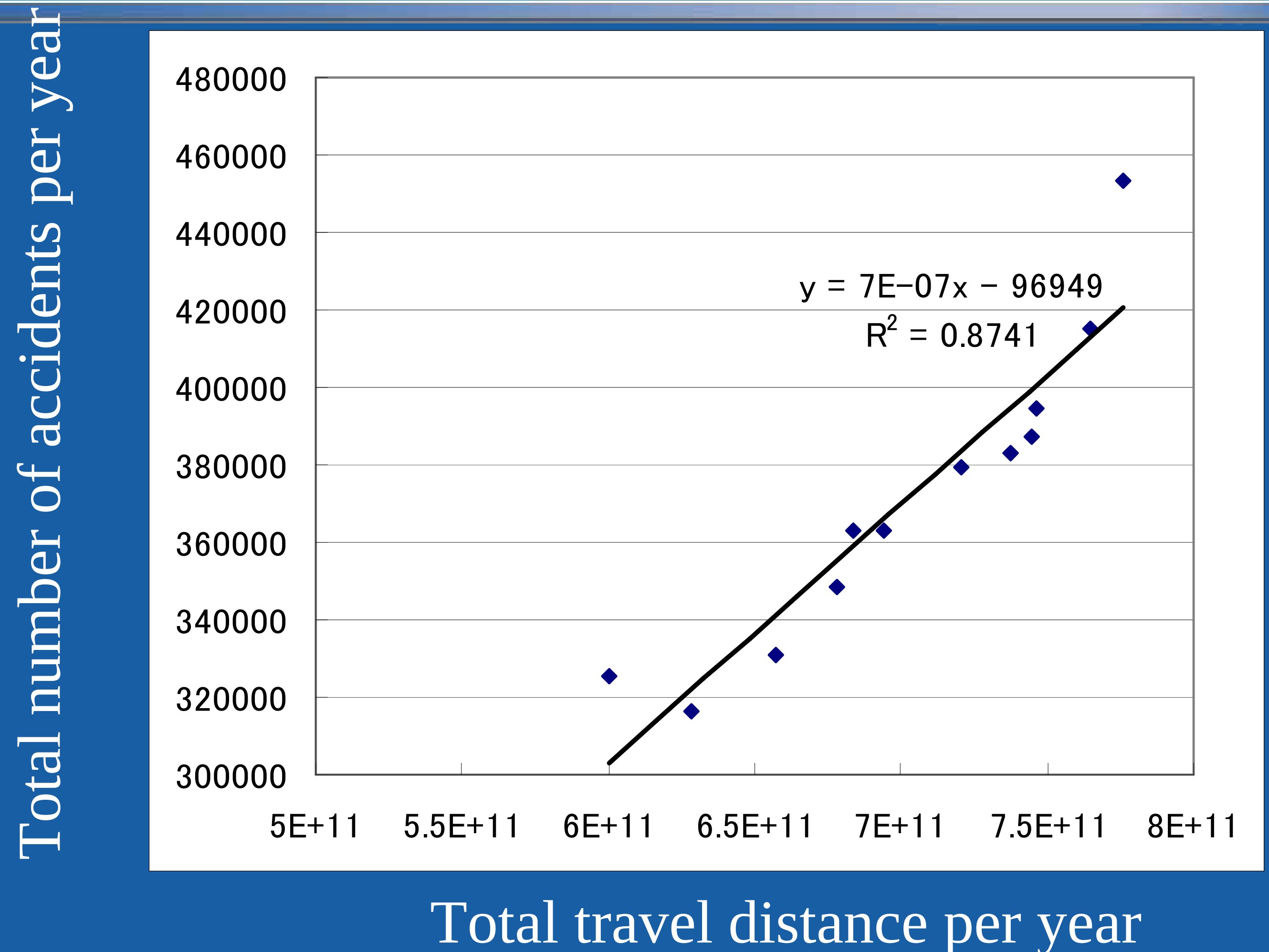
=> Shannon, 1986: Road accident data --- gave new contrary evidence

=> Evans 1986: Risk Homeostasis theory and traffic --- gave some new contrary evidences and denied

=> Wiled, 1986; Evans, 1986 does not mean contrary evidence. field experiments are sufficient analyses

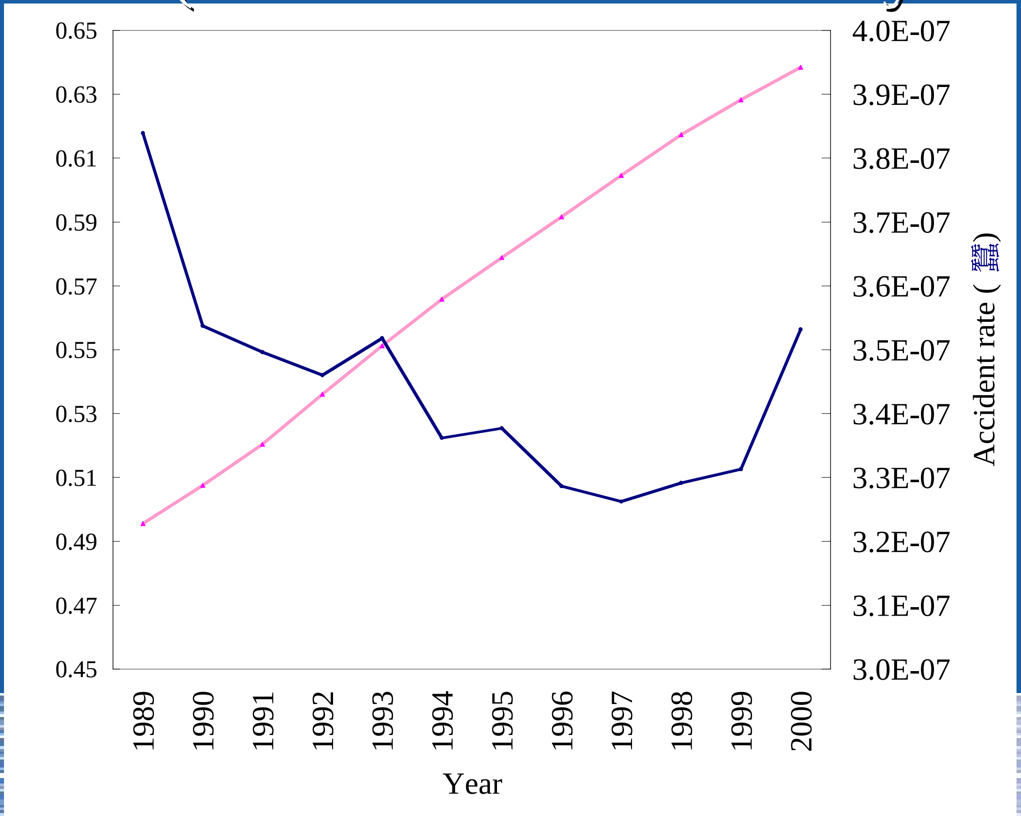
→ More arguments were yields

# Strong correlation



# Transition of accident rate

- Accidents in intersections with traffic signals
  - Accident rate:
    accidents / ( travel distance × density of signal)



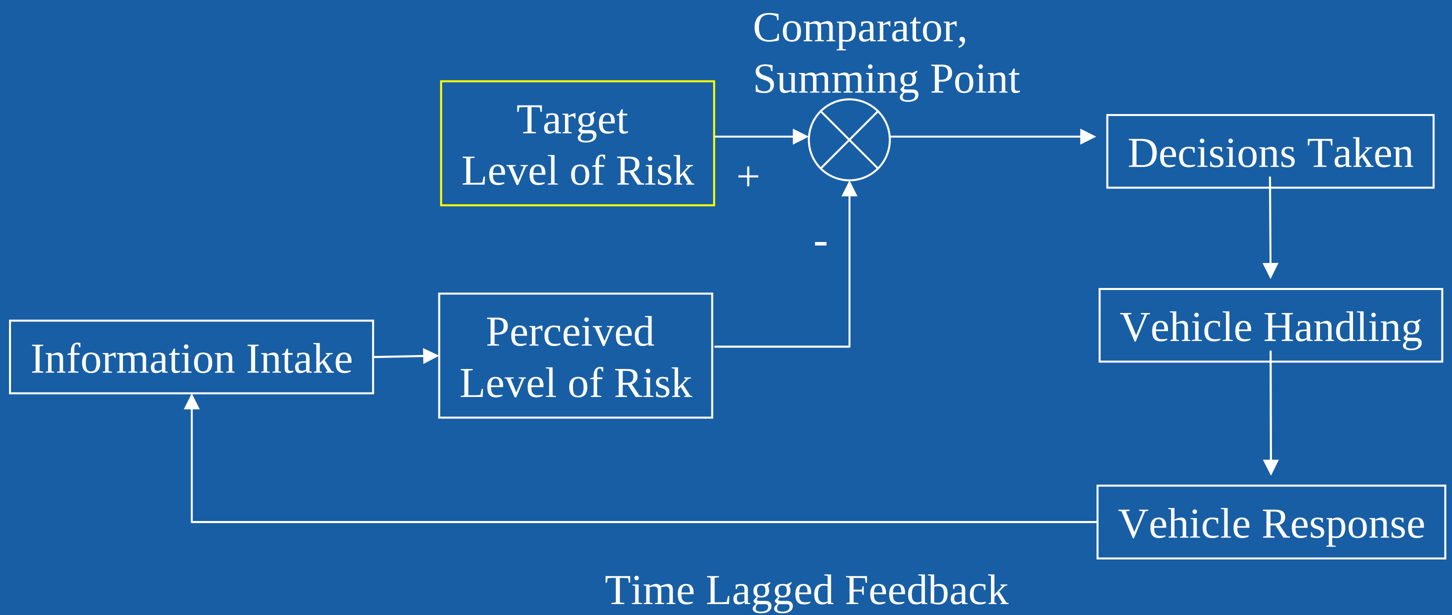
# *Topics*

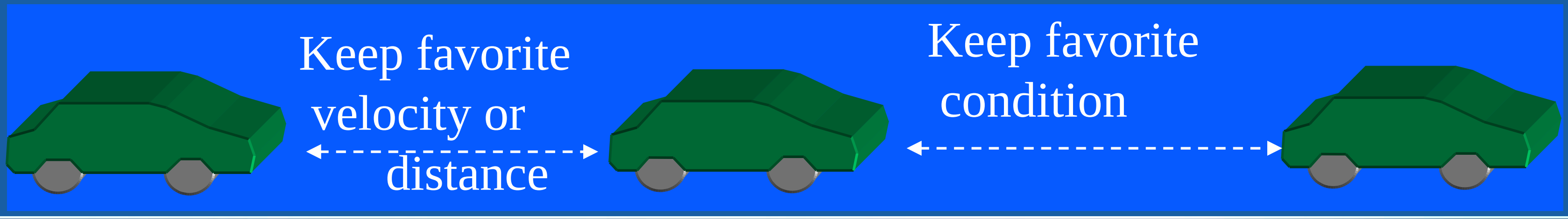
- Cognitive Driver Model
  - Concept: risk homeostasis hypothesis
  - Our proposed model: maximum acceptable risk model
    - based on Target Risk Model
    - Risk Homeostasis => ?: never concluded

      => Risk Compensation would be preferable

# Target Risk Model

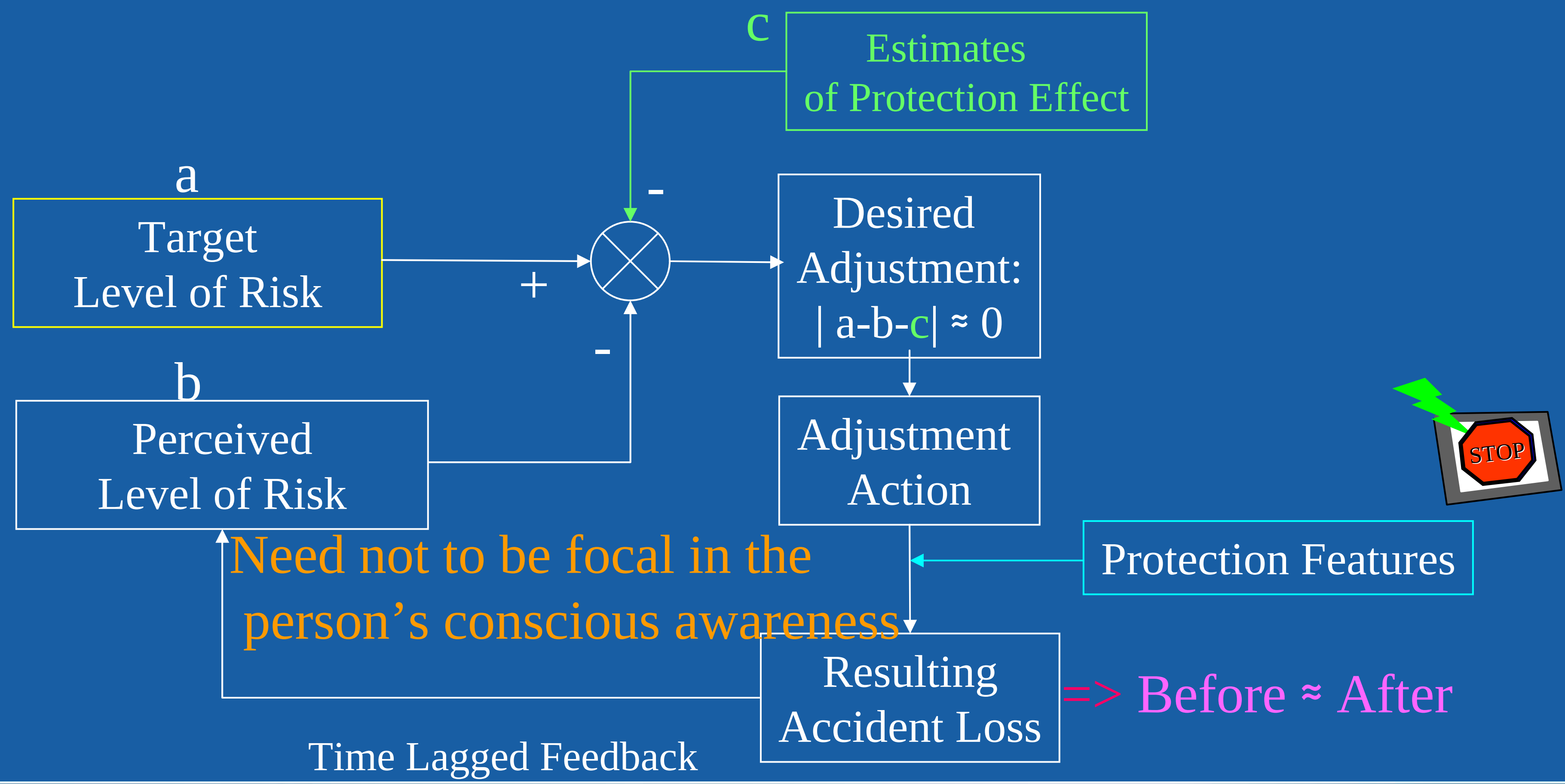
- Target Risk Model shows the mechanism of *Risk Compensation*



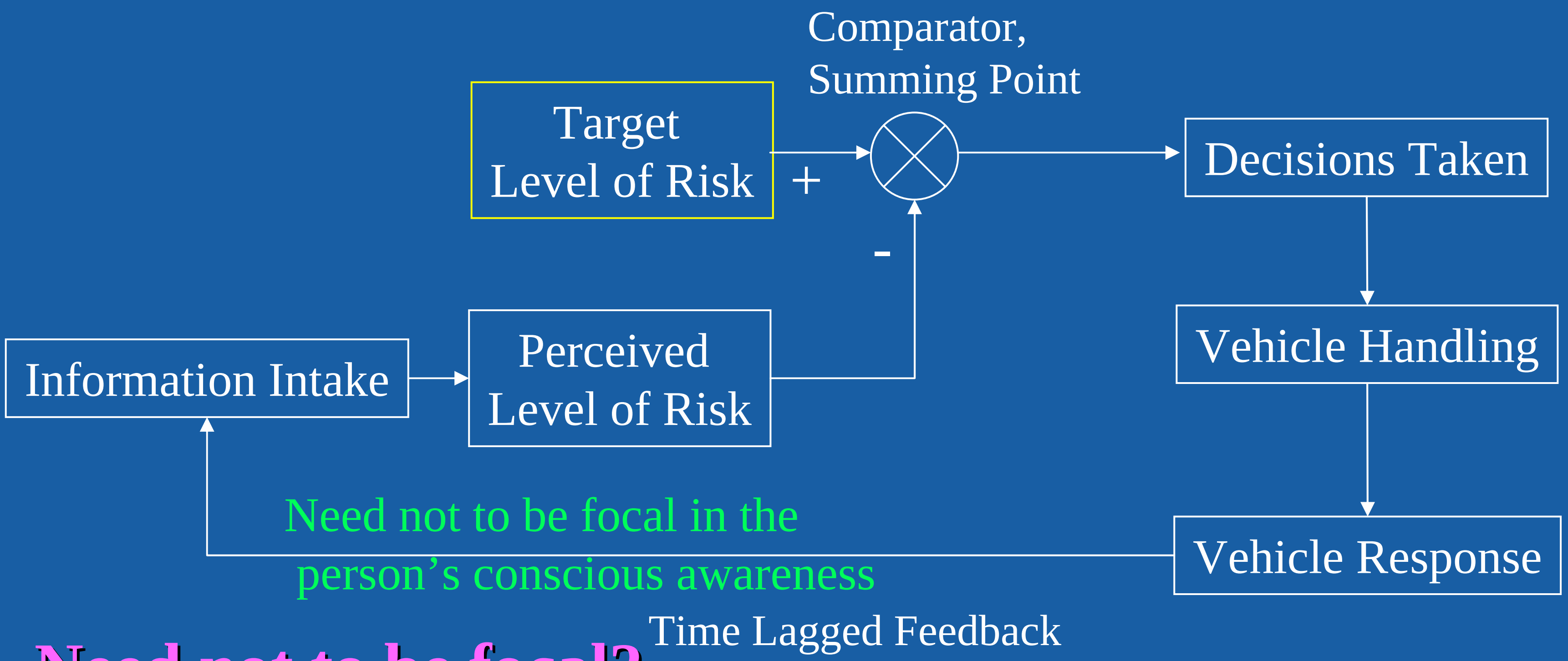
# Risk Homeostasis: unconsciousness

- An accident rate fluctuates around a stable mean



# Consciousness

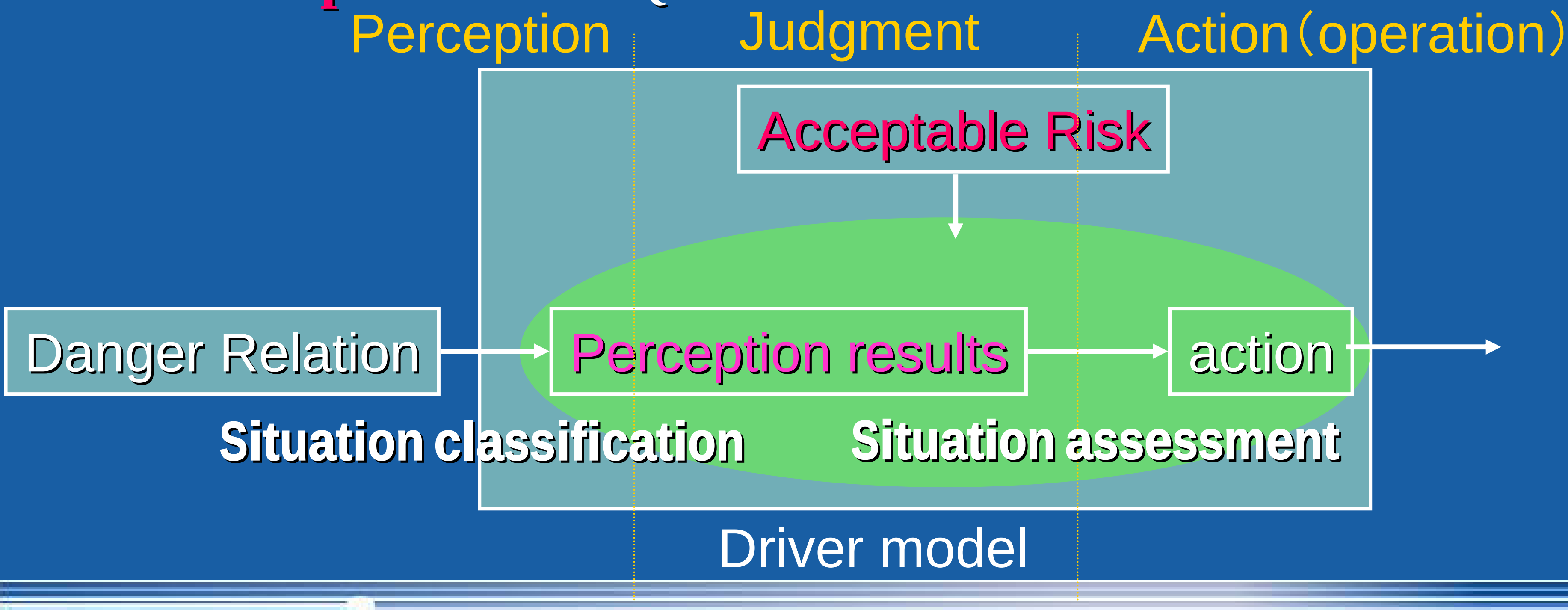
- Target Risk Model shows the mechanism of <u>Risk Compensation</u>




**<u>Need not to be focal?</u>**

# Perception Based Driver Model

- Perception result & acceptable risk
  - **Perception results**: Qualitative classificatory criteria
  - **Acceptable risk**: Quantitative assessment criterion

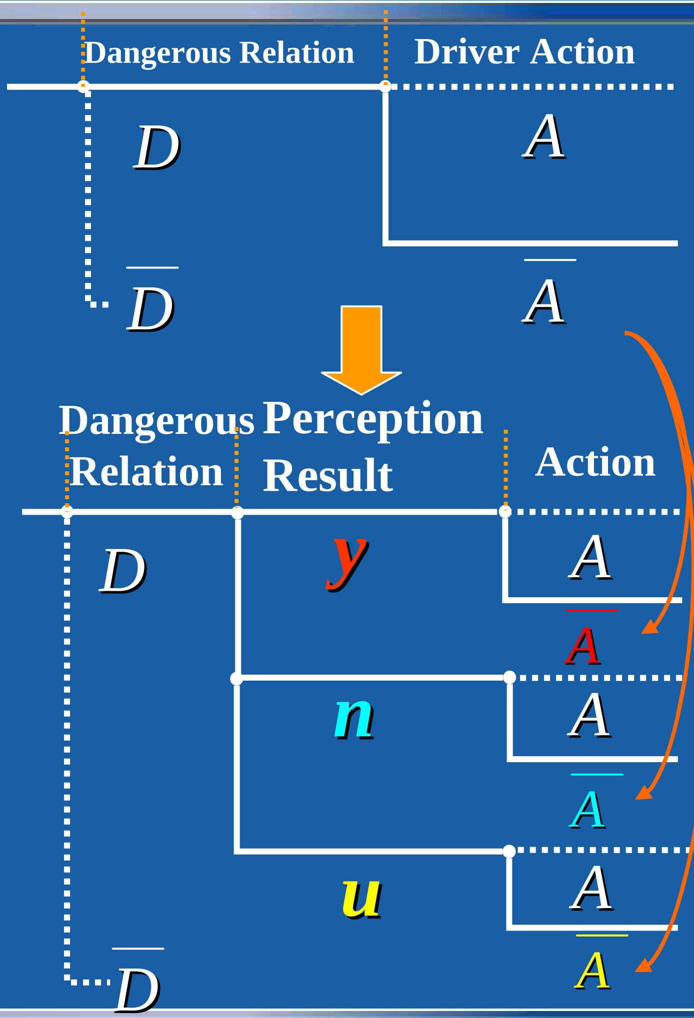


# Perception Result (Perception Representation)

- Three perception results
  - **Yes ($y$)**: I'm in danger
    - Ex. traffic signal is **red**

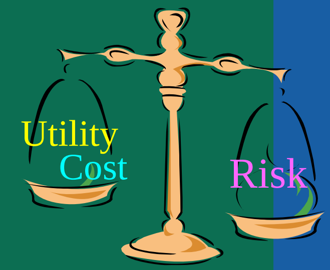
  - **No ($n$)**: I'm not in danger
    - Ex. traffic signal is **blue**

  - **Unknown ($u$)**: I can't decide between Yes & No
    - Ex. traffic signal is **yellow**



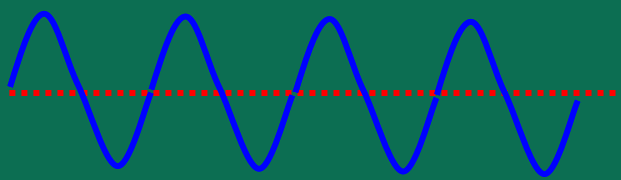
# Acceptable Risk

- Subjective driver action
  - accident occurrence ≤ Acceptable Risk level
  - utility maximization & cost minimization




➡ accident occurrence = <u>maximum</u> of Acceptable Risk

- Objective driver action
  - accident probability = constant



➡ QuickTime?and a Photo - JPEG decompressor are needed to see this picture.

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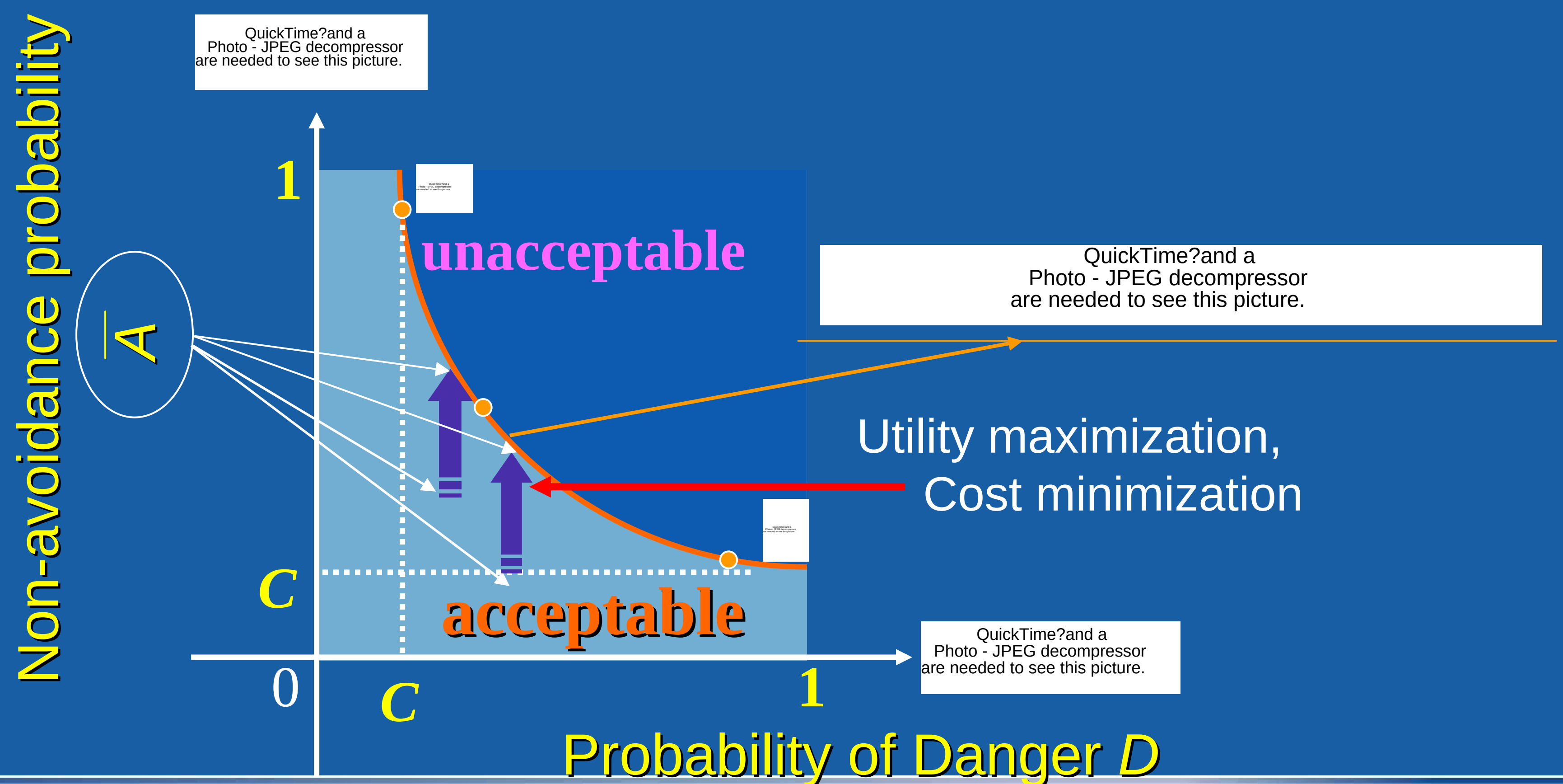
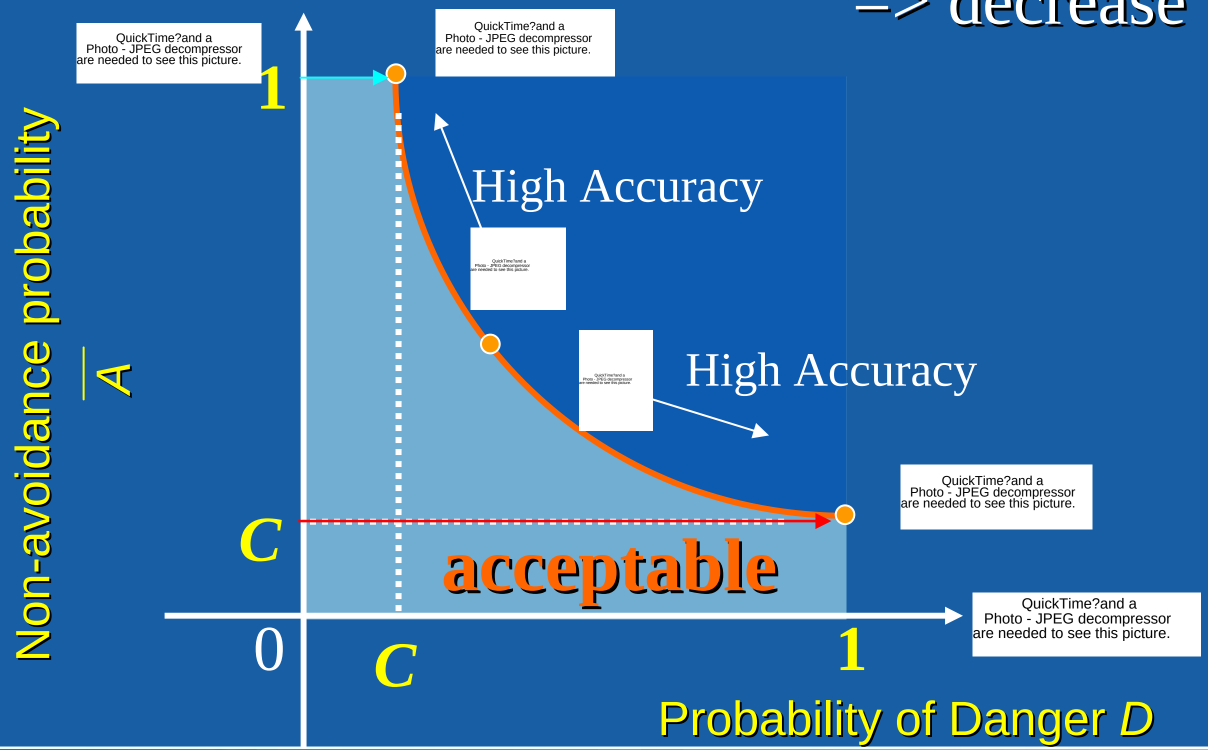
# Maximum Acceptable Risk Model

- Accident probability : QuickTime?and a Photo - JPEG decompressor are needed to see this picture.

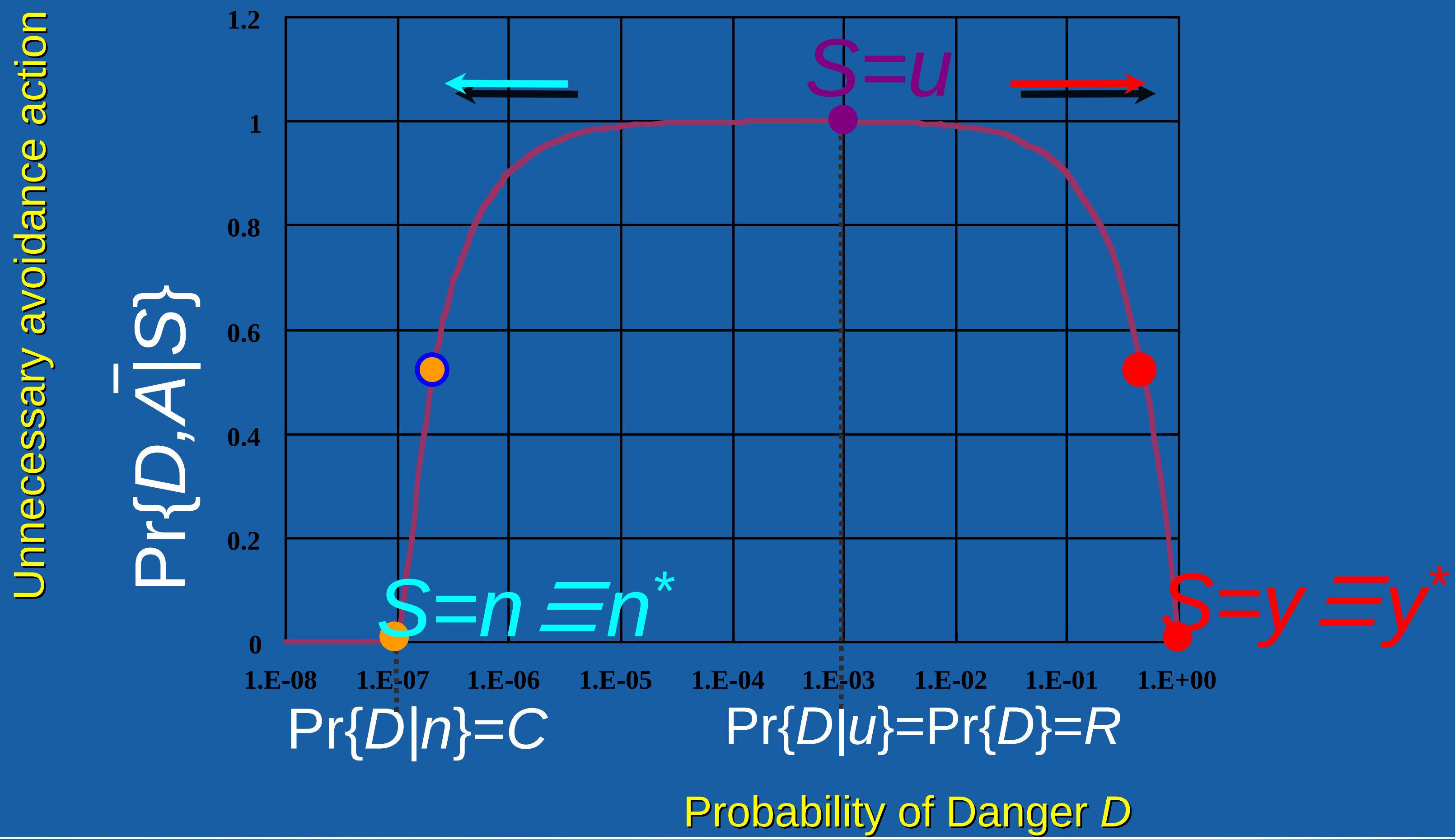


# Perception & Action

- Performance of perception
  - Accurate perception cuts of *unnecessary* avoidance
    => decrease travel time

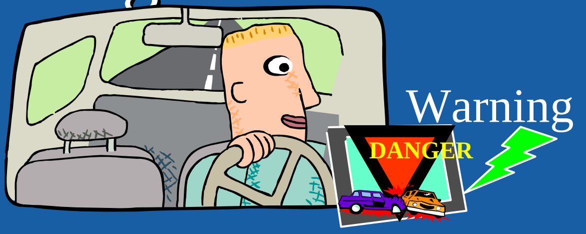


# Unnecessary avoidance



# Driver Dependence on System

- Drivers depend completely on the message
  - Shift attention from $D$ to message



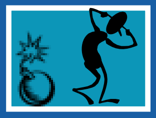

e.g. Fault warning type

**Dangerous relation** | **Message** | **Perception result**

$D$

Success


$y$



QuickTime?and a Photo - JPEG decompressor are needed to see this picture.

$y$ $n$ $u$

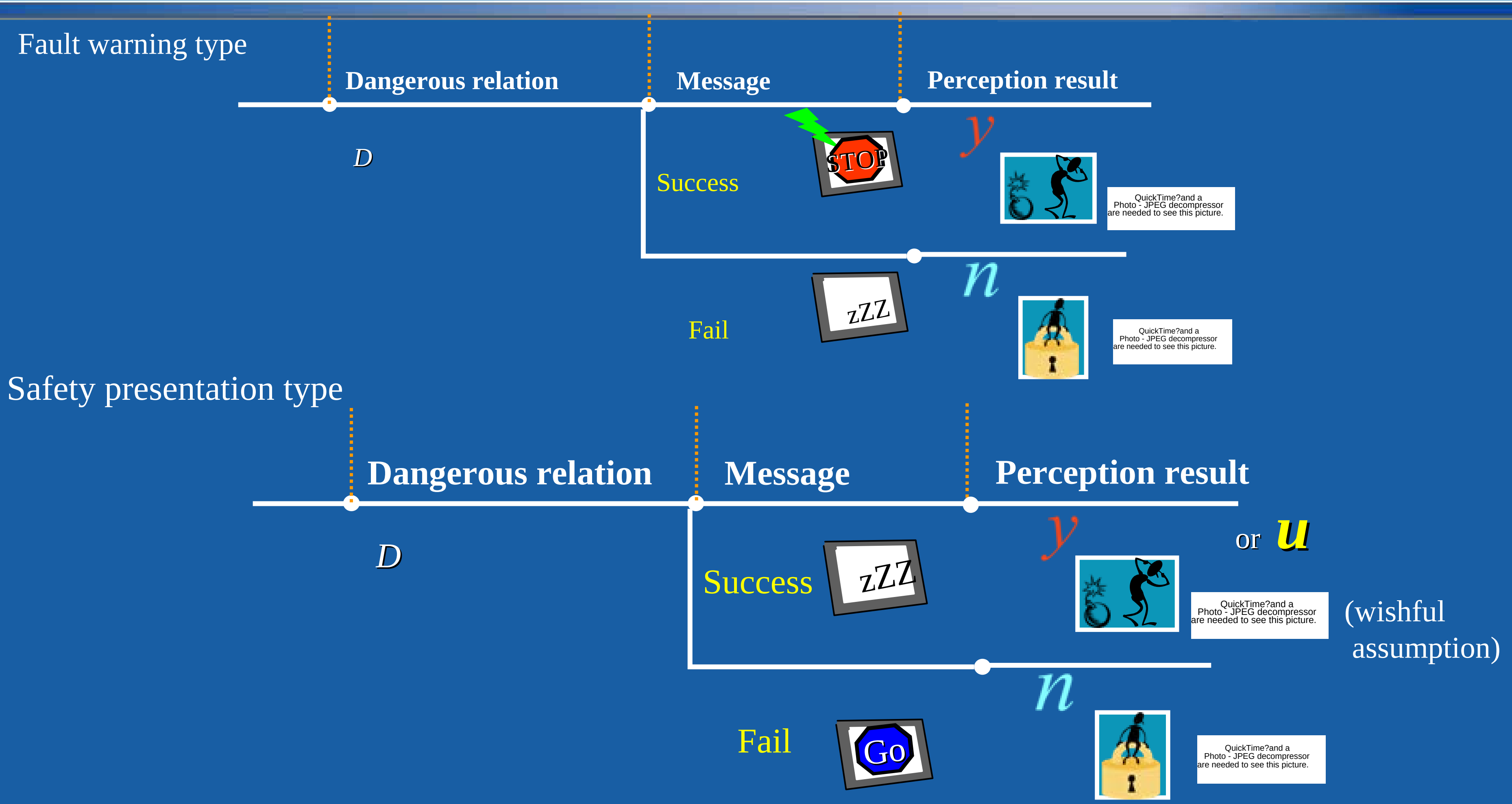
$n$

Fail

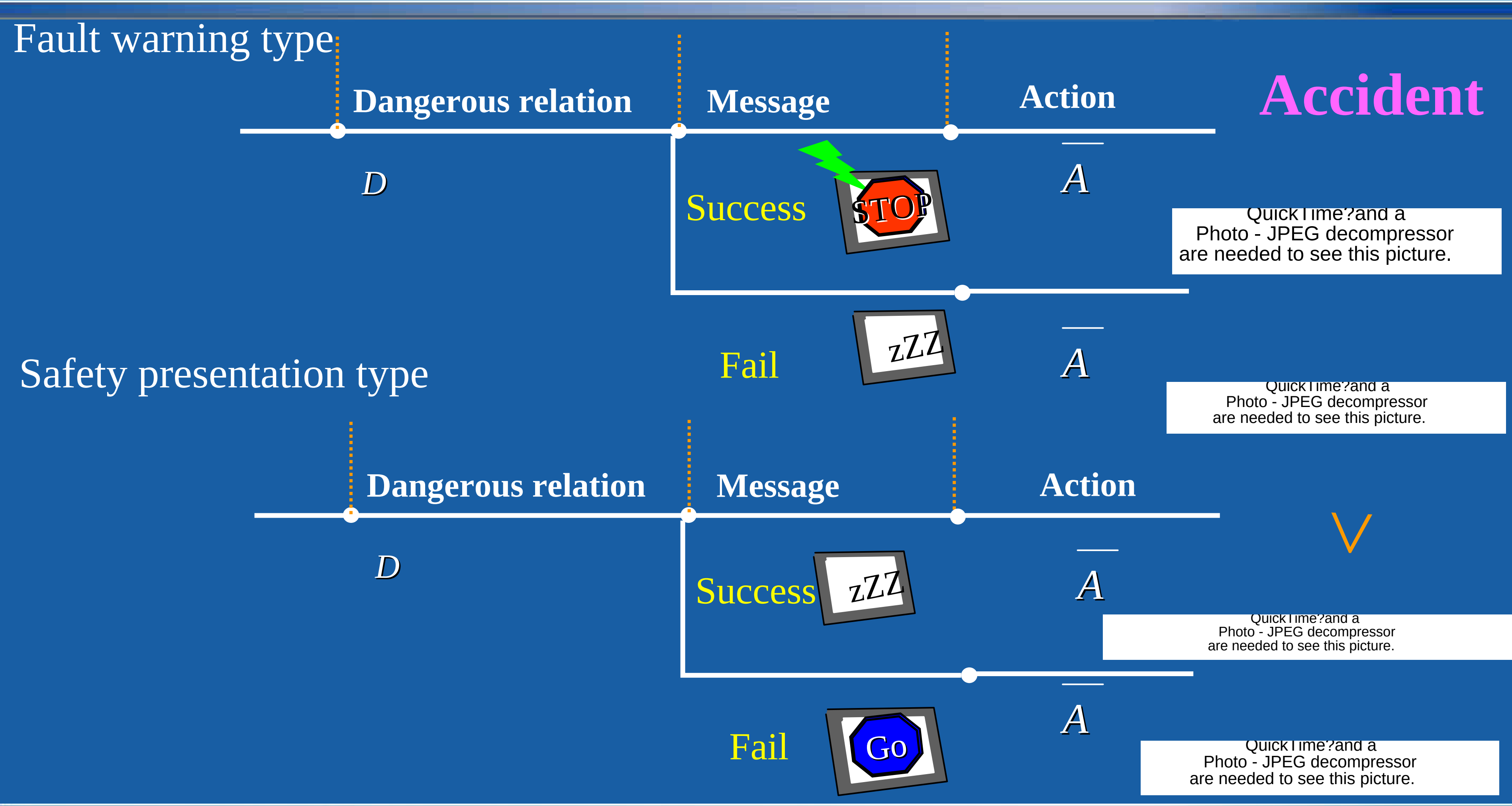

QuickTime?and a Photo - JPEG decompressor are needed to see this picture.

$\overline{D}$

# Driver Dependence on System



# Accident Probability



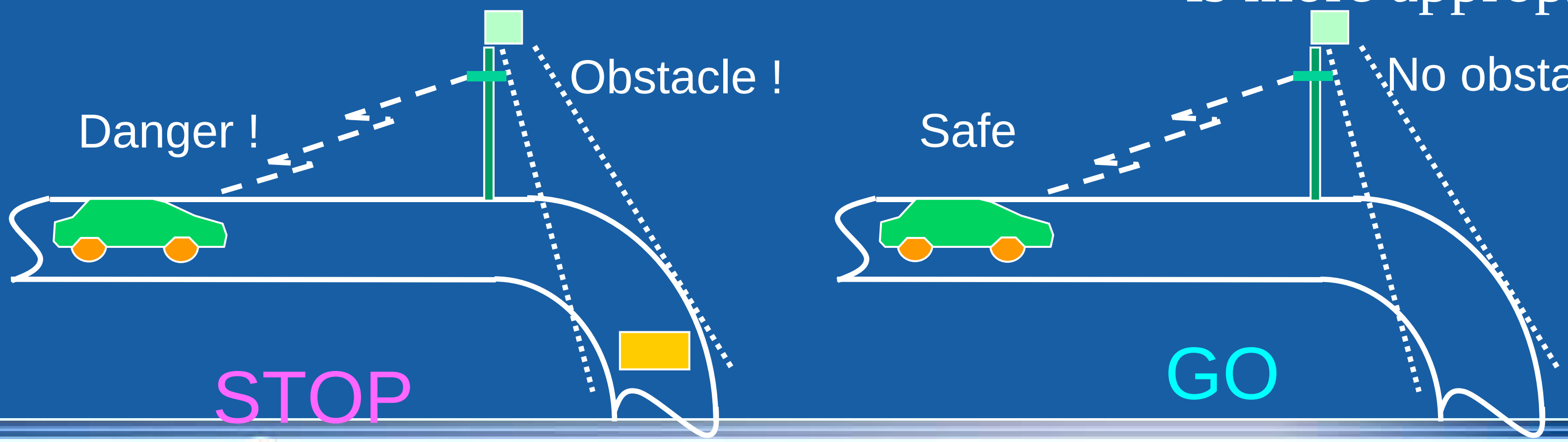
# Study Result #2

- Evaluation of implementation effect
  - Possibility of decreasing accidents (normal operation)
  - Scarcity of increasing accidents (abnormal operation)

=> Accident Probability

Fault Warning

Safety Presentation is more appropriate



# Thank you for your attention

- Contact address.
  - okabe@sl.t.u-tokyo.ac.jp

# Result of Safety Assessment

- Devices may fail to alarm
  - Current alarm reliability is enough ?
    - Available reliability : 90% – 95%

=> Not sufficient, but can reduce accident

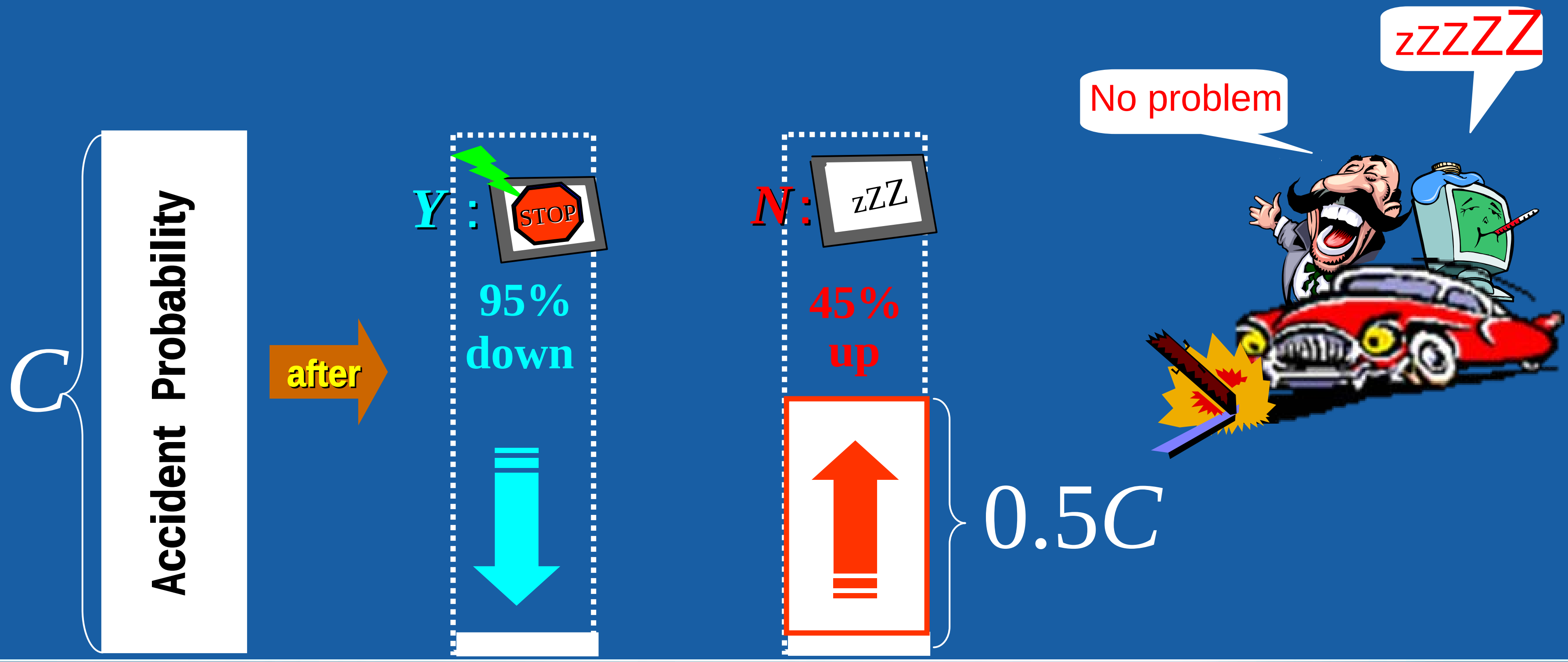
- How many accidents may be cut down?

=> Depend on drivers' reliability

=> Up to drivers dependency on safety device (50% cut off is possible)

# Implementation Effect (Case 1)

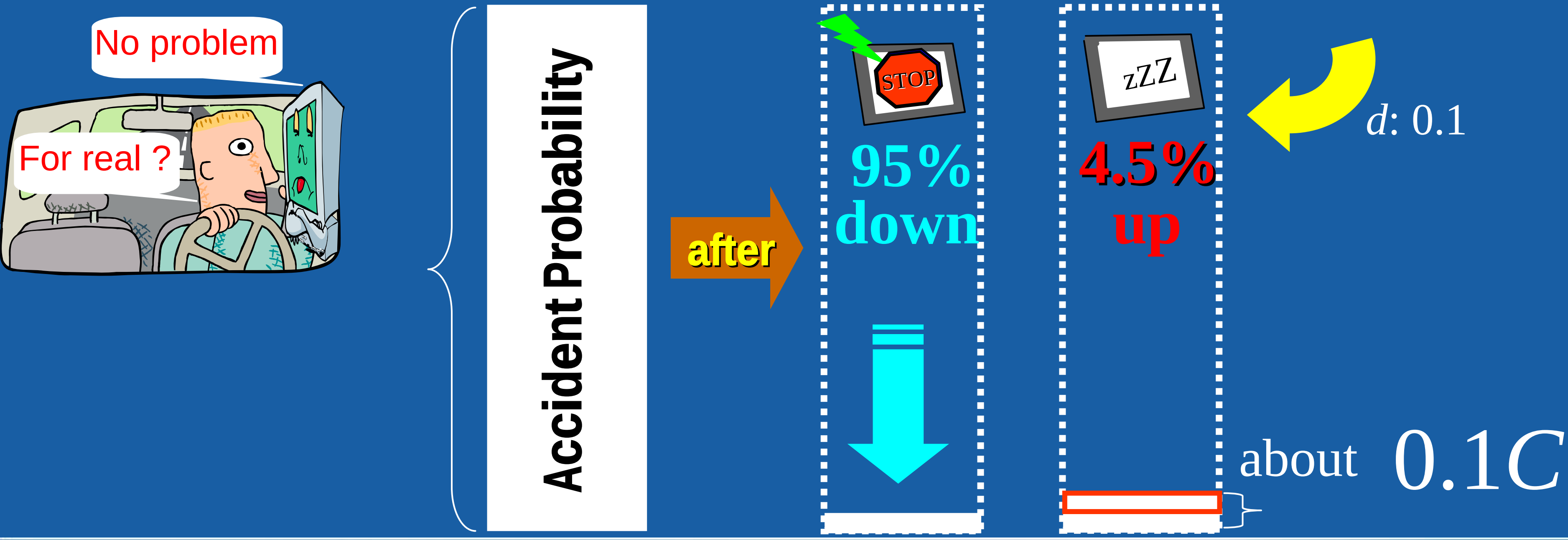
- All drivers depend on safety device
- Alarm reliability *r*: 95% , Driver reliability 1- *P* : 90%



# Implementation Effect (Case 2)

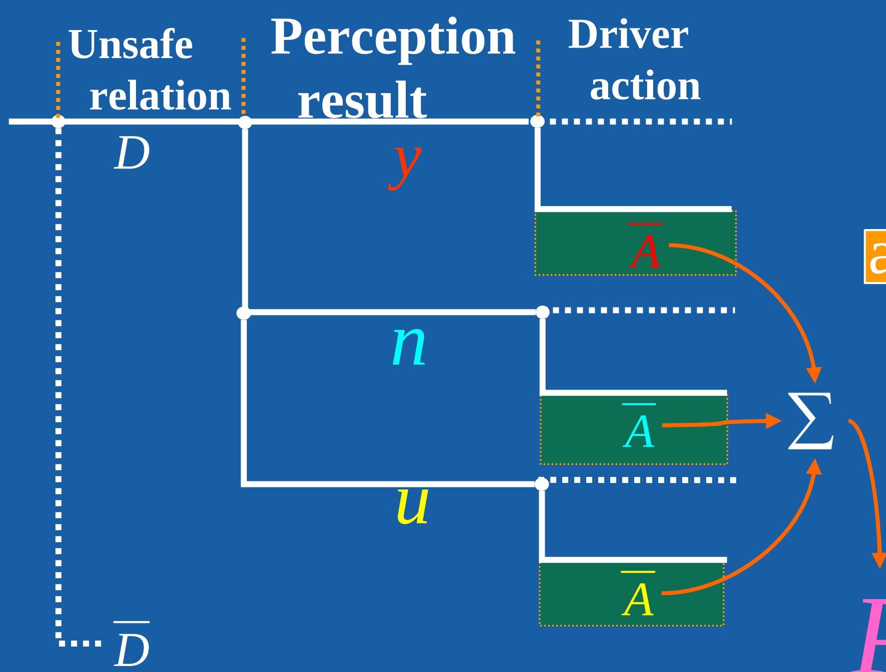
- Some drivers depend on
- Alarm reliability $r$: 95%, Driver reliability $1- P$ : 90%
  - Dependence ratio $d$ : $10^{-1}$

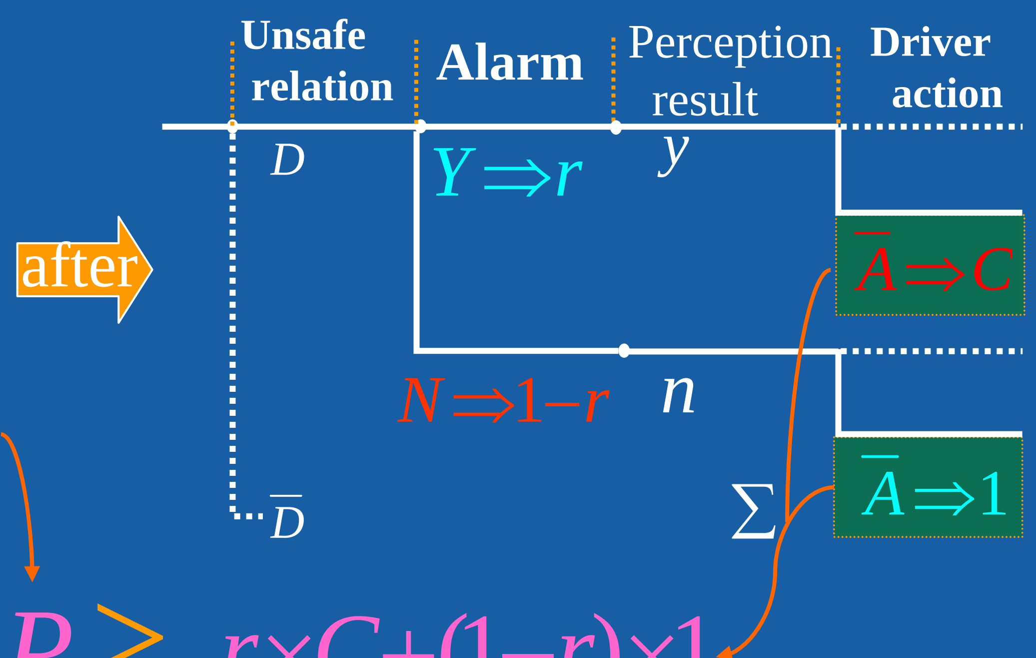
**Dependence of all drivers : 45%**



# Required Reliability

- Alarm reliability: $r$




$$P \ge r \times C + (1-r) \times 1$$

$$r \ge \frac{1-P}{1-C} \simeq 1-P$$

Driver reliability

# Conclusions

- Perception based driver model
- Required reliability for the alarm
- Implementation effect of the safety devices
- Importance of HI