国際シンポジウム International Symposium

次の時代の交通と安全

～ 東日本大震災の教訓を踏まえて ～

Transportation and Safety for the Coming Age

Learning from the Lessons of the Great East Japan Earthquake

● 平常時の交通と安全 ～交通安全の変遷と展望～

Transportation and Safety during Normal Times: Changes in Traffic Safety and Prospects for the Future

シンポジウム部会主催セッション

「これからの交通安全」

“Traffic Safety in the Future”

Session by IATSS Symposium Department

2012年9月20日（木） 13:30～17:30

Thursday, 20 September 2012

資料集

Handouts

IATSS 公益財団法人 国際交通安全学会

International Association of Traffic and Safety Sciences

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Prof. David F. Dinges / USA

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Transportation Safety and Operator Fatigue: Where Biology Needs Technology

Transportation Safety and Operator Sleepiness: Where Biology Needs Technology

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"Traffic Safety in the Future"
20 September 2012
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Tokyo Japan

Transportation Safety and Operator Sleepiness: Where Biology Needs Technology

Four key points

I. Transportation systems involve continuous operations.

II. Healthy sleep is essential to operate a motor vehicle safely.

III. Driving sleepy is common and a risk to transportation safety.

IV. Driver incapacitation from sleep loss requires novel solutions.

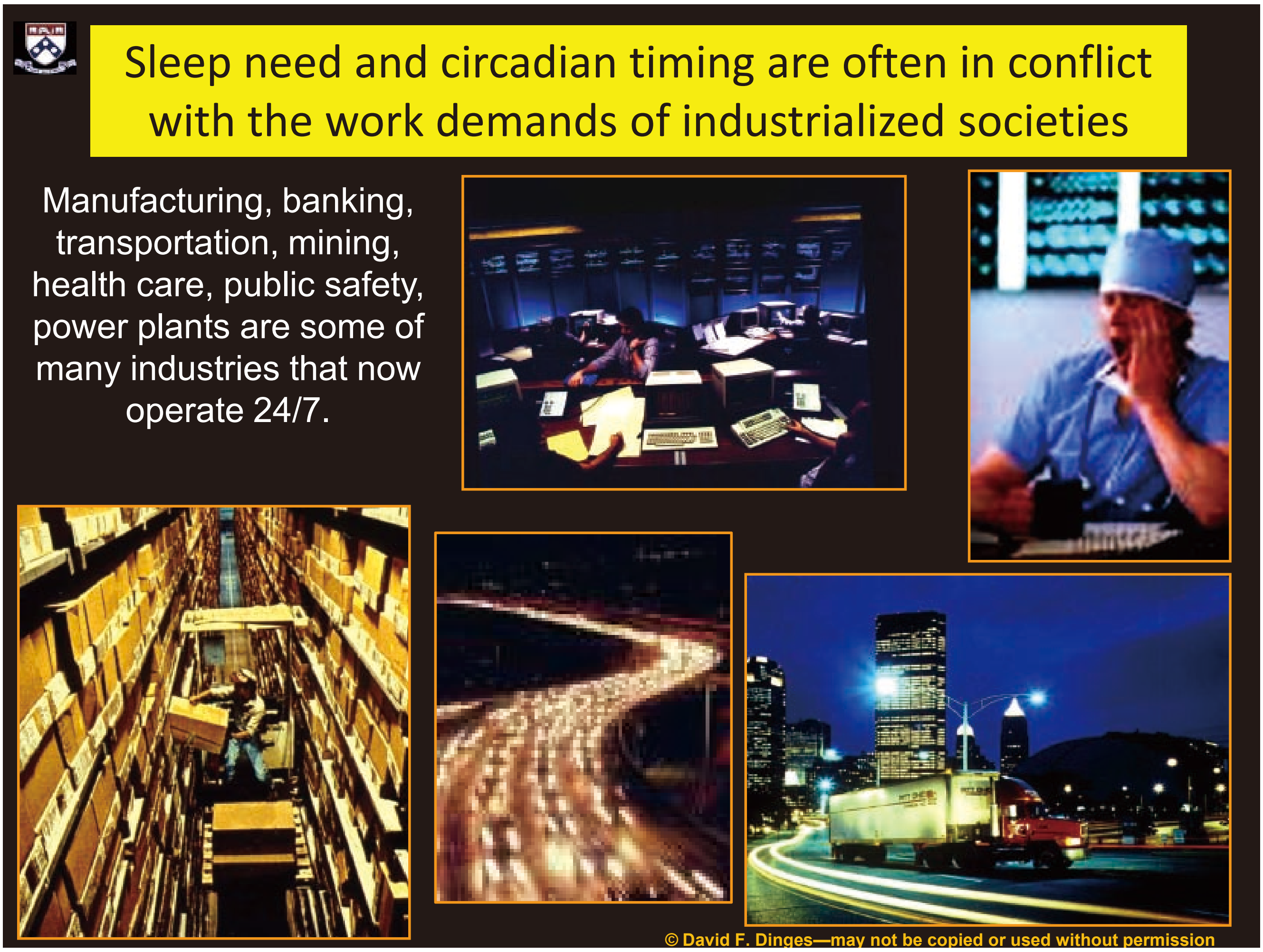
Transportation Safety and Operator Sleepiness: Where Biology Needs Technology

I. Transportation systems involve continuous operations.

A. 24-hour operations in transportation modalities

B. Inadequate sleep has been associated with major transportation accidents

C. The commute conundrum: Evidence that time spent driving can affect sleep time



Contributors to human behavior 24/7

- global economy (investment markets, banking, etc.)
- proliferation of around-the-clock industries
- widespread use of nonstop automated systems
- increased exposure to night shift work
- growing trend toward prolonged work hours
- overnight and just-in-time delivery
- emergency operations
- physical access to entertainment, shopping, etc.
- internet access around the clock
- early school start times coupled with later bed times
- life style chronic sleep restriction
- 24-h vigilance by police and military
- increased international commercial aviation

Human activity often exceeds human sleep requirements

Commercial airplane flights in a 12-h period—each yellow dot is an airplane

Earth is rotating on its axis from left to right.

Driving with inadequate sleep results in fatigue, sleepiness, and drowsiness that pose a significant risk

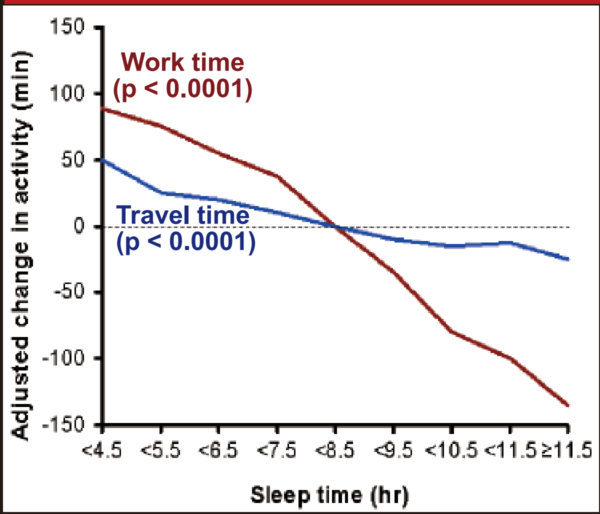
- Fatigue can be a risk to safety in general, and driving in particular. (Mitler et al., 1988; Dinges, 1995; Lyznicki et al., 1998; Stutts et al., 2003; Barger et al., 2005)
- Fatigue is the physiological consequence of inadequate sleep. (Dinges et al., 1997; Belenky et al., 2003; Van Dongen et al., 2003; Banks et al., 2010, 2011)
- Sleep loss degrades the ability to remain awake, alert and reactive. (Lim & Dinges, 2008, 2010; Basner & Dinges, 2011; Roehrs et al., 2011)
- Sleep loss induced performance deficits equivalent to alcohol limits. (Dawson & Reid, 1997; Williams & Feyer, 2000; Williams et al., 2001; Roehrs et al., 2003).
- Driving drowsy is common and frequently results in injury and fatality. (Pack et al., 1995; Philip et. al., 2001; Connor et. al., 2002; Flatley et al., 2004).
- Driving drowsy had a 4-6 times higher crash risk relative to driving alert, and a higher crash risk than distracted driving. (Klauer et al., 2006)

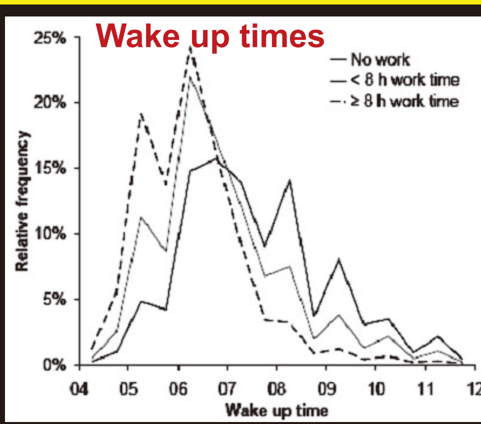
Excessive sleepiness is a common and serious problem due primarily to life style decisions and secondarily to medical disorders and medications

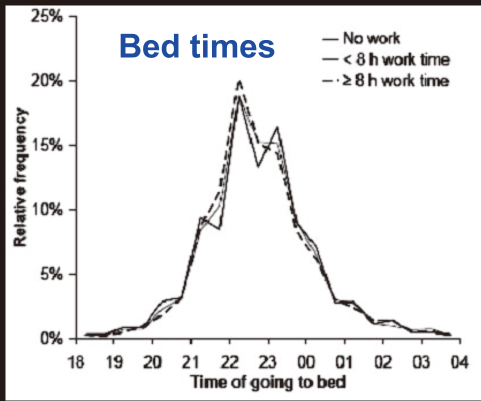
- **Most common cause—Insufficient sleep syndrome**
- Shift work and jet lag disorders
- Obstructive sleep apnea syndrome
- Narcolepsy and hypersomnolence syndromes
- Certain insomnias

Americans exchange sleep time for compensated work time, travel and prime time television

Work time and travel time were the primary activities that were reciprocally related to sleep time among 47,731 Americans (Basner et al., 2007)







Evening television programming and morning alarm clocks were the primary factors predicting sleep onset and offset, respectively (Basner et al., 2009)

Transportation Safety and Operator Sleepiness: Where Biology Needs Technology

II. Healthy sleep is essential for the alertness required to operate a motor vehicle

A. Evidence for the biological basis of sleep need

B. Evidence on how acute and chronic sleep loss affect alertness and performance

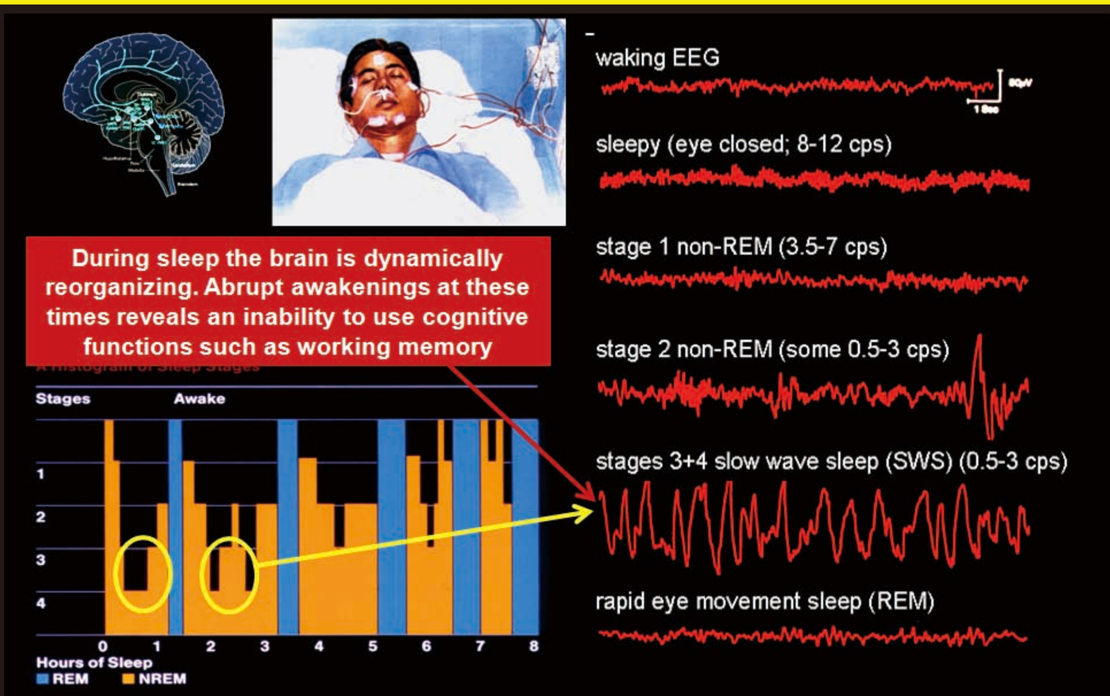
C. Evidence that sleep need can pose a performance risk equivalent to alcohol

Sleep has not been eliminated by evolutionary adaptation. It is ubiquitous in the animal kingdom when defined by behavioral criteria (sans EEG)

- behavioral quiescence
- stereotypical posture
- reduced response to stimulation
- spontaneously reversed in <24h
- resists deprivation
- increased following deprivation
- no EEG criteria required

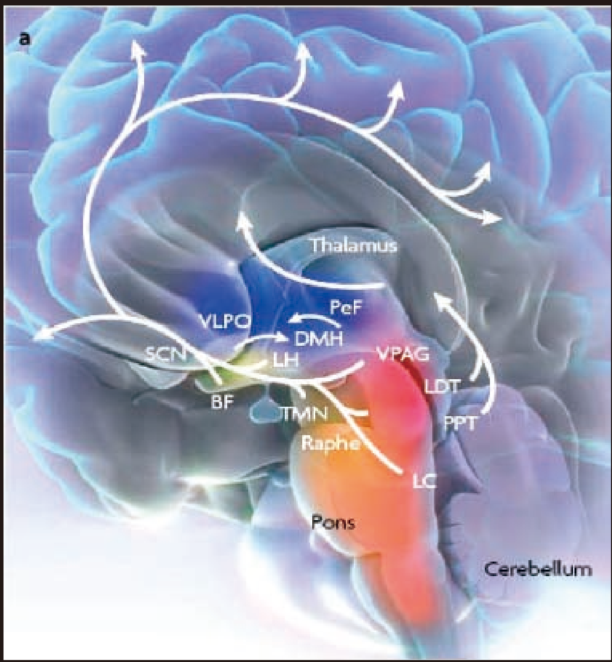
On the basis of these criteria, we can conclude that "sleep" is present throughout the animal kingdom. It has been identified in alligators, turtles, lizards, frogs, salamanders, bees, wasps, flies, dragon flies, grasshoppers, butterflies, scorpions, and the primitive invertebrate sea hare. Its presence in simpler animal models (*C elegans, Zebrafish, Drosophila melanogaster*).

Sleep continuity, intensity and duration provide the "recovery" that restores alertness: Sleepiness increases when any of these aspects are denied.

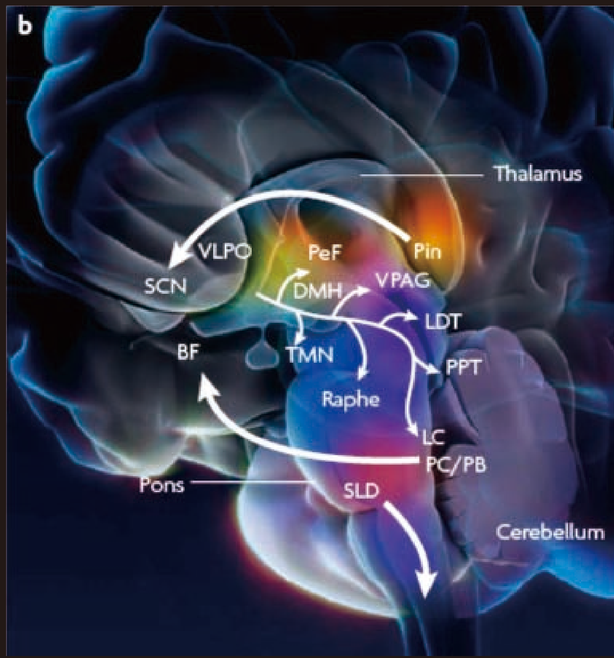


Brain areas and receptors that maintain wake and sleep are increasingly identified and targeted for medications

The human brain AWAKE



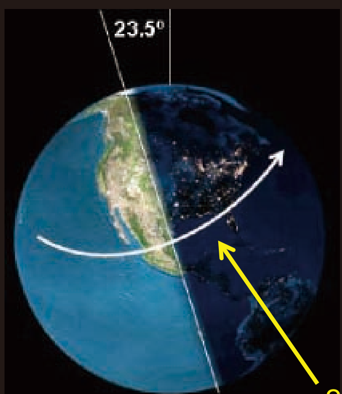
The human brain ASLEEP



Wafford & Ebert (2008)

Earth's orbital mechanics are instantiated in (and entrain) a circadian genetic "clock" and sleep need in the human brain

Genes enforce the imperative of daily sleep and its timing



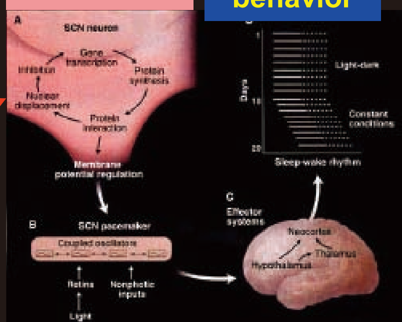
Human brain

24-hr period

SCN

SCN neuron

Human behavior



Sunset over North America Feb.1, 2003

Melatonin receptor binding on the human suprachiasmatic nucleus (SCN) (courtesy of David Weaver)

Circadian clocks are based on negative feedback loops:

Factors stimulate transcription of genes encoding proteins.

As the proteins accumulate they act as transcriptional repressors of their own genes.

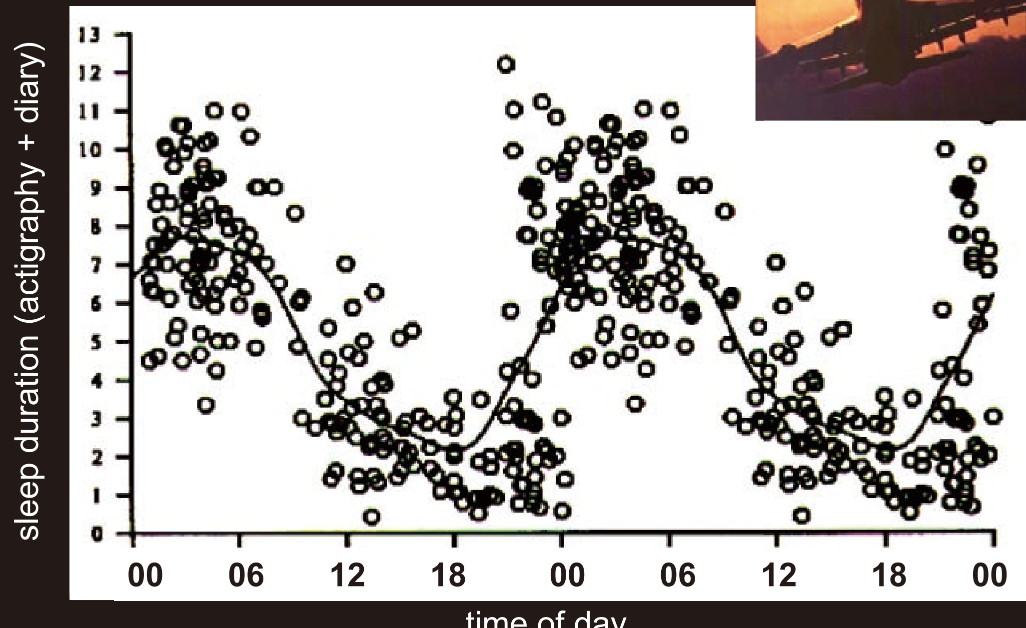
The SCN is the master biological (circadian) clock

From Moore, *Science* (1999)

Our circadian clock also has strong influence over the timing of our sleep periods (sleep duration)

Circadian timing from home dictates sleep duration in long-haul pilots.

Duration of 247 layover sleeps in long-haul commercial pilots flying Pacific routes



Rosekind et al. (1994)

Meta-analysis of the impact of 24-48h total sleep deprivation on cognitive performance

Impact of 48h total sleep deprivation on speed and accuracy measures in 6 cognitive categories:

70 articles (147 cognitive tests) met inclusion criteria.

Both speed and accuracy were affected across cognitive domains.

Effect sizes were largest for lapses in simple attention, and smallest (nonsignificant) for reasoning accuracy)

Outcome variable	Combined effect size
Simple attention	
Lapses	−0.762**
Reaction time	−0.732**
Complex attention	
Accuracy	−0.479**
Reaction time	−0.312**
Processing speed	
Accuracy	−0.245
Reaction time	−0.302**
Working memory	
Accuracy	−0.555**
Reaction time	−0.515**
Short-term memory	
Recall	−0.383*
Recognition	−0.378*
Reasoning	
Accuracy	−0.125

*p<.01, **p<.001

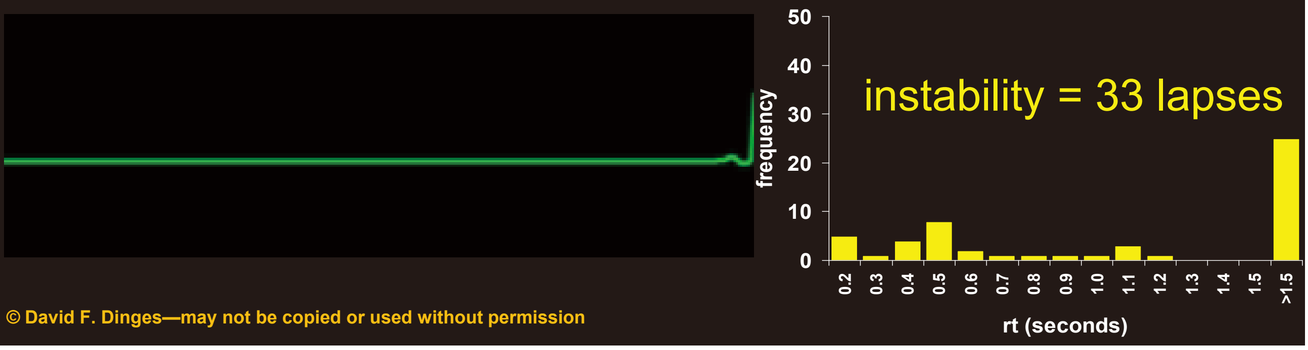
Lim & Dinges (2010)

Illustration of **wake state instability** due to sleep loss: PVT lapses of attention and uneven performance

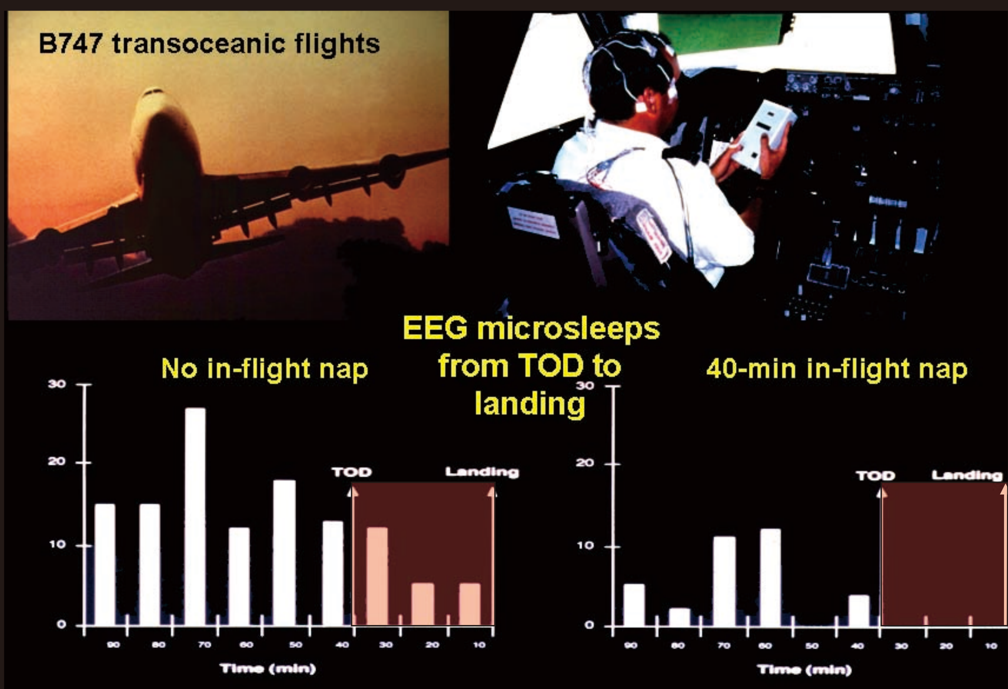
Stable responses after an 8-hr sleep opportunity

Doran et al. (2001); Lim & Dinges (2008)

Unstable responses after a night without sleep

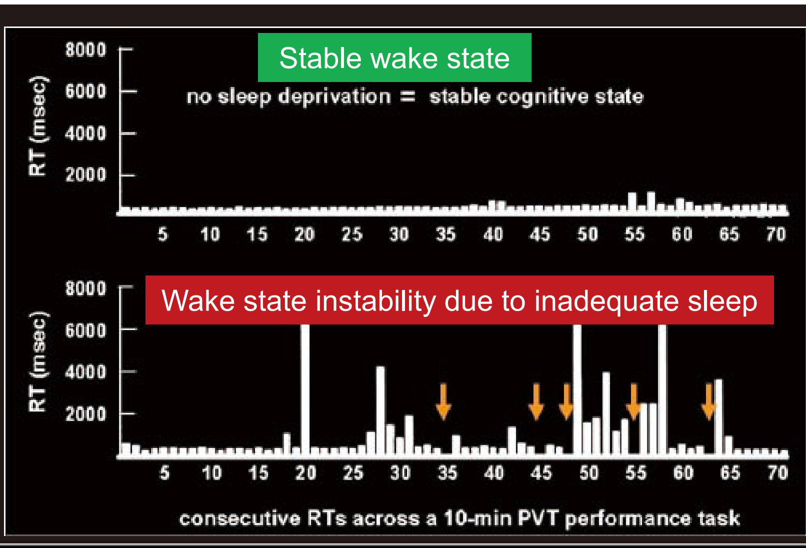


No matter what humans are doing—sleepiness can intrude into wakefulness even in highly motivated and well trained individuals engaged in safety-sensitive activities



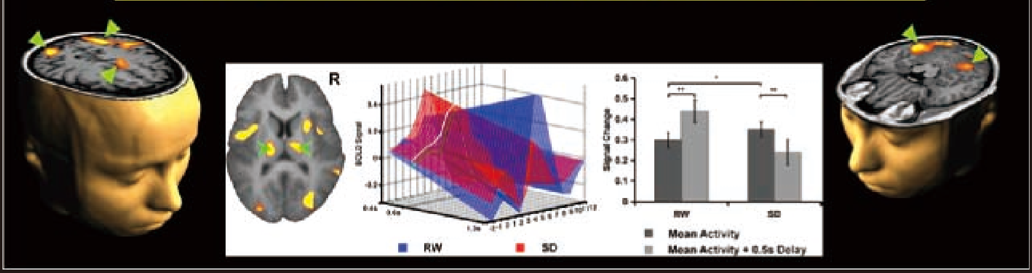
Rosekind et al. (1994).

Lapses are errors of omission and when they occur errors of commission can increase



Doran et al. (2001) ; Lim & Dinges (2008)

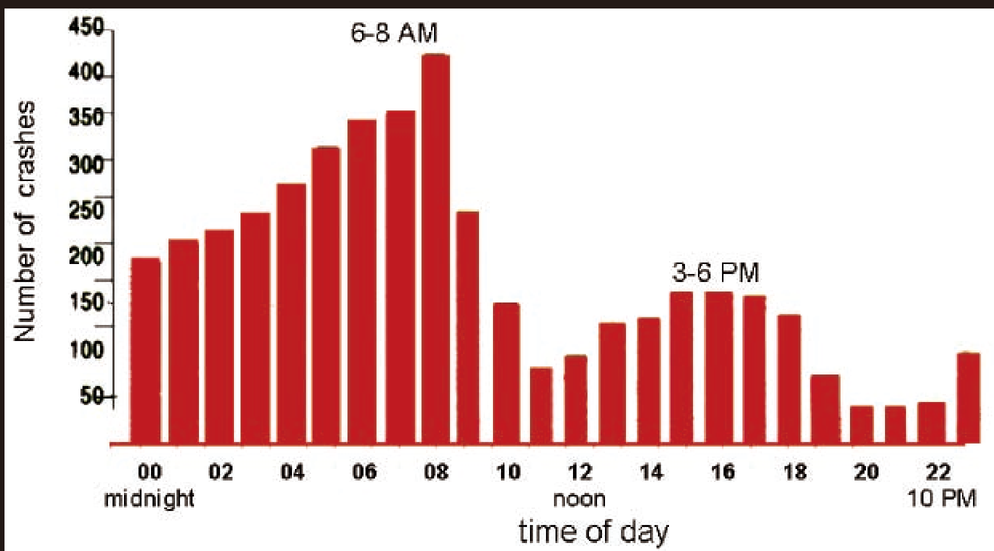
Neuroimaging evidence shows lapses when sleepy involved distributed brain areas



Drummond et al. (2005); Chee et al. (2008)

Drowsy driving crash risk varies across the day in a manner reflecting (nonlinear) circadian and sleep need dynamics

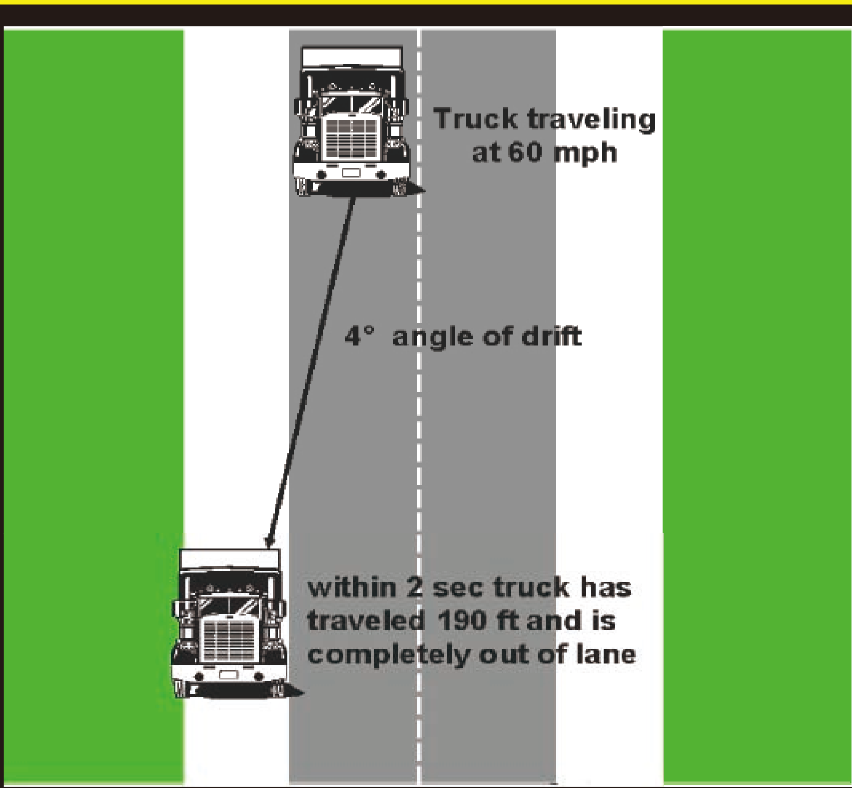
USA National Highway Traffic Safety Administration (NHTSA) estimates driver fatigue annual costs to be: $12.5 billion, 100,000 police-reported crashes 1,550 deaths (4% of fatalities) 71,000 injuries



Time of day of 4,333 highway crashes in which the driver was judged to be asleep but not intoxicated.

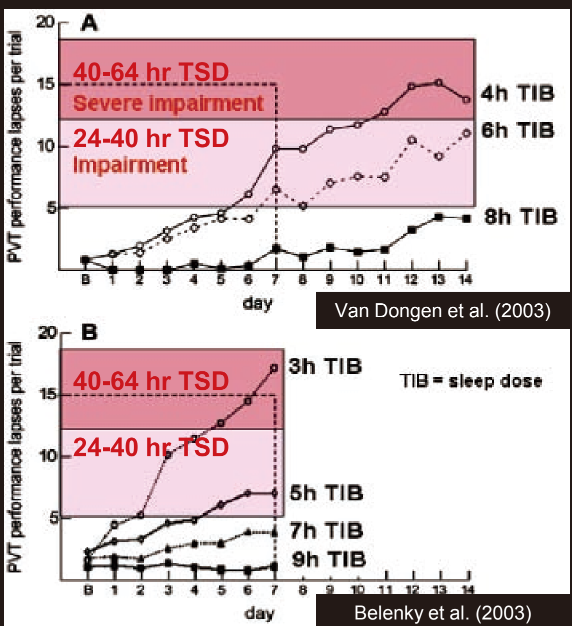
(Pack et al., 1995)

A drowsy driving crash requires a lapse of only a few seconds to result in a crash

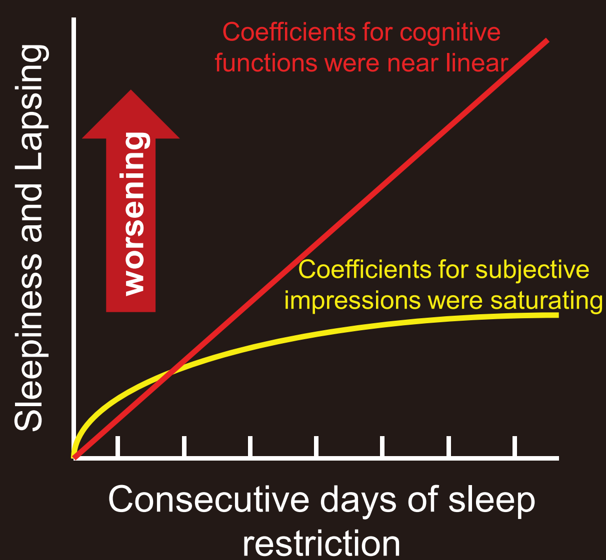


Sleep loss is cumulative and people are often not aware of how much it is affecting alertness and performance

Vigilance lapses occur more frequently with each day of sleep duration below 7 hours

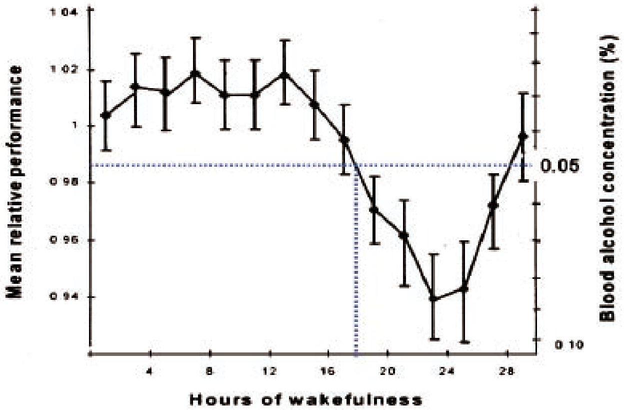


Vigilance lapses increased across days of sleep restriction, but ratings of fatigue changed much less



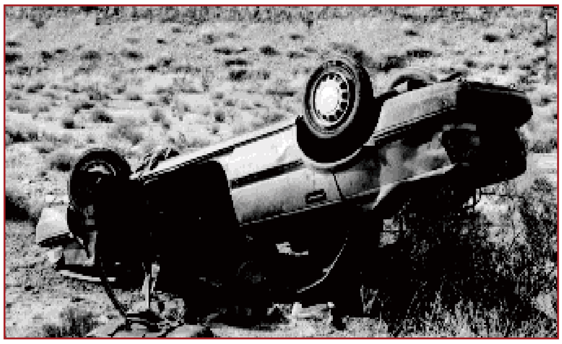
Studies equating the effects of alcohol on performance to those of time awake on performance have found 18h awake ≈ 0.05 g%

(8 other studies also equate prolonged wakefulness with BAC >0.04 g%)



Dawson & Reid (1997)

In the USA fall asleep crashes are often as lethal as alcohol crashes



Pack et al. (1995)

Transportation Safety and Operator Sleepiness: Where Biology Needs Technology

III. Driving sleepy is common enough to be a concern in transportation safety

A. Evidence that driving sleepy is common

B. Evidence that driving sleepy increases crash risk

USA National Survey of Distracted and Drowsy Driving Attitudes and Behaviors: 2002

- Telephone interviews with nationally representative survey of 4,010 drivers (age ≥ 16 yr)

- 37% of the driving population reports having nodded off or fallen asleep while driving at some time in their life. Males (49%) are more likely to report this than female drivers (26%).

- About 22% of male drivers who have nodded off at the wheel report having done so within the past month, compared to 19% of females.

- Among drivers who had a drowsy driving event in the past 6 months
  - 28% reported it occurred between midnight and 6:00 a.m.
  - 35% reported it occurred between 6:00 a.m. and 5:00 p.m.
  - 17% reported it occurred between 5:00 p.m. and 9:00 p.m.

National Survey of Distracted and Drowsy Driving Attitudes and Behaviors: 2002. Volume 1-Findings Report. Submitted to the National Highway Traffic Safety Administration by The Gallup Organization. http://www.nhtsa.dot.gov/people/injury/drowsy_driving1/survey-distractive03/index.htm

National Survey of Distracted and Drowsy Driving Attitudes and Behaviors: 2002

- Average of 6 hours sleep reported the night prior to a drowsy driving experience
  - 24% reported having just ≤4 hours of sleep the prior night
  - 26% reported having 6 hours sleep the prior night
  - 33% reported having ≥7 hours of sleep the prior night

- Drowsy drivers under age 30 reported an average of 5.5 hours of sleep the night before they nodded off at the wheel. The average sleep time of drowsy drivers increased with age. Those ≥ 65yr reported episode after an average of 7.7 hours of sleep

- Relatively few drivers who nod off at the wheel report having had consumed alcohol (2%) or allergy or other medications (12%) prior to their trip

National Survey of Distracted and Drowsy Driving Attitudes and Behaviors: 2002. Volume 1-Findings Report. Submitted to the National Highway Traffic Safety Administration by The Gallup Organization. http://www.nhtsa.dot.gov/people/injury/drowsy_driving1/survey-distractive03/index.htm

National Survey of Distracted and Drowsy Driving Attitudes and Behaviors: 2002

- When feeling sleepy while driving, 43% say they pull over and nap (especially males); 26% open a window to get air; 17% get a coffee or soda to drink; 14% turn on the radio or increase its volume; 3% sing/talk

- 92% of drivers who have nodded off while driving within the past 6 months report that they startled awake.
  - 33% wandered into another lane or onto the shoulder
  - 19% crossed the centerline
  - 10% ran off the road

  - While it happened in only about 2% of the most recent drowsy driving episodes, it is estimated that approximately 292,000 drivers were involved in some type of crash within the past six months as a result of nodding off at the wheel.

National Survey of Distracted and Drowsy Driving Attitudes and Behaviors: 2002. Volume 1-Findings Report. Submitted to the National Highway Traffic Safety Administration by The Gallup Organization.
http://www.nhtsa.dot.gov/people/injury/drowsy_driving1/survey-distractive03/index.htm

National Survey of Distracted and Drowsy Driving Attitudes and Behaviors: 2002

NHTSA (2002)
"NHTSA data indicate that in recent years there have been about 56,000 crashes annually in which driver drowsiness/fatigue was cited by police. Annual averages of roughly 40,000 nonfatal injuries and 1,550 fatalities result from these crashes. It is widely recognized that these statistics underreport the extent of these types of crashes. These statistics also do not deal with crashes caused by driver inattention, which is believed to be a larger problem."

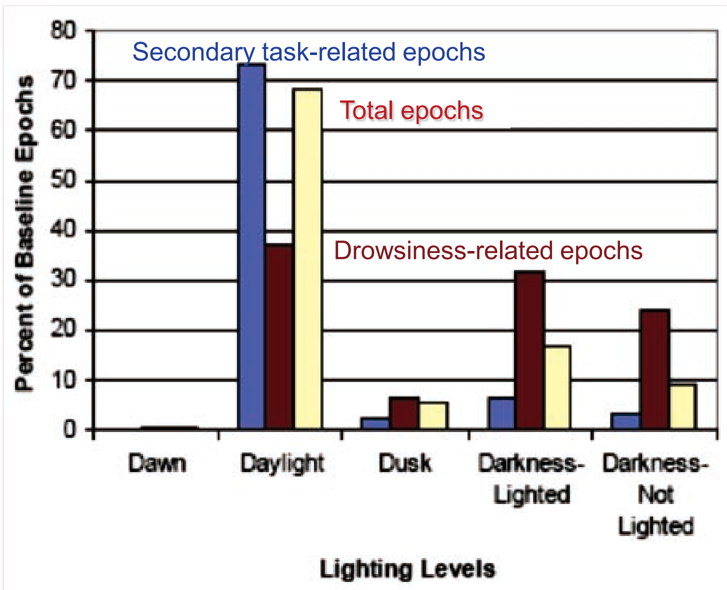
NHTSA (2002)
While the proportion of drivers involved in a crash as a result of nodding off at the wheel is very small, the actual numbers of drivers involved in such crashes over the past five years is sizable. An estimated 1.35 million drivers have been involved in a drowsy driving related crashes in the past five years (270,000 crashes annually). About seven in ten of these drivers, or 972,000 were males, while 379,000 were females.

National Survey of Distracted and Drowsy Driving Attitudes and Behaviors: 2002. Volume 1-Findings Report. Submitted to the National Highway Traffic Safety Administration by The Gallup Organization.
http://www.nhtsa.dot.gov/people/injury/drowsy_driving1/survey-distractive03/index.htm

Driving sleepy has been found to be a significant factor in injury-related and fatal crashes in many countries

- **New Zealand:** "There was an eightfold increased risk if drivers reported sleepiness and almost a threefold risk for drivers who were driving after five hours or less of sleep." (Connor et al., 2002)
- **France:** A survey of 67,671 crashes in France determined 10% were fatigue related. (Philip et al., 2001)
- **United Kingdom:** The authors of a recent study that examined 1828 crashes in the UK reported that 17% of the accidents resulting in injury or death were sleep related. (Flatley et al., 2004)

Drowsy driving in metropolitan Washington, DC, USA was found to be as common as distracted driving, and it occurred more often during daylight/lighted conditions.



"It appears driving drowsy during the daylight may be slightly riskier than driving drowsy in the dark. While it is commonly thought that most drowsiness-related crashes occur at night, a majority of the drowsiness-related crashes in this study occurred during the daytime in heavy traffic (during morning and evening commutes). Thus, the risks of driving drowsy during the day may be slightly higher than at night due to higher traffic density." (p. 41)

Klauer SG et al. The Impact of Driver Inattention on Near-Crash/Crash Risk: An Analysis Using the 100-Car Naturalistic Driving Study Data. USA DOT HS 810 594 IS NHTSA, pp1-224, April, 2006

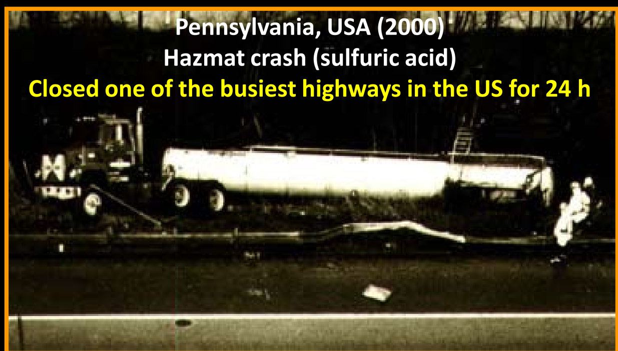
People often believe they can drive and work (even on safety-sensitive tasks) when they have a sleep debt

Truck drivers are at risk for drowsy driving crashes from sleep disorders and work-rest schedules

Drowsy driver crashes cost $12 billion and contribute to a third of the ~4,000 annual truck driver deaths in the US.

Study of 406 commercial truck drivers found increases in subjective sleepiness (ESS), MSLT, and performance (PVT, DADT) were linearly associated with shorter sleep durations, but associations with severity of sleep apnea were not as robust and not strictly monotonic. Severe sleep apnea (AHI >29/h) was found in 4.7% of drivers, while sleep duration <5h/night was found in 13.5% , and these conditions were similar in their impact on objective sleepiness.

Pack A. et al. Impaired Performance in Commercial Drivers: Role of Sleep Apnea and Short Sleep Duration; *AJRCCM,* 174:446–454, 2006



Bus drivers are at risk for drowsy driving crashes from sleep disorders and work-rest schedules

Bus driver with sleep debt and untreated sleep complaint (could sleep only 3-4h)
Pennsylvania, USA (1998)
7 killed, 16 injured

Bus driver had <4h sleep in 51h, stayed awake to gamble,
New York, USA (2002)
5 killed, 42 injured

Sleep-related crash involving two modes of transportation

UK (2001): A motor vehicle operator who had been awake all night began driving his Land Rover at 05:00 h. He fell asleep at the wheel, veered off the motorway and lodged his vehicle on the southbound East Coast railway line. After exiting his vehicle, a commuter train traveling 125 mph smash into his vehicle. The southbound train was derailed, only to collide with a northbound freight train running at 60 mph. The crash killed 10 and injured >60. The driver was convicted of convicted of 10 counts of causing death by dangerous driving.

Sleep loss has contributed to serious maritime catastrophes

People have difficulty believing that a human can make a fatigue-related error while performing an over-learned task under highly motivated (even life-threatening) conditions. But it happens because fatigue is a risk state that degrades behavioral efficiency. These maritime allisions illustrate this point.

Grounding of the oil super tanker Exxon Valdez
Prince William Sound, Alaska, USA (1989)
Severe environmental damage and costs in the tens of billions of dollars

Transportation Safety and Operator Sleepiness: Where Biology Needs Technology

IV. Are there solutions to driver incapacitation from sleep need?

A. Is education to avoid sleepy driving likely to be effective?

B. Are increased rest stops a cost-effective solution without unintended consequences?

C. Are vehicle technologies feasible that safely inform, warn and/or alert sleepy drivers?

Using technology to help manage fatigue

Maintaining Human Behavioral Capability: Where Biology Needs Technology

Why technologies can help humans cope behaviorally

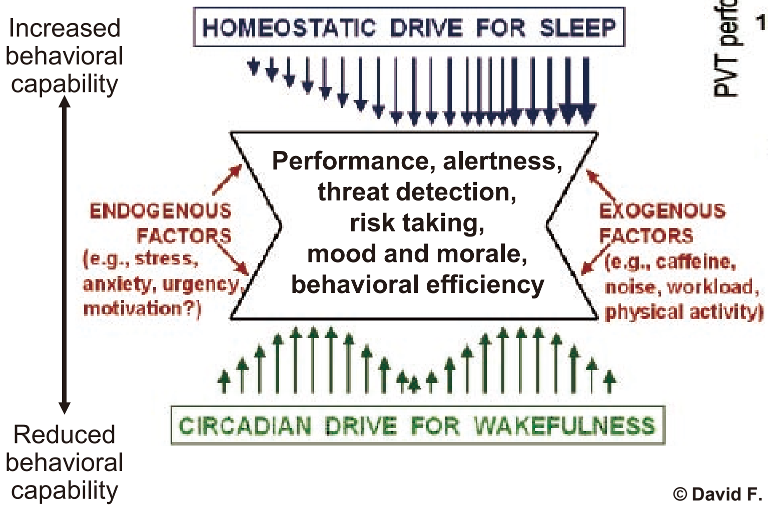
- Performance is dynamically nonlinear (C+S)—work rules aren't
- Large differences among people in neurobehavioral vulnerability
- Lack of awareness of relationship between "fatigue" and risk
- Need to inform people of when recovery is essential & how much

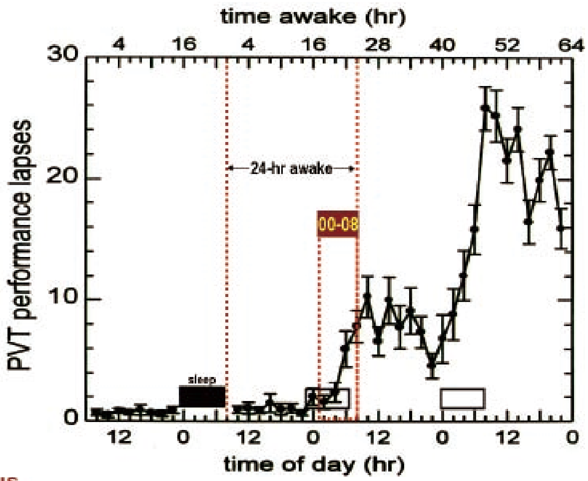
Accurate feedback regarding an individual's sleepiness level

- evaluate clinically for treatment needs
- to prevent/reduce imminent risk
- to manage fatigue from life style

Sleep and circadian drives in the brain interact to control performance and alertness: Mathematical models attempt to predict this performance timing

Two-process model: oscillator interacting with a quasi-linear process

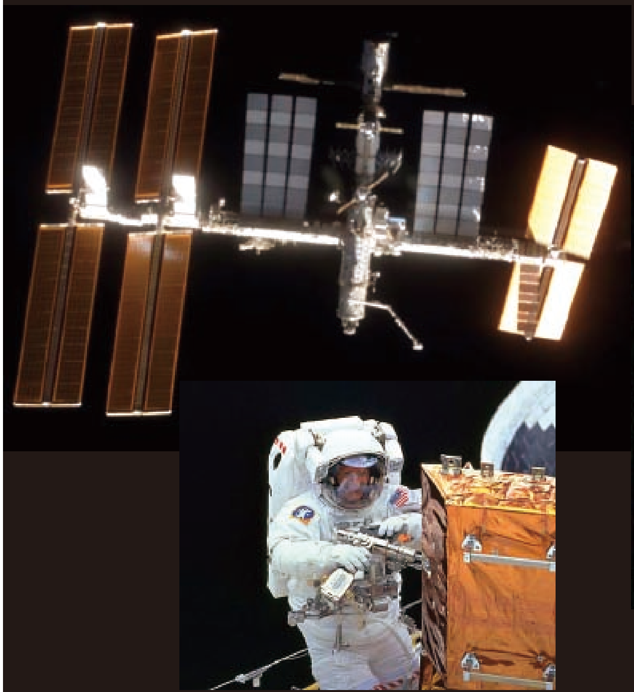




Resulting behavioral alertness from nonlinear interaction

Van Dongen & Dinges (2000)

Tracking astronaut alertness with the **PVT-B (Reaction Self Test)** during 6-month missions on the International Space Station (ISS)



Study of effects of feedback on driver sleep and sleepiness

WRAIR SleepWatch

SafeTRAC lane-tracking monitor

PVT-192

CoPilot infrared retinal reflectance monitor

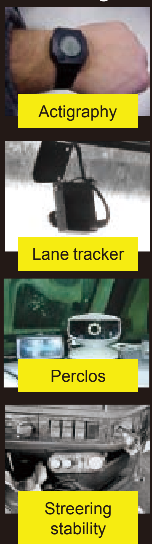
Eye images from CoPilot

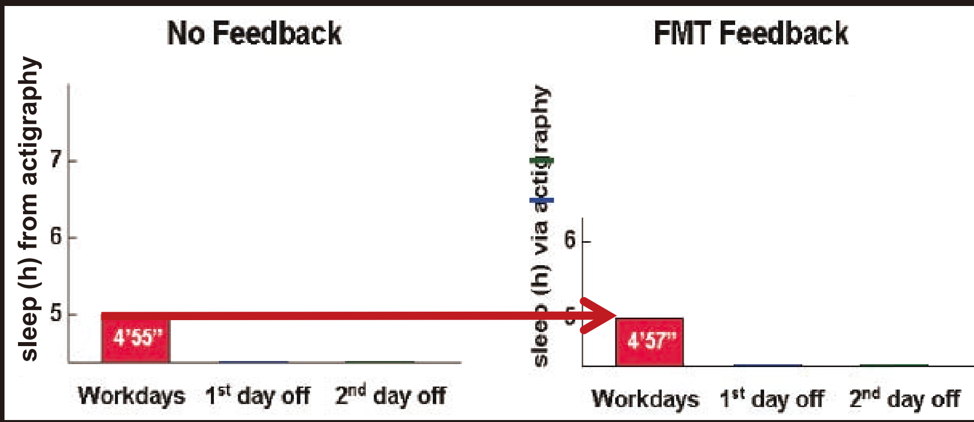
Howard Power Center Steering System

Dinges DF et al (2005)

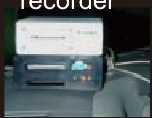
Objective feedback (FMT) on drowsiness/performance while driving at night led to reductions in driver drowsiness and lane tracking variability, and more sleep on days off duty

Technologies provided feedback on alertness during night driving

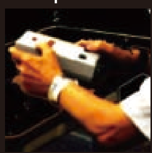




APP+ black box recorder



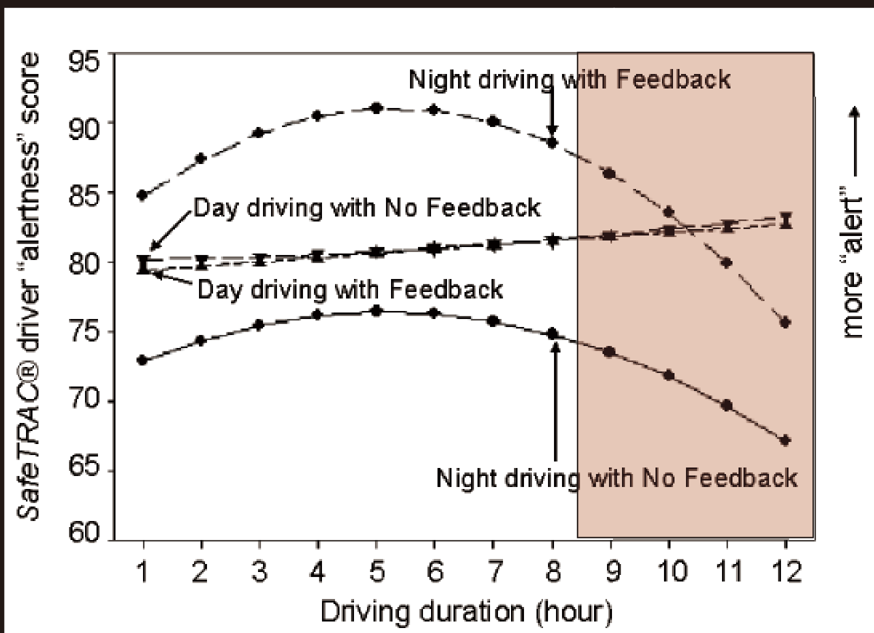
PVT perf. test



Dinges DF et al. *J Transportation Res Board* No. 1922, National Academies, Wash. DC, 175-182 (2005).

During night driving, fatigue feedback decreased lane tracking variability ($p < 0.0001$)

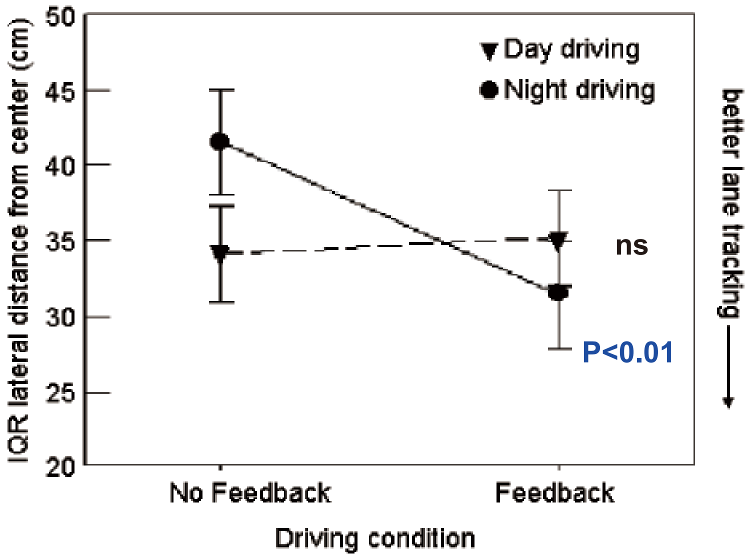
Expected "alertness" decreased after hour 8 of night driving.



Dinges et al. *J Transportation Res Board* No. 1922, TRB of the National Academies, Washington, DC, 175-182, 2005.

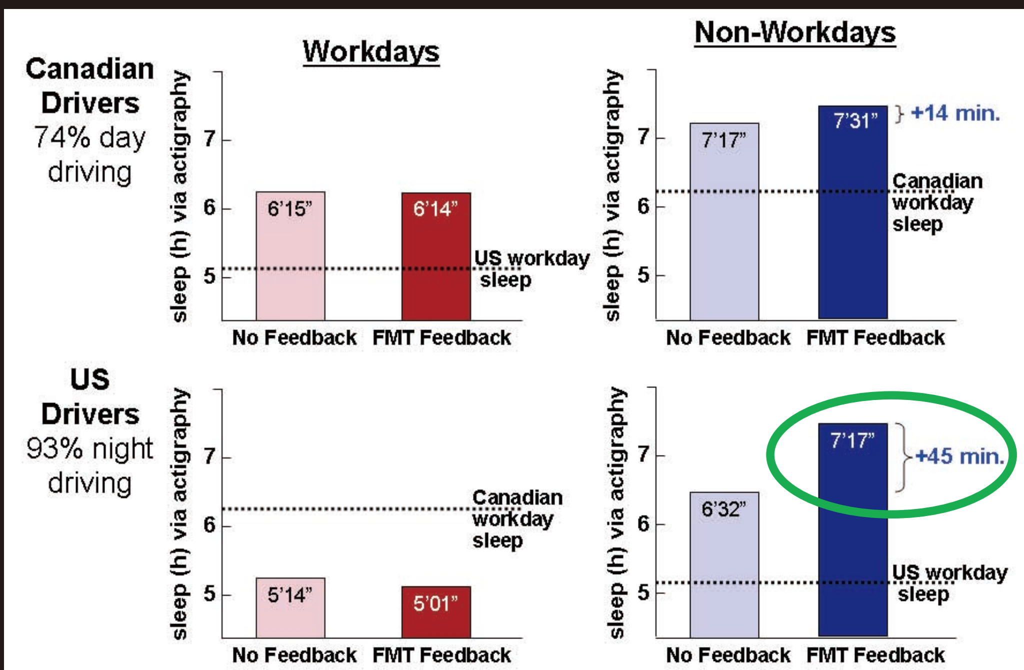
Feedback improved lane tracking at night in commercial truck drivers

Feedback by driving time interaction was significant P<0.0001



Dinges et al.*J Transportation Res Board* No. 1922, TRB of the National Academies, Washington, DC, 175-182, 2005.

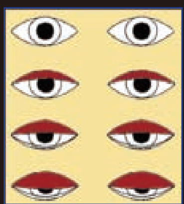
Feedback to truck drivers about their sleepiness increased sleep time on days off



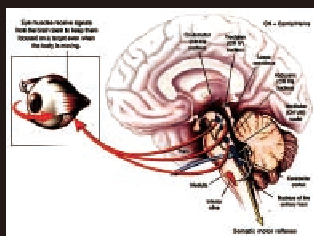
Dinges et al. *J Transportation Res Board* No. 1922, TRB of the National Academies, Washington, DC, 175-182, 2005.

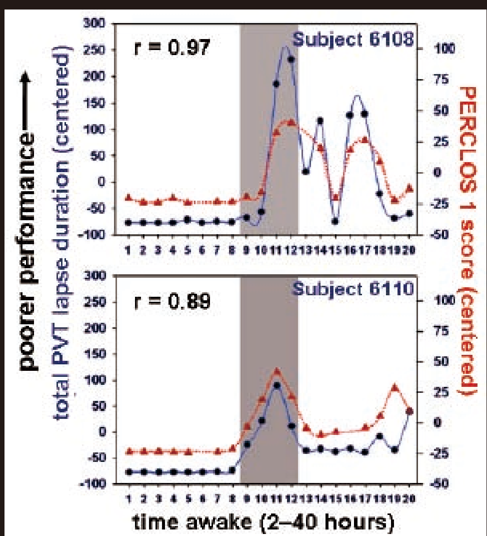
Drowsiness has a characteristic neurobehavioral profile

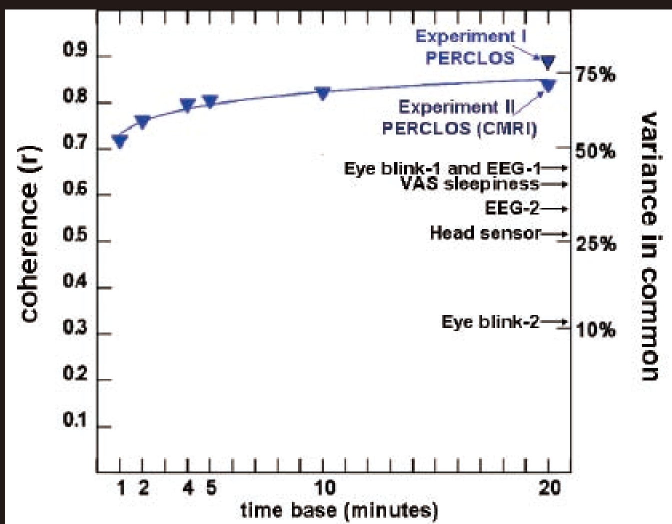
Changes in neurobehavioral markers can reflect sleepiness—tracking ocular sleepiness



PERCLOS refers to the percent of time slow eyelid closures cover the pupil. PERCLOS was the best predictor of PVT lapses of attention



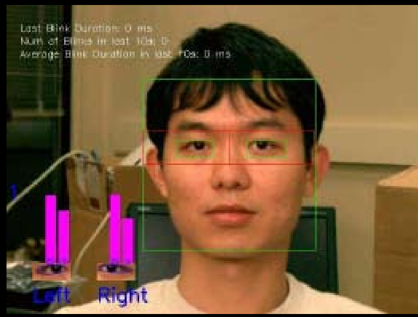




Dinges et al. (1998); Dinges et al. (2002)

D Metaxas, PhD

Measure of sleepiness based on optical computer recognition (OCR) of eyelids (levator palpebrae superioris muscle)



No sleep deprivation
PVT lapses = 0 in 1-min video below
4 in 20-min test bout
Eyes closed epochs = 125 (4.1 sec)
Avg. blink duration = 132 ms

Sleep deprivation
PVT lapses = 4 in 1-min video below
42 in 20-min test bout
Eyes closed epochs =308 (10.2 sec)
Avg. blink duration = 205 ms (+54%)

Research supported by:
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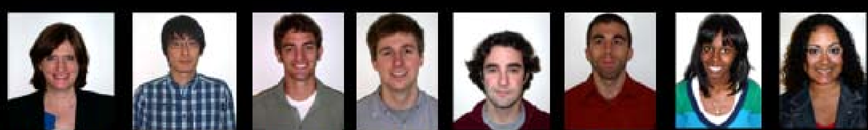
NASA & National Space Biomedical Research Institute
Department of Transportation; Department of Defense

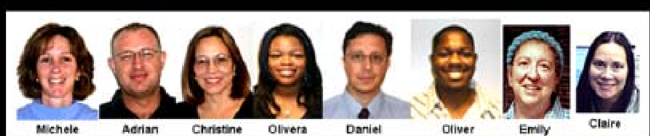
Colleagues, collaborators, trainees and technical staff

Epidemiology of sleep timing and fatigue detection | Recovery sleep dose response to sleep restriction | Phenotypic / Genotypic responses to sleep loss | Neuroimaging of differential responses to sleep restriction and neurocognitive responses

Mathias Basner, MD, PhD, MSc · Siobhan Banks, PhD · Namni Goel, PhD · Hengyi Rao, PhD · Siyuan Shu, PhD · Julian Lim, PhD



Marcia Braun, PhD · Takashi Abe, PhD · David Bergamo · Kris Szalc · Chris Jones · Adrian DiAntonio · Nicole Fraker · Sylmarie Arroyo



~75 undergraduates

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Daniel Mollicone, PhD
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Hans Van Dongen, PhD
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Americas 1st medical school

講演者　Presenter

Prof. Ekkehard Brühning / Germany

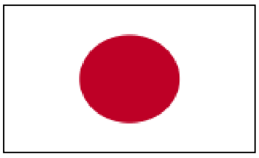
日本とドイツの交通安全 — 成功と失敗、そして今後の可能性

Traffic Safety in Japan and Germany – Success, Deficiencies, Future Potentials

Traffic Safety in Japan and Germany – Success, Deficiencies, Future Potentials

Director and Professor a.D.
Dr.-Ing. Ekkehard Brühning

Similarities in motorization and road safety in 2010



- Capital: Tokyo
- 128 million inhabitants
- 646 vehicles / 1000 inh.
- 5 745 road fatalities
- 4.5 fatalities / 100 000 inh

- Capital: Berlin
- 81.8 million inhabitants
- 614 vehicles / 1 000 inh.
- 3 648 road fatalities
- 4.5 fatalities / 100 000 inh

IRTAD (2011)

Downward trend in fatality figures

		1990	2010	% change
Fatalities	J	14 595	5745	- 60 %
	G	11046	3648	- 67 %
Fatalities / 100 000 inhabitants	J	11.8	4.5	- 62 %
	G	14.0	4.5	- 68 %
Fatalities / billion vehicle-km	J	23.2	7.7	- 67 %
	G	20.0	5.2	- 74 %
Motorization (mot. veh. / 1000 inh.)	J	216	646	+ 299 %
	G	529	614	+ 116 %

IRTAD (2011)

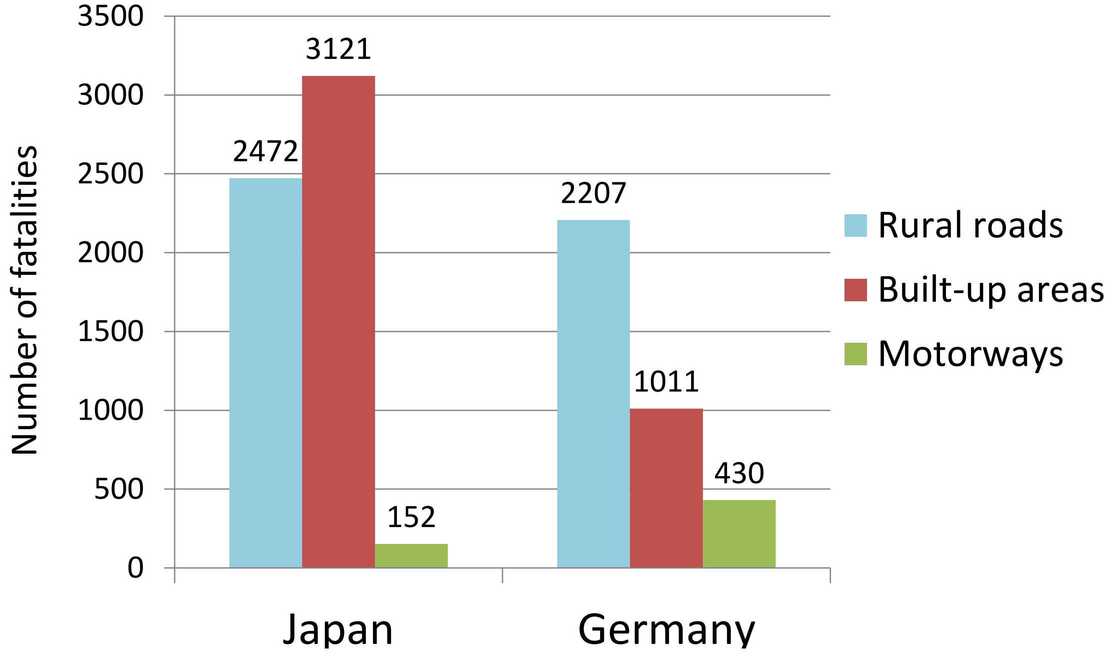
3

Reasons for safety improvements

- **E**ngineering
  (road, vehicle, traffic planning, …)
- Legal measures
  (speed, alcohol, safety belt, …)
- **E**ducation
  (driver training, pedestrian behaviour, …)
- **E**nforcement
  (police …)
- Emergency Medical Service at road accidents

4

Fatalities by road type / location in 2010



IRTAD (2011)

5

The German Road Safety Programme 2011 requires for Rural Roads

- Preventing accidents involving a collision with a roadside obstacle
- Motorcycle-friendly safety systems
- Providing additional overtaking lanes to prevent overtaking accidents
- Enhancing road safety at junctions
- Deploying speed monitoring at accident blackspots
- Evaluating measures to prevent accidents involving wildlife

Tree-lined roads in Germany

Example: Dangerous road segment

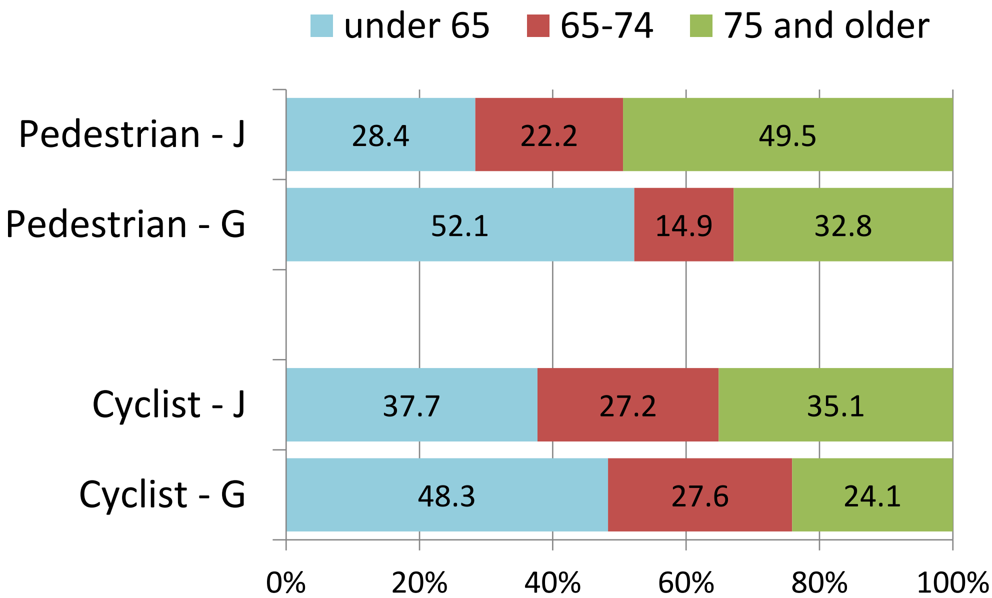
- Before treatment

- After treatment

Weber (2003)

7

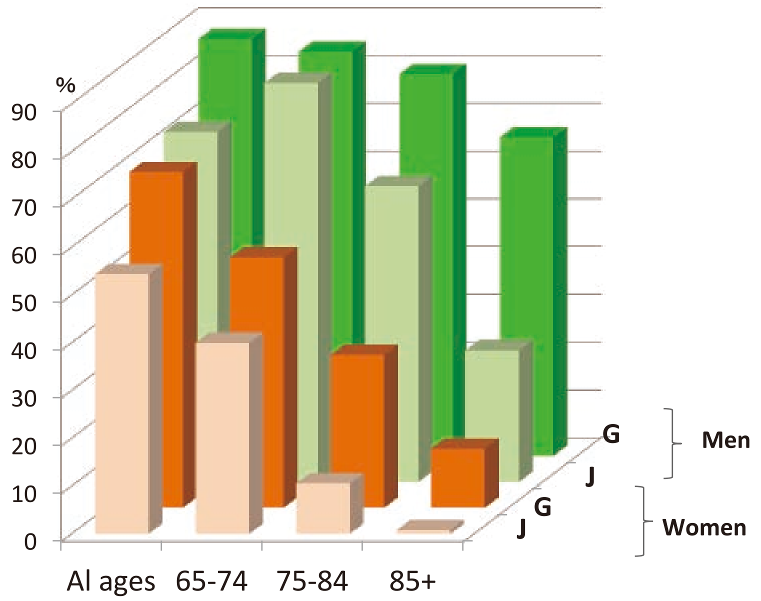
Fatally injured pedestrians and cyclists by age group in 2010



National Police Agency (2011)
Statistisches Bundesamt (2011)

8

Proportion of driving license holders by age and gender



Japanese data derivefrom 2010 (Ministry of Health, Labour &Welfare/National Police Agency)
Germany data derive from 2004 (Kalinowska et al, 2007) (Okamura, 2011)

9

Bicycle crossing at a main arterial street in Tokyo

The Japanese Traffic Safety Programme has 3 strategic objectives and 8 pillars.

The 3 strategic objectives are:

1. **Safety for the elderly and children,**
2. **Pedestrian and bicycle safety,**
3. **Ensuring safety on roads serving the community and on main roads.**

Among the 8 pillars are:

1. **Improvement of the road traffic environment,**
2. **Dissemination and reinforcement of traffic safety messages,**
3. **Safe driving.**

There are a great number of possible measures outlined in detail

Improving road traffic environment

Small streets in a residential area nearby a school

Photos: Nishida (2012)

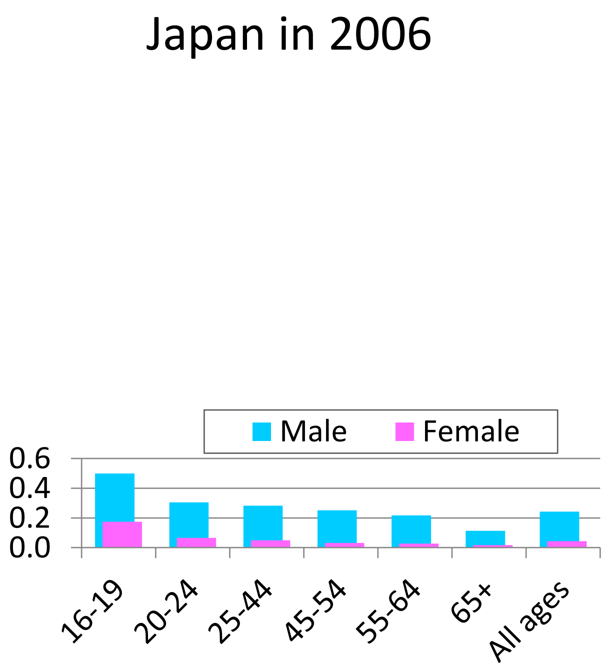
Fatalities
caused by alcohol-impaired drivers

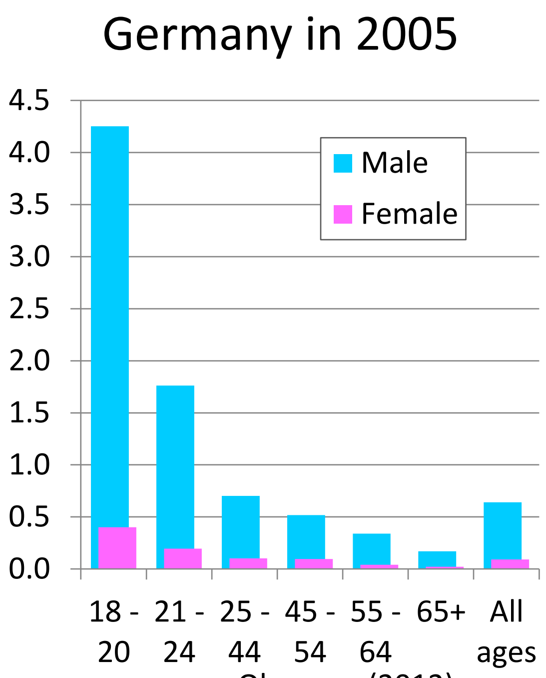
Alcohol is tolerated in most countries/societies –
in Germany and Japan, too

Alcohol-related road fatalities

J - 6.0 % of all fatalities in 2010
G - 9.4 % of all fatalities in 2010

Alcohol-impaired drivers (involved in crashes) per 1 000 driving licenses

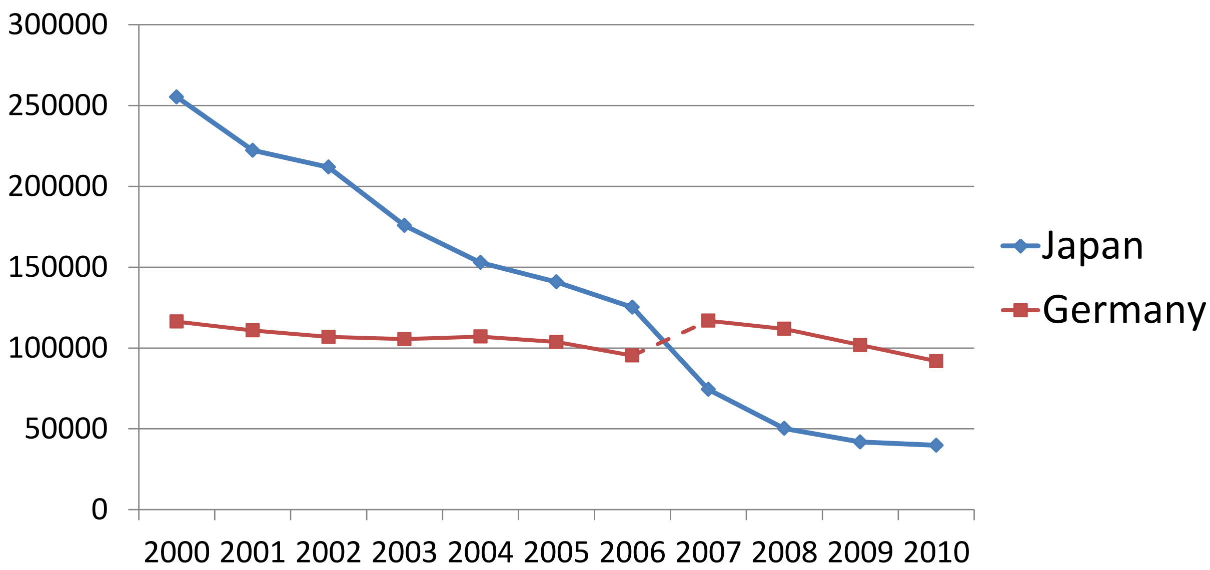




Okamura (2012)

15

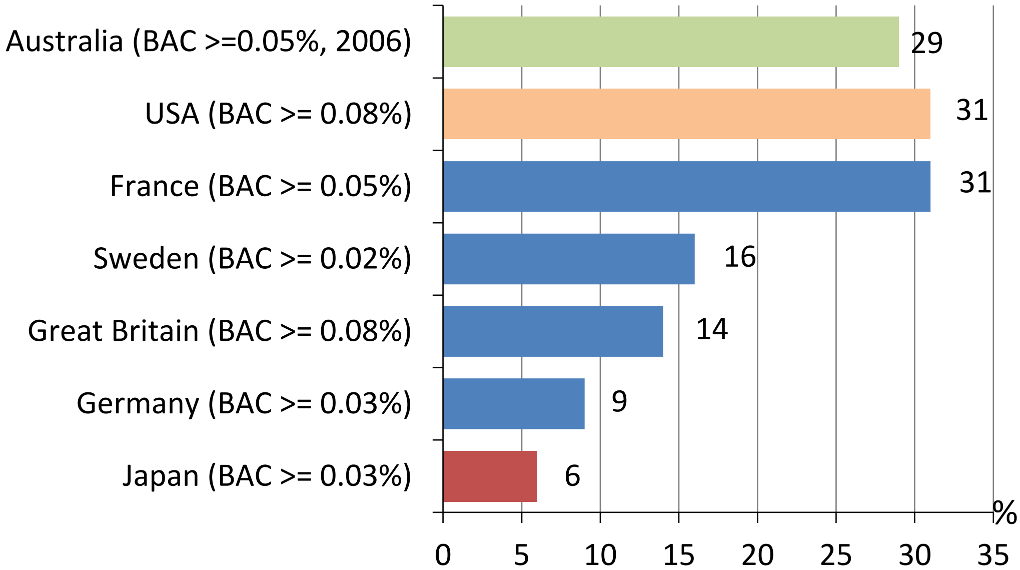
Trend in number of convicted alcohol-impaired drivers



National Police Agency (2011)
Statisches Bundesamt (2011)

16

Proportion of fatalities caused by alcohol-impaired drivers in 2010



Austroads (2010), European Transport Safety Council (2012), NHTSA (2012), National Police Agency (2012)

17

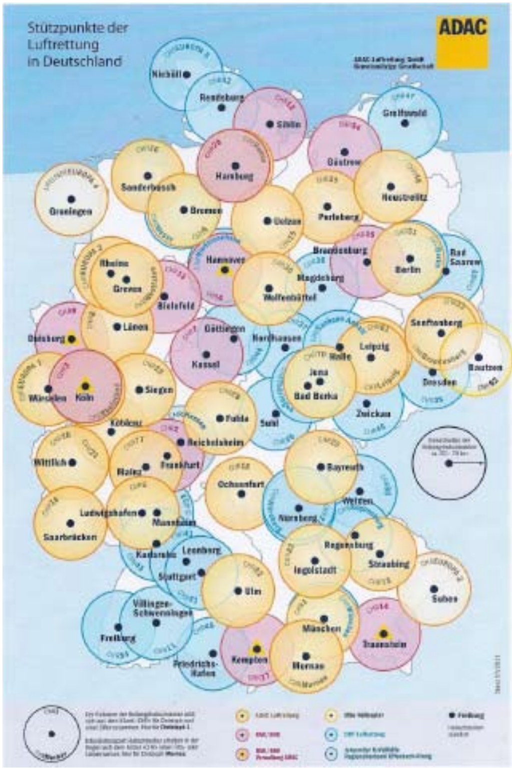
Emergency service at road accidents in Germany

- Arrivals of ambulance vehicle on the accident spot
  average = 9.0 min
  95 % < 18.4 min
- Arrival of rescue physician on the spot by vehicle
  average = 12.0 min
  95 % < 26.6 min
- HEMS – Helicopter Emergency Medical Service
  at 2.5% of road accident emergency cases

Unfallverhütungsbericht Straßenverkehr 2008/2009

HEMS: Helicopter Emergency Medical Service

Ca. 100 air rescue helicopters in G
for medical emergencies of any kind
System established in the 1970s and 1980s
HEMS provided by different organizations



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Progress in vehicle safety

- Great success in the past through improvements in passive safety

- New horizons through accident avoiding electronic (driver) assistance systems

Passive safety – state of the art

- **Stiff Passenger Compartment Cell**
- **Belt Pretensioner**
- **Belt Load Limiter**
- **Multi-Stage Airbags**
- **“Soft“ Interior Design**
- **Crash-Design: “Self Protection“**

Pre-Crash-Safety
(Crosslinking with systems of the Active Safety)

Benefit for Passive Safety:

- **Collision mitigation**
- **Time for optimization of parameters**
- **Pre-deployment of airbag**

Conclusion:

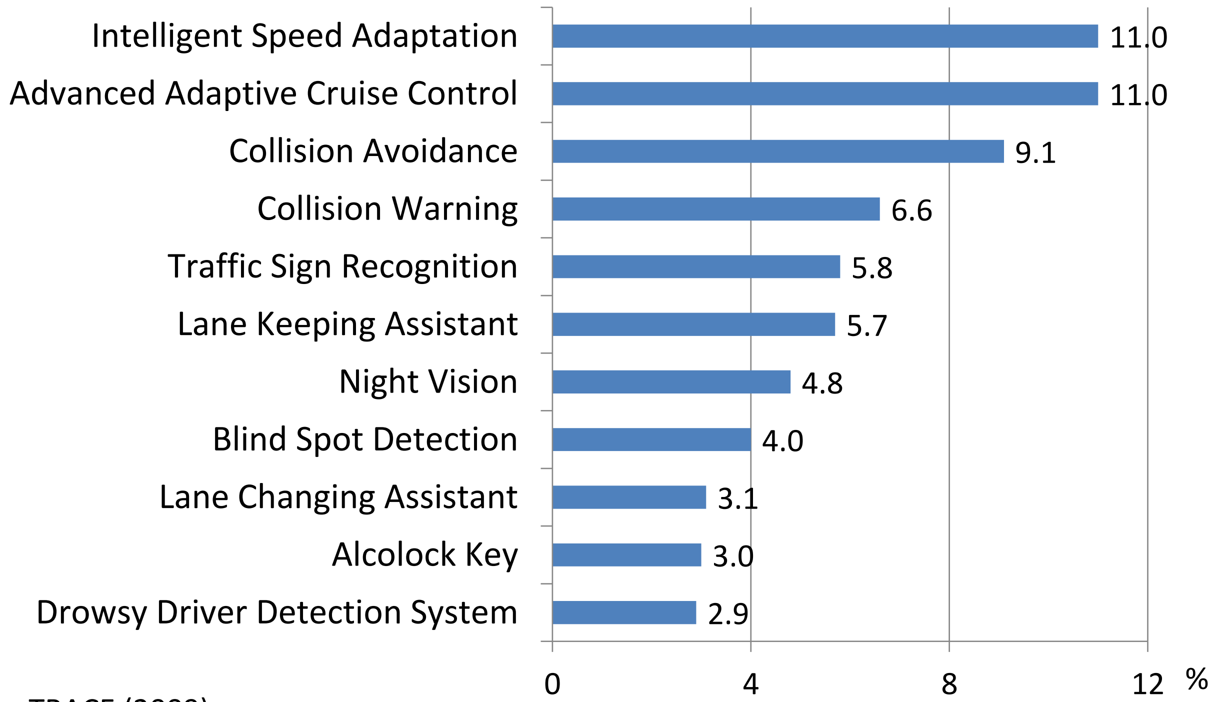
Future Improvements of Passive Safety – significant, substantial improvement, but not a new “dimension“

Accident avoiding electronic (driver) assistance systems

For many years on the market:

- **Anti-lock Braking System (ABS)**
- **Electronic Stability Control (ESC)**
- **Brake Assist System (BAS)**

Evaluation of (driver) assistance systems – Reduction of serious injuries in the EU



TRACE (2009)

“Forward collision avoidance systems, particularly those that brake autonomously, show some of the biggest crash reductions.”

IIHS (2012)

How to increase the market penetration of driver assistance systems?

Mandatory Fitment Requirements for Active Safety Systems in the EU

Year	System	Type approval for
1991	**ABS** Anti-lock Breaking System	Trucks >7.5 t
2009	**BAS** Brake Assist System	Cars
2011	**ESC** Electronic Stability Control **DRL** Daytime Running Light	Cars
2012	**TPM** Tire Pressure Monitoring System	Cars
2013	**AEBS** Advanced Emergency Breaking System **LDWS** Lane Departure Warning System	Trucks >7.5 t
2014	**ESC** Electronic Stability Control	Trucks >3.5 t
2016	**AEBS** Advanced Emergency Breaking System **LDWS** Lane Departure Warning System	Trucks 3.5 – 7.5 t
	AEBS Increased speed reduction	Trucks >7.5 t
2016/17?	**ABS** Anti-lock Breaking System	Motorcycles >50ccm

(EU Directives / Regulations)

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Euro NCAP Driver Assist

(Decision of 12 June 2012)

Fitment requirements in EU	2012	2013	2014	2015	2016	2017
SBR Seatbelt Reminder	100 %	100 %	100 %	100 %	100 %	100 %
ESC Electr. Stability Controle (= EU Regulation, 2011)	100 %	100 %	100 %	100 %	100 %	100 %
SAS Speed Assist Systems		50 %	50 %	70 %	100 %	100 %
AEB Advanced Emergency Braking (Inter Urban > 40km/h)			50 %	50 %	70 %	100 %
AEB (City < 50km/h)			100 %	100 %	100 %	100 %
AEB (Pedestrian)					100 %	100 %
LDW/LKD Lane Departure Warning / Lane Keeping Device			50 %	50 %	70 %	100 %

Euro NCAP (2012)

30

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- **Yasushi Nishida,** Institute of Traffic Accident Research and Data Analysis (Tokyo)
- **Nobuaki Takubo**, PhD, National Research Institute of Police Science (Kashiwa)

講演者　Presenter

Prof. Werner Brilon / Germany

高速道路運営の信頼性

Reliability of Motorway Operations

Reliability of Motorway Operation

Prof.(em.) Dr.-Ing. Werner Brilon

Ruhr-University Bochum / Germany
and BPS GmbH Karlsruhe / Germany

Tokyo Sept. 21st 2012

1

Reliability of Motorway Operation

1. Introduction:
   What is reliability? Why do we use this term?
2. How do we describe reliability?
3. How to improve reliability?
4. What is the advantage of reliability concepts?

2

German „Autobahn“

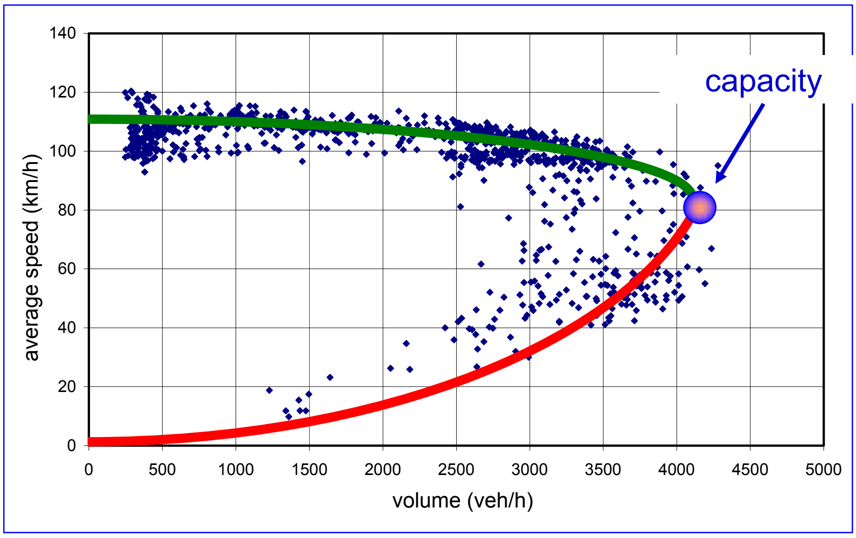
Objectives

Traditional objectives for highway design and operation:

■ Safety	accident cost rates
■ traffic efficiency	speed
■ economic efficiency	ratio: benefit / costs
■ environmental compatibility	miscellaneous indicators

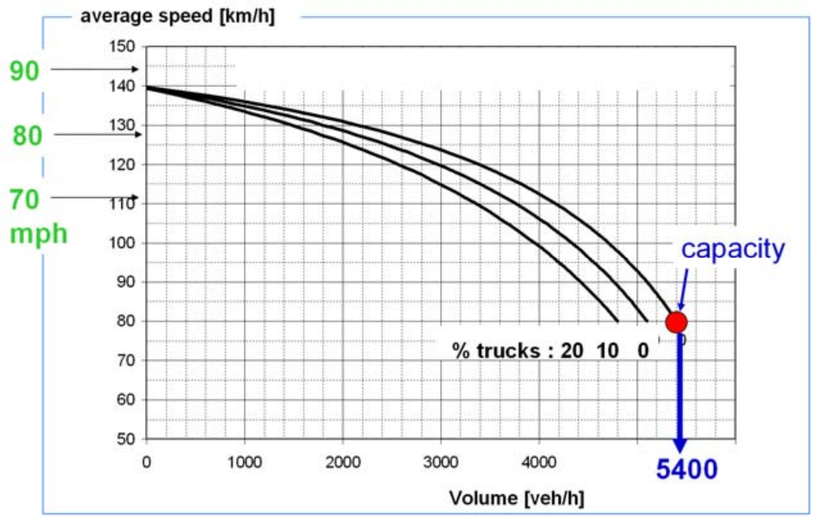
4

Classic macroscopic description of traffic flow : q-v-diagram



5

Classic macroscopic description of traffic flow : q-v-diagram



e.g. German HBS 2001 : 3-lane freeway

6

Highway Design Process

Traditional:

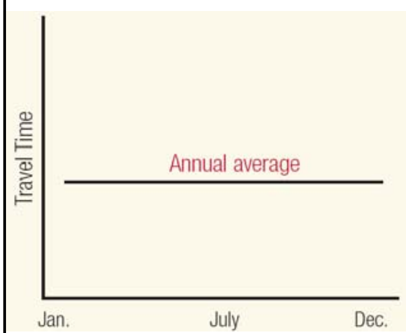
Choice of a specific single peak hour (e.g. 30th hour).

Comparison of this traffic demand and capacity to assess the quality of traffic flow.

7

Highway Design Process

Traditional:



Reality:

source of pictures: FHWA

8

Limitations of traditional analysis:

- A single peak hour can not reflect the whole life cycle of a road infrastructure.
- Highest demands are not considered.
- Average Speed is not of too much importance to the drivers.
- Small increase of speed does not produce economic benefit.
- Only applicable for proper operation; no consideration of disturbance due to work-zones, accidents, incidents, weather
- No assessment of overloaded conditions (LOS F).

Consequences:

- We need a modified scale to evaluate traffic performance.
- The concept should focus on the intrinsic purpose of the highway infrastructure.
- The concept must consider incidents, accidents, work-zones, etc.
- This concept should be interrelated with traffic safety.

More timely Approach to express Traffic Efficiency

Objective of the road user (both passengers and cargo):

- **to arrive within a time margin which can reasonably expected.**

Scale for traffic efficiency important to the road user:

- **risk of a remarkable delay.**

→ Reliability

11

Future Parameters of Traffic Performance

Reliability =

Probability that the motorway operates at a performance level better than a defined minimum standard (i.e. a still satisfactory service quality; e.g. LOS D)

Indicators for reliability:

probability of congestion
delays per year due to freeway overload
duration of all congestions during a year
ratio of real travel time to average travel time
....

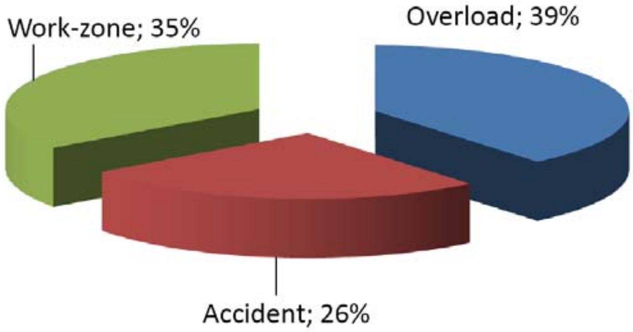
12

Potential reasons for breakdowns on motorways:

- failure of infrastructure
- accidents
- incidents (vehicle malfunction, road closure, …)
- demand exceeds capacity
- work-zones with reduced capacity
- bad weather (storm, snow, heavy rain, bad visibility…)
- other events: like festivals, sporting events, catastrophes, …

Disfunctioning of motorways

Observed reasons for breakdowns on motorways:



Reliability is a function of:

- basic capacity of the infrastructure
- maintenance of the infrastructure
- performance of control systems
- qualification of operational staff
- quality of vehicles
- behavior of drivers
- weather
- …

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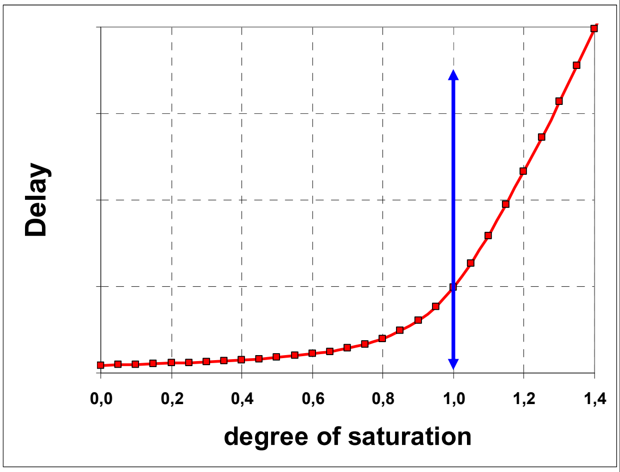
Two basic features of transportation systems:

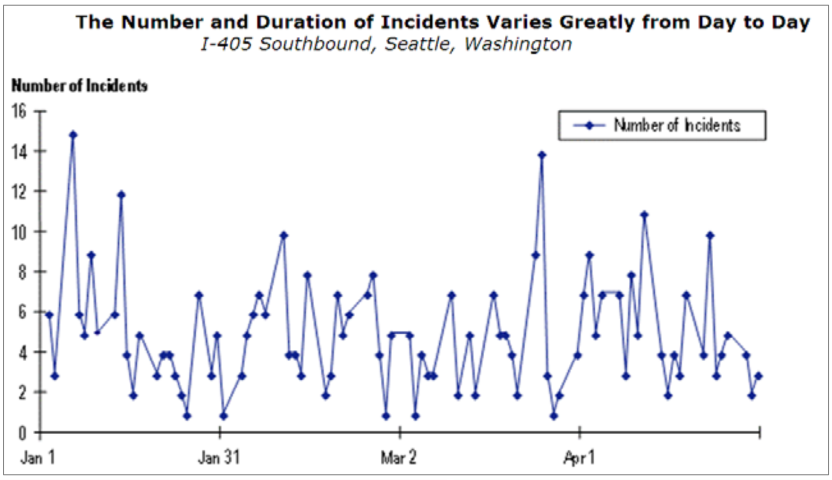
1. Non-linearity
   - Up to ≈ 60% of capacity
     traffic systems are not sensible to moderate disturbances.
   - at-capacity:
     Small incidents
     cause
     severe congestion.



16

Two basic features of transportation systems:

2. Normal operation (like designed) is happening very seldom.
   (always more than 10 % of the network are work-zones.)



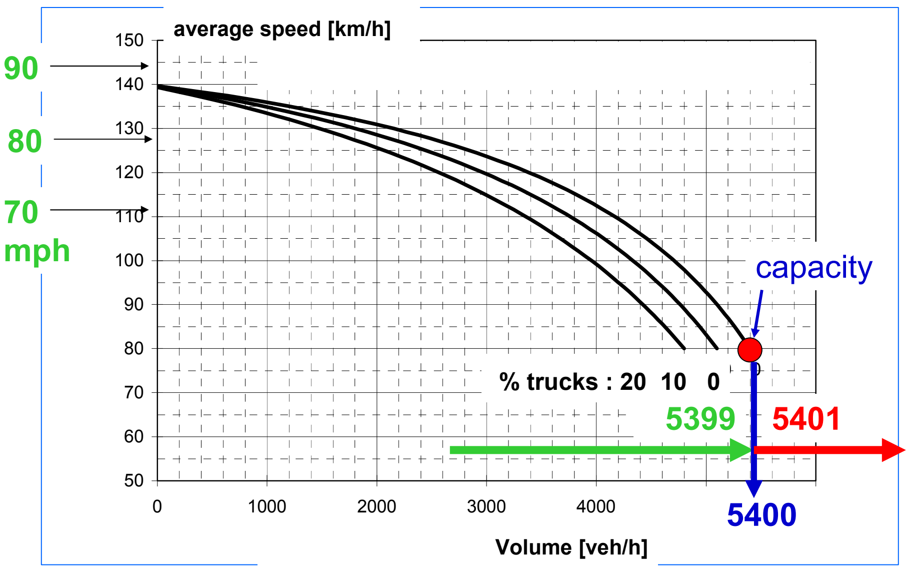
source of picture: FHWA

17

2. How to measure reliability?

- **variability of travel times**
  - variance of travel times
  - 95th percentile of travel time
  - travel-time index (TTI) $= \dfrac{\text{average travel time}}{\text{travel time (free flow speed)}}$
  - planning time index (PTI) $= \dfrac{95\%\ \text{travel time}}{\text{travel time (free flow speed)}}$
  - buffer index $= \dfrac{\text{expected max. lost time}}{\text{average travel time}} \cdot 100$
- **percent of on-time arrivals**
- **lost times due to congestion**
- **probability that a driver experiences congestion; i.e. percent failure based on a target minimum speed.**

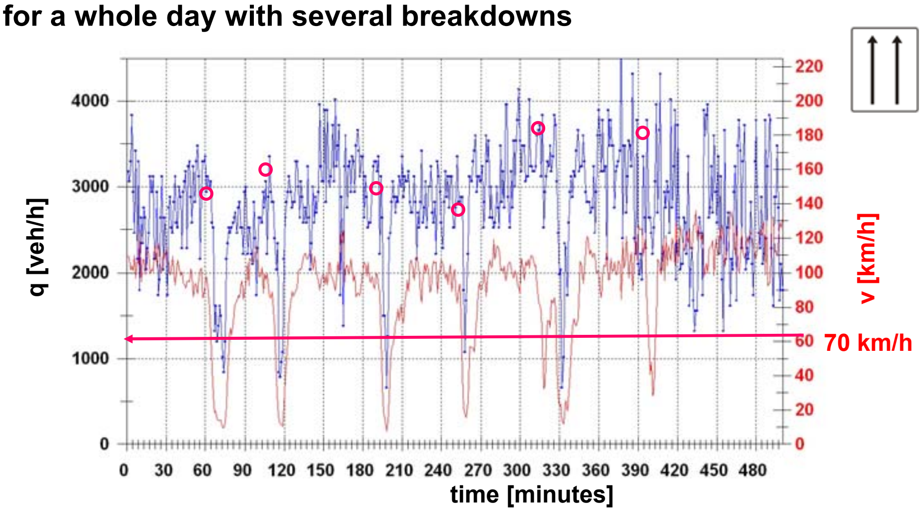
18



19

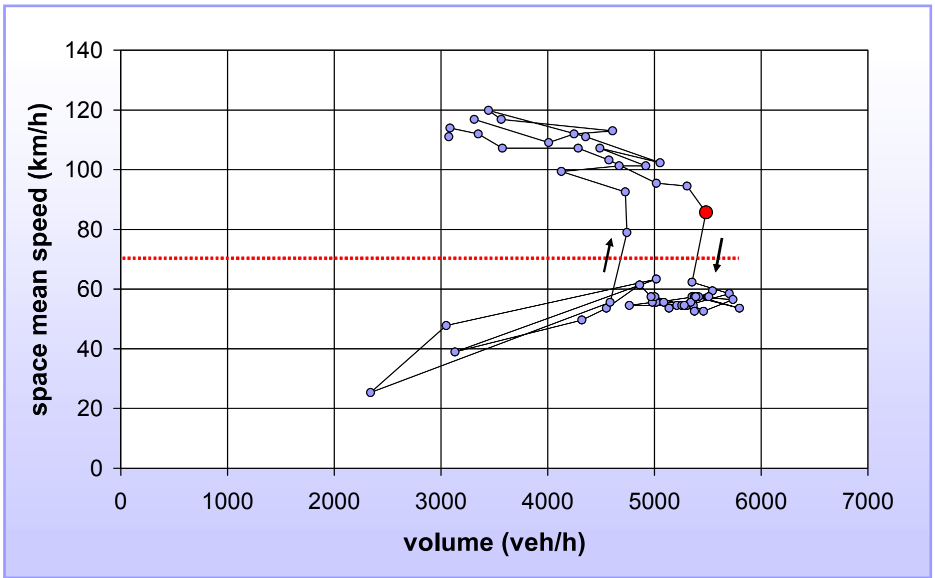
Randomness of Capacity

Pattern over time for traffic volume and speed (1-minute-intervals) for a whole day with several breakdowns



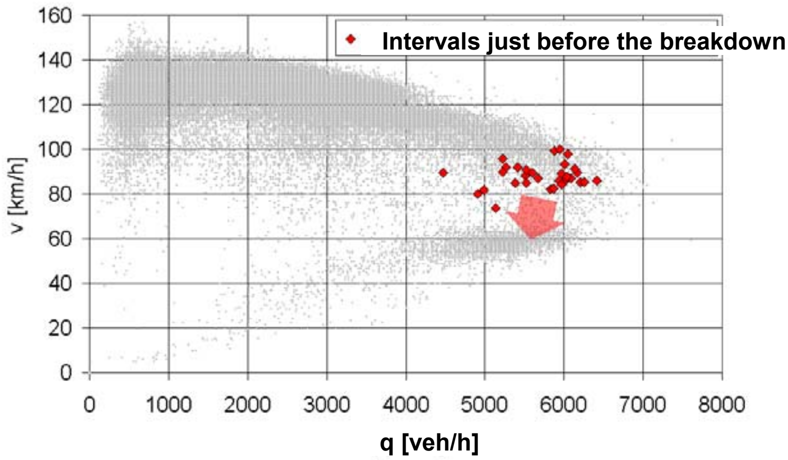
20

Randomness of Capacity

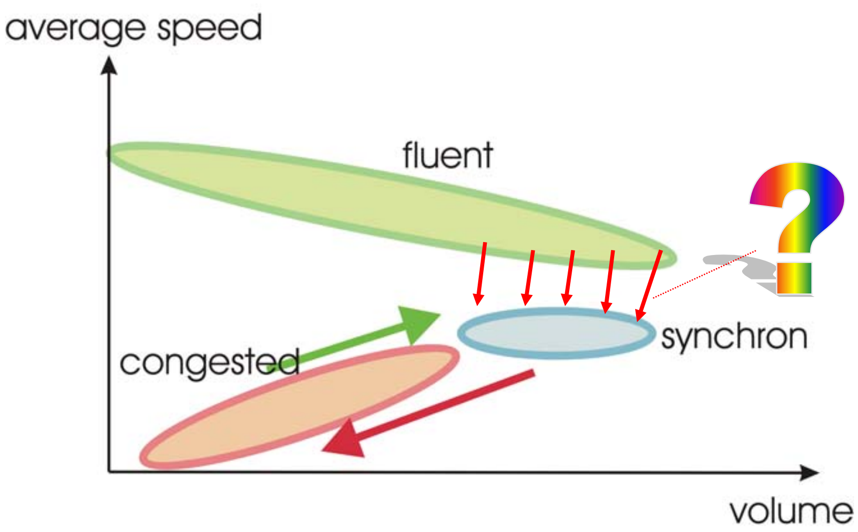


Randomness of Capacity

Variability of traffic volumes preceding a breakdown



Randomness of Capacity



Weibull-Distribution for the Breakdown Capacity

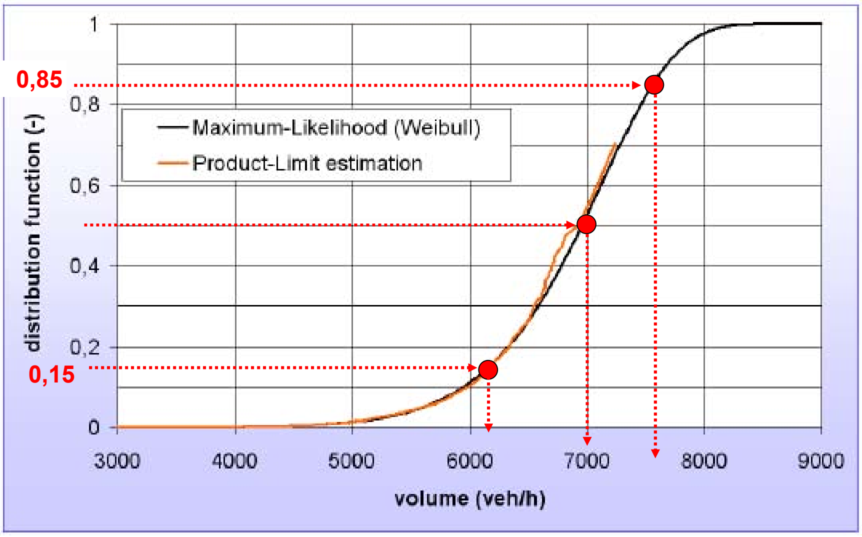
Density function	Distribution function
$f(x) = \frac{\alpha}{\beta^{\alpha}} x^{\alpha-1} e^{-\left(\frac{x}{\beta}\right)^{\alpha}}$	$F(x) = 1 - e^{-\left(\frac{x}{\beta}\right)^{\alpha}}$

β = scale parameter α = form parameter

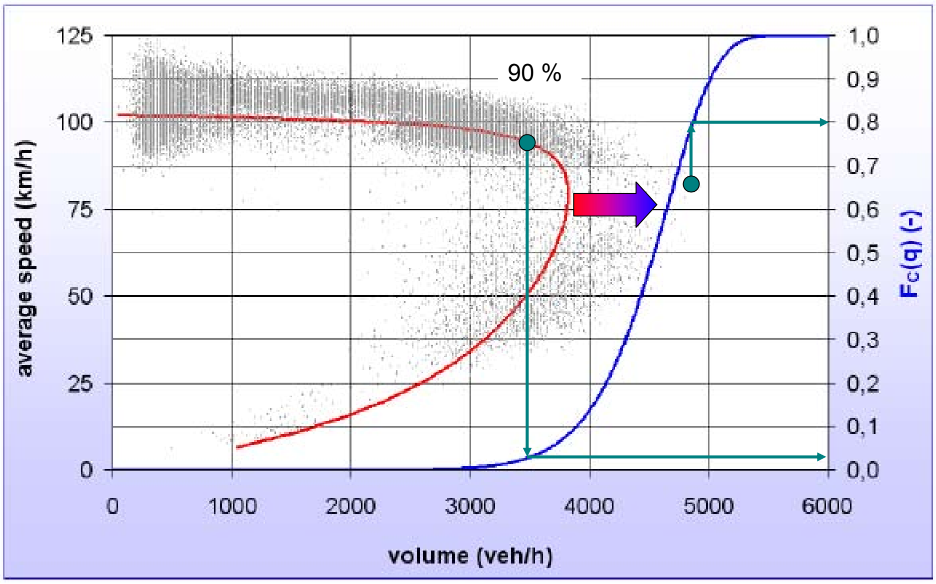
Maximum-Likelihood Estimation with Weibull-distribution

$$L = \prod_{i=1}^{n} \left[\left(\alpha \cdot \beta^{-\alpha} \cdot q_i^{\alpha-1} \cdot e^{-\left(\frac{q_i}{\beta}\right)^{\alpha}} \right)^{\delta_i} \cdot \left(e^{-\left(\frac{q_i}{\beta}\right)^{\alpha}} \right)^{1-\delta_i} \right]$$

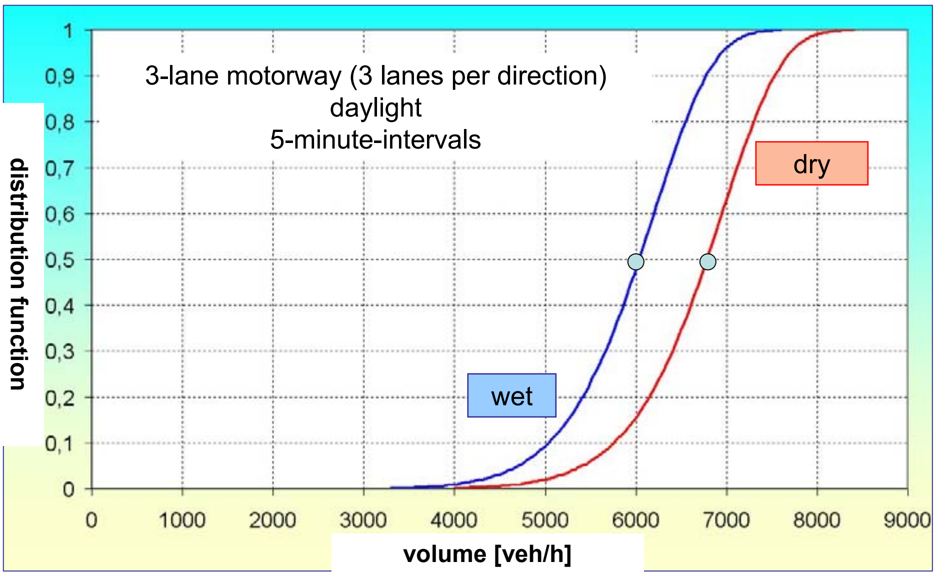
Distribution Function of Freeway Capacity (3 Lanes, 5-Minute Intervals)



Deterministic versus Stochastic Capacity



Comparison : dry / wet road surface



27

Whole year analysis (WYA) of traffic performance

A year is generally long enough
to capture nearly all of the variability
caused by various kinds of breakdown

and, thus, to represent also longer periods:

Congested situations:

- How often?
- Worst situation to be expected?
- Total impacts?

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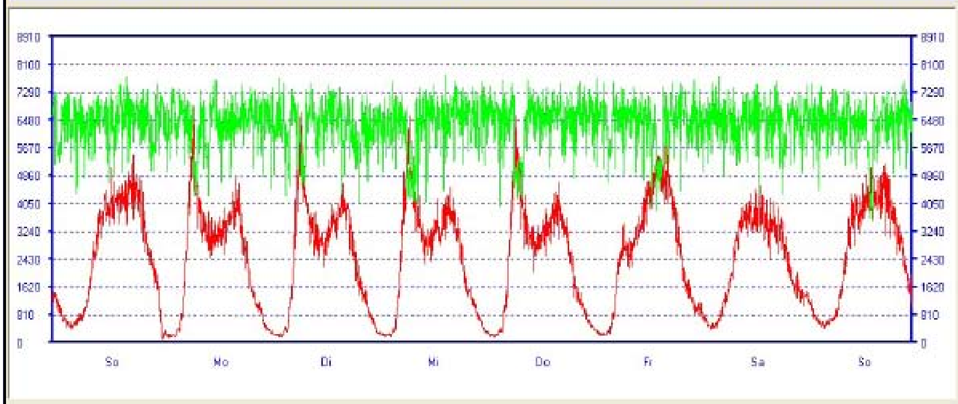
Whole year analysis (WYA) of traffic performance



capacity

demand

29

Whole year analysis (WYA) of traffic performance

Taken into account :

- random variation of capacity and of demand
- capacity drop
- accidents and incidents
- wet road surface capacity reduction

Method:
Monte-Carlo-simulation with mutliple evaluation of delays etc. for a whole year
+ subsequent calculation of expectations

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Whole year analysis (WYA) of traffic performance

Results :

- duration of congestion
- sum of all delays
- number of vehicles involved
- percentage of vehicles involved
- economic value of delays
  (all as expectation per year)
- Travel time index, Planning time index, Buffer-index
  …

can be combined with evaluation of ecological parameters (e.g. fuel consumption,…)

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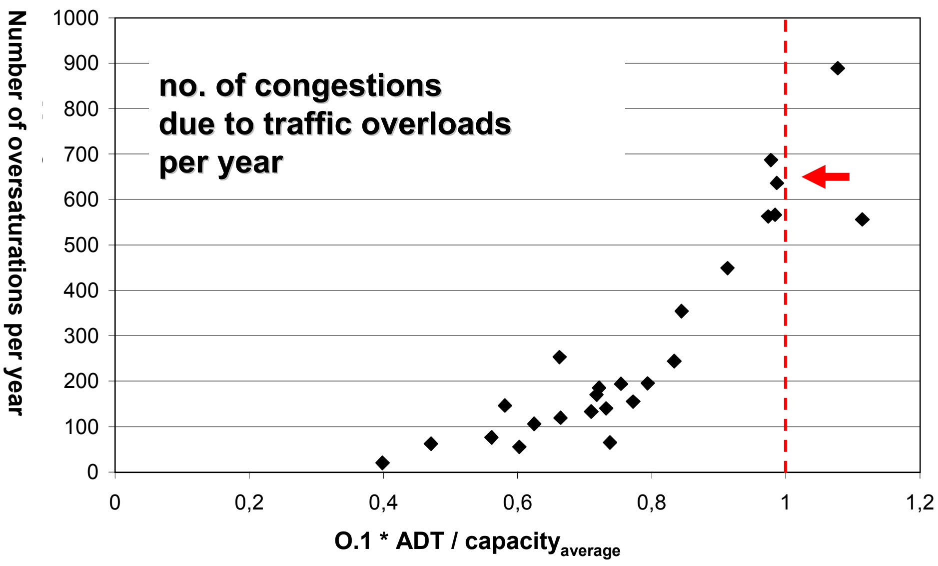
Whole year analysis (WYA) of traffic performance



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Whole year analysis (WYA) of traffic performance

Results from with/without analysis:

- effects of accidents + incidents
- effects of traffic control devices
- effects of organizational improvements (fast accident removal, work-zone management,…)
- effects of structural improvements

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3. How to improve reliability?

- capacity and infrastructure
  - adequate infrastructural capacity
  - active traffic control
  - temporary hard-shoulder running
  - work-zone management
  - emergency management (accidents & incidents)
  - high-quality construction of infrastructure → less maintenance

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Adequate capacity of the infrastructure

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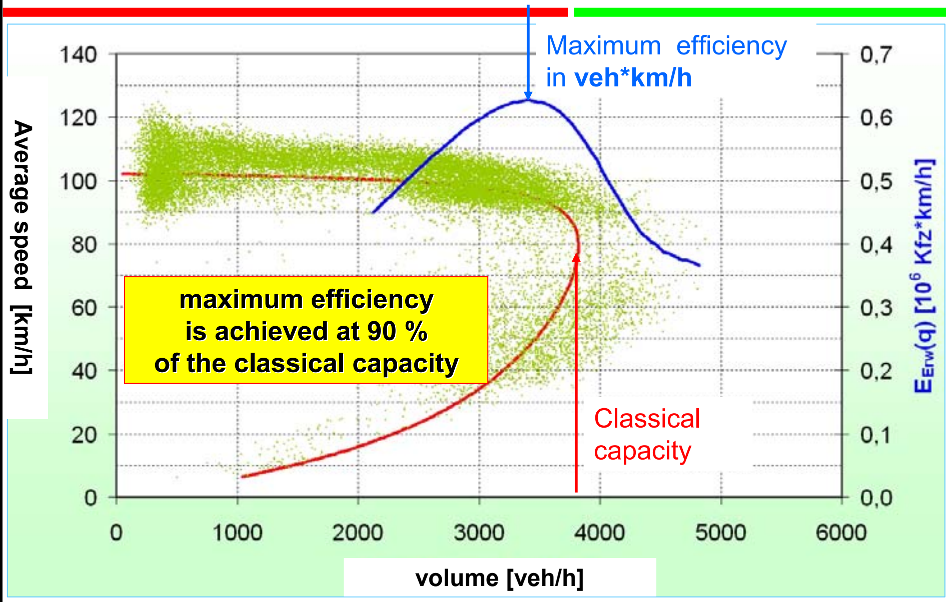
Optimization of efficiency [veh*km/h]



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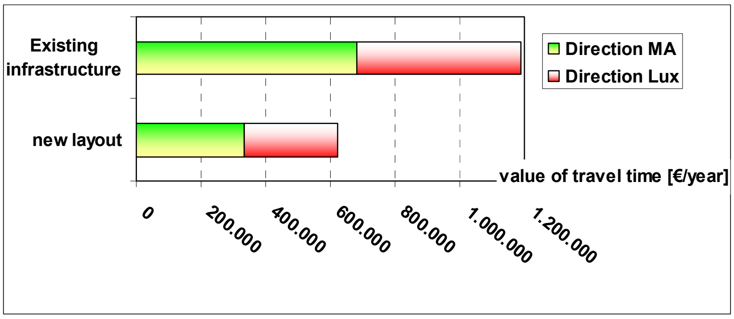
Appraisal of motorway design schemes by WYA

example: restructuring of an urban motorway (A620):



reduced delays: 76 600 veh-h/year	reduced cost of time: 570 000 €/year
justifies an investment of	8.4 Mio €

+ improved safety

Active traffic control

Motorway traffic control center

(with manpower, video supervision, …)

+

mandate to take action

(police, emergency services, traffic control devices, road workers)

Temporary hard shoulder running

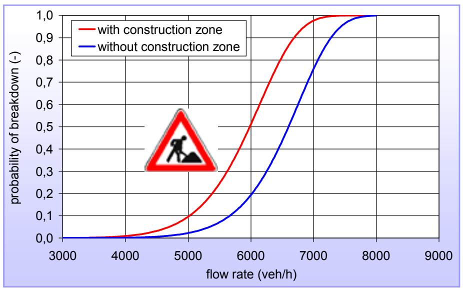
- → only during peak hours
- → always with a speed limit of 100 km/h
- → + 25 % capacity
- → no additional risks

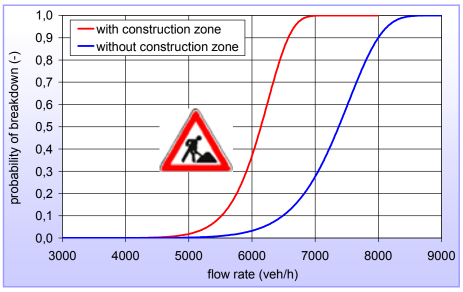
Work-zone management

Work-zones reduce capacity → reduced reliability

Freeway Sections with work-zone (5-Minute Intervals)

Freeway A3, 4+2 scheme	Freeway A5, 5+1 scheme





Median Capacity -9.4%	Median Capacity -16.7%

Standard deviation is significantly lower

Median of capacity distribution of a construction zone (3-lane carriageway) is in the range of 6000 to 6300 veh/h

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Work-zone management

a) timing of construction works and maintenance
   (e.g. during holiday season; in off-peak periods;…)

b) reduction of work-zone duration
   by rewarding construction firms for work acceleration

to be tested by WYA

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Emergency management (incidents & accidents)

- less accidents → more reliabilty

  Everything which avoids accidents
  will improve the reliability of the system.

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Emergency management (incidents & accidents)

- Reduction of the duration of lane closures due to accidents
  - modified strategies for the police
  - presence of tow-trucks during peaks at bottlenecks
- Charging drivers (accidents & incidents)
  according to the degree of congestion caused (conceptual)

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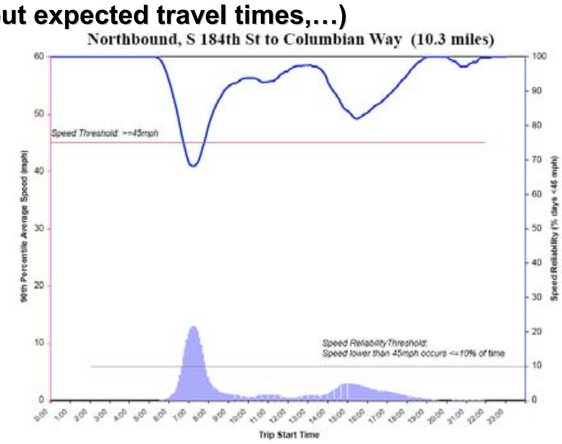
3. How to improve reliability?

- **demand**
  - **time dependent tolls**
  - **demand management**
    (e.g. rewards for off-peak travel; (e.g. NL: Sitsmijden)
    better information about expected travel times,…)

Seattle freeway reliability scheme



source of picture: WS-DOT

3. How to improve reliability?

Best time to leave

Where are you starting from: Seattle

Where are you going? Redmont

When do you need to et there? 8:25

Your 95% travel time is 31 minutes.
95% of the time
you would need to leave at 7:54 AM to arrive by 8:25 AM.

source of picture: WS-DOT

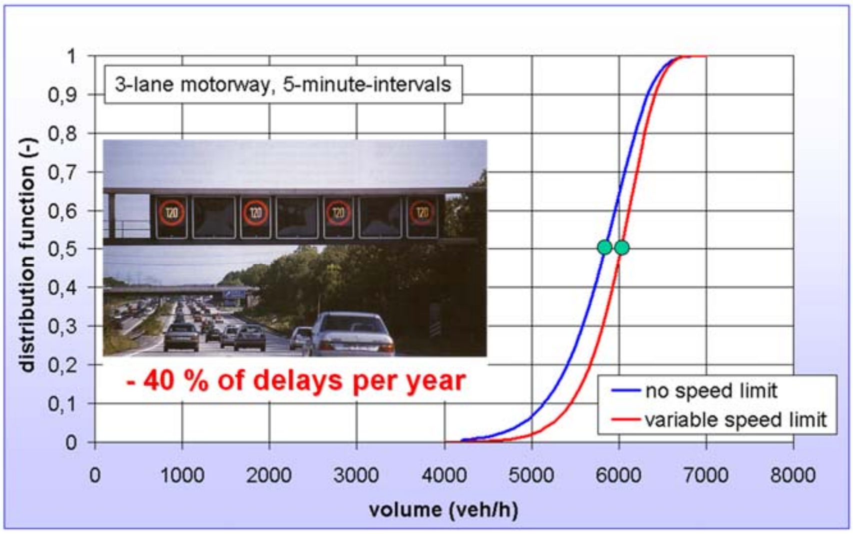
3. How to improve reliability?

- **smoothening traffic flow**
  - traffic adaptive speed control
  - truck overtaking restrictions
    (above specified levels of traffic flow)
  - ramp metering
  - integration of in-vehicle and stationary guidance systems
  - driver education

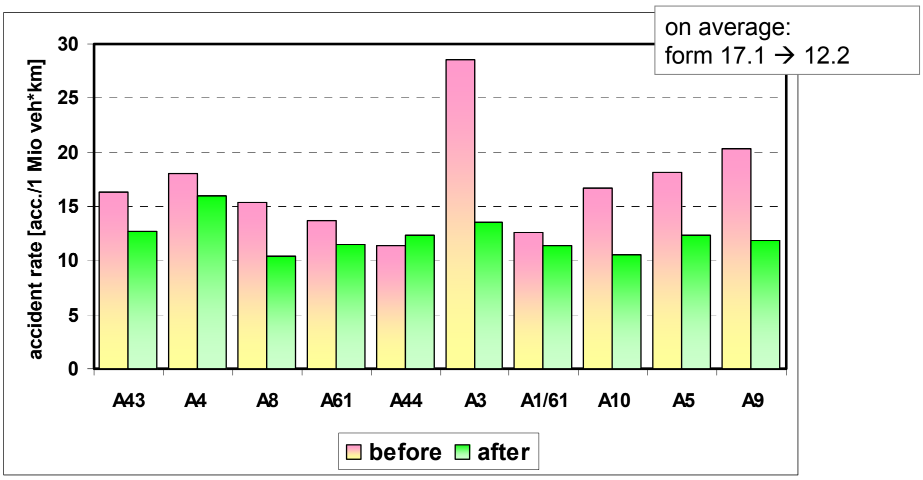
Active adaptive speed control

with additional temporary truck overtaking prohibition

Impact of dynamic speed control



Impact of dynamic speed control on safety



Accident rate: before/after analysis at 10 traffic actuated speed control sites (Siegener e.a. 2000)

Ramp metering

Bochum / Germany

UK

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Travel time indication

Frankfurt / Germany

Paris

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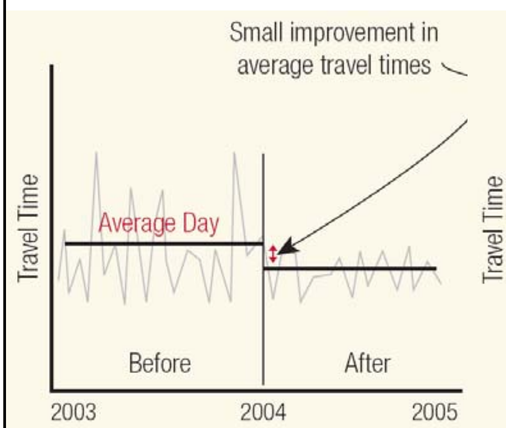
Travel time indication

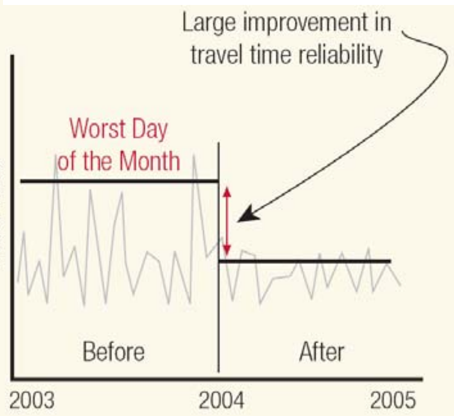
Travel time indication by navigation systems

teaches drivers that aggressive driving does not save travel time.

Traditional concept

Reliability concept





source of pictures: FHWA

Focus on Reliability in the USA

Figure 5. A reliability measure is included in FHWA's Monthly Congestion Dashboard Report

Status: Green Progress: Green	NATIONAL CONGESTION INDICATORS								
	Hours of Congested Travel Per Day			Travel Time Index			Planning Time Index		
Current Quarter	4.823			1.284			1.690		
Same Quarter, Previous Year	5.181			1.294			1.707		
Change vs. Previous Year	6.91% ⬇			0.77% ⬇			1.00% ⬇		
National Congestion Pattern	# of Cities DOWN >5%	# of Cities NO CHANGE	# of Cities UP >5%	# of Cities DOWN >5%	# of Cities NO CHANGE	# of Cities UP >5%	# of Cities DOWN >5%	# of Cities NO CHANGE	# of Cities UP >5%
Total Cities: 19	9	4	6	2	17	0	4	13	2

source of picture: FHWA

Advantage of Reliability Concepts

- **Reliability is more important than speed both for travelers and cargo**
- **Reliability paves the way towards traffic performance based on**
  - **infrastructure improvements**
  - **traffic control measures**
  - **organizational input**
- **Full integration of overloaded situations (LOS F) into the system of performance assessment.**
- **More reliability → more safety**
- **These integrated concepts meet today's necessities**

Conclusion

- Safety is target #1
- beyond safety the central objective for motorway design and operation → Reliability
- mathematical description of breakdown probabilities = key to reliability management
- WYA (whole year analysis) = adequate method for analysis
- In addition to infrastructure organizational (soft) measures provide a significant contribution to improved reliability.
- Reliability and safety complement each other: = 2 sides of the same medal.

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Thank you for listening

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講演者　Presenter

Dr. Dominique Fleury / France

交通安全への地域的アプローチに関する研究

Research on the territorial approach to safety

Research
on the territorial approach to safety

D. Fleury
IFSTTAR - France

IATSS 2012 International Workshop
20 – 21 September

The trend of safety in France: from 8,253 deaths in 2001 to 3,963 in 2011

Research on the territorial approach to safety

- **The evolution of the territorial approach to safety**
- **Safety as an area of complex system management.**
- **The conditions for improvement**

I - The evolution of the territorial approach to safety

How safety had structured traffic network design

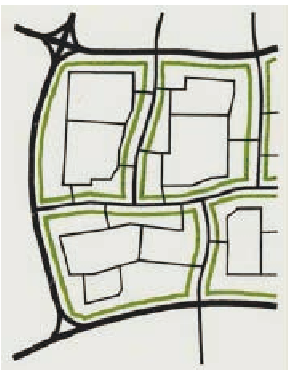
- 19th century: the development of motorised transportation has a tremendous impact.
- Great specialisation of traffic areas (according to speed)

Cerda, Henard, Le Corbusier, ..

*Principles of **segregating modes** of transportation and the **hierarchy of roads***

How safety had structured traffic network design

- Buchanan



Principle of environmental area

- The SCAFT guide of 1968

-Reduce traffic by *localising activities*

-*Separate modes of transportation*

-*Differentiate the network* by functions

-*Differentiate the various traffic flows*

-*Clarify, simplify and standardise the design*

-Design a *safe road side*

How safety had structured traffic network design

The "Woonerf" in the 70’s

Integrating modes and functions
"traffic calming" principles

The dynamic of design resulting from an “Island Strategy”

Controversies

30-km/h city

- In Great Britain, Living Streets has launched a campaign to reduce speed in London to 20 mph.
- In Switzerland, ATE (Association of Transports and the Environment) pushed for a vote on a popular initiative held on 4 March 2001 (rejected by 79.7%)
- In France : Fontenay aux Roses, Nogent sur Marne, Sceaux, Clamart, Sèvres, Clichy la Garenne, Lorient, Neuilly-les-Dijon… but…
- In 2011, 54.9% of the population of Strasbourg rejected the project to turn the city center into a 30 km/h zone

Naked Street

- *“A street or public space where vehicle movement and other activities are combined through informal social protocols, negotiation and design solutions rather than through formal regulations and controls*.” (Living Streets, 2009).
- Many towns have experimented with this concept.
- But there is no consensus : Blind People, Deaf People, Cyclists

II - Safety as an area of complex system management

The actual design

- Road safety not the main challenge in public space layouts
- other considerations : accessibility, urban quality, sociability, etc…

Concerns sometimes contradictory:

- fewer cars in front of houses but greater accessibility
- lower speeds and rerouted lorry traffic
- shopkeepers want more parking spaces and better vehicle rotation
- associations want more cycling paths
- less nuisance and fewer traffic jams

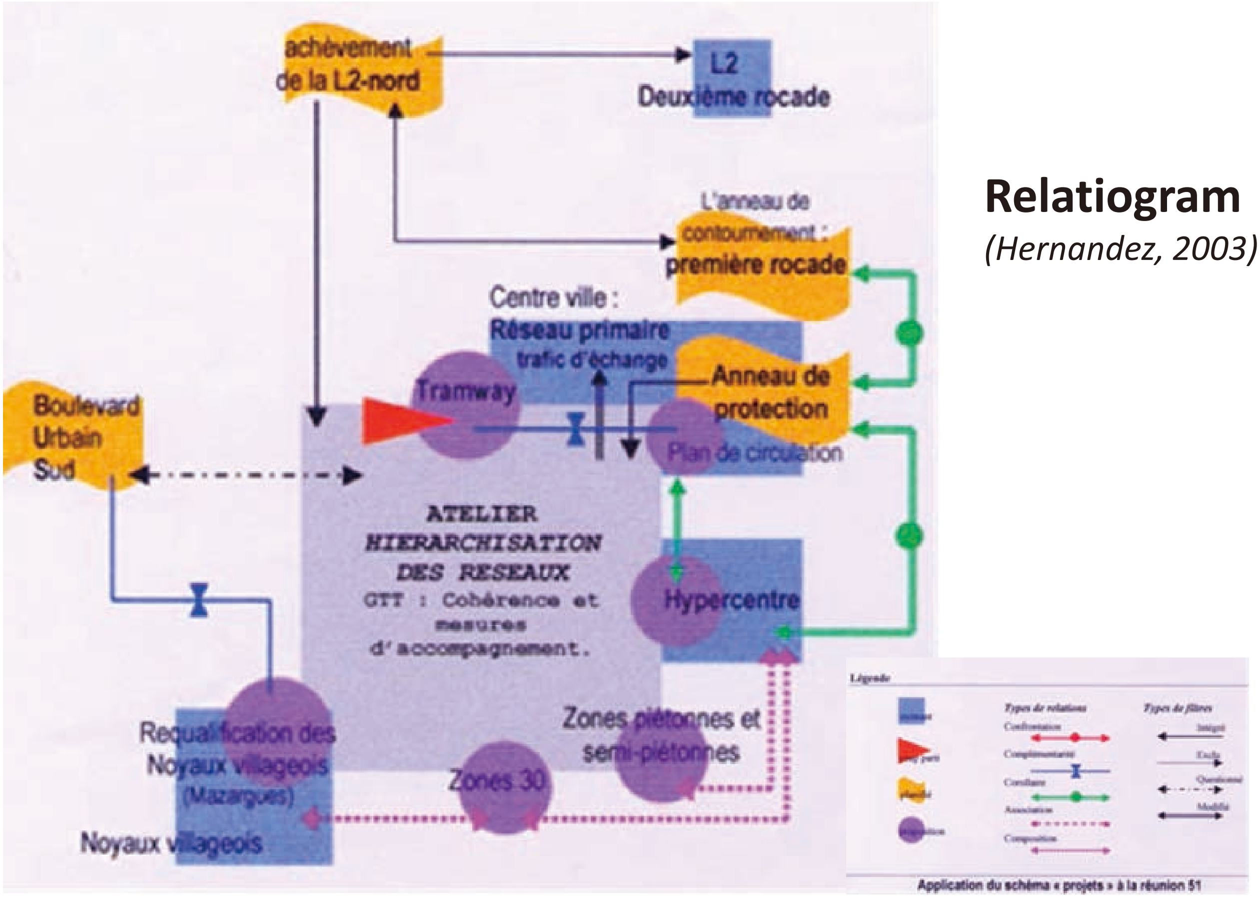
But *all constraints involving private transportation are politically difficult to promote*.

In practice

A safety diagnosis is carried out, soon forgotten

Thesis of Frédérique Hernandez (2003) on Local Transport Plan in Marseille.

- An action scene with the decision-making actors
- confrontation between possible solutions
- precise projects and more general technical notions



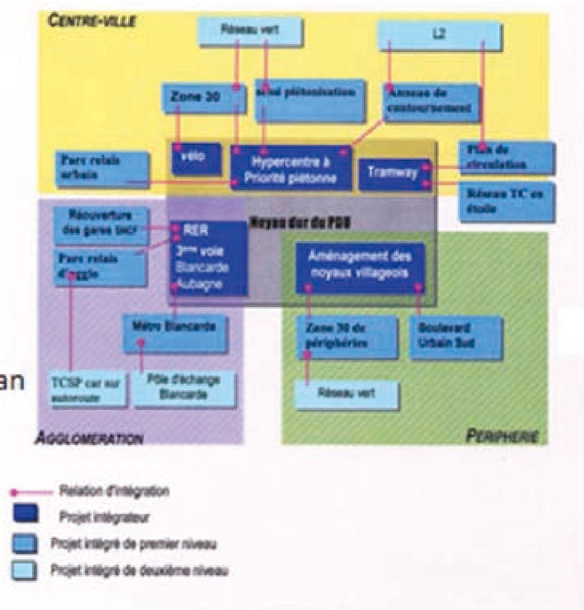
Relatiogram
(Hernandez, 2003)

A process:

- certain projects disappear from the technical landscape
- relations become clearer
- coherence arises
- the Local Transport Plan scheme takes form

an “island strategy”:
- automobile traffic bypasses the central areas
- dense zones are connected by public transport
- the primary network is requalified with the tramway, reducing room for private travel modes
- high-performance cycling network is created…

Central Business District



"island strategy" at different scale

Marseille Metropolitan Area

The entire town

A current practice

INSECURITY —Reference to→ OPERATIONAL TOOLS —Laid down in→ TECHNICAL DESIGN

Complexity

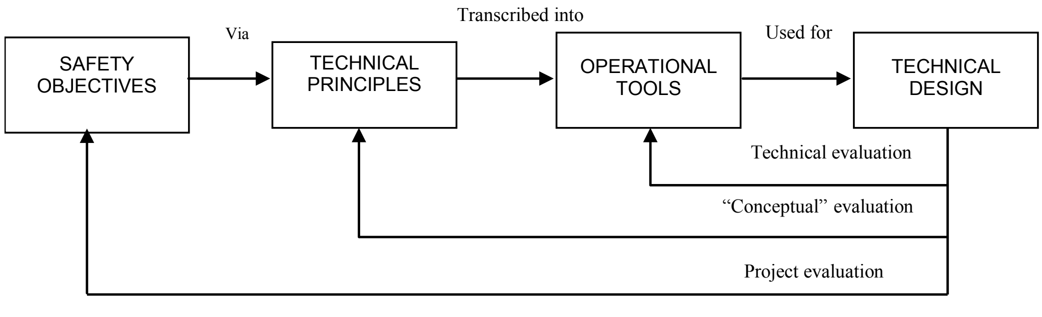
- Because of the **adaptability of users**, drivers, pedestrians – users of public spaces

The road system is a **complex system** and is therefore unpredictable.
- The relationship between the decision maker and the population using traffic spaces is a two-player game.
- the user will adapt his behavior in a way that is more effective for him, and not necessarily in a way that is better for collective safety

- *improvements to visibility that reduce attention*
- *road resurfacing that increases speed*
- *creating cycling lanes used by powered two-wheelers*
- *misuse of on-board systems …*

All decisions are taken in a context of uncertainty. It is then necessary to measure the results of actions

But let us imagine that safety could become a priority objective…



This use of **objectives**, then technical **principles**, and then **tools** for integration, requires a real evaluation effort in return

- The *technical evaluation* measures the impact of a project's implementation on safety
- The *conceptual evaluation* provides feedback used to apply a particular tool in several
- The *project evaluation* widens the viewpoint to the entire decision-making process

III - The conditions for improvement

Training in road safety

Ezra Hauer (2007) describes two styles of thought on road safety

- The first is "pragmatic", based on beliefs and the immediate interests of organizations.
- The second style defined by Ezra Hauer is "rational"

Four reasons explain the shift from the first style to the second:

- The first is that humanity has always evolved that way
- what remains to be done requires more serious knowledge
- legislation requires safety to be taken into account when planning
- many initiatives go in the right direction

But little demand for people with road safety training, which pleads in favor of the third condition, i.e. resorting to legal obligation

The conditions for improvement

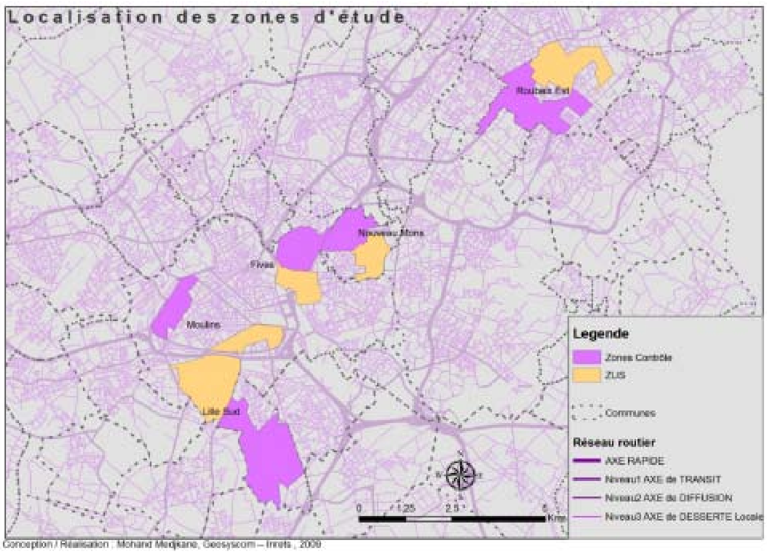
Availability of accident data.

- In 2004 in France, the transmission of current judicial proceedings to IFSTTAR
- after text recognition, automatic requests are performed
- geolocation software is used to spatialise the information

Geographic Information Systems

- Data: geographical, economic, socioeconomic, demographic or financial, networks, notably transportation networks, business or recreational areas, built-up areas by function, etc…
- The link between these two sources of information lead to the measure of risk (group of inhabitants)
- This created a change of perspective in the foundation of local public policies on road safety

Example : the relative risk of depraved areas



Estimation of the Ajusted Relative Risk : 1,363, interval [1,238 ; 1,502].

The conditions for improvement

Accident prototypical scenarios

- “A *prototypical traffic accident scenario* can be defined as a prototype of an accident process corresponding to a group of accidents with overall similarities in terms of the chain of events and causal relationships in the different phases leading to the collision”

- The construction of a real *accident nosology* in the form of prototypical scenarios

- It makes it possible to target actions to specific users, vehicles and environments

In conclusion

Who is **responsible** for safety, the urban layout designer or the user?

- avoiding all driver errors and, if an accident does occur minimal consequences.
  -> responsibility lies with the engineer (see “Vision Zero” in Sweden)
- calling for “civic behavior” or “good manners”
  -> responsibility lies with the user (see the “Naked Street”)

Coming back to the second diagram

- a good evaluation of the design processes and the layout tools
- well-documented and well-evaluated feedback

Effectiveness depends on :

- The location
- The quality of the layout
- The kinds of users present
- we need a good evaluation of the design processes and therefore to evaluate projects, rather than only evaluating layout tools independently of their location.

In conclusion

For a higher level of safety:

- the progress of knowledge and its dissemination,
- the development of technical tools for the design as well as for accident analysis and safety diagnosis,

But

- the lack of involvement of local politician and of the public, when they stress already made solution and “common sense” approach, not taking into account the complexity of the problem

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