PROGRAM ROZWOJOWY
POLITECHNIKI WARSZAWSKIEJ

Expert methods

in risk analysis

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Delphi method

A method for eliciting and synthesizing expert opinion

RAND Corporation - **R**esearch **AN**d **D**evelopment

think tank

Studies into the effects of thermonuclear war and civil defence for the U.S. Air Force.

By 1974 Delphi method used in over 10,000 studies. Most applications were concerned with technology forecasting. The method has also been applied to many types of policy analysis.

Table 1.4 A Delphi Questionnaire

Questionnaire #1

This is the first in a series of four questionnaires intended to demonstrate the use of the Delphi Technique in obtaining reasoned opinions from a group of respondents.

Each of the following six questions is concerned with developments in the United States within the next few decades.

In addition to giving your answer to each question, you are also being asked to rank the questions from 1 to 7. Here "1" means that in comparing your own ability to answer this question with what you expect the ability of the other participants to be, you feel that you have the relatively best chance of coming closer to the truth than most of the others, while a "7" means that you regard that chance as relatively least.

Rank	Question	Answer*
☐	1. In your opinion, in what year will the median family income (in 1967 dollars) reach twice its present amount?	☐
☐	2. In what year will the percentage of electric automobiles among all automobile in use reach 50 percent?	☐
☐	3. In what year will the percentage of households that are equipped with computer consoles tied to a central computer and data bank reach 50 percent?	☐
☐	4. By what year will the per-capita amount of personal cash transactions (in 1967 dollars) be reduced to one-tenth of what it is now?	☐
☐	5. In what year will power generation by thermonuclear fusion become commercially competitive with hydroelectric power?	☐
☐	6. By what year will it be possible by commercial carriers to get from New York's Times Square to San Francisco's Union Square in half the time that is now required to make that trip?	☐
☐	7. In what year will a man for the first time travel to the Moon, stay for at least 1 month, and return to Earth?	☐

*"Never" is also an acceptable answer.

Please also answer the following question, and give your name (this is for identification purposes during the exercise only; no opinions will be attributed to a particular person).

Check one:

☐ I would like
☐ I am willing but not anxious
☐ I would prefer not

} to participate in the three remaining questionnaires

Name (block letters please):

....

Source: Helmer (1968).

Self-rating of experts

Questionnaire #1

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The questions

Rank	Question	Answer*
☐	1. In your opinion, in what year will the median family income (in 1967 dollars) reach twice its present amount?	☐
☐	2. In what year will the percentage of electric automobiles among all automobile in use reach 50 percent?	☐
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Comparison of Delphi results

Question	RAND	Conference forecast
Electric autos 50%	1988	1997
Home computer consoles	2002	2010
Economical fusion power	1990	1988

Subjective data: spread

A section of pipe about 10 meters long

Used value 10^{-10} ($3 \cdot 10^{-12} \div 3 \cdot 10^{-9}$)

8 responses fall above the upper confidence bound!

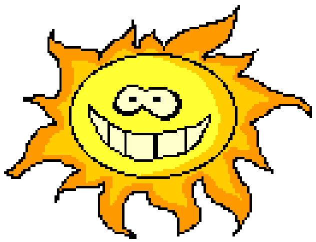
Table Estimates of Failure Probability per Section-Hour of High-Quality Steel Pipe of Diameter $\geqslant 7.6$ cm

Source	Value
1. LMEC	5×10^{-6}
2. Holmes	1×10^{-6}
3. G.E.	7×10^{-8}
4. Shopsky	1×10^{-8}
5. IEEE, a	1×10^{-8}
6. IEE, b	1×10^{-8}
7. NRTS Idaho	1×10^{-8}
8. Otway	6×10^{-9}
9. Davies	3×10^{-9}
10. SRS	2×10^{-9}
11. IKWS Germany	2×10^{-10}
12. Collins	1×10^{-10}
13. React. Incd.	1×10^{-10}
RSS estimate	1×10^{-10}
90% confidence bounds	3×10^{-9}–3×10^{-12}

Source: U.S. NRC, 1975, p. III-7.

Heuristics and biases

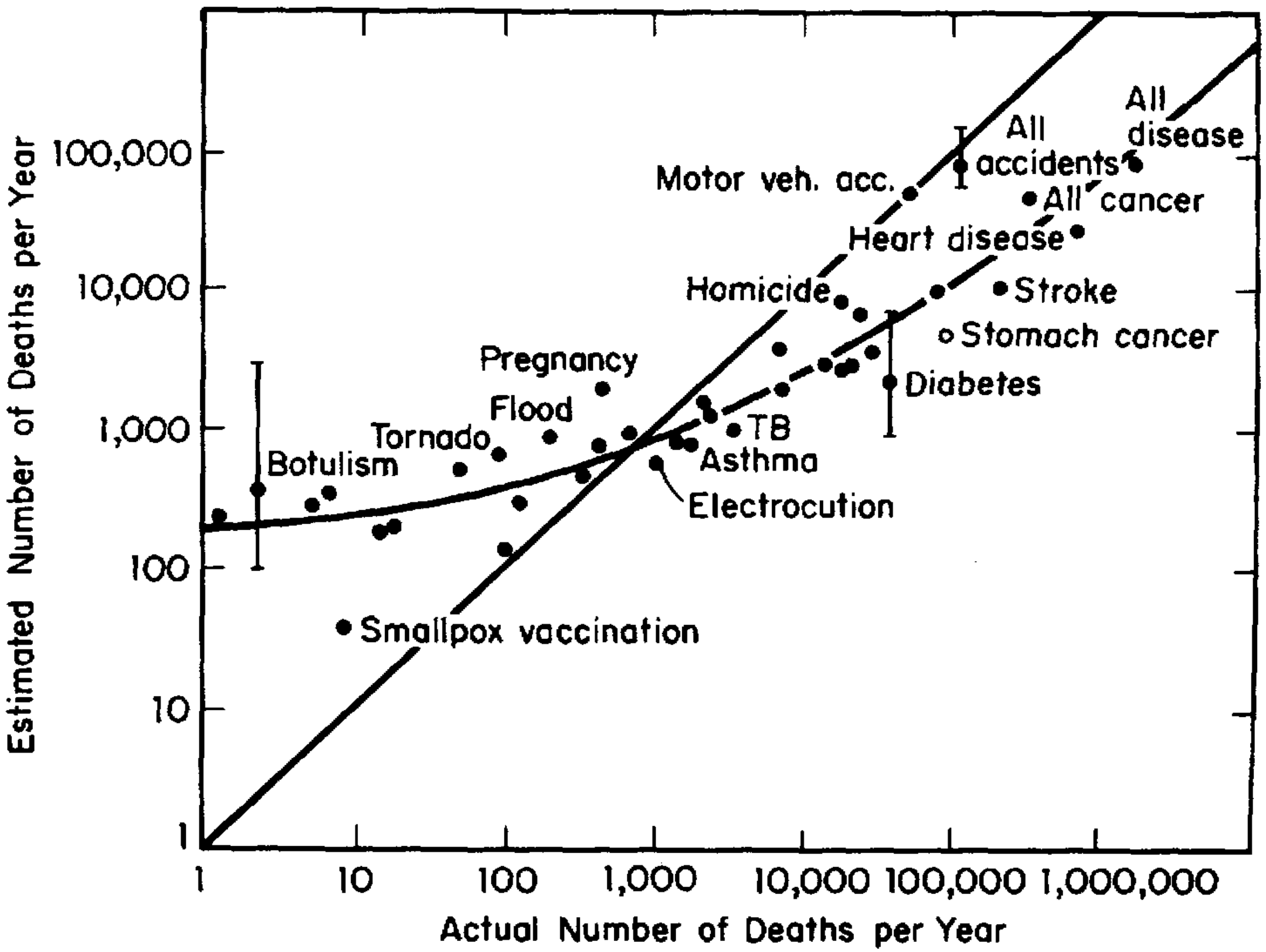
Using simple rules from everyday life (rules of thumb)



Biases due to**:**

- Distortions of judgement through ideology
- Wilful distortions of judgement (in lying)
- Misperceptions of probabilities

Availability



Anchoring

Estimate the result in 5 seconds

8 x 7 x 6 x 5 x 4 x 3 x 2

2 x 3 x 4 x 5 x 6 x 7 x 8

Median estimate

2250

512

Correct answer **40320**

Overconfidence

Control

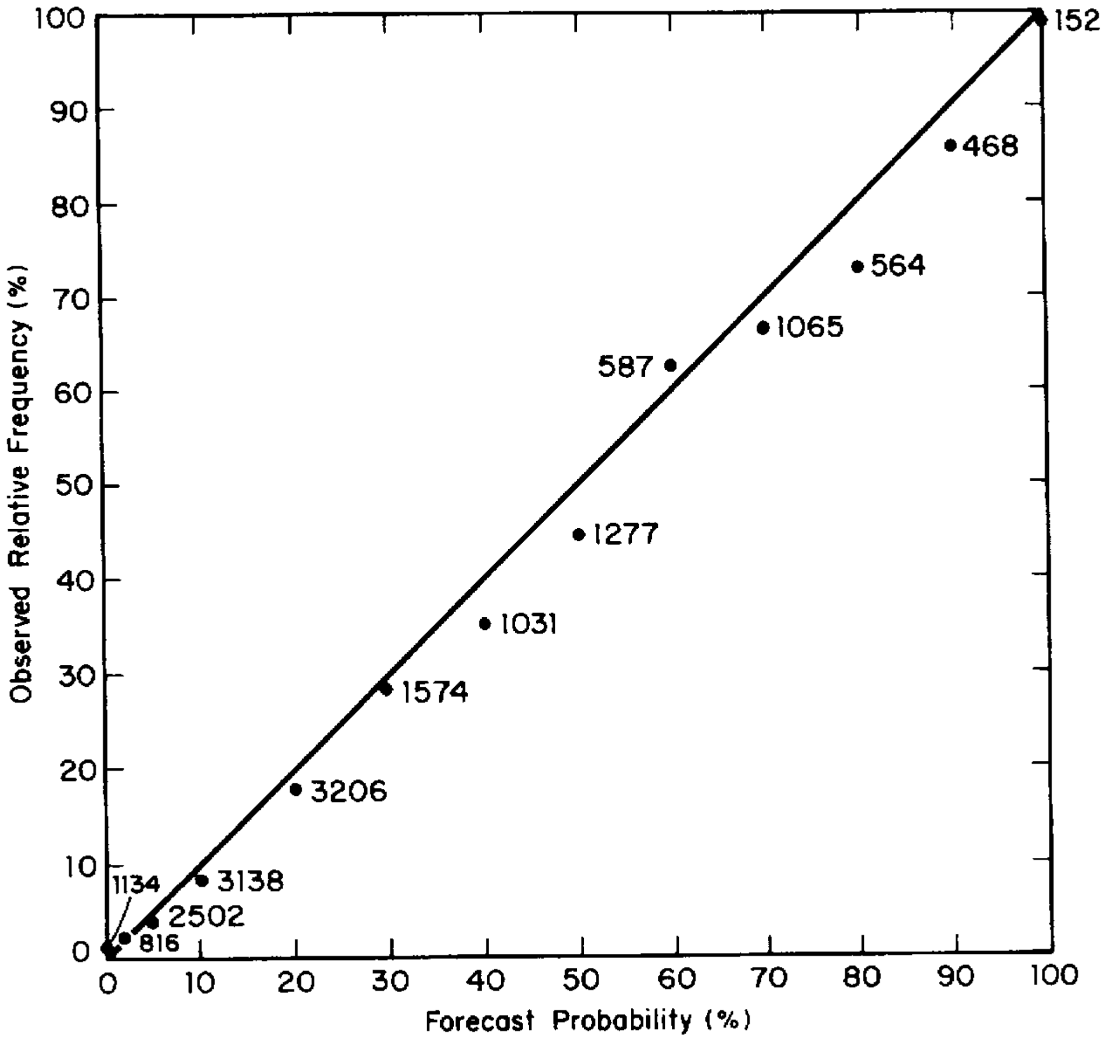
Representativeness

$$p(A|B) = \frac{p(B|A) \cdot p(A)}{p(B)}$$

Bill is 34 years old. He is intelligent, but unimaginative, compulsive and generally lifeless. In school, he was strong in mathematics but week in social studies and humanities.

A	Bill is an accountant	2
B	Bill plays jazz for a hobby	3
C	Bill surfs for a hobby	1
D	Bill is an accountant and plays jazz for a hobby	4

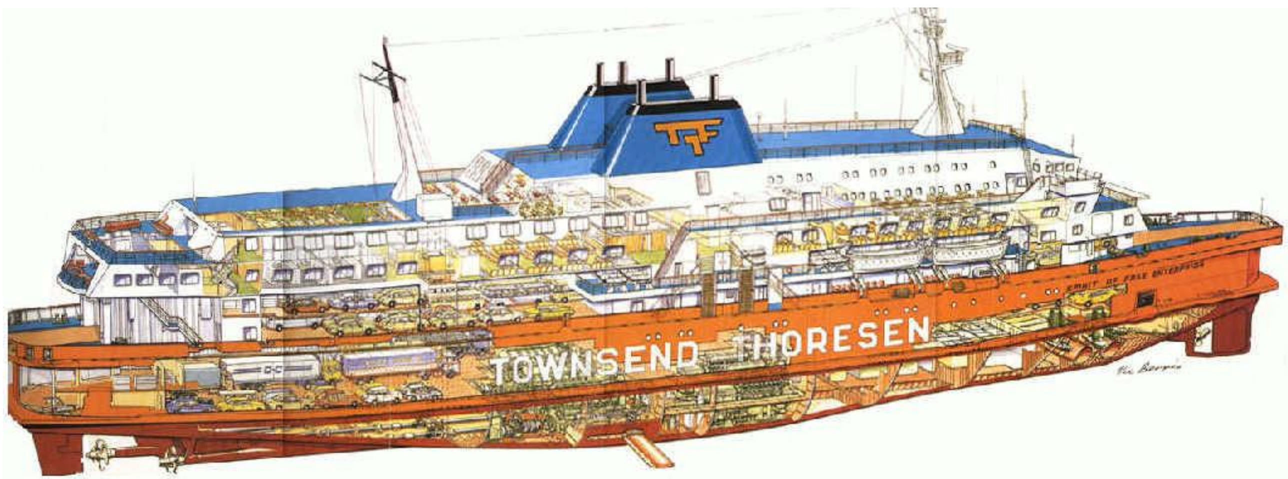
Expert calibration



The **Zeebrugge** disaster

Herald of Free Enterprise

The ferry construction



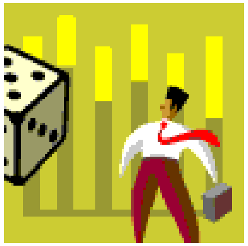
ro-ro – roll-on roll-off car ferries


TOWNSEND THORESEN


TOWNSEND THORESEN

The methods for probability assessment

Direct method



APJ – Absolute Probability Judgement

e.g. a question

How often occurs the event $\boldsymbol{A}^{(k)}$?

Possible answers:

everyday, once a week, once per month, once per year, once in a lifetime, very rarely

Procedure for the direct method

1. Select expert group
2. Prepare description of estimated values
3. Prepare questionnaires for the experts
4. Obtain judgements from every expert
5. Check agreement of expert opinions
6. Combine expert opinions
7. Estimate confidence bounds

Expert group

- safety engineers
- workers
- supervisiors
- constructors

The ranking method

In the **Ranking Method** the undesirable events are positioned in an order by every member of the expert group.

The events $\boldsymbol{A}^{(k)}$ are placed in the **ranking list**, starting from the least likely to occur and ending with the most likely to occur.

Calibration method

$$\log Q^{(l)}(1) = a \cdot (scale^{(l)}) + b$$

Paired comparisons method

PC Method

n	events
n(n-1)/2	possible pairs

calibration:

$$\log [Q(1)] = a(scale) + b$$

Advantages – good results are obtained, easy task for experts

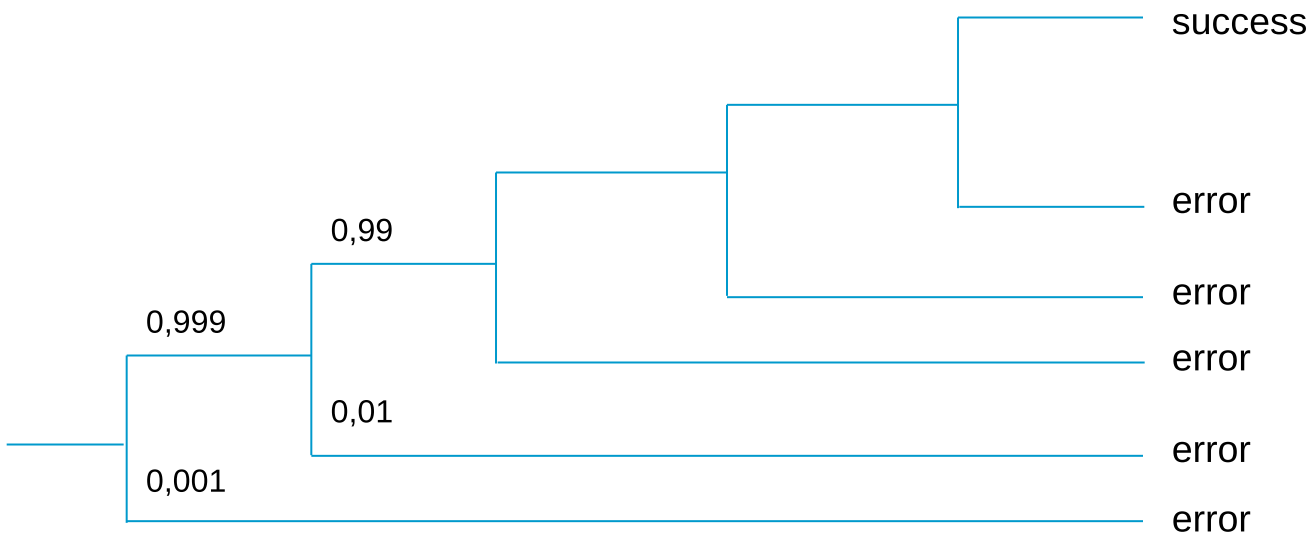
Disadvantages – calibration, complexity, requires many experts

Example

The **ranking method** application

EXAMPLE
work on a machine tool

Human action	clamps machined part	determines machining parameters	sets transmission ratio	reads and sets depth of cut	controls the turning process
Event number	B1	B2	B3	B4	B5



Expert ranking

Expert 1	B1	B5	B3	B2	B4
Expert 2	B1	B3	B5	B2	B4
Expert 3	B1	B5	B3	B2	B4
Expert 4	B1	B5	B3	B4	B2
Expert 5	B1	B3	B5	B4	B2

Average position of events

	Event number				
	B1	B2	B3	B4	B5
Expert 1	1	4	3	5	2
Expert 2	1	4	2	5	3
Expert 3	1	4	3	5	2
Expert 4	1	5	3	4	2
Expert 5	1	5	2	4	3
Sum of positions	**5**	**22**	**13**	**23**	**12**
average position (Sum of positions /5)	**1**	**4.4**	**2.6**	**4.6**	**2.4**

Probabilities of two events occurrence

Probabilities of occurrence for B1 and B2 are known:

$$Q_1 = 10^{-3},\ Q_2 = 10^{-2}$$

Error probability estimation based on statistical data

The probability $Q(1)$ of an event A occurrence in one year per one employee

$$Q(1) = \frac{W_j(\Delta\tau)}{N \cdot \Delta\tau \cdot Z(c_j)} \quad [1/\text{year}]$$

$W_j(\Delta\tau)$ – the number of accidents due to occurrence of the event A, that caused loss not less then c_j, $j = 1 \div 5$

$\Delta\tau$ – the number of data collection years

N – the number of concerned workers

$Z(c_j)$ – the probability that occurrence of the event A causes a loss in category at least c_j

Calculations

$$\begin{cases} \log[10^{-3}] = a(1) + b \\ \log[10^{-2}] = a(4{,}4) + b \end{cases}$$

or

$$\begin{cases} -3 = 1a + b \\ -2 = 4{,}4a + b \end{cases}$$

calculated values are:

a = 0,29412; **b** = -3,294

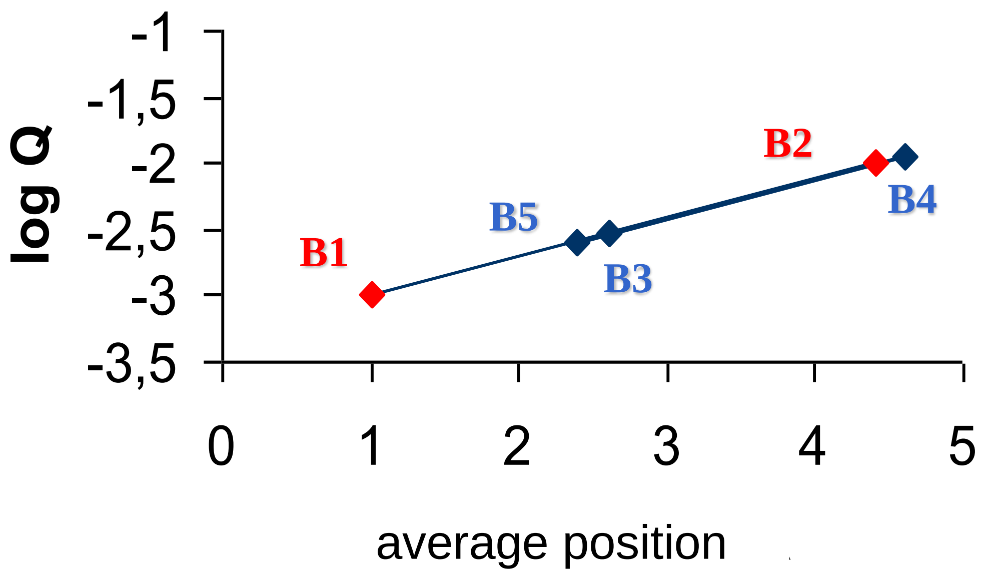
Results

Formula to calculate the unknown probabilities of occurrence for the events B3÷B5

$$\log Q = 0{,}29412 \cdot (\text{scale}) - 3{,}294$$

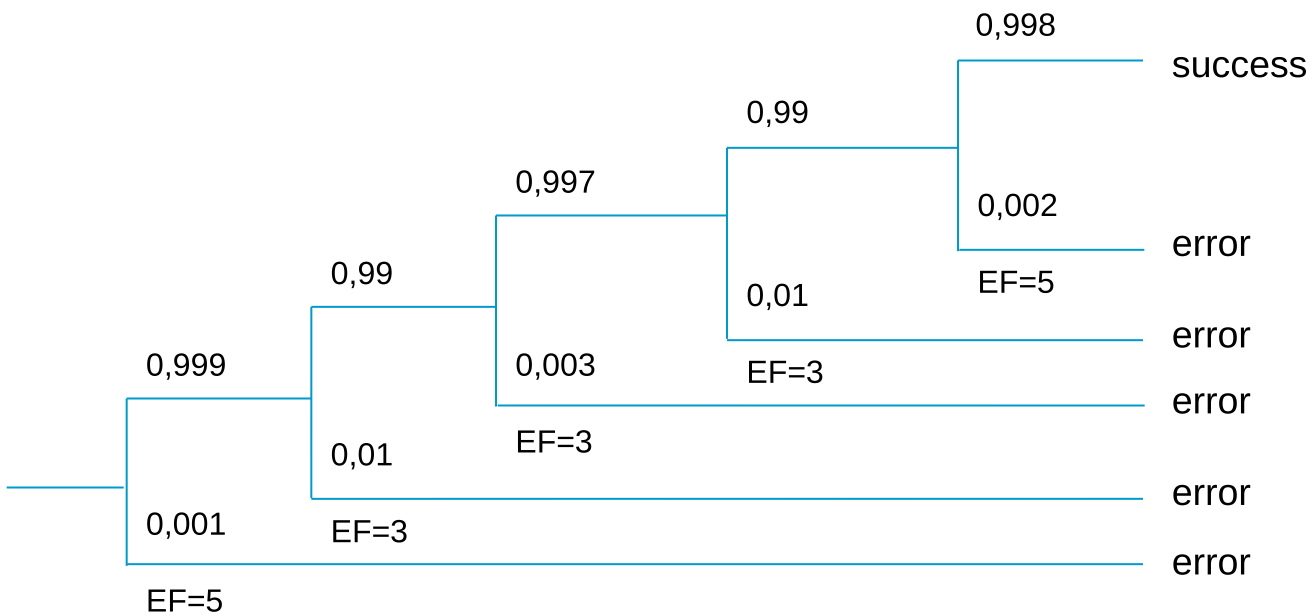
$\log Q_3 = 0{,}29412 \cdot 2{,}6 - 3{,}294 = -2{,}529$	$Q_3 = 10^{-2{,}529} \approx 0{,}0030$
$\log Q_4 = 0{,}29412 \cdot 4{,}6 - 3{,}294 = -1{,}941$	$Q_4 = 10^{-1{,}941} \approx 0{,}011$
$\log Q_5 = 0{,}29412 \cdot 2{,}4 - 3{,}294 = -2{,}588$	$Q_5 = 10^{-2{,}588} \approx 0{,}0026$

Calibration



The final event tree

Human action	clamps machined part	determines machining parameters	sets transmission ratio	reads and sets depth of cut	controls the turning process
Event number	B1	B2	B3	B4	B5



R = 0,974

Task error probability **Q = 1- 0,974=0,026**

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Human reaction time

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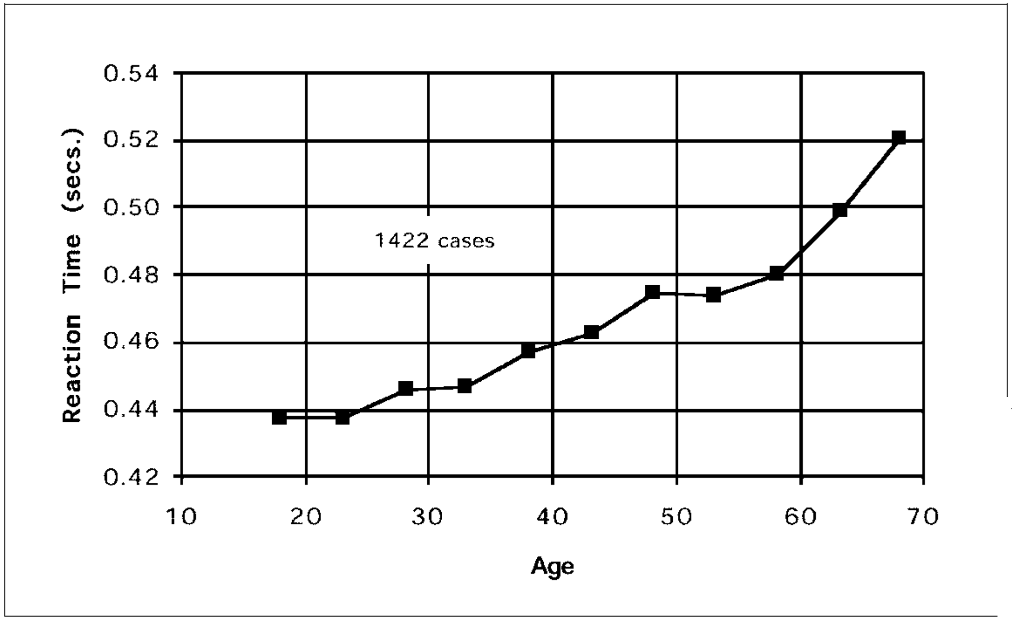
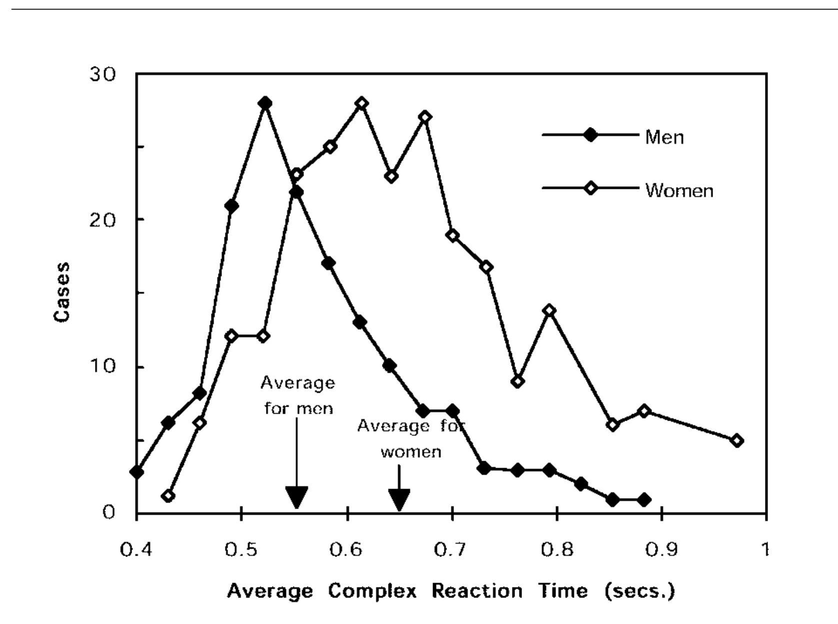
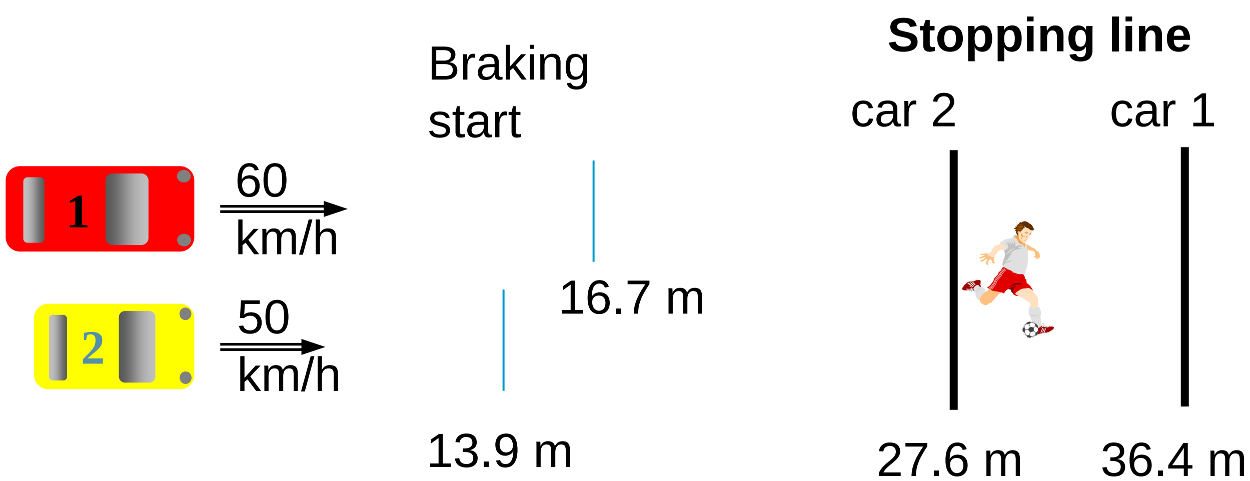
The reaction time





The influence of speed on the stopping distance



driver reaction time **1s**

car deceleration = **$7 m/s^2$**

The influence of speed on the stopping distance

car 1 in the distance of **10,9** meters decelerates by **19.7 km/h**

car 1 passes the stopping line of car 2 with the speed over **40 km/h**