JCSS
Joint Committee on Structural Safety

IABSE
COMMISSION 1

Target reliability in (building) codes of practice

Ton Vrouwenvelder (TNO, the Netherlands)

Workshop on Risk Acceptance Criteria in Civil Engineering Decision Making
Session 3: Regulatory Context
19-20 June 2023, Trondheim, Norway

Time line

< 1970
- no formal targets in codes

1970-1985
- Scientific research
  - 1971: Ligtenberg (JCSS/TNO)
  - 1976: CEB 117
  - 1978: NKB
  - 1981: DIN

> 1985
- in codes of practice

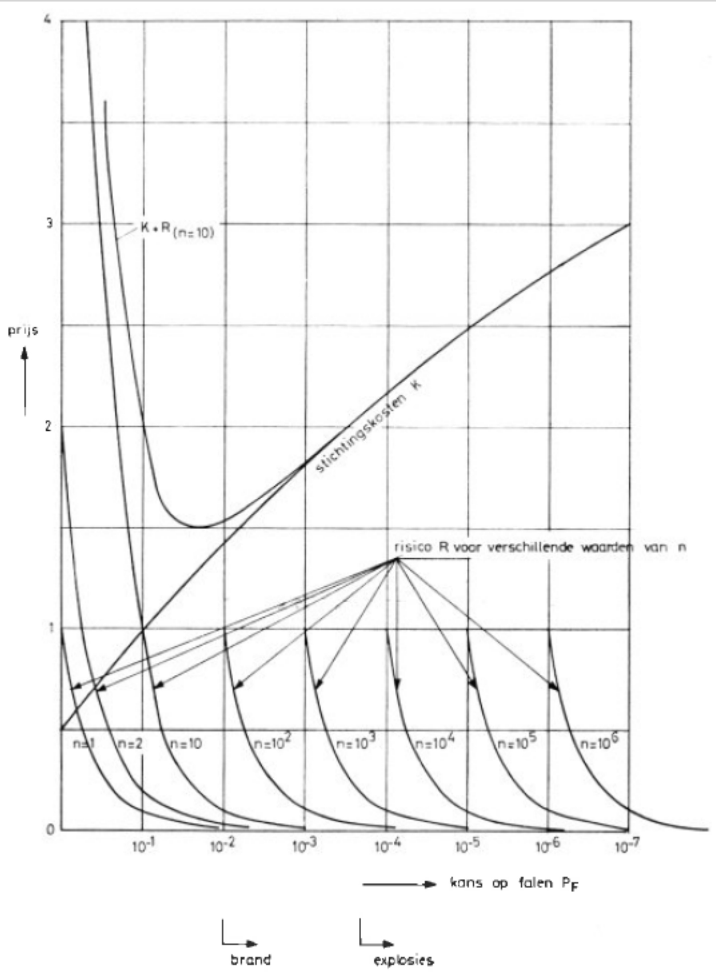

Fig. 4. De bepaling van de meest economische waarden voor P_F.

(Ligtenberg, 1971)

Target reliabilities ULS (one year)

costs	consequences		
	Minor	Moderate	Large
Large	β=3.1	β=3.3	β=3.7
Normal	β=3.7	β=4.2	β=4.4
Small	β=4.2	β=4.4	β=4.7

jcss model code / ISO 2394

Loss of human lives	Economic consequences		
	Minor	Moderate	Large
Small	β=3.1	β=3.7	β=4,2
Normal	β=3.7	β=4.2	β=4.7
Large	β=4.2	β=4.4	β=5.2

consequences	Failure type		
	Ductile	Ductile, no extra capacity	Brittle
Less serious	β=3.1	β=3,7	β=4,2
serious	β=3.7	β=4.2	β=4.7
Very serious	β=4.2	β=4.7	β=5.2

NKB-Report 36 (1978) CEB127 (1980)

Published values around 1985

Country	Study	Ref [year]	β_t 1 yr	β_t 50 yr
USA	Galambos	1982		3,0
Germany	DIN	1981	4,7	
Germany	Koenig/Hosser	1981	4,7	3,8
Scandinavia	NKB	1978	4,2	
Belgium	SECO	1984		3,3
Netherlands	NEN	1987		3,6[d]
UK	CIRIA	1977	>4	
International	CEB-112	1976		
International	CEB-116	1976		4,3
International	CEB-124/125	1978		4,3
International	CEB-127/128	1980	?	
Euro Com	Eurocode 1	1984		
International	ISO	1998		3,1[f]

Background of codified target reliabilities

Economy

Human safety (number of persons killed)

Human safety (individual risk)

Environment

Calibration to previous codes

Background of codified target reliabilities

Economy

Human safety (number of persons killed)

Differentiation

Human safety (Individual risk)

Environment

Central value → **Calibration to previous codes**

CC		Reliability index β	
		β_a for T_a= 1 yr	β_d for T_d= 50 yr
CC3		5,2	4,3
CC2		4,7	3,8
CC1		4,2	3,3

Eurocode

EN 1990

(2000)

Consequences Class	Description	Examples of buildings and civil engineering works
CC3	**High** consequence for loss of human life, *or* economic, social or environmental consequences **very great**	Grandstands, public buildings where consequences of failure are high (e.g. a concert hall)
CC2	**Medium** consequence for loss of human life, economic, social or environmental consequences **considerable**	Residential and office buildings, public buildings where consequences of failure are medium (e.g. an office building)
CC1	**Low** consequence for loss of human life, *and* economic, social or environmental consequences **small or negligible**	Agricultural buildings where people do not normally enter (e.g. storage buildings), greenhouses

Codified target reliabilities β for one year (including safety differentiation)

	3.1				3.5					4.0					4.5					5.0		
Artentina	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Canada	X	X	X	X	X	X	X	X	X	X	X	X	X	X								
China	X	X	X	X	X	X	X	X	X	X	X											
Denmark							X	X	X	X	X	X	X	X	X	X	X					
Estonia												X										
Germany												X										
Holland						X	X	X	X	X	X											
SouthAfrica				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
Spain												X										
Sweden							X	X	X	X	X	X	X	X	X	X	X	X				
UK																			X			
USA										X												

IABSE COMMISSION 1

IABSE Enquiry (2000)

For discussion:

- annual vs life time
- mean vs minimum
- explicit cost of safety measures
- degree of warning (e.g. brittle versus ductile failure)
- anticipated design working life
- Normal vs accidental actions
- environmental issues
- use of recourses in view of sustainability targets
- total number of human lives vs individual risk.
- taking account of deterioration
- inspection and maintenance
- relation with QA and robustness
- member vs system level

Economy: simplified analysis

$$C = C_0 + C_1 X + n\, C_f\, P_{fa}$$

X = design parameter

$$P_{fa} = \exp(-X/a)$$

$$dC/dX = 0 \rightarrow P_{fa} = a\, C_1 / n\, C_f$$

Parameters a, C1, Cf and n have similar influence
Human life loss may be included in Cf (LQI…)
Degree of warning is part of human loss

Individual risk criteria

$$P_d = P_f\, P(d|f) < \text{factor} \times 10^{-5} \; [1/yr]$$

1. Assessment of $P(d|f)$ is difficult

2. Factor depends on:

   costs of safety measures, degree of voluntariness … (ALARP)

3. Factor inspired by (accepted) risks related in other activities

4. Injuries not included

Fatal Accident Rates (FAR)

Cause of Death	**During activity [/10^8 hrs]**	**Annual probability [1/year]**
Rock climbing	4000	1 / 500
Travel by air	15	1 / 70000
Travel by car	15	1 / 13000
High rise building industry	70	1 / 700
Offshore oil and gas-rigs	20	1 / 2500
Construction industry	5	1 / 10000
30-40 age group	8	1 / 1200
Chemical industry	1	1 / 50000
Accidents in the home	1.5	1 / 9000
California earthquake	0.2	1 / 50000

Systems

Two approaches:

- ❑ Targets on system level
- ❑ Targets on member level,
  system effects included in member failure consequences

degradation

Fatigue steel structures

Chloride/carbonation of concrete

$$C_t = C_b + E\,(C_f + C_{in} + C_{ma} + C_{un}..)$$

$$P_{fi} = P(\,R_i - S_i < 0 \quad \cap \quad ..)$$

In codes two requirements:

(1) Standard requirement for the undamaged structure
(2) P (damage < some limit) < target

For discussion:

- annual vs life time
- mean vs minimum
- explicit cost of safety measures
- degree of warning (e.g. brittle versus ductile failure)
- anticipated design working life
- Normal vs accidental actions
- environmental issues
- use of recourses in view of sustainability targets
- total number of human lives vs individual risk.
- taking account of deterioration
- inspection and maintenance
- relation with QA and robustness
- member vs system level