Assessing and Affording the Control of Flood Risk

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Managing Risks in the Public Interest considering

The Societal Capacity to Commit Resources to sustainable Risk Reduction, (SCCR)

C

Outline

1. Probable Maximum Precipitation (PMP), Probable Maximum Flood (PMF) ?
2. *Monoscopic* → Relative Entropy Estimation
3. LQI →Societal Capacity to Commit Resources *(SCCR)* to sustainable life risk reduction
4. Discounting Risks and the *Financing Horizon*
5. Example: Optimum Design of a Levee

Two Uses of Probability:

- *Panscopic* – populations, ensembles, . . .

  e.g. Structural Standards

- *Monoscopic* – single events, unique phenomena

  e.g. a flood control structure

- Reference:

Georges Matheron, *Estimating and Choosing*, Springer-Verlag, 1989

translated by A. M. Hasofer

("Matheron's Masterpiece")

Monoscopic Probability

Pick 2 numbers at random. What is the probability P that the last number picked is the ith largest?

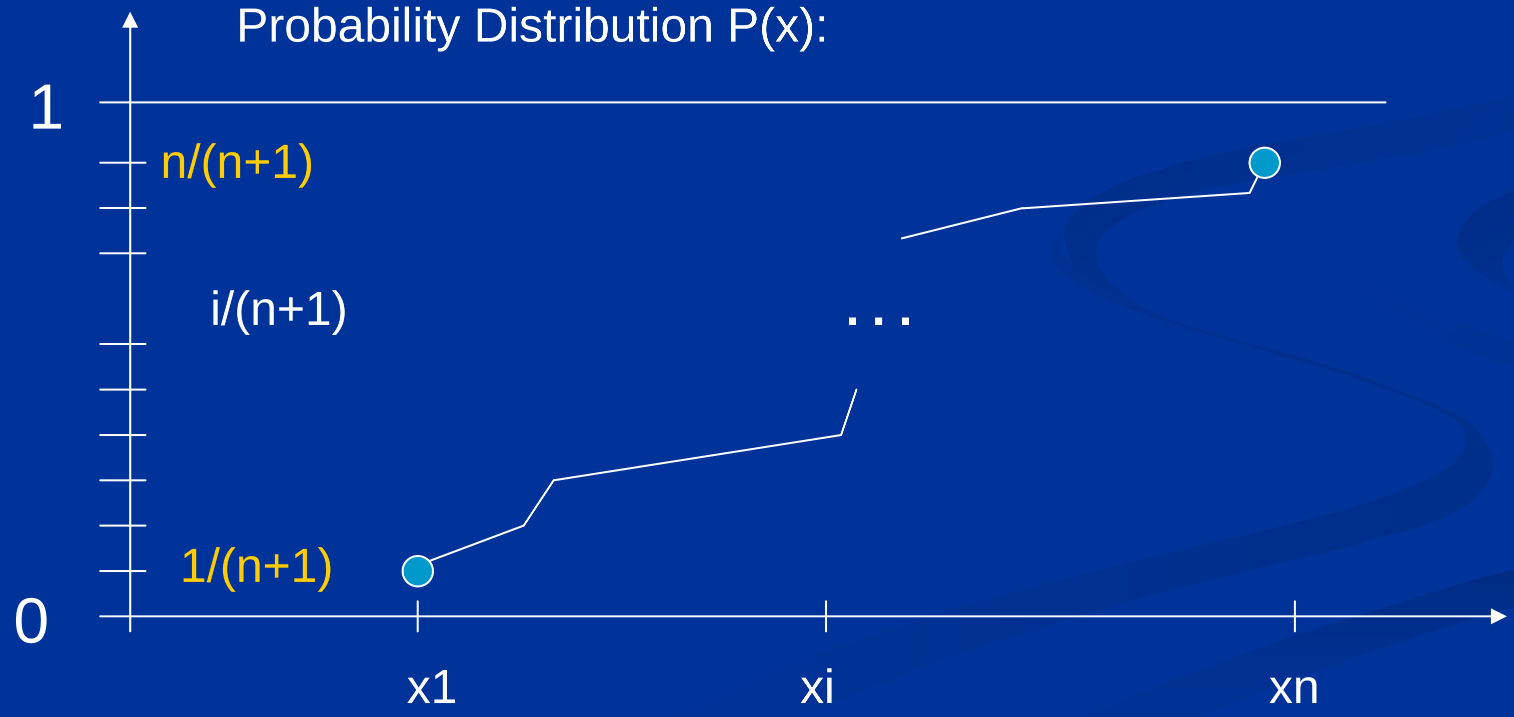
p = 1/2 -- distribution-free.

Pick n+1 numbers at random. What is the probability P that the second number is the largest?

p = 1/|(n+1) -- a distribution-free result.

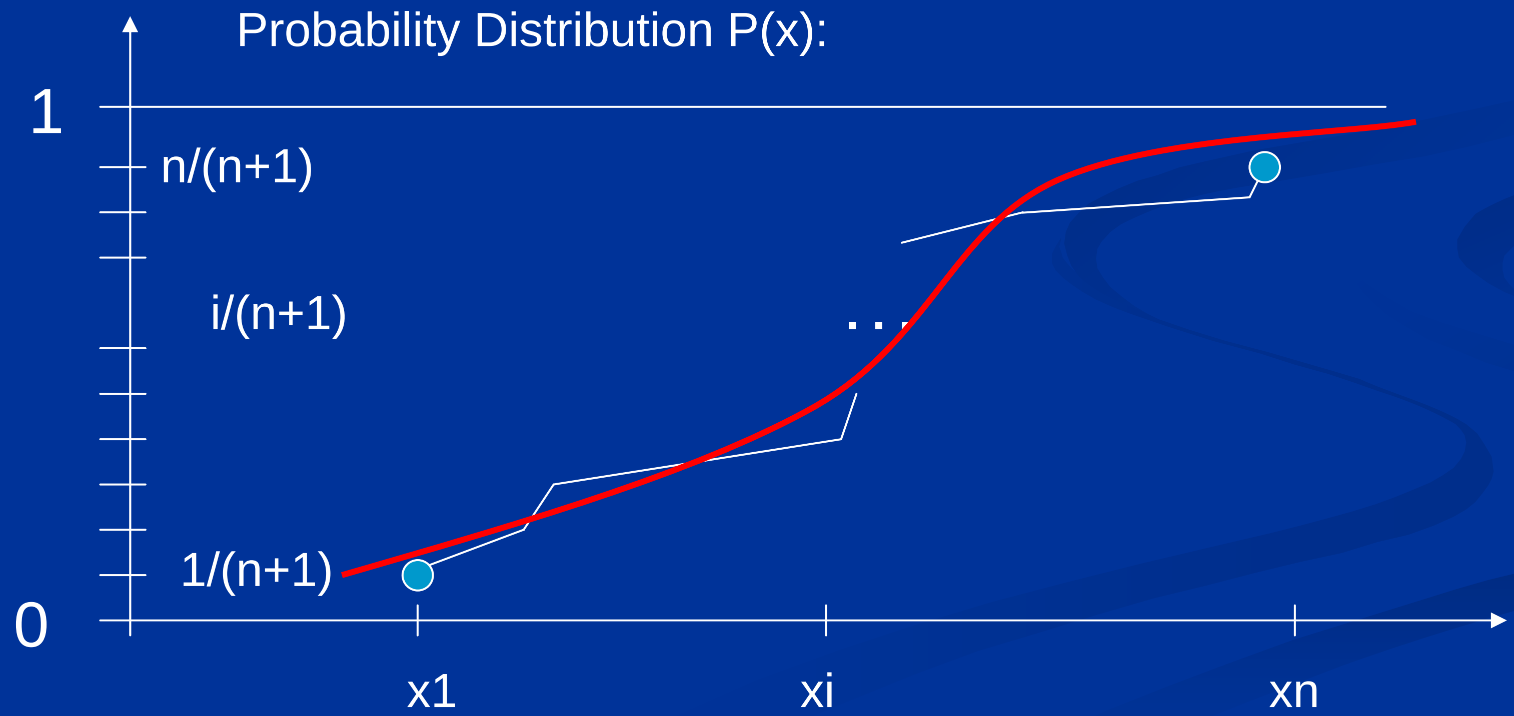
Monoscopic Probability

- We picked n numbers at random from a set or sequence, x1, x2, . . . xn. The probability P that the next number (yet to picked) is the ith largest? Ans: p = 1/(n+1).



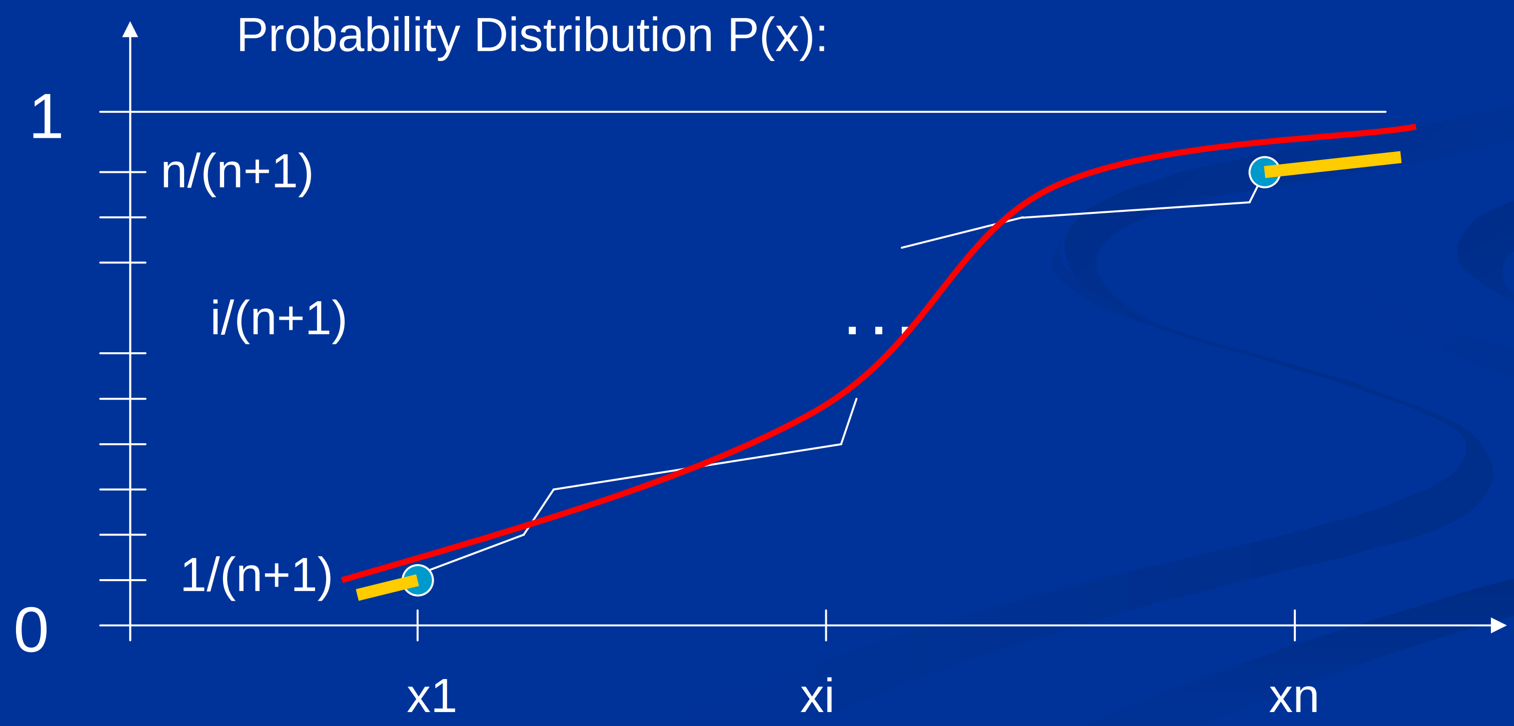
Panscopic Probability

- We can fit one or more standard probability distributions Q(x) to {x1, x2, . . . Xn} by moments, by max entropy (best)
- or by any other method.



Monoscopic Probability -- Tails

- Relative to distribution Q(x), the minimum cross-entropy distribution P(x) in the tails is *affine* to Q(x) and passes through x1 resp. xn.



Life Quality Index LQI

$$L = F(E,G) = E^K G$$

where

E = Life expectancy at birth

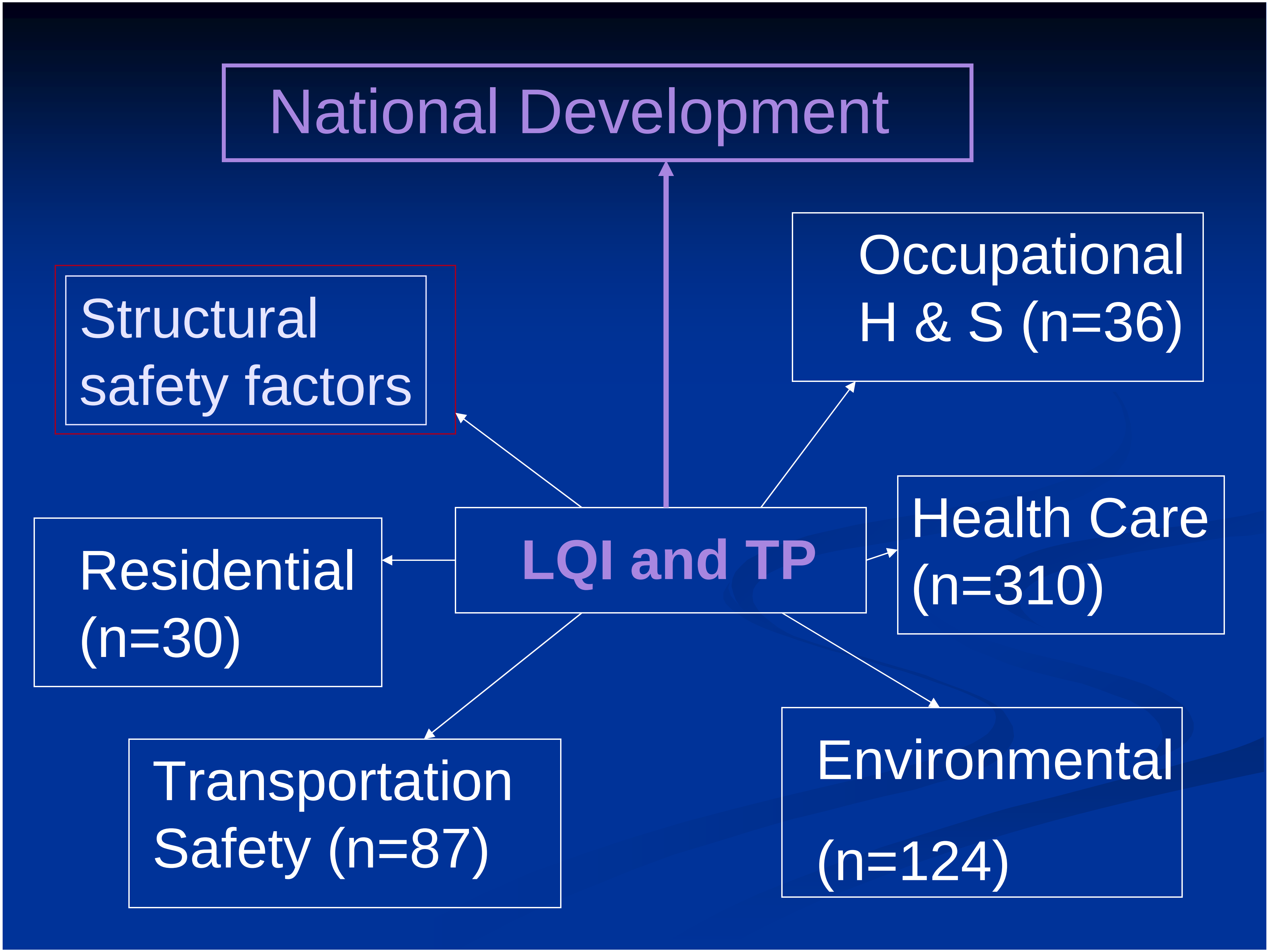
in good health

G = gross domestic product GDP

per person

K is an important constant parameter

K= 5.0 approx. in developed countries


National Development
Occupational H & S (n=36)
Structural safety factors
Health Care (n=310)
LQI and TP
Residential (n=30)
Environmental (n=124)
Transportation Safety (n=87)

Derivation and Calibration of LQI by Welfare Economics

Cobb-Douglas Production Model:

$GDP = A\ C^{\alpha}\ w^{\beta}$

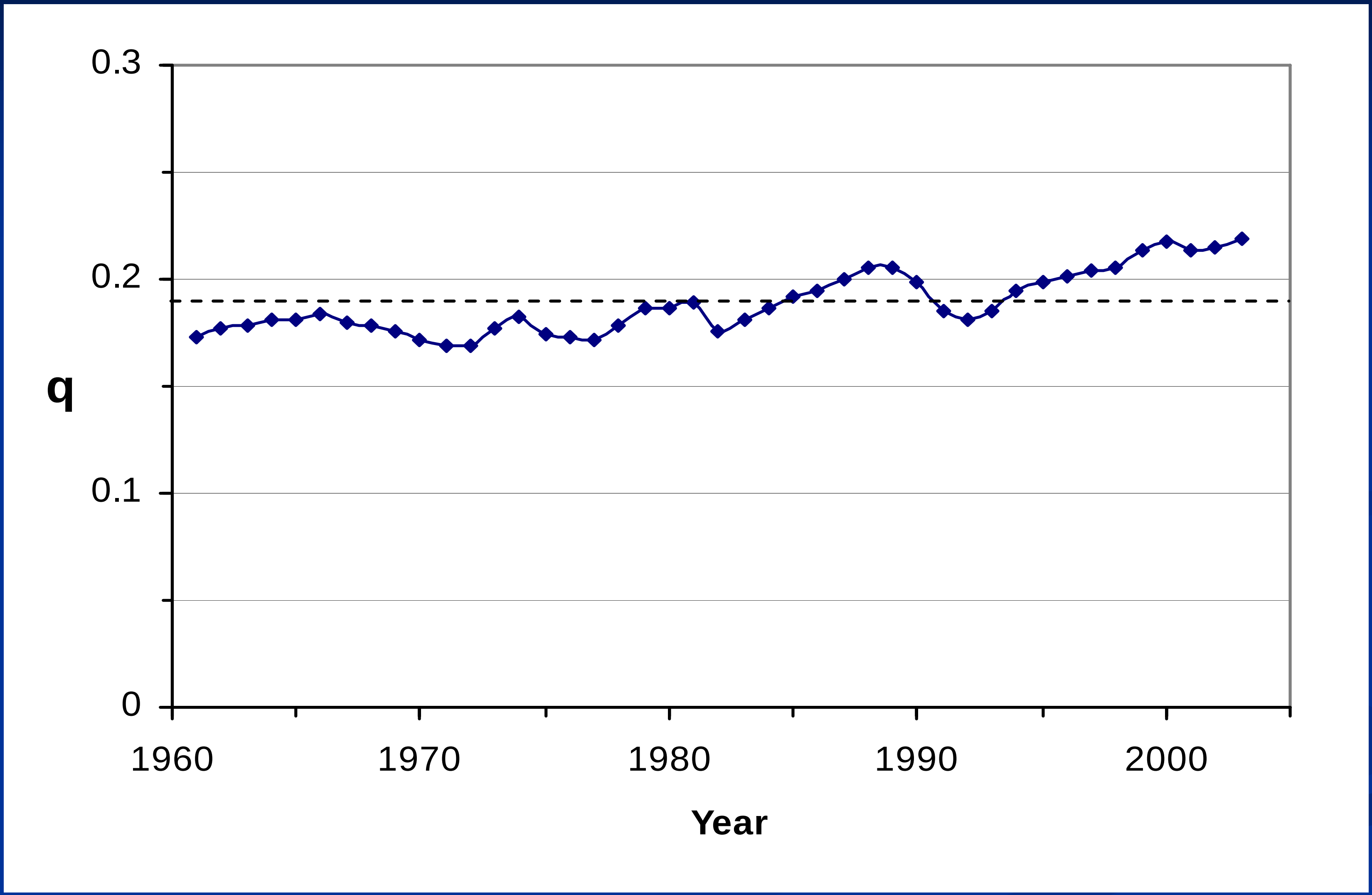
C = Capital

w = proportion of life used to work

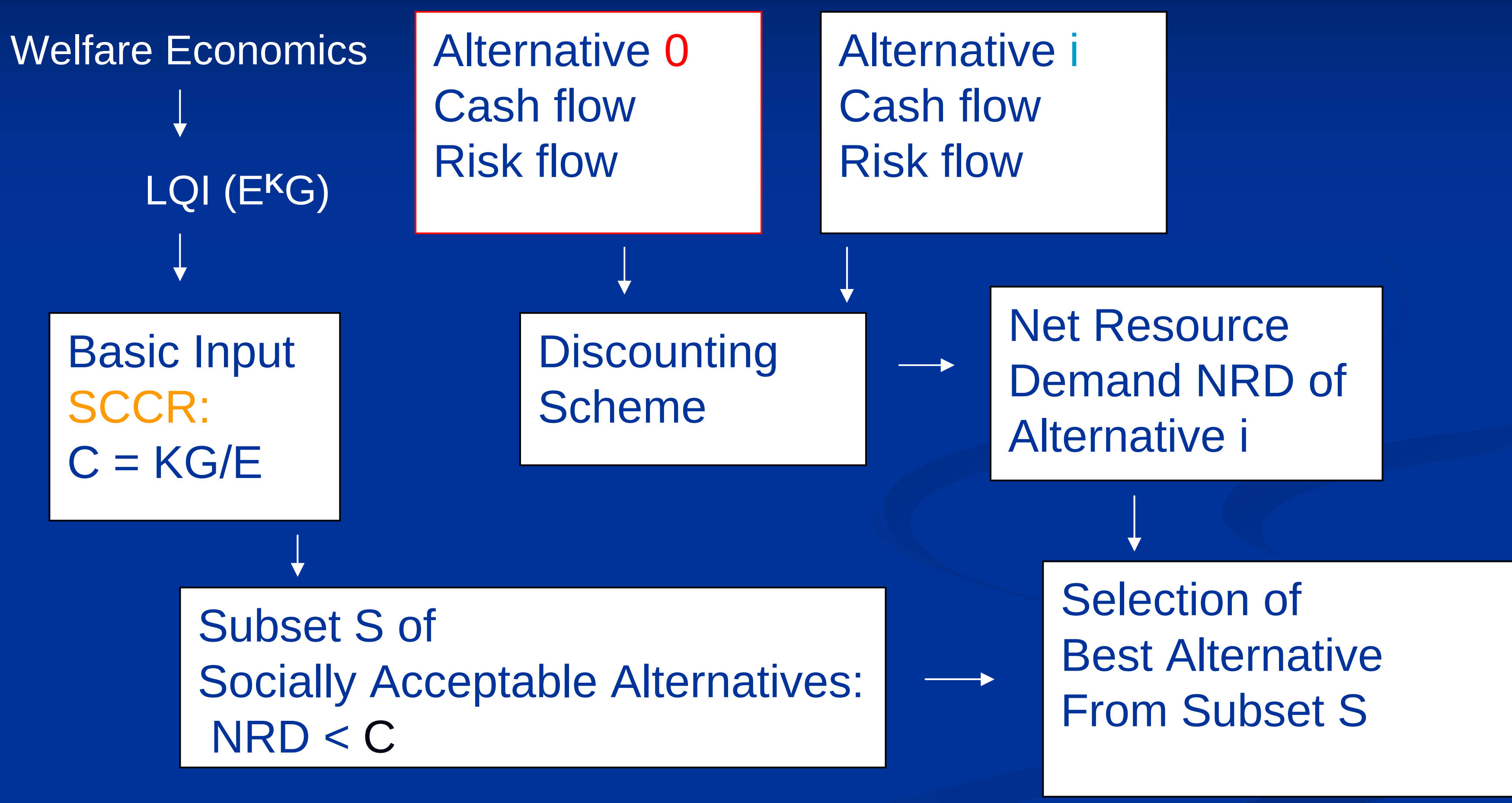
w and β can be measured

$$K = \beta(1-w)/w$$

Historical Trend of q = 1/K for Canada



Typical Scheme of SCCR (LQI) Analysis in Civil Engineering.



$K = 1/q = \beta(1-w)/w$

Calibration of LQI

	NL&P 1997	Canada 1960-2003 Min.	Canada 1960-2003 Max.	Canada 1960-2003 Ave.		USA 1960-2003 Min.	USA 1960-2003 Max.	USA 1960-2003 Ave.		NL&P 2005
w	1/8	0.082	0.099	0.091		0.08	0.105	0.09		
b	1	0.51	0.56	0.53		0.48	0.54	0.5		
q	1/7	0.17	0.21	0.19		0.17	0.24	0.21		0.2
K	7	**4.8**	**5.9**	**5.3**		**4.2**	**5.9**	**4.8**		**5**

Societal Capacity to Commit Resources **to Sustainable Life Risk Reduction, C**

Derivation:

net benefit = net increase in LQI: $dL>0$.

$\mathbf{L = E^K G}$, so

$dL/L = K\, dE/E + dG/G > 0$,

so

$$C = -dG/dE = KG/E.$$

Societal Capacity to Commit Resources

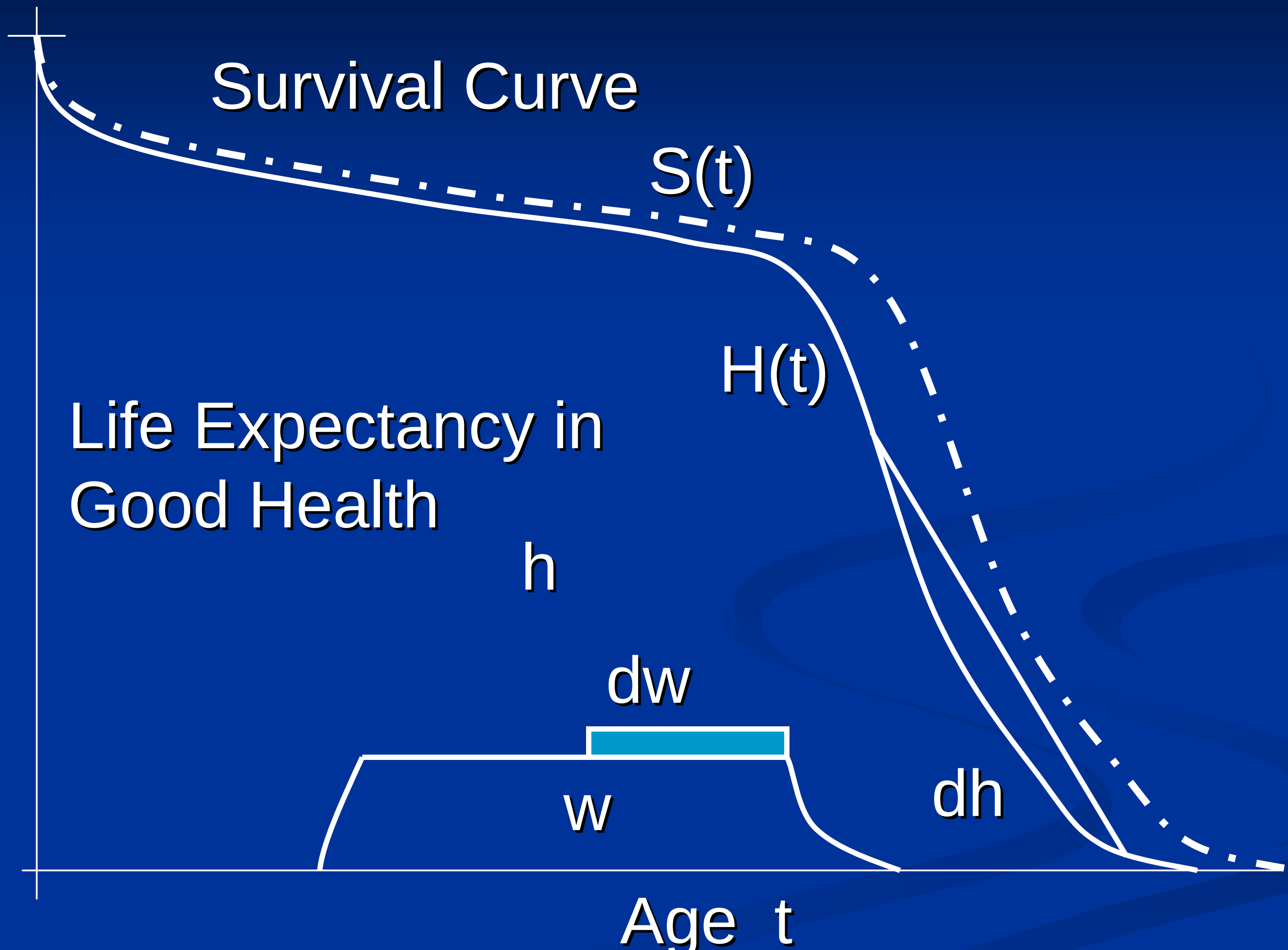
to Sustainable Life Risk Reduction SCCR:

C = KG/E

K=5, G= $40,000 approx.,

E=78 years, ➔ SCCR

SCCR C = $8.0M per fatality approx.


Survival Curve
S(t)
H(t)
Life Expectancy in
Good Health
h
dw
w
dh
Age t

The *Time Principle:*

A prospect to save life is preferable (to an alternative) only if the increase in quality-adjusted life expectancy (dE) net of work is greater than its work-time cost(dw).

A prospect is to be preferred if its **human time efficiency** (dh/dw) is greater than that of any alternative.

When you consume life to save life,
you should return more than you take.

TP follows from two postulates:

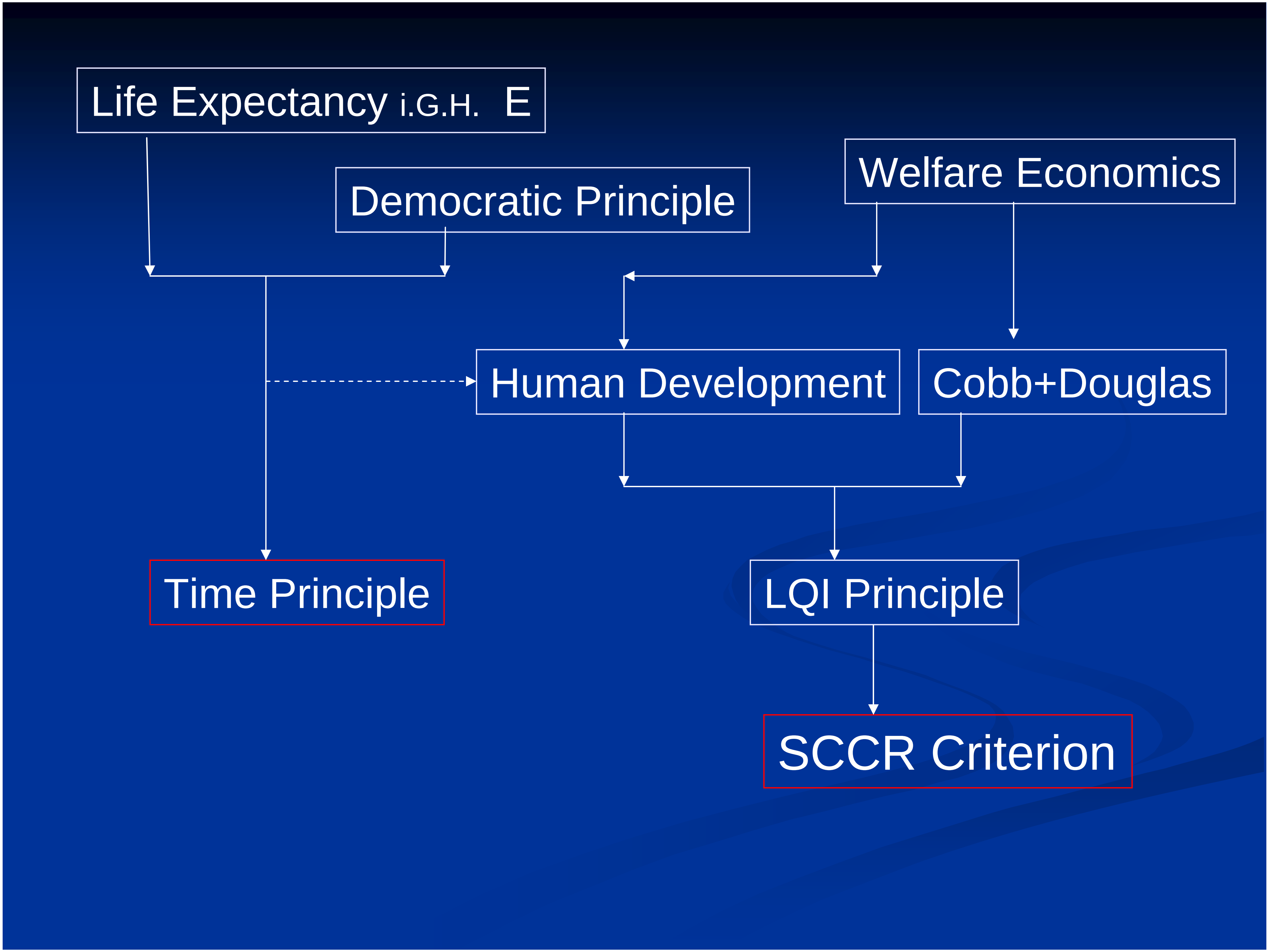
1 The democratic principle

2 The Life Expectancy Measure

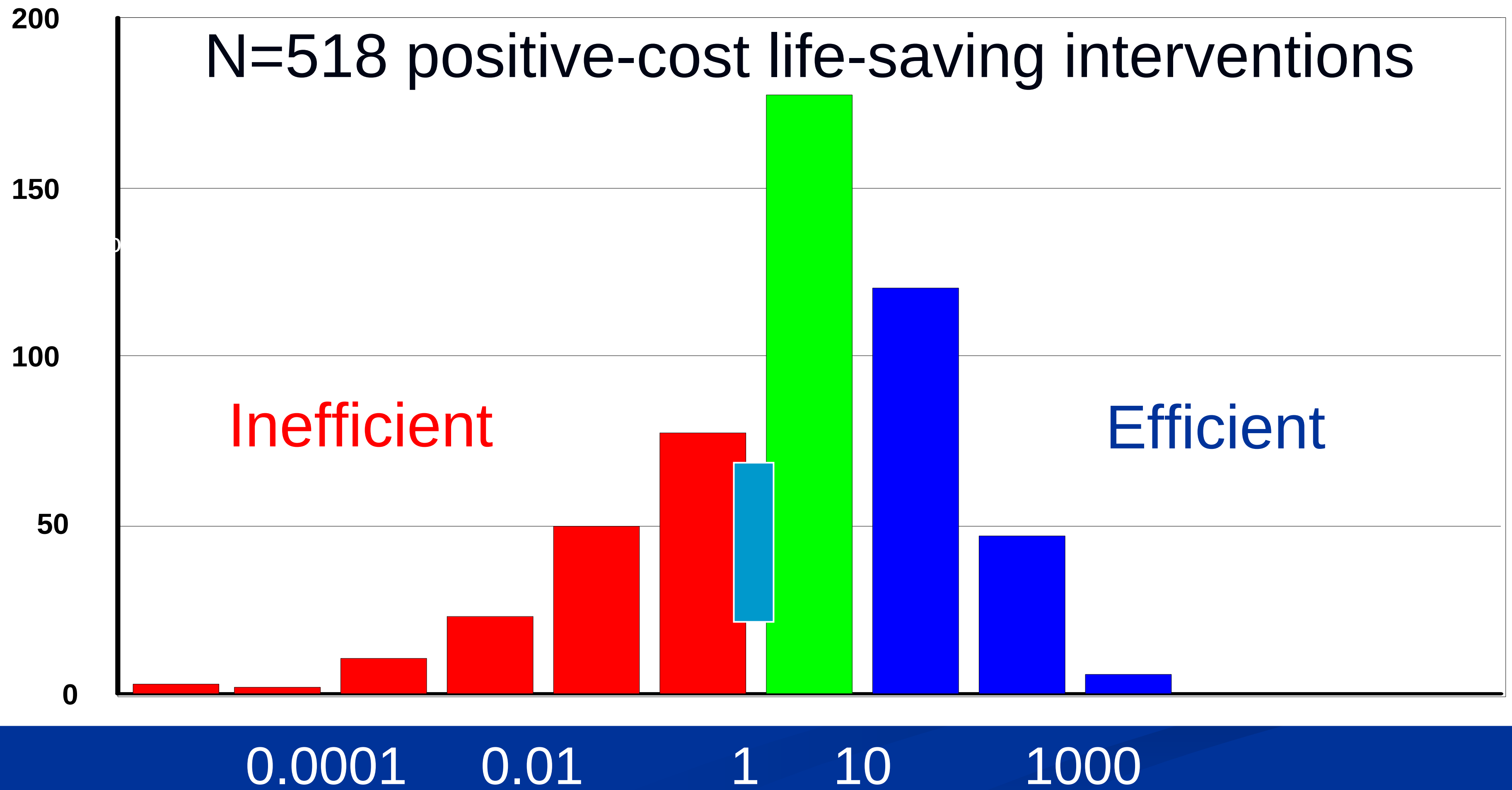
1.The value of an hour of life in good health is the same for all in society.

2.A measure of life risk reduction for a person is the expected number of hours gained (in good health).

The Time Principle and the Life Quality Index yield identical acceptance criteria !


Life Expectancy i.G.H. E
Democratic Principle
Welfare Economics
Human Development
Cobb+Douglas
Time Principle
LQI Principle
SCCR Criterion

Gain Factor:
Hours of life expectancy returned per hour of work



Data: T. Tengs &al 1996

Application of SCCR in Structural Engineering

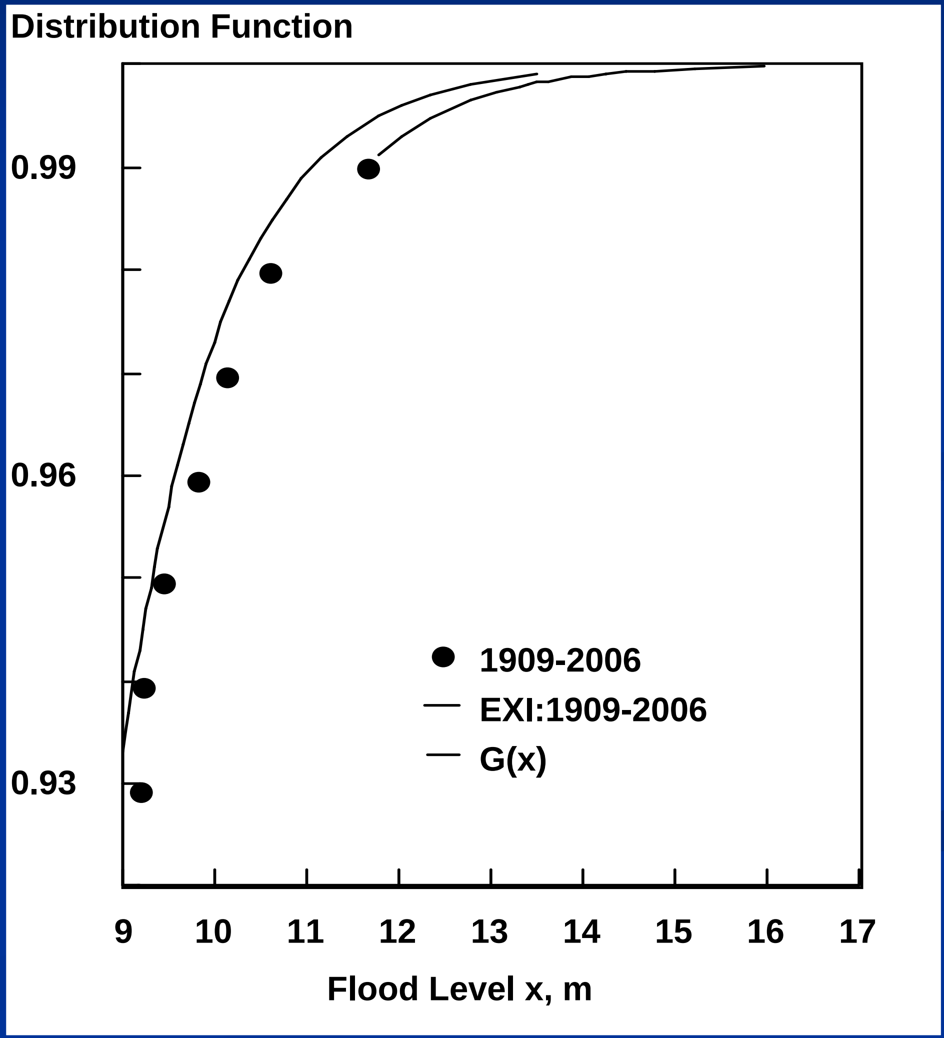
- Aero/space Structures
- Naval/Offshore Structures
- Major CE Facilities with significant Life Risk: Earthquake, Flood, . . .
- Codes and Standards:
  - Earthquake
  - Hurricane
  - Tornado
  - Tsunami

Example Application:

Flood Risk Management

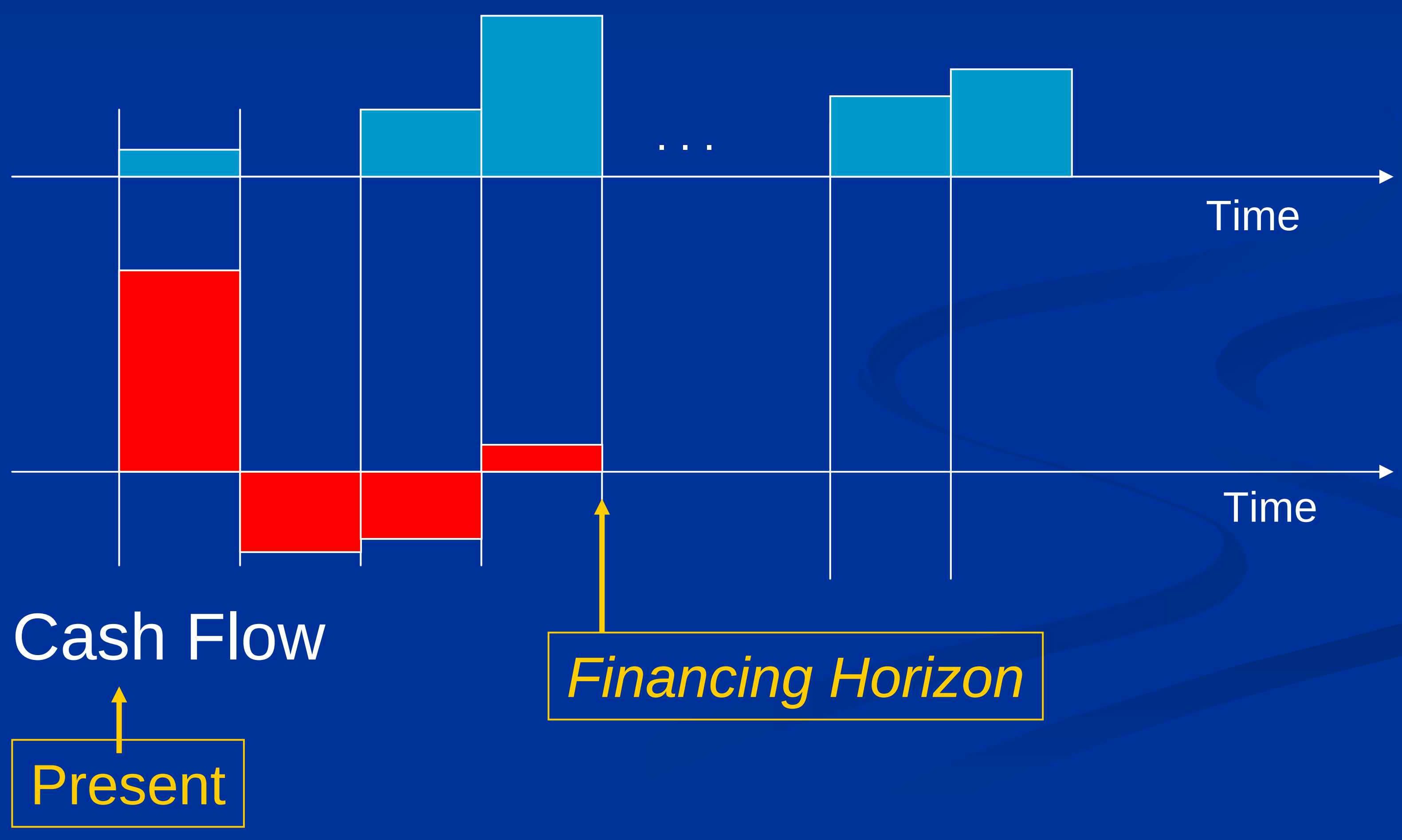
- City, population 100,000, protected by a levee.
- Flooded in 1904: several thousand lives lost.
- New levee 1955: 11.5 m.
- Flooded again in 2006: loss of 240 lives.
- Material losses $450M (est.).
- Expected loss | future failure: 500 lives and $400M est. (e.g. Hartford and Baecher (2004).
- Rebuild now to a higher elevation.
- Design life: 200 years.
- Financed by 30yr municipal bonds at 2%+infl.

Statistics: REQ (REF) Method: Minimizing the Relative Entropy With Quantile (or Fractile) constraints between the monoscopic distribution and a slate of panscopic candidates

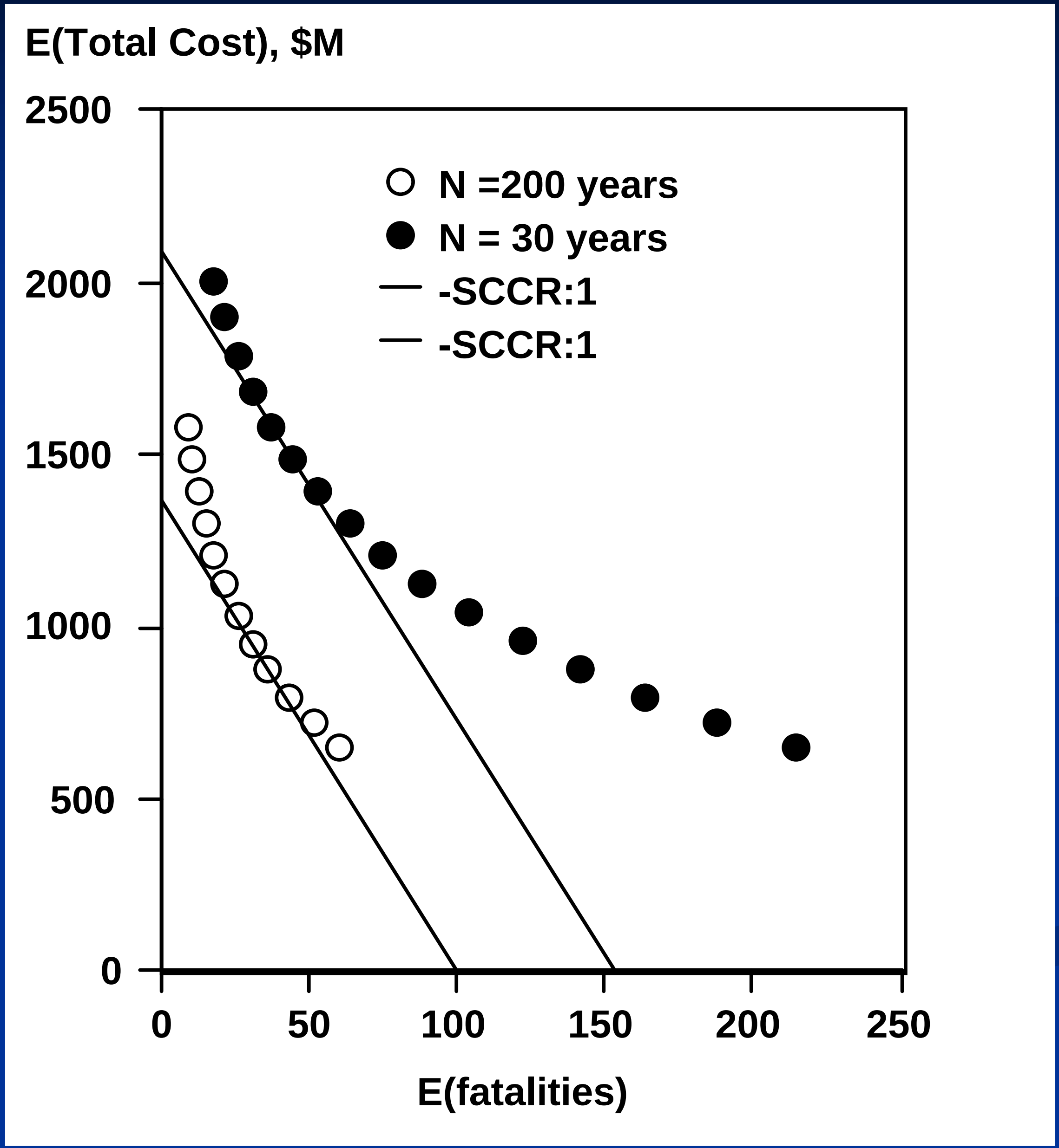


Discounting
risk flows and cash flows.

Risk Flow:



Optimization:



Conclusions

1. T**ransparent** life safety management is **possible** and **in the public and professional interests**.

2. The SCCR, $C = KG/E$, derived from welfare economics, links safety and life risk management to the public welfare.

3. All quantities (E,K,G) entering in the SCCR are readily available, reliable national statistics. $K = 5.0$

4. The Time Principle is equivalent to the max-LQI principle.

Conclusions continued

5. The LQI approach is workable for major projects that have significant public health and safety consequences.

6. Many Problems in Civil and Structural Engineering are monoscopic. The data constrain the probability model, which can and should be determined by Cross-Entropy minimization.

7. Details of financing can have decisive influence on the optimum design.