The reasonable man adapts himself to the world; the unreasonable one persists in trying to adapt the world to himself.

Therefore all progress depends on the unreasonable man.

George Bernard Shaw (1856 - 1950), Man and Superman (1903)
"Maxims for Revolutionists

NTNU

Innovation and Creativity

Risk Weighted Cash Flow, a Communications Tool for Engineers and Financial Professionals on New Technology Projects

Presented by: M.W. Kennedy (NTNU)
Co-Authors: Cameron Harris (SNC-Lavalin), and Allan MacRae (MacRae Technologies).

MacRae Technologies Inc.

SNC·LAVALIN

Risk and new technology

Technical risks exist in metallurgical projects even in the absence of 'new technology'.

- **Technical risk** is the risk that the designed process equipment is not fit for purpose due to project specific issues, such as size or composition of feed material, project location or selection of inexperienced suppliers.

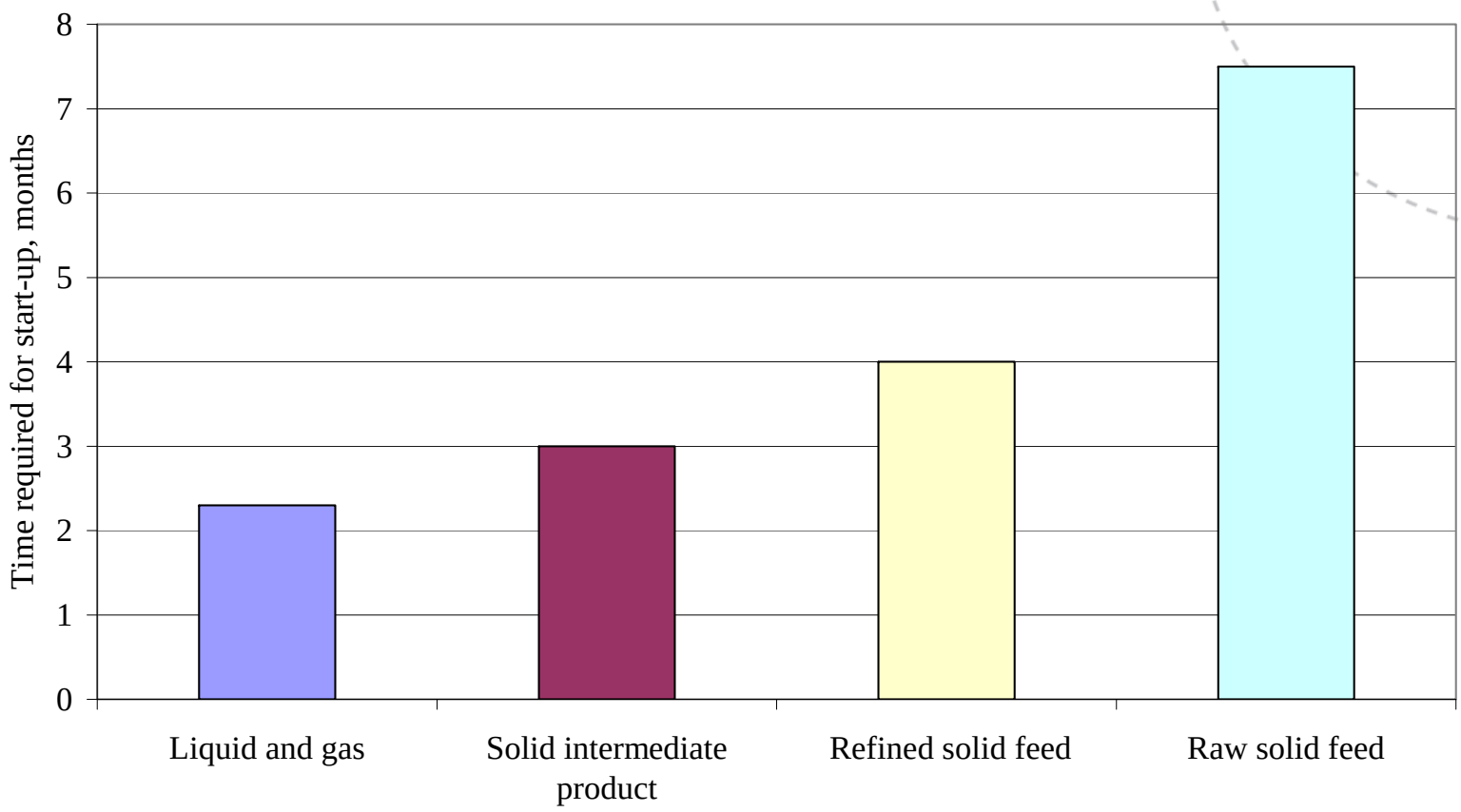
- **Technological risk** can be present in the form of new processes or products, scaled-up equipment designs, first of a kind prototypes, or completely new technology and is **additive** to Technical risk.

Key project deliverables for engineers

1. Capital cost
2. Operating cost
3. Schedule
4. Safety
5. Environment
6. Plant throughput
7. Online time
8. Product quality
9. Product price (by achieving customer specific properties)

Natural raw materials add to start-up risk

Merrow, 1986.



SNC·LAVALIN

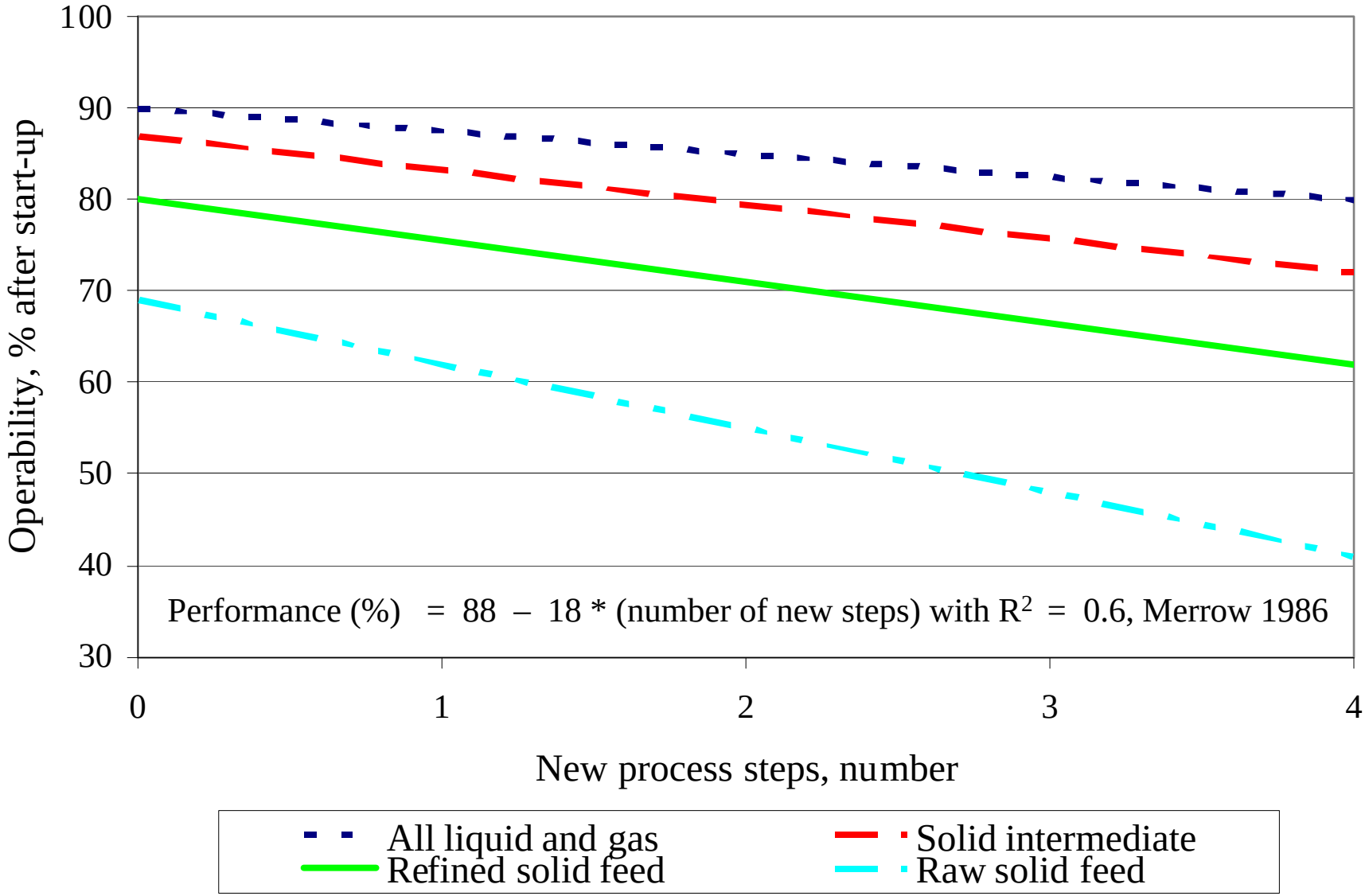
MacRae Technologies Inc.

NTNU Innovation and Creativity

Impact of new technology on plant performance

(by feed type)

Merrow, 2000.



New technology increases owners costs

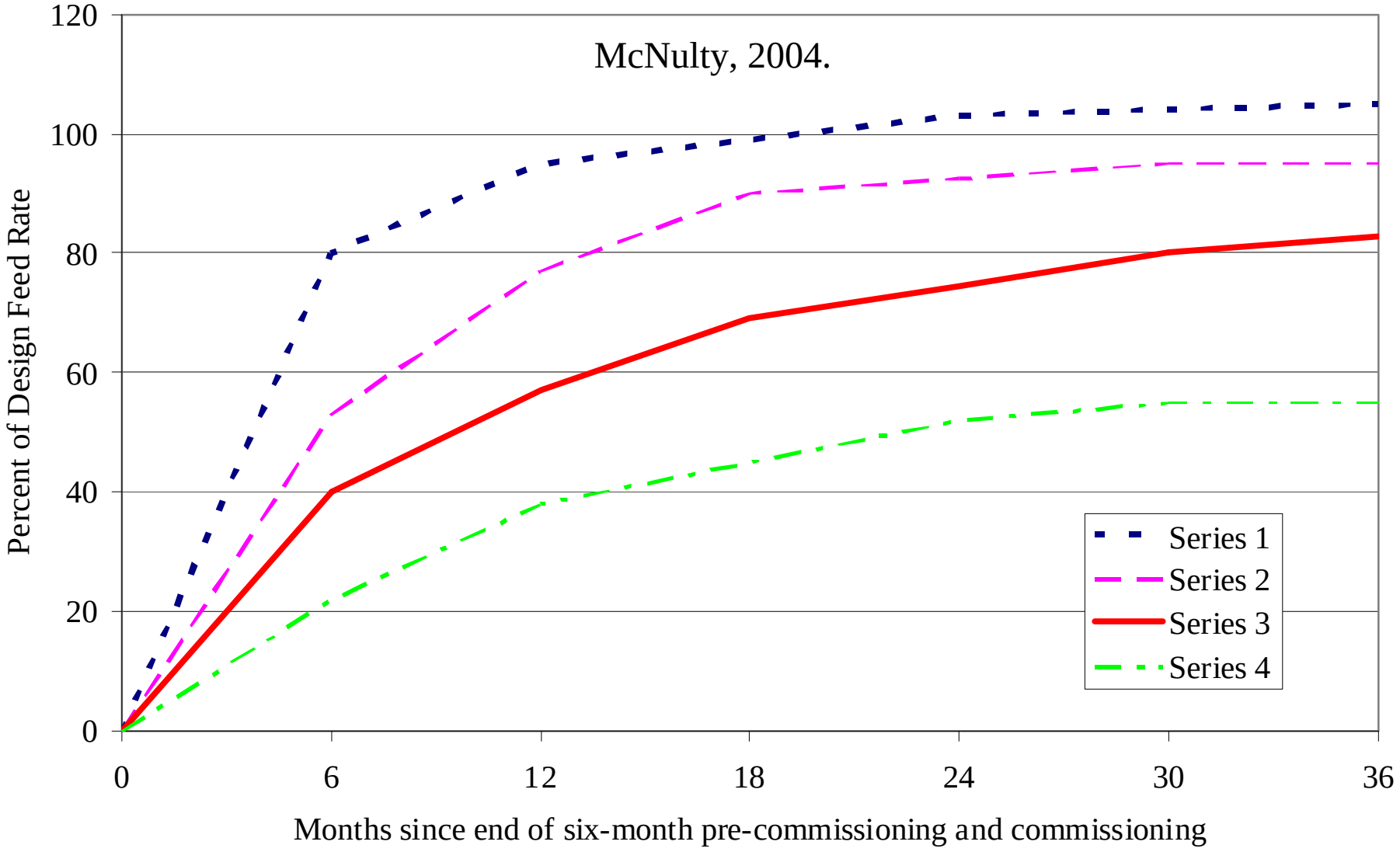
Wallgrove and Butler, 2007.

Owners costs ~6% of total installed cost

With new technology:

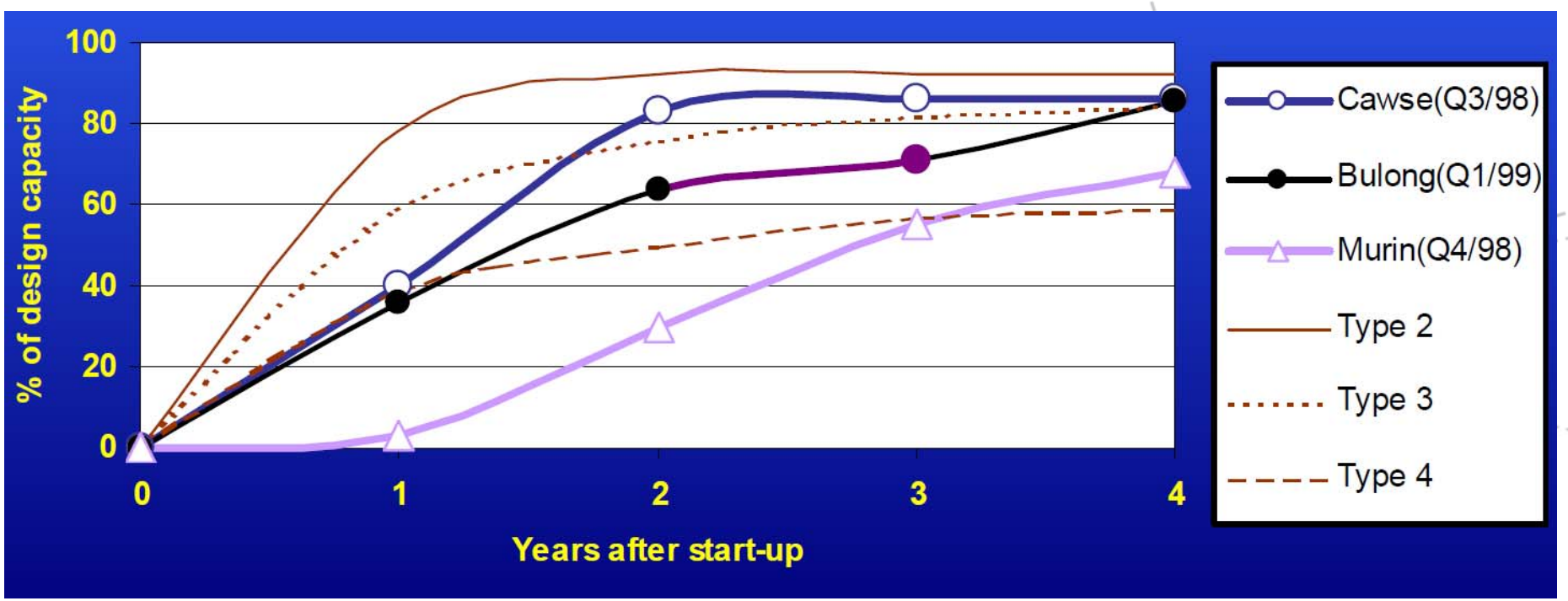
1. New product – scaled from lab	+7%
2. New product – scaled from pilot plant	+5.5%
3. Old product – new process	+4%
4. Standard process, major size increase	+3%
5. New technology, first-of-a-kind facility	+10%
6. Based on non-commercial prototype	+5%

Impact of project management and technology on ramp up



Real world examples of McNulty's Series

P.J. Mackey, J.E. Nesset, 2003.



New technology, complex flowsheets, high feed variability, limited test work. 'Series' 3 or 4.

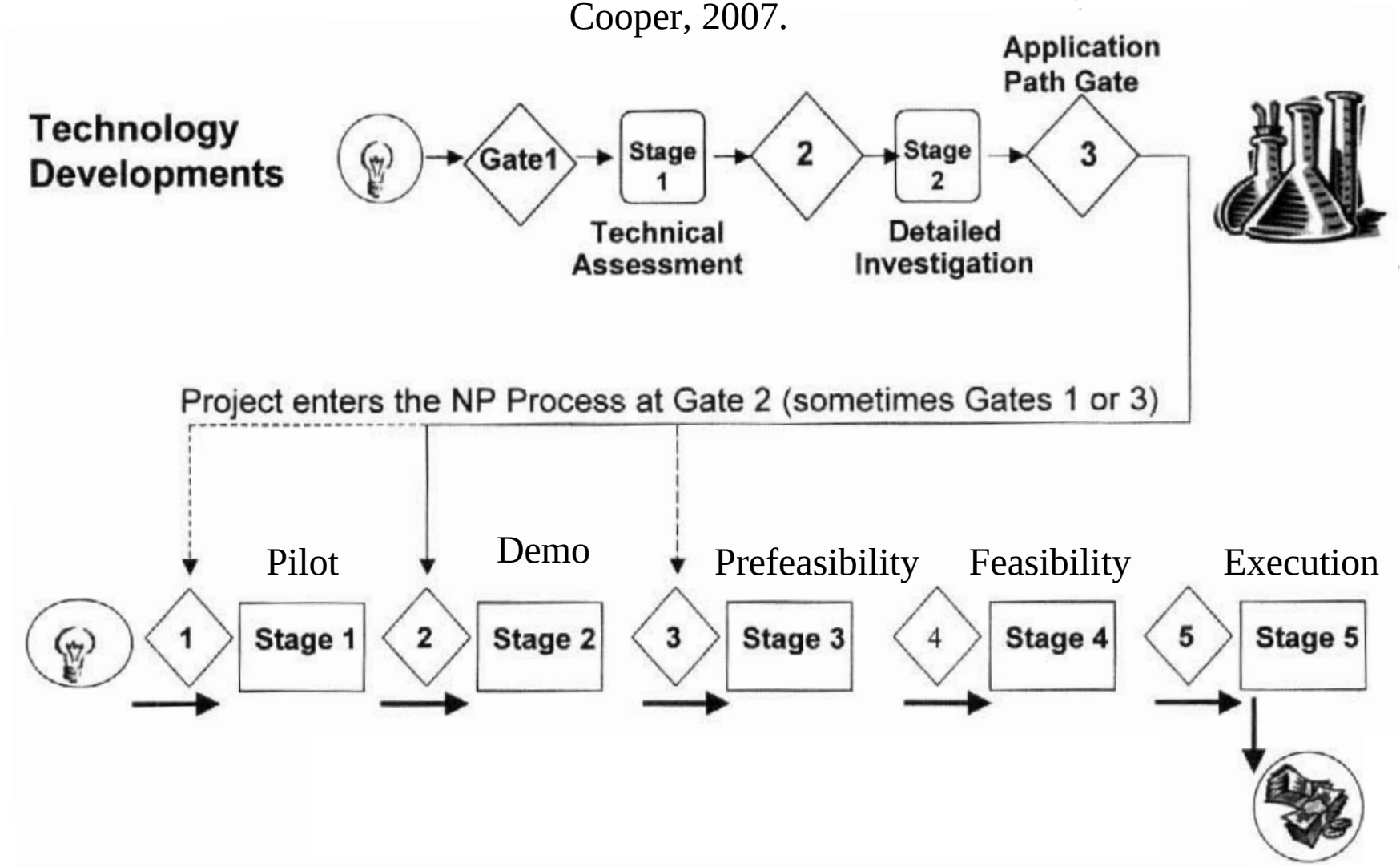
SNC·LAVALIN

MacRae Technologies Inc.

NTNU Innovation and Creativity

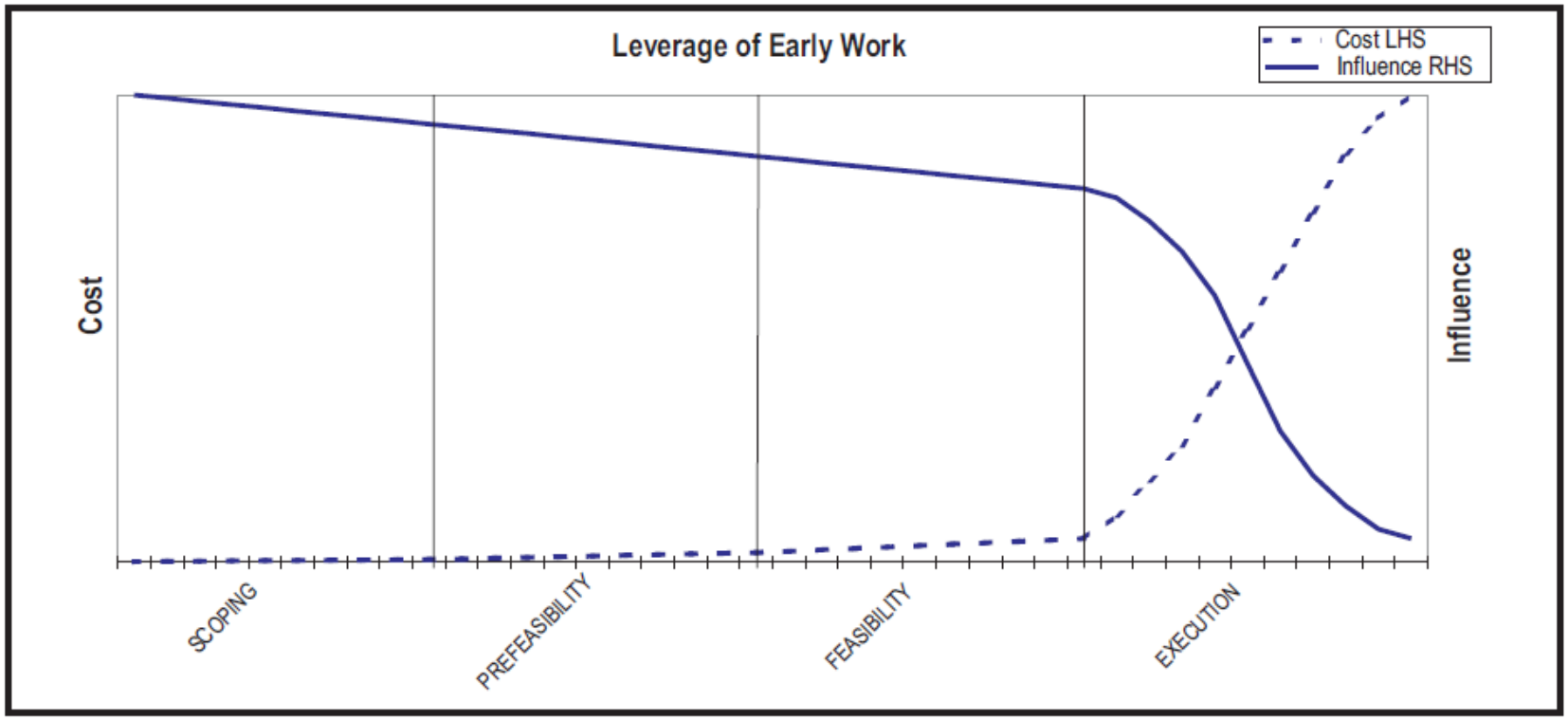
Typical new technology 'stage-gate' system

Cooper, 2007.



It costs almost nothing to repeat an early project phase

MacKenzie and Cusworth, 2007.



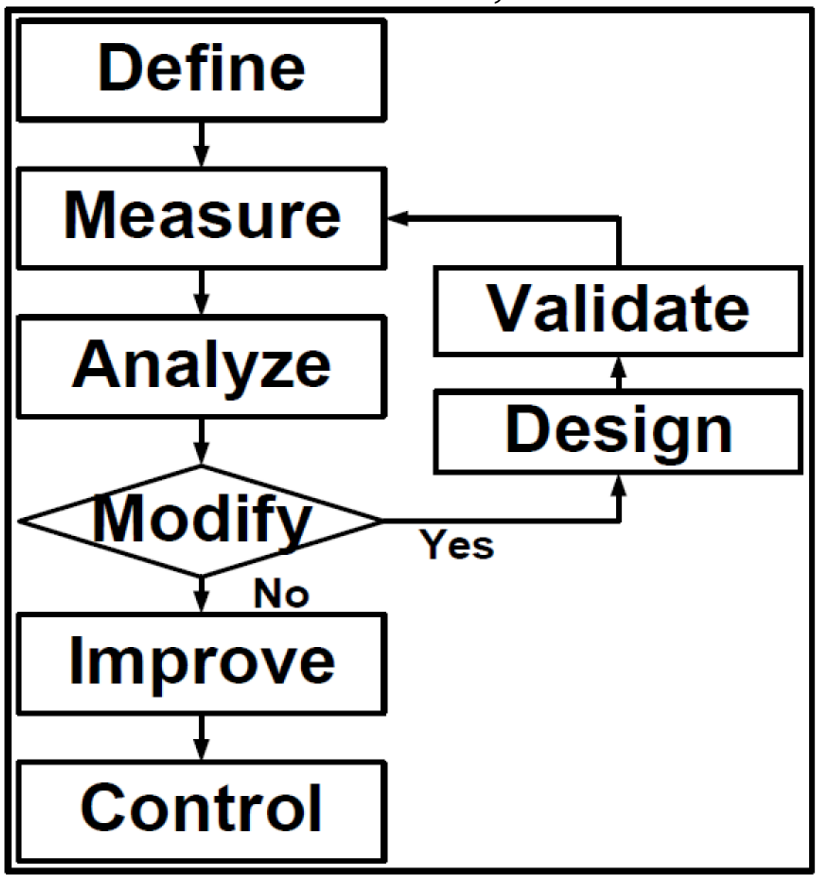
SNC·LAVALIN

MacRae Technologies Inc.

NTNU
Innovation and Creativity

New technology development based on validated designs and design criteria

Huber and Mazur, 2002.



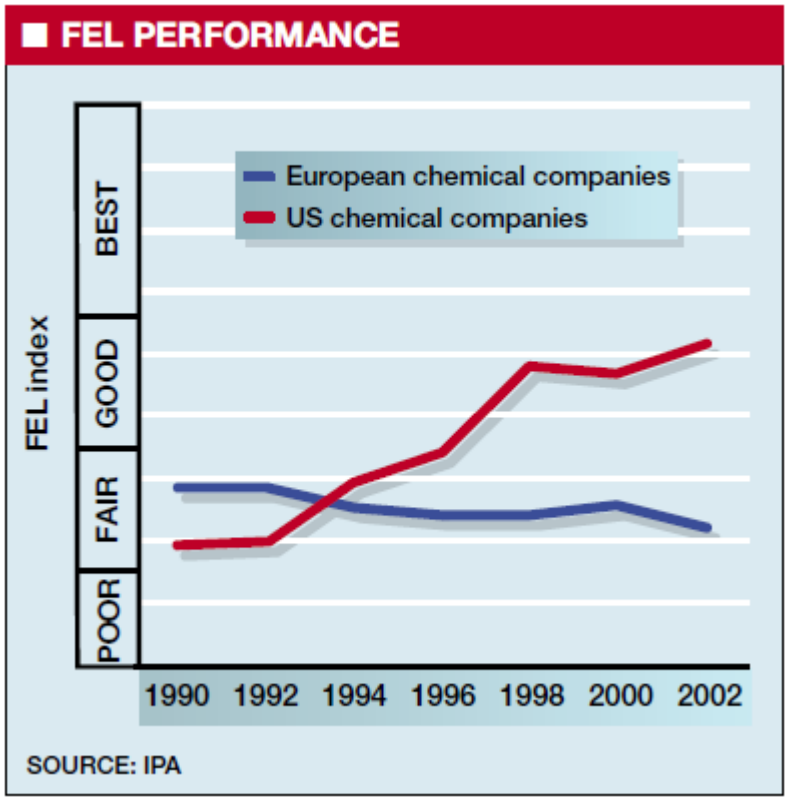
SNC·LAVALIN

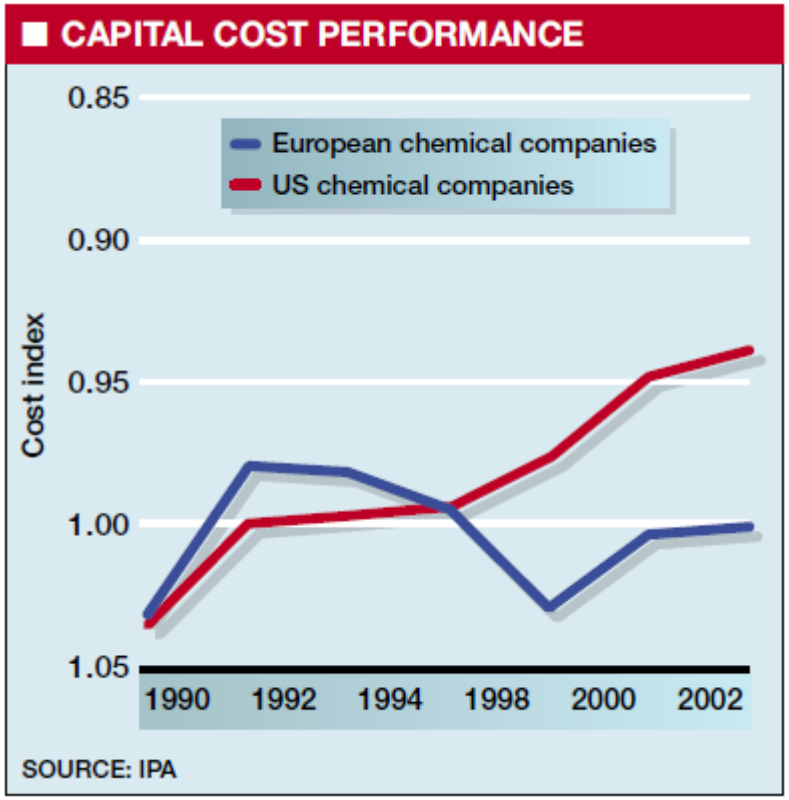
MacRae Technologies Inc.

NTNU
Innovation and Creativity

Benefits of FEL

Barshop, Independent Project Analysis (IPA), 2003.





SNC·LAVALIN

MacRae Technologies Inc.

NTNU Innovation and Creativity

Hypothetical $1.0 billion ‘new technology’ project

Base case scenario

Laboratory-pilot scale: $10 million
Pilot-demonstration plants: $50 million
Engineering cost to feasibility: 3.4% or $34 million, (greenfield incorporating new technology [17]).
Total engineering cost: 10% or $100 million
Cost before project decision: $95.6 million
Commissioning and ramp-up owner’s non-capitalized costs: 10% or $100 million
Fixed operating costs: $300 million/year
Production: 100 million units of product/year
Variable cost: $3/unit of production (total variable cost = fixed cost)
Value of product: $8.49/unit of production
6 month commissioning and start-up followed by 12 months of ramp-up
15 years from idea to full plant production
25 years of cash flows after full production achieved or 40 year base case project life
8% Discount rate for NPV

Definition of ‘Financial Risk’

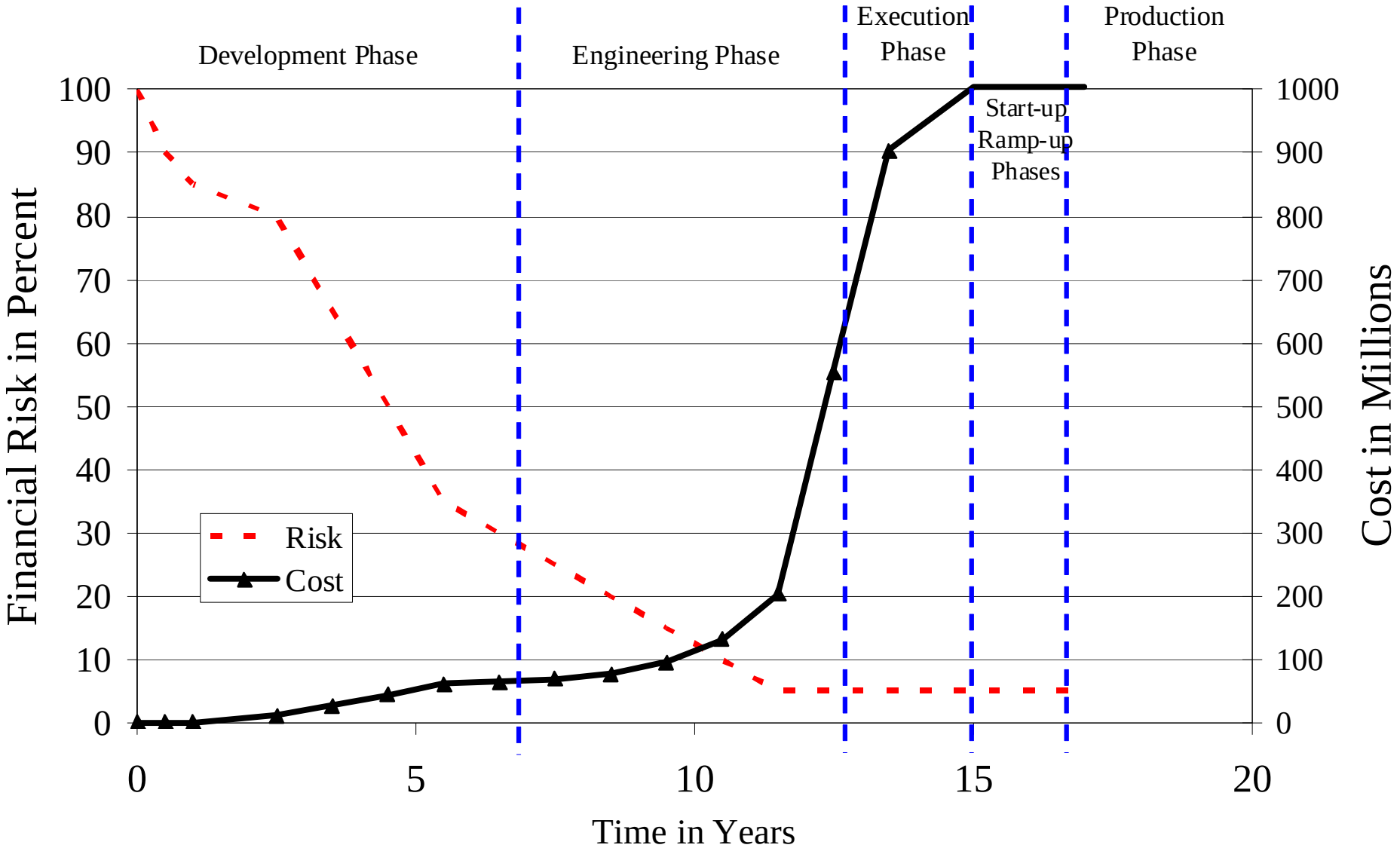
The purpose of a new technology project is to build a new business

- Risk in this context is financial in nature, i.e. the risk of failing to achieving the predicted cash flows (or in an extreme case, the risk that ultimately that the business may fail).

% Financial Risk = (1 - probability of achieving the desired cash flows) * 100%

(Individual companies must establish a risk identification, quantification and tracking system.)

Project timeline, risk profile and cost



Risk weighted NPV's

- Future cash flows discounted by the risk in order to properly manage a project or compare NPV's between projects

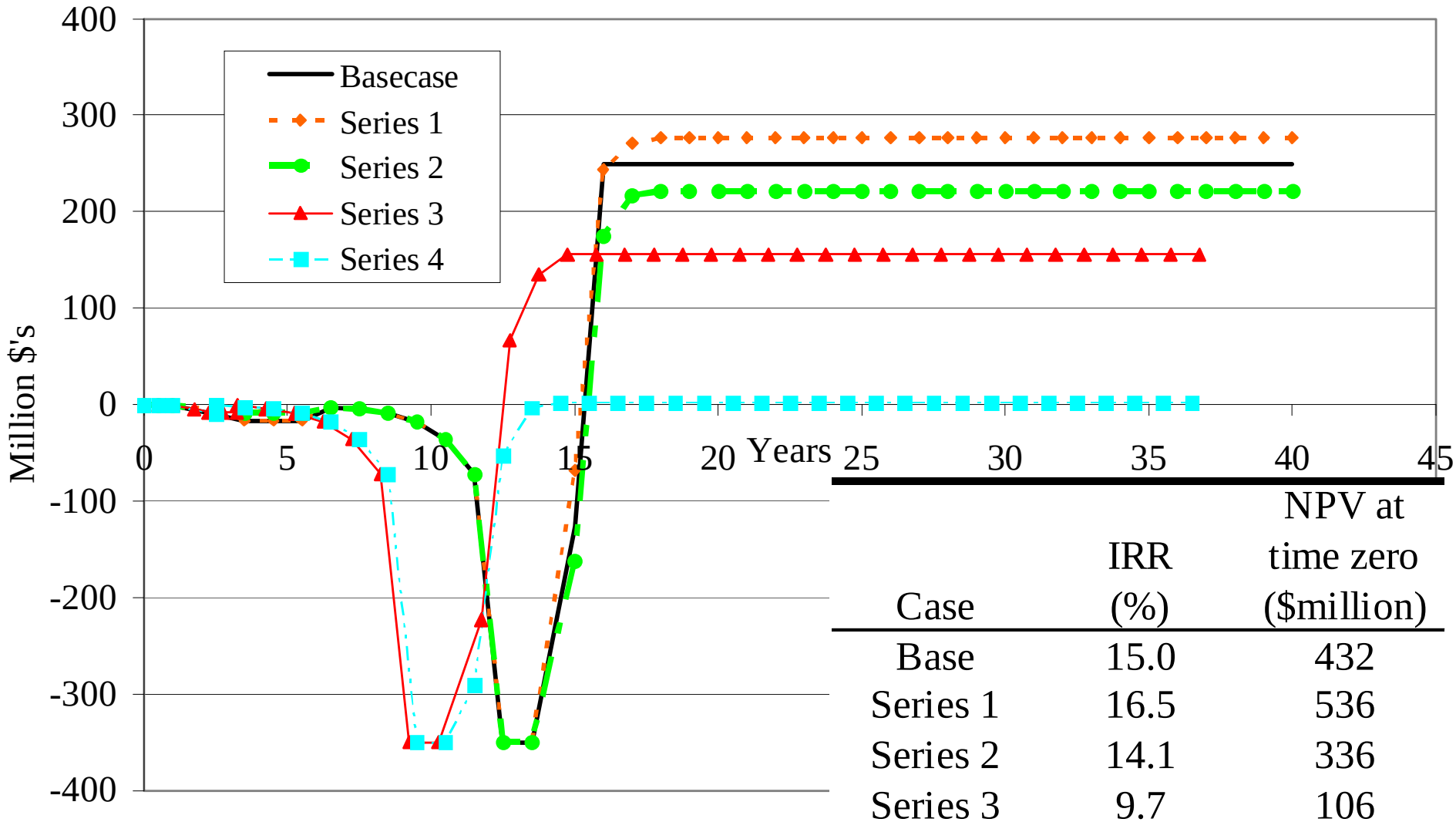
- Risk Weighted Value of Future Cash =

$$\frac{(100 - \%\text{Financial Risk})}{100} \times \text{Cash Value}_{\text{future time, T}}$$

A high risk project with insufficient financial benefit once risk weighted cashflow risk are taken into account **should not be built in preference to an established technology with a better risk weighted NPV.**

SNC·LAVALIN MacRae Technologies Inc. NTNU Innovation and Creativity

Project cash flows by ‘Series’



Case	IRR (%)	NPV at time zero ($million)
Base	15.0	432
Series 1	16.5	536
Series 2	14.1	336
Series 3	9.7	106
Series 4	N/A	-548

Conclusions

- Solid feed stock have more technical risk than projects treating non-solid raw materials.
- Technical risk is larger when treating natural as opposed to pre-processed feeds.
- New technology risk adds to the existing high technical risk in metallurgy.

Conclusions

- Front-end-loading improves the quality design criteria, results in lower technical and technological risk and a higher probability of building a financially successful business.

- Engineers and financial professionals should agree on a methodology to define and manage the magnitude of financial risk present at each project stage/stage-gate.

Thank you

Mark Kennedy
mark.kennedy@material.ntnu.no

Cameron Harris
Cameron.Harris@snclavalin.com

Allan MacRae
amacrae@macraetechinc.com

SNC·LAVALIN

MacRae Technologies Inc.

NTNU
Innovation and Creativity