Aalto University
School of Business

Capital Budgeting (22E12000)

Real Options
Risk Analysis

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Real Options

Real options

What are they?

For what type of managerial flexibilities are they applicable?

When are they used?

What influences the value of real options?

What calculative approaches are available?

What challenges relate to their use?

Do companies use them in practice?

Real options – what are they?

An option/ability to alter the course of action in response to changing circumstances

Real options methodology seeks to assess the value of managerial flexibility

Real Options - for what type of managerial flexibilities are they applicable?

Option to:

Defer
- defer investment

Switch
- switch inputs, outputs or risky assets

Alter
- alter operating scale

Abandon
- abandon investment

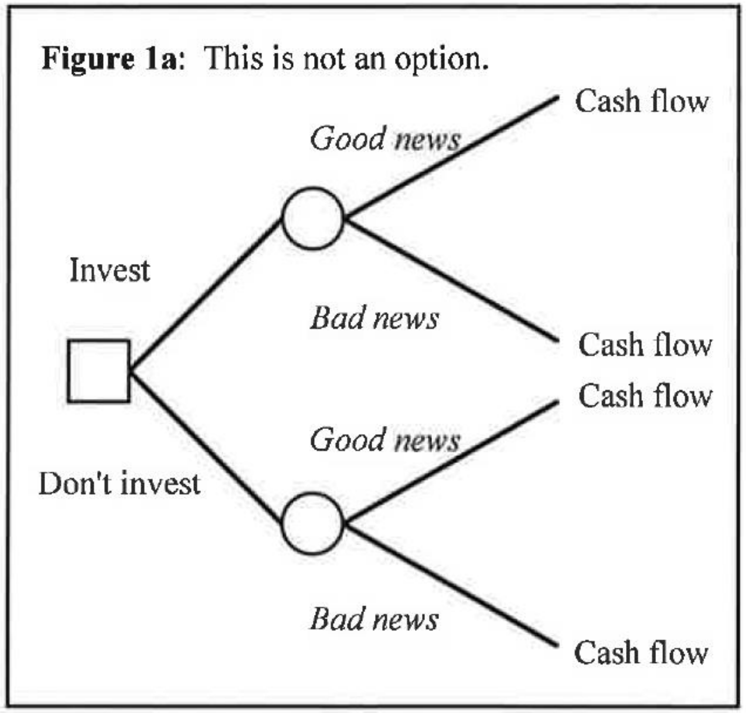
Extend
- extend to new markets, product areas etc. (growth option)

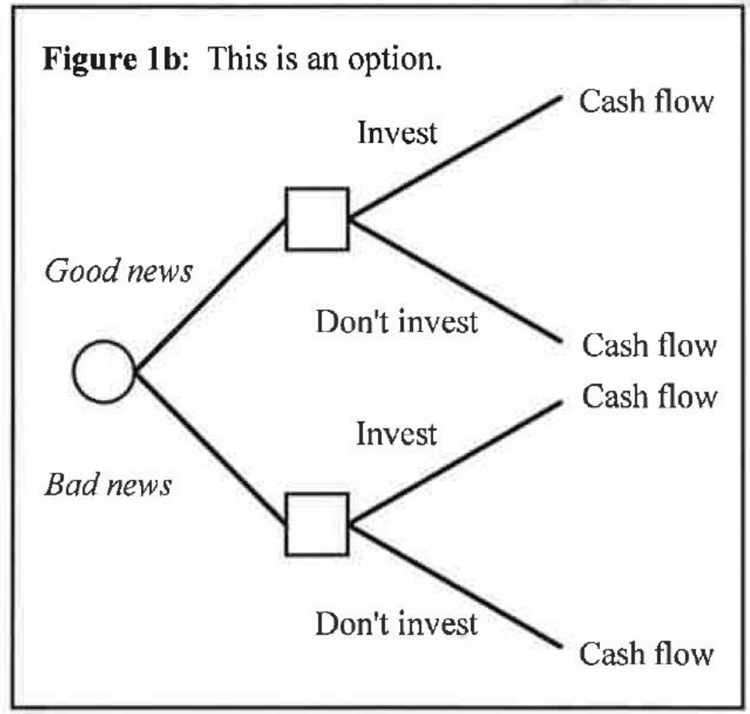
Real options – when are they applied?

When the opportunity to alter the course of action in response to new information has significant value (e.g. gold mine, R&D investments)

When DCF analysis fails to capture investment's strategic value (e.g. potential product/market extensions, possibility to abandon a project)

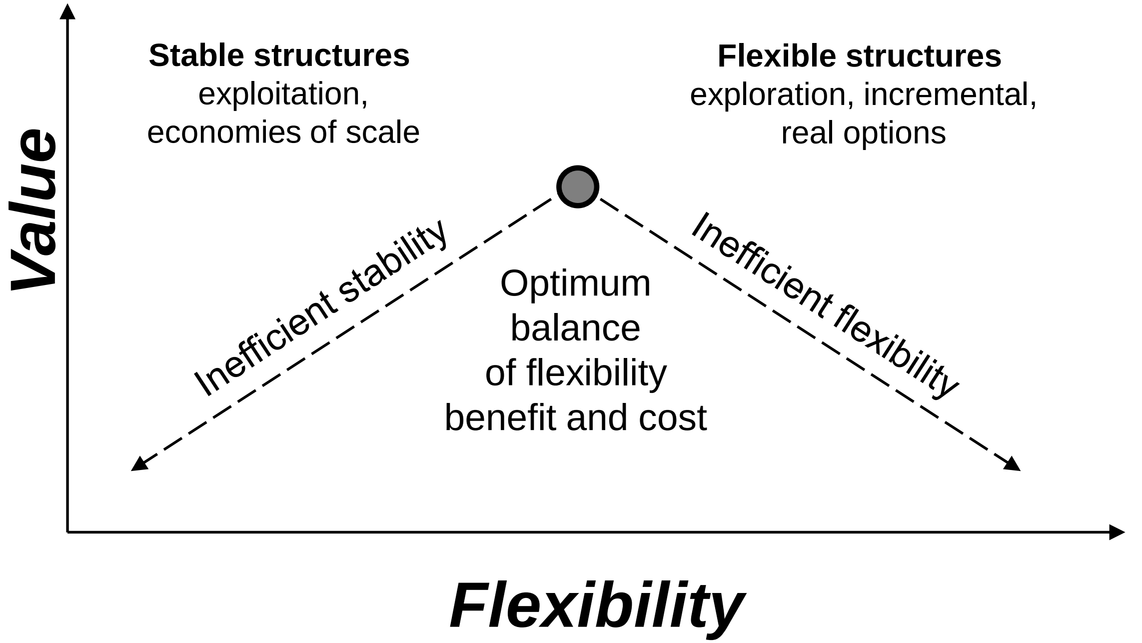
The difference between an option – and not an option





Source: Luehrman,T.A., 1994. Capital Projects as Real Options: An Introduction. Harvard Business School, 9-295-074.

Real options approach recognizes that organizations will always face a challenge to fit their practices and structures with the volatility of their environment (modified from Klingebiel, 2010)



Comparing real options to financial options

Figure 3: Mapping Project Characteristics Onto Call Option Variables

Project	*Variable*	*Call Option*
Expenditures required to acquire the assets	X	Exercise price
Value of the operating assets to be acquired	S	Stock price
Length of time decision may be deferred	t	Time to expiration
Riskiness of the underlying operating assets	σ^2	Variance of returns on stock
Time value of money	r	Risk-free rate of return

Source: Luehrman,T.A., 1994. Capital Projects as Real Options: An Introduction. Harvard Business School, 9-295-074.

Real options – what influences the value of real options? How?

- The length of the time the project can be deferred
- The risk of the project
- The proprietary nature of the option

Real options – what calculative approaches are available?

- Financial option models
- Decision trees
- Break-even analysis
- Qualitative assessment

Real Options - What challenges relate to their use in Decision-Making?

Required information not readily available	Terms are ambiguous	Real management decisions may be too complex to be scrutinized into a few variables
Decision-making can become very complex	Decision-making may require advanced mathematical skills	Calculation can be a black box (lack of transparency)

Real Options - What challenges relate to their use?

Management issues

-Potential disconnect between the *valuation* and the *management* of real options

-If real option is exercised sub-optimally, a significant part of the option's value may be lost

Organizational issues

-Lack of organizational commitment

-Difficulty to abandon investments

-Effectiveness of information gathering and flexibility design

-Perceptions of external stakeholders

Real options – do companies use them in practice?

- Majority of companies pay attention to managerial flexibilities
- Yet, companies have rarely established formal procedures for calculating the value of this flexibility
- The assessment tends to be qualitative in nature

Management views on real options in Capital Budgeting: Canadian evidence

Reasons not to use real options (10% use often or always; 81% never)

		Level of importance (%)				
Statement	**N**	**None, 0**	**Some, 1**	**Moderate, 2**	**High, 3**	**Mean**
Lack of expertise or knowledge	**166**	**12,6**	**9,5**	**15,8**	**62,1**	**2,27**
Lack of applicability to our business	**161**	**55,9**	**7,5**	**15,1**	**21,5**	**1,02**
Too complex to apply in practice	**163**	**52,2**	**9,8**	**22,8**	**15,2**	**1,01**
Difficulty in estimating inputs	**164**	**60,9**	**7,6**	**19,6**	**12,0**	**0,83**
Requires unrealistic assumptions	**163**	**64,1**	**8,7**	**18,5**	**8,7**	**0,72**
Does not help managers make better decisions	**158**	**67,4**	**4,4**	**18,5**	**9,8**	**0,71**
Limited support for real-world applicability of real options models	**153**	**64,8**	**9,1**	**18,2**	**8,0**	**0,69**
Requires many internal resources	**159**	**63,0**	**15,2**	**14,1**	**7,6**	**0,66**

Baker et al. (2011). Journal of Applied Finance

The use of real option theory in Scandinavia’s largest companies: A survey by Horn et al. (2015)

Surveyed real option practices in Sweden, Norway and Denmark (CFOs, 384 responses, response rate 33%)

Only 6% use real options

More often used by companies in energy and biotech sectors

70% of CFOs not familiar with real options

For those familiar with real options, the complexity of real options the main hinder for implementation

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Practical Example of a Real Option Calculation
Case: R&D Investment (Shapiro, 2005, p. 97-100)

R&D investment: Background information

The product development cost:

$ 5 million annually from 2005 to 2007 (beginning of year)

The plant cost:

$ 100 million in the beginning of year 2008

Operating cash flow:

$ 13 million annually from year-end 2008 to 2017

Terminal value

$ 105 million at the year-end 2017

Discount rate: 14%

Net Present Values (as of January 1, 2005)

R&D costs (Occur at the beginning of the year)

Year	Cash Flow	Present Value Factor (14%)	Present Value	Cumulative Present Value
2005	-5,0	1,000	-5,0	-5,0
2006	-5,0	0,877	-4,4	-9,4
2007	-5,0	0,769	-3,8	**-13,2**

Plant Cost (Occurs at the beginning of the year)

Year	Cash Flow	Present Value Factor (14%)	Present Value	Cumulative Present Value
2008	-100	0,675	-67,5	**-67,5**

Operating Cash Flows (Occur at the end of year)

Year	Cash Flow	Present Value Factor (14%)	Present Value	Cumulative Present Value
2008	13,0	0,592	7,7	7,7
2009	13,0	0,519	6,8	14,4
2010	13,0	0,456	5,9	20,4
2011	13,0	0,400	5,2	25,6
2012	13,0	0,351	4,6	30,1
2013	13,0	0,308	4,0	34,1
2014	13,0	0,270	3,5	37,6
2015	13,0	0,237	3,1	40,7
2016	13,0	0,208	2,7	43,4
2017	13,0	0,182	2,4	**45,8**

Terminal value (Occur at the end of year)

Year	Cash Flow	Present Value Factor (14%)	Present Value	Cumulative Present Value
2017	105,0	0,1821	19,1	**19,1**

Net Present Values (as of January 1, 2008)

Plant Cost (Occurs at the beginning of the year)

Year	Cash Flow	Present Value Factor (14%)	Present Value	Cumulative Present Value
2008	-100,0	1,000	-100,0	**-100,0**

Operating Cash Flows (Occur at the end of year)

Year	Cash Flow	Present Value Factor (14%)	Present Value	Cumulative Present Value
2008	13,0	0,877	11,4	11,4
2009	13,0	0,769	10,0	21,4
2010	13,0	0,675	8,8	30,2
2011	13,0	0,592	7,7	37,9
2012	13,0	0,519	6,8	44,6
2013	13,0	0,456	5,9	50,6
2014	13,0	0,400	5,2	55,7
2015	13,0	0,351	4,6	60,3
2016	13,0	0,308	4,0	64,3
2017	13,0	0,270	3,5	**67,8**

Terminal value (Occur at the end of year)

Year	Cash Flow	Present Value Factor (14%)	Present Value	Cumulative Present Value
2017	105,0	0,270	28,3	**28,3**

Summary of the DCF calculation

Cash Flow Item	Present Value as of January 2005	Present Value as of January 2008
Research and Development Costs	-13,2	0,0
Plant Cost	-67,5	-100,0
Operating Cash Flows	45,8	67,8
Terminal Value	19,1	28,3
Net Present Value	**-15,8**	**-3,9**

Option valuation

- Takes into account the opportunity NOT to build the plant
- Assumes many possible outcomes, and measures each separately

Option valuation

Scenario I

Cash Flow Item	Present Value 1.1.2005	Present Value Factor (14%)	Present Value 1.1.2008
Research and Development Costs	-13,2		
Plant Cost	-67,5	0,675	-100
Possible Payoff	151,1	0,675	223,9
Net Present Value	**70,4**		**123,9**

Scenario II

Cash Flow Item	Present Value 1.1.2005	Present Value Factor (14%)	Present Value 1.1.2008
Research and Development Costs	-13,2		
Plant Cost	-67,5	0,675	-100
Possible Payoff	79,7	0,675	118,1
Net Present Value	**-1,0**		**18,1**

Scenario III

Cash Flow Item	Present Value 1.1.2005	Present Value Factor (14%)	Present Value 1.1.2008
Research and Development Costs	-13,2		
Plant Cost	0,0	0,675	
Possible Payoff	0,0	0,675	33,9
Net Present Value	**-13,2**		

Scenario IV

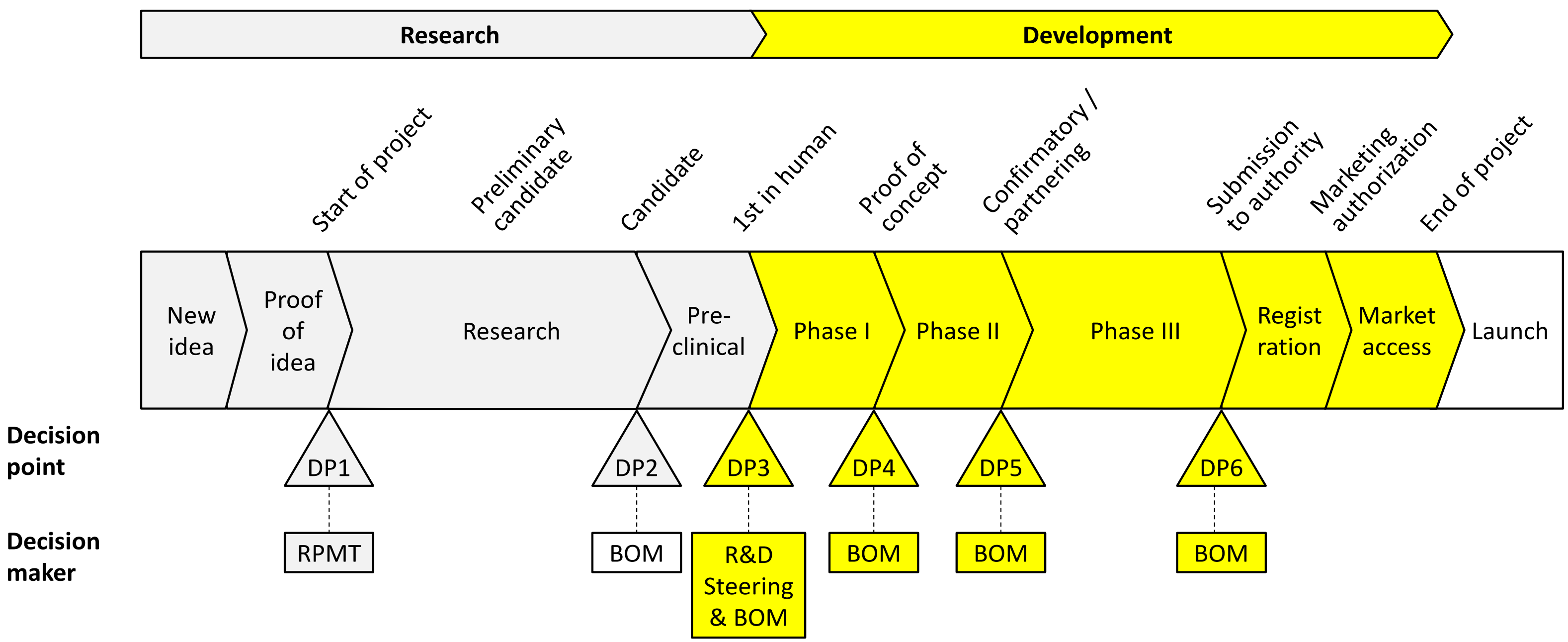
Cash Flow Item	Present Value 1.1.2005	Present Value Factor (14%)	Present Value 1.1.2008
Research and Development Costs	-13,2		
Plant Cost	0,0	0,675	
Possible Payoff	0,0	0,675	8,6
Net Present Value	**-13,2**		

Summary of the option valuation

Scenario	Decision	Plant Cost	Payoff	NPV (1.1.2008)	Probability	Value 1.1.2008	Value 1.1.2005	R&D Cost 1.1.2005	Final Value
I	Build plant	-100	223,9	123,9	0,25	31,0			
II	Build plant	-100	118,1	18,1	0,25	4,5			
III	Not build plant	0	0	0	0,25	0			
IV	Not build plant	0	0	0	0,25	0			
						35,5	**24,0**	**-13,2**	**10,8**

Appendix 1: Stage gate model NPD process in pharmaceutical industry

(Huikku and Kolehmainen, 2024)



RPMT = Research portfolio management team
BOM = Board of managers

* BOM decisions precede recommendation from R&D Steering and the Business Team

Small group discussions

- In what kinds of cases are DCF models superior to real options?
- How companies know what is the optimal trigger and its level to exercise a real option?
- Are there any effective ways of dealing with lack of commitment from employees when conducting a real option approach?

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Risk Analysis

Risk analysis

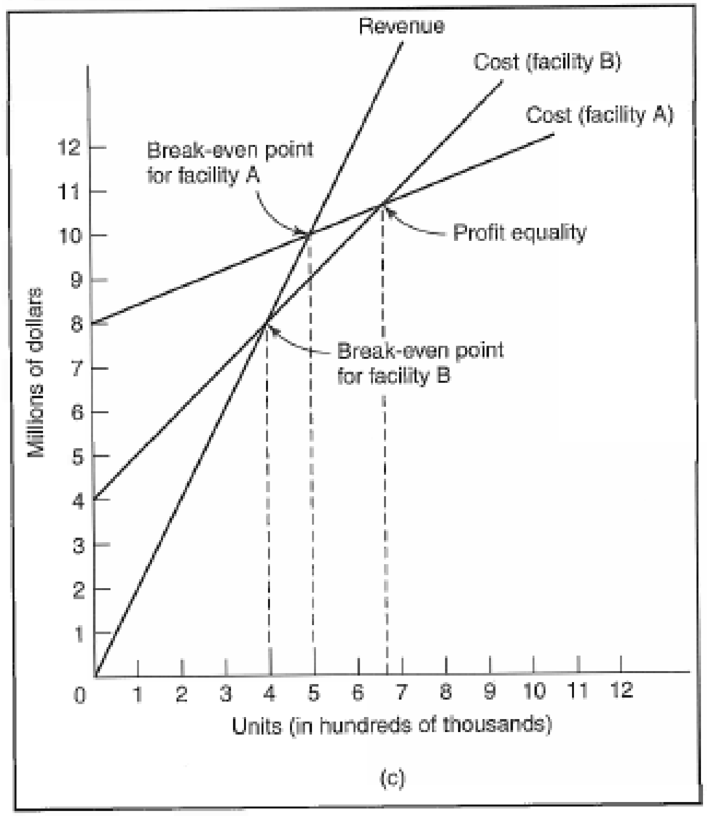
- What type of approaches are available for assessing risk?
- How can the calculations be adjusted for risk?
- How do companies account for risk in practice?

What type of approaches are available for assessing risk?

Break-even analysis	• Determines the quantity of sales at which the project NPV is zero
Sensitivity analysis	• Analyses the project's sensitivity for changes in one key variable at a time
Scenario analysis	• Entails changing several key variables at the same time
Simulation analysis	• As above, but presents project's NPV as a probability distribution

Break-even analysis is often presented in a graphic format

EXHIBIT 5.1 (c) Break-Even Analysis for Facilities A and B



Source: Shapiro, A.C., 2005. Capital Budgeting and Investment Analysis, p. 114.

Practical example: Sensitivity and scenario analysis

- **An iron mine is considering replacement of some machinery.**
- **The new conveyor belt will cost $5 million and lower the cost of removing ore from the mine by $4 per ton. The old belt can be scrapped for $500,000.**
- **The life of the new machine as well as the annual amount of ore that will be moved are uncertain, estimates below:**

	Low	Medium	High
Tons per year	200 000	250 000	350 000
Life of new machine	6 years	9 years	13 years

- **Conduct a sensitivity analysis and a scenario analysis of NPV of the replacement project assuming a discount rate of 10%. Ignore taxes.**

Source: Shapiro, A.C., 2005. Capital Budgeting and Investment Analysis, p. 142.

Practical example: Sensitivity analysis

	Annual Cash Flows (sensitivity of volume)					Annual Discounted Cash Flows			
	Low	Medium	High		Discounting factor	Low	Medium	High	
0	-4 500 000	-4 500 000	-4 500 000		1	-4 500 000	-4 500 000	-4 500 000	
1	800 000	1 000 000	1 400 000		0,909	727 273	909 091	1 272 727	
2	800 000	1 000 000	1 400 000		0,826	661 157	826 446	1 157 025	
3	800 000	1 000 000	1 400 000		0,751	601 052	751 315	1 051 841	
4	800 000	1 000 000	1 400 000		0,683	546 411	683 013	956 219	
5	800 000	1 000 000	1 400 000		0,621	496 737	620 921	869 290	
6	800 000	1 000 000	1 400 000		0,564	451 579	564 474	790 264	
7	800 000	1 000 000	1 400 000		0,513	410 526	513 158	718 421	
8	800 000	1 000 000	1 400 000		0,467	373 206	466 507	653 110	
9	800 000	1 000 000	1 400 000		0,424	339 278	424 098	593 737	
10					0,386	0	0	0	
11					0,350	0	0	0	
12					0,319	0	0	0	
13					0,290	0	0	0	
NPV						**107 219**	**1 259 024**	**3 562 633**	
Estimated probabilities						33 %	33 %	33 %	
Expected value of NPV						35 740	419 675	1 187 544	**1 642 959**

The sensitivity of NPV to changes in production volume:
Vary the production volume; use medium time duration in the analysis

Practical example: Sensitivity analysis (cont.)

	Annual Cash Flows (sensitivity by time duration)					Annual Discounted Cash Flows			
	Low	Medium	High		Discounting factor	Low	Medium	High	
0	-4 500 000	-4 500 000	-4 500 000		1	-4 500 000	-4 500 000	-4 500 000	
1	1 000 000	1 000 000	1 000 000		0,909	909 091	909 091	909 091	
2	1 000 000	1 000 000	1 000 000		0,826	826 446	826 446	826 446	
3	1 000 000	1 000 000	1 000 000		0,751	751 315	751 315	751 315	
4	1 000 000	1 000 000	1 000 000		0,683	683 013	683 013	683 013	
5	1 000 000	1 000 000	1 000 000		0,621	620 921	620 921	620 921	
6	1 000 000	1 000 000	1 000 000		0,564	564 474	564 474	564 474	
7		1 000 000	1 000 000		0,513	0	513 158	513 158	
8		1 000 000	1 000 000		0,467	0	466 507	466 507	
9		1 000 000	1 000 000		0,424	0	424 098	424 098	
10			1 000 000		0,386	0	0	385 543	
11			1 000 000		0,350	0	0	350 494	
12			1 000 000		0,319	0	0	318 631	
13			1 000 000		0,290	0	0	289 664	
NPV						**-144 739**	**1 259 024**	**2 603 356**	
Estimated probabilities						33 %	33 %	33 %	
Expected value of NPV						-48 246	419 675	867 785	**1 239 214**

The sensitivity of NPV to changes in production duration: Vary the duration; use medium volume level in the analysis

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Practical example: Scenario analysis

	Annual Cash Flows				Annual Discounted Cash Flows			
	Low	Medium	High	Discounting factor	Low	Medium	High	
0	-4 500 000	-4 500 000	-4 500 000	1	-4 500 000	-4 500 000	-4 500 000	
1	800 000	1 000 000	1 400 000	0,909	727 273	909 091	1 272 727	
2	800 000	1 000 000	1 400 000	0,826	661 157	826 446	1 157 025	
3	800 000	1 000 000	1 400 000	0,751	601 052	751 315	1 051 841	
4	800 000	1 000 000	1 400 000	0,683	546 411	683 013	956 219	
5	800 000	1 000 000	1 400 000	0,621	496 737	620 921	869 290	
6	800 000	1 000 000	1 400 000	0,564	451 579	564 474	790 264	
7		1 000 000	1 400 000	0,513	0	513 158	718 421	
8		1 000 000	1 400 000	0,467	0	466 507	653 110	
9		1 000 000	1 400 000	0,424	0	424 098	593 737	
10			1 400 000	0,386	0	0	539 761	
11			1 400 000	0,350	0	0	490 691	
12			1 400 000	0,319	0	0	446 083	
13			1 400 000	0,290	0	0	405 530	
NPV					**-1 015 791**	**1 259 024**	**5 444 699**	
Estimated probabilities					33 %	33 %	33 %	
Expected value of NPV					-338 597	419 675	1 814 900	**1 895 977**

Calculate NPV for the three scenarios. If estimates of the probabilities of the three scenarios are available, you may also calculate expected value of NPV.

Simulation analysis

Conventional investment appraisal analysis (such as NPV) uses deterministic probability distribution of variable values

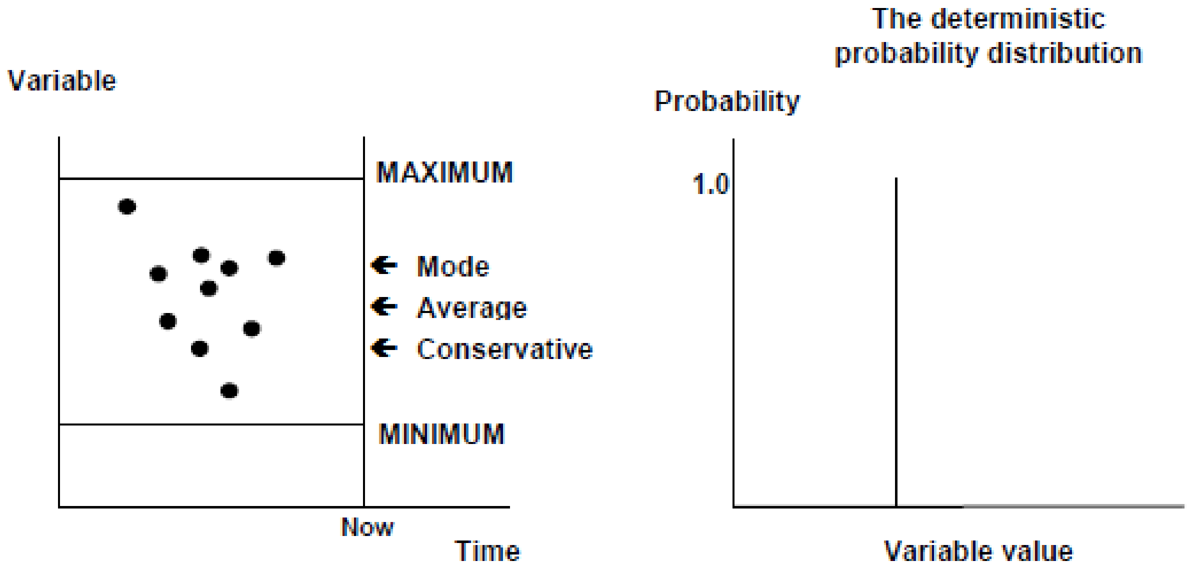


Figure 5. Forecasting the outcome of a future event: single-value estimate

Source: Savvides, S.C., 1994, Risk Analysis in Investment Appraisal. Project Appraisal Journal, 9, 3-18 .

Simulation analysis, on the other hand, uses probabilities of variable values as input variables

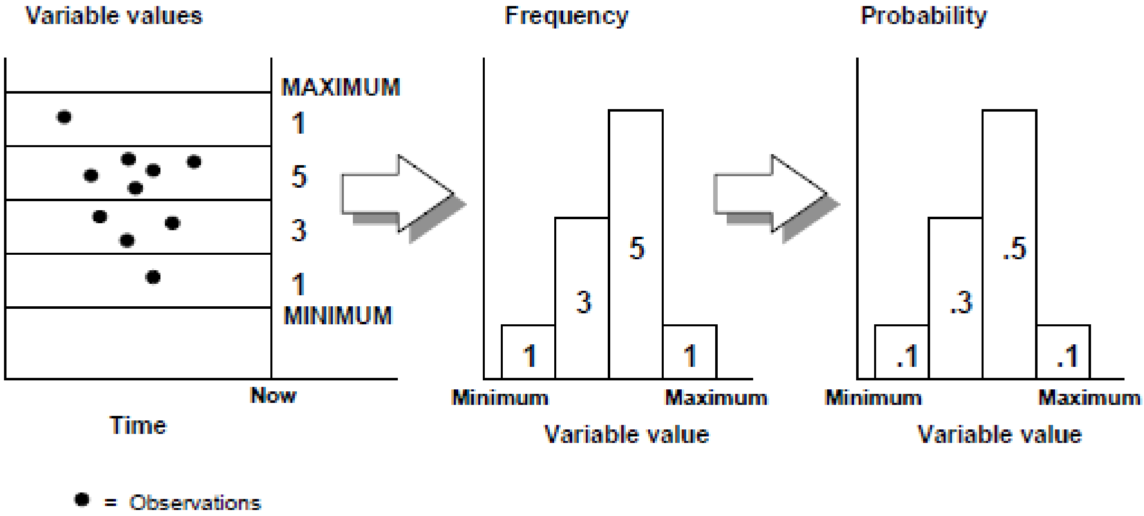


Figure 4. From a frequency to a probability distribution

Source: Savvides, S.C., 1994, Risk Analysis in Investment Appraisal. Project Appraisal Journal, 9, 3-18 .

The probability distributions of variable values can take different forms

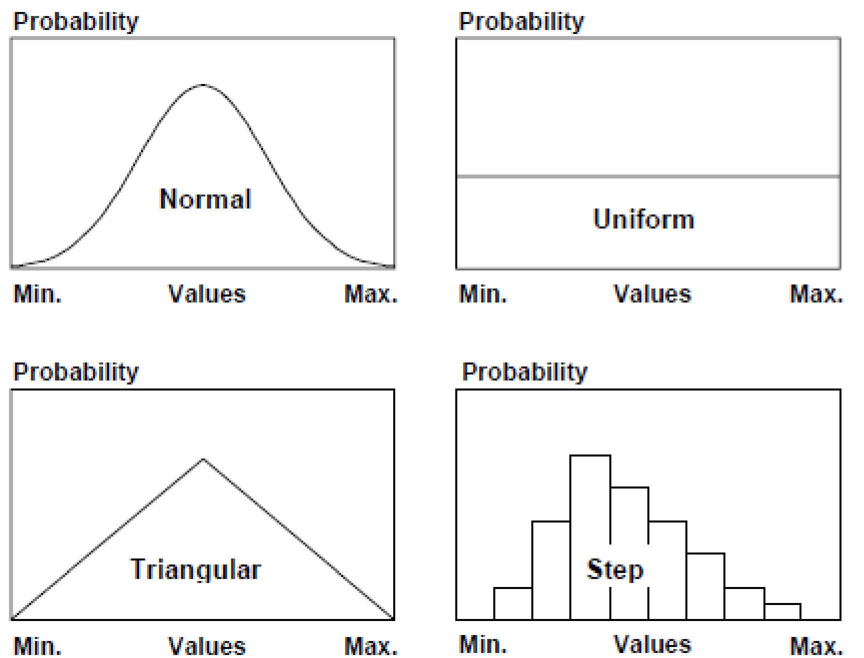


Figure 6. Multi-value probability distributions

Source: Savvides, S.C., 1994, Risk Analysis in Investment Appraisal. Project Appraisal Journal, 9, 3-18 .

Simulation analysis allows for incorporating correlations between variables

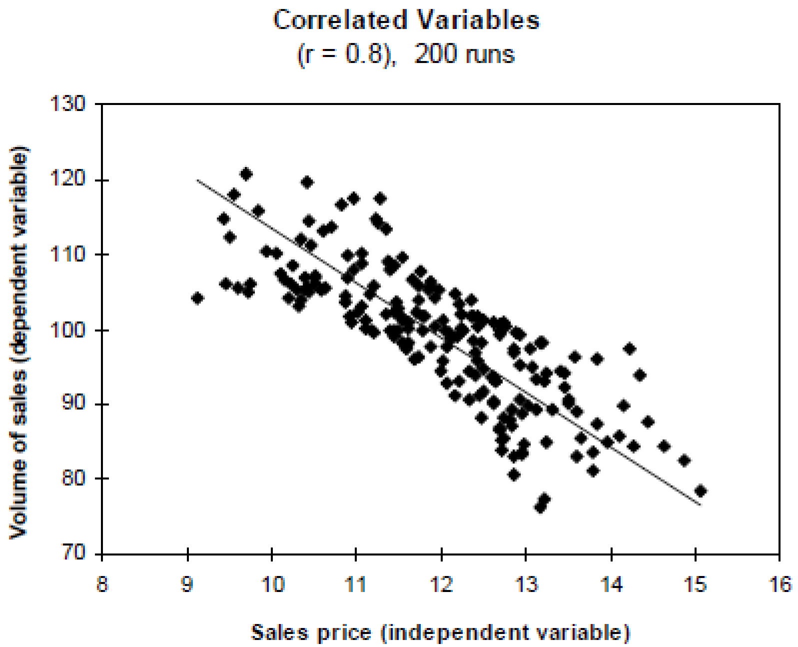


Figure 8. Scatter diagram

Source: Savvides, S.C., 1994, Risk Analysis in Investment Appraisal. Project Appraisal Journal, 9, 3-18 .

Simulation analysis results in a probability distribution of results (typically NPV)

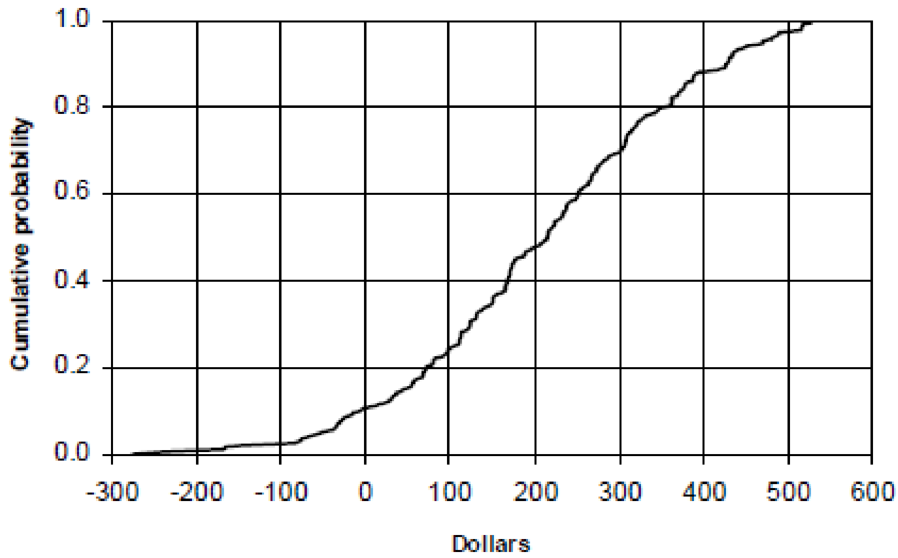
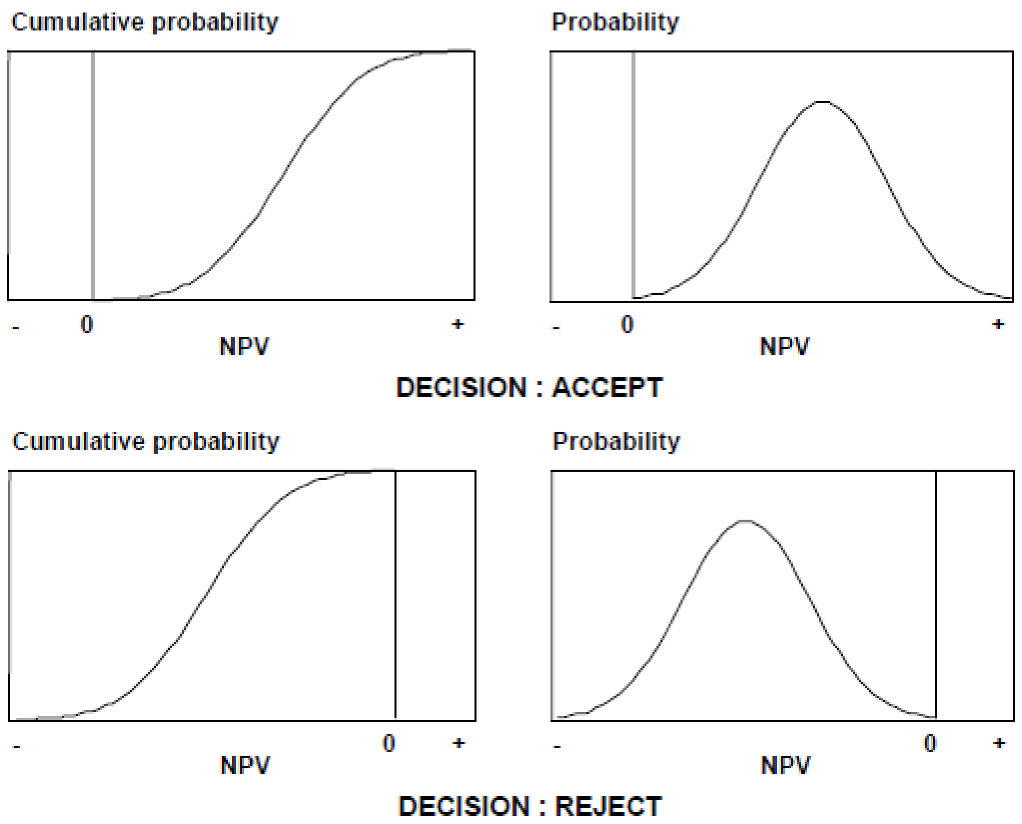


Figure 10. Distribution of results (net cash flow)

Source: Savvides, S.C., 1994, Risk Analysis in Investment Appraisal. Project Appraisal Journal, 9, 3-18 .

Interpreting the results of simulation analysis: The probability vs. NPV 0



Source: Savvides, S.C., 1994, Risk Analysis in Investment Appraisal. Project Appraisal Journal, 9, 3-18 .

Interpreting the results of simulation analysis: The probability of 0<NPV<1

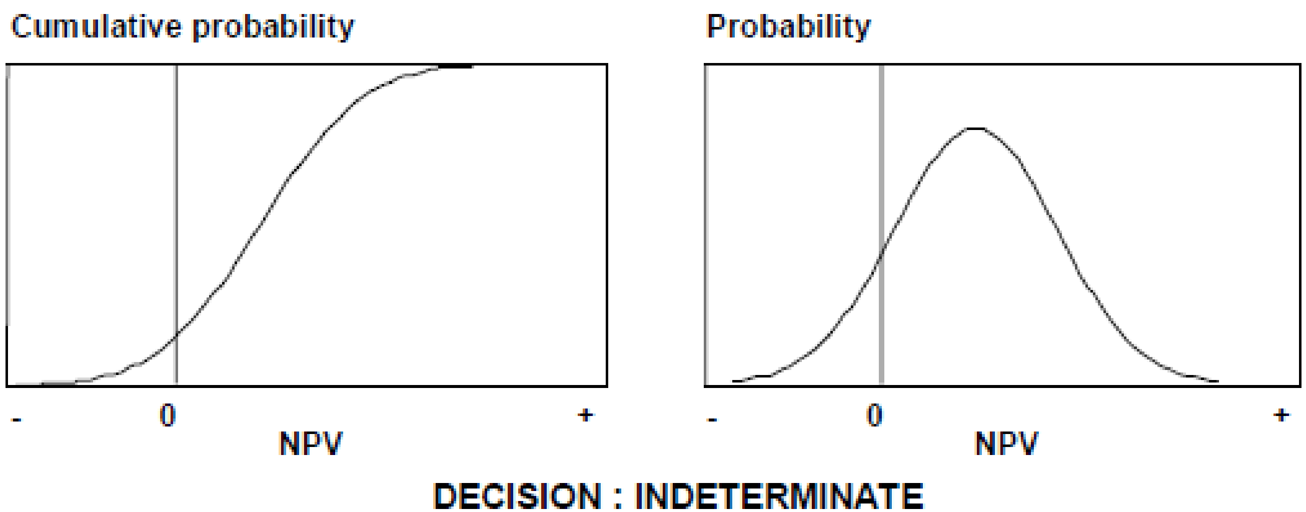


Figure 14. Case 3: Probability of zero NPV greater than 0 and less than 1

Source: Savvides, S.C., 1994, Risk Analysis in Investment Appraisal. Project Appraisal Journal, 9, 3-18 .

Interpreting the results of simulation analysis: Comparing projects A and B

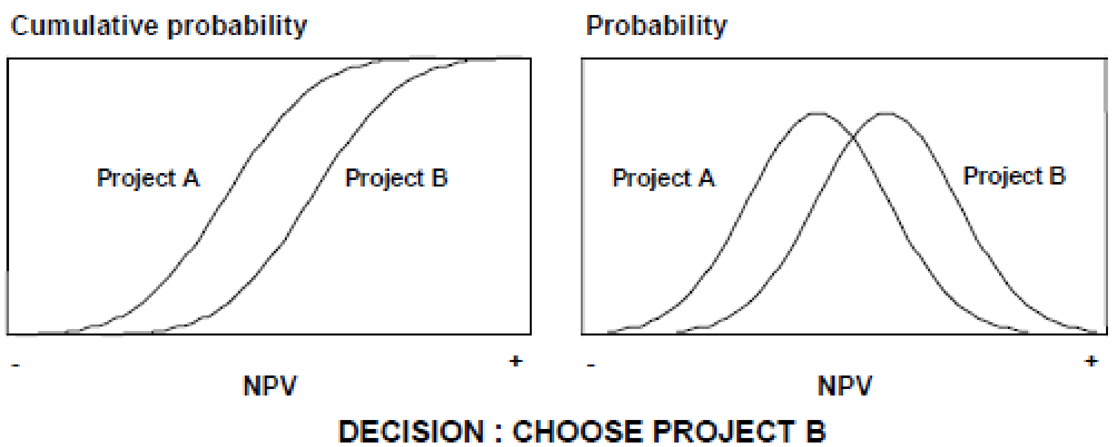


Figure 15. Case 4: Mutually exclusive projects

Source: Savvides, S.C., 1994, Risk Analysis in Investment Appraisal. Project Appraisal Journal, 9, 3-18 .

How can financial analysis be adjusted for project risk?

Payback	Discount rate	Cash flows	Certainty-equivalent
Adjusting the payback period	Adjusting the discount rate	Adjusting cash flows to reflect the year-by-year expected effects of a given risk	Using certainty equivalents • Entails converting each expected cash flow into its certainty equivalent • Allows for different time patterns of risk • Defining certainty-equivalent conversion factors can be challenging

Practical example: Calculating certainty-equivalent NPV

Year	Expected Cash Flow	Conversion Factor	C-E Cash Flow	Discount Factor	Present Value
0	-15 000	1,0	-15 000	1,0000	-15 000
1	8 000	0,8	6 400	0,9174	5 872
2	9 000	0,7	6 300	0,8417	5 303
3	6 000	0,6	3 600	0,7722	2 780
4	5 000	0,5	2 500	0,7084	1 771
5	3 000	0,4	1 200	0,6499	780
			Certainty-equivalent NPV		**1 505**

Source: Shapiro, A.C., 2005. Capital Budgeting and Investment Analysis, p. 132.

How do companies account for risk in practice?

Companies tend to use rather simple methods for risk analysis and adjustment

- -Sensitivity and scenario analysis
- -Subjective, qualitative analysis
- -Higher hurdle rate, shorter PB, conservative cash flows

Companies have less experience of using sophisticated techniques, such as simulation

Risk analysis required in strategic investment appraisal

Huikku, Karjalainen & Seppälä (2018) (108/150 largest Finnish manufacturing companies)

Techniques	Never	Sometimes	Regularly	Almost always	Always
a) Sensitivity analysis	13 %	14 %	24 %	23 %	25 %
b) Scenario analysis	20 %	27 %	21 %	17 %	14 %
c) Simulation analysis	88 %	8 %	3 %	0 %	0 %
d) CAPM analysis	83 %	12 %	2 %	0 %	2 %

Risk adjustment techniques: Project-specific risk

Huikku, Karjalainen & Seppälä (2018) (108/150 largest Finnish manufacturing companies)

Change	Never	Some-times	Regu larly	Almost always	Always
a) Required Payback period shortened	30 %	44 %	14 %	6 %	4 %
b) RRR raised according to project risk	41 %	33 %	13 %	7 %	3 %
c) More conservative cash flow estimates	31 %	30 %	22 %	10 %	5 %

Forest industry: Risk mapping

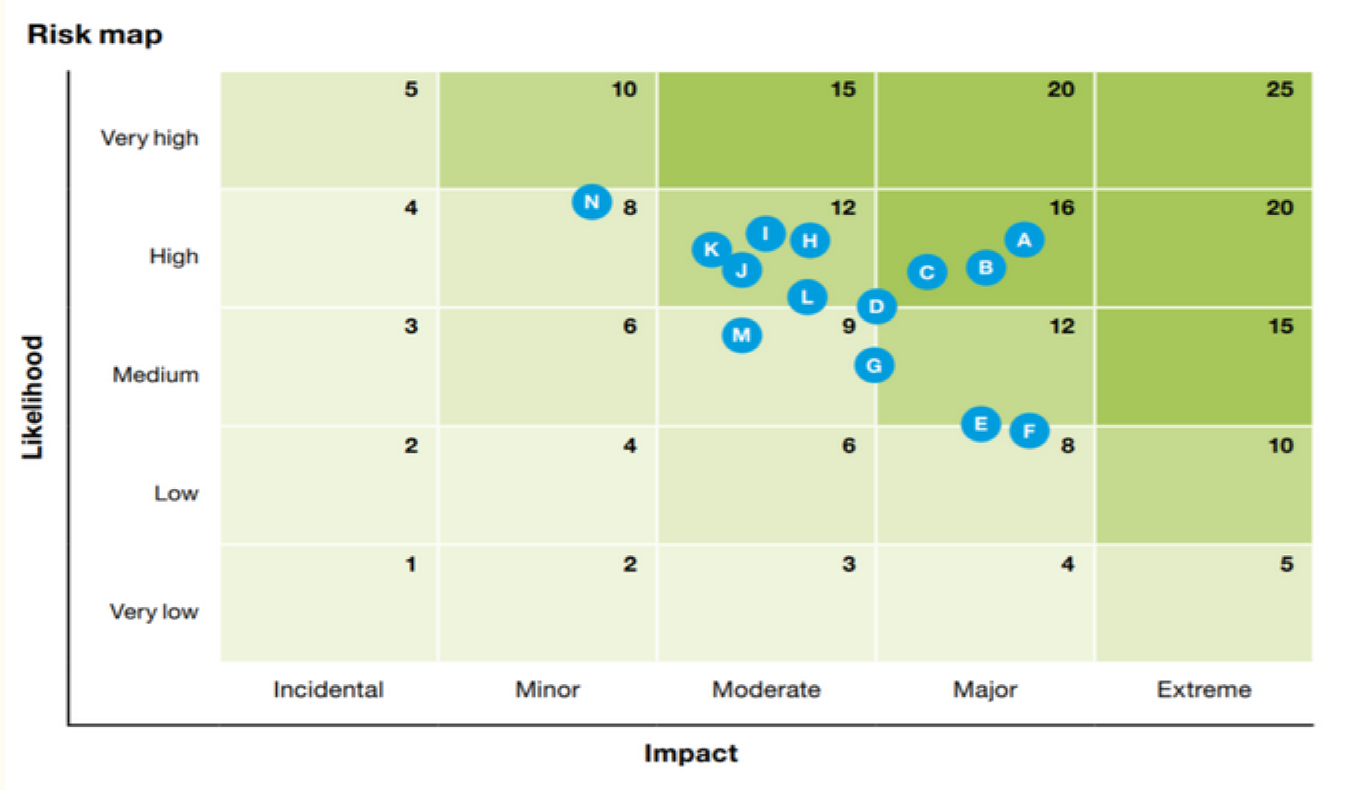


Figure 2. Example of a risk map based on an ERM process. Source: Stora Enso, 2016 [2].

Forest industry: ERM Risk Categories

Strategic risks related to:	Operational risks related to:
-Vision, mission and values -Organisation and governance -Planning processes (strategic, operational, business) -Strategic investments incl. mergers and acquisitions and divestures -Macro-economic development -Market trends and customer preferences -Technology changes -Competition changes	-Occupational risk and safety (OHS) -Production management and planning -Physical asset management, maintenance and business interruption planning -Sourcing and raw material management -Inventory management -Sales and marketing processes -Information technology infrastructure management and development -Human resources planning and development -Product development and R&D
Compliance and responsibility risks related to:	**Financial risks related to:**
-Code of conduct issues e.g. related to conflict of interests, bribery, fraud, insider regulations, competition law -Human rights issues -Data privacy issues -Sustainable sourcing -Environmental sustainability e.g. related to waste, emissions to air, energy and water -Social responsibility issues -Political and regulation-related issues -Liabilities and legal matters	-Market and pricing changes -Financing -Currency exchange development -Financial capability and funding -Tax planning -Accounting and reporting principles -Credit losses -Internal control

Figure 3. Selected typical ERM risk categories.