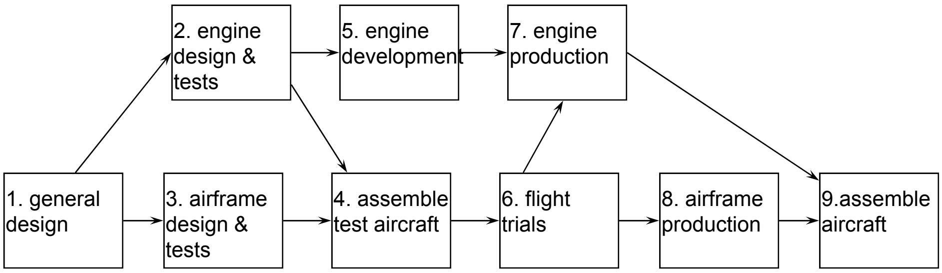
Schedule Risk Analysis

Monte Carlo simulation of a project network

- specify network logic (e.g. precedences)
- estimate activity durations: best estimate & uncertainties
- embed project network analysis within a Monte Carlo framework
- approach can be extended to consider resources & costs

A new aircraft



Network simulation with a spreadsheet

preceding activities

specify uncertainty

activity 4 has preceding activities: 2 & 3

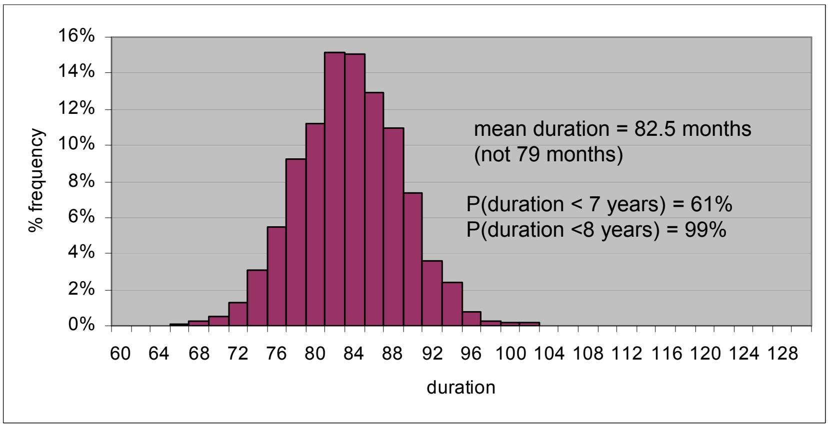
PROJECT RISK ANALYSIS USING MONTE CARLO SIMULATION								
manual								
							sample	
Activity		PA1	PA2	PA3	mean	sd	dur	complete
0								
1	general design				10.6	3.2	9.2	9.2
2	engine design & tests	1			31.8	9.5	33.4	42.6
3	airframe design & tests	1			21.2	6.4	23.7	32.9
4	assemble test aircraft	2	3		6.2	2.8	7.3	50.0
5	engine development	2			12.5	5.6	10.4	53.0
6	flight trials	4			15.5	9.3	3.9	53.8
7	engine production	5	6		11.9	1.8	12.8	66.7
8	airframe production	6			5.9	0.9	5.5	59.3
9	assemble aircraft	7	8		11.9	1.8	8.5	75.1
Project duration =								75

Another iteration

PROJECT RISK ANALYSIS USING MONTE CARLO SIMULATION								
manual								
							sample	
Activity		PA1	PA2	PA3	mean	sd	dur	complete
0								
1	general design				10.6	3.2	13.7	13.7
2	engine design & tests	1			31.8	9.5	42.1	55.8
3	airframe design & tests	1			21.2	6.4	12.8	26.4
4	assemble test aircraft	2	3		6.2	2.8	7.9	63.7
5	engine development	2			12.5	5.6	21.1	76.8
6	flight trials	4			15.5	9.3	6.9	70.6
7	engine production	5	6		11.9	1.8	9.1	85.9
8	airframe production	6			5.9	0.9	8.0	78.5
9	assemble aircraft	7	8		11.9	1.8	11.4	97.4
Project duration =								97

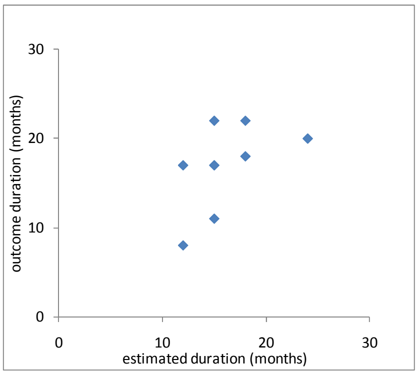
- project duration changes
- critical path may also change

Output



- consider financial implications of overrunning
  - is a 7 year schedule vital given possible competition?
- and effects on reputation
- criticality count to identify activities causing risk

How do we estimate variability of activity outcome durations?



- e.g. consider the estimating record for previous, similar “design” activities
- variability = consistent bias + uncertainty
- take care that “estimates” are made at similar stages of the projects’ life cycles; uncertainty should reduce

Summarising the past experience

project	estimate	outcome	outcome: estimate
A	12	17	1.42
B	18	22	1.22
C	15	11	0.73
D	15	17	1.13
E	12	8	0.67
F	18	18	1.00
G	24	20	0.83
H	15	22	1.47
mean			1.06
s.d.			0.30

- consider rations outcome: estimate for the sample of design activities
- historic data suggest:
  - outcome duration of design activities is approximately 6% more than estimate
  - s.d. of the ratios is 0.30 or 30% = “uncertainty rating”

Using the statistics from past projects

- use the mean ratio to adjust mean estimate of duration
- standard deviation = uncertainty rating * mean estimate

category	mean adjustment	uncertainty rating	description
trials	1.03	0.60	very high
tests	1.04	0.45	high
design	1.06	0.30	medium
bureaucratic	1.02	0.20	low
manufacture	0.99	0.15	very low

Using the understanding of past variability to estimate the mean & s.d.'s

allocate activity to relevant category

apply appropriate adjustment to mean

deduce s.d. = uncertainty rating * mean

adjusted estimates

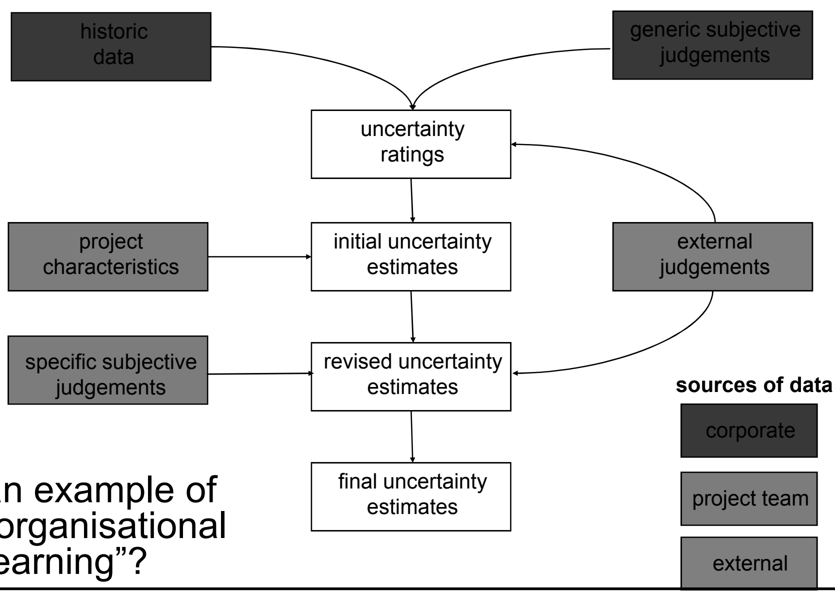
activity	initial estimate	category	description	mean adjustment	uncertainty rating	mean	s.d.
1.general design	10	design	medium	1.06	0.30	10.6	3.2
2.engine design & tests	30	design	medium	1.06	0.30	31.8	9.5
3.airframe design & tests	20	design	medium	1.06	0.30	21.2	6.4
4.assemble test aircraft	6	tests	high	1.04	0.45	6.2	2.8
5.engine development	12	tests	high	1.04	0.45	12.5	5.6
6.flight trials	15	trials	very high	1.03	0.60	15.5	9.3
7.engine production	12	manufacture	very low	0.99	0.15	11.9	1.8
8.airframe production	6	manufacture	very low	0.99	0.15	5.9	0.9
9.assemble aircraft	12	manufacture	very low	0.99	0.15	11.9	1.8

- use results of analysis of historic variability to estimate mean and standard deviations of activities of the new project
- could also include correlations?
- uncertainty should be dependent on stage of project life cycle

Exploiting more specific knowledge

- other forms of knowledge beyond the historic quantitative data
- general corporate judgements
  - e.g. estimating methods may have improved so perhaps the uncertainty ratings should be reduced
- external judgements might refine the uncertainty ratings
  - e.g. a review of similar projects undertaken by other companies might suggest a change in the ratings
- the project team may make judgements about the specific uncertainty estimates
  - e.g. staff experience may important
- further external judgements may affect the uncertainty estimates
  - e.g. consultants may be employed to review the analysis
- an example of “organisational learning”?

Flows of experience



- an example of “organisational learning”?

Incorporating more knowledge

					uncertainty ratings		adjusted estimates		
activity	initial estimate	category	description	mean adjustment	UR1	UR2	mean	s.d.	comment
1.general design	10	design	medium	1.06	0.30	0.30	10.6	3.2	
2.engine design & tests	30	design	medium	1.06	0.30	0.15	31.8	4.8	particularly experienced engine design team
3.airframe design & tests	20	design	medium	1.06	0.30	0.40	21.2	6.4	new materials
4.assemble test aircraft	6	tests	high	1.04	0.45	0.45	6.2	2.8	
5.engine development	12	tests	high	1.04	0.45	0.45	12.5	5.6	
6.flight trials	15	trials	very high	1.03	0.60	0.60	15.5	9.3	
7.engine production	12	manufacture	very low	0.99	0.15	0.15	11.9	1.8	
8.airframe production	6	manufacture	very low	0.99	0.15	0.30	5.9	0.9	new materials could cause production problems
9.assemble aircraft	12	manufacture	very low	0.99	0.15	0.15	11.9	1.8	

- uncertainty ratings are revised to include specific knowledge
- record/ justify change (with source)
- use adjusted standard deviations in Monte Carlo simulation analysis

Costs of delay

- additional overheads, see time-cost trade off notes from IS07
- penalty clauses
- loss of reputation
- cashflow
- loss of market/ reduced service
  - old product/ system may not be acceptable
  - customers may move to competitors introducing new product/ system
- additional cost of finance
- reduced NPV/ IRR

Interaction of time and money: project duration & NPV

£million

discount rate	20%														
year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
expenditure	50	500	200	100	20	20	20	20	20	20	20	20	20	20	20
income	0	0	0	0	300	300	300	300	300	300	300	300	250	200	100
profit	-50	-500	-200	-100	280	280	280	280	280	280	280	280	230	180	80
NPV=	6.0														

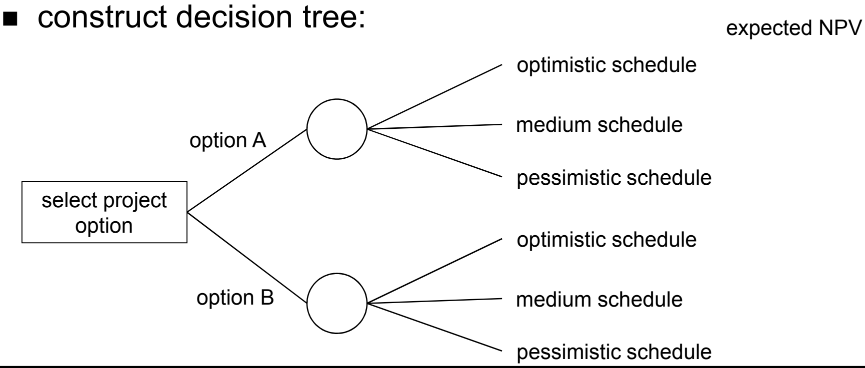
- intensive capital investment
- but NPV > 0 implying that the project generates sufficient profit to provide an average return of more than 20%

discount rate	20%																
year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
expenditure	50	500	100	100	50	50	20	20	20	20	20	20	20	20	20	20	20
income	0	0	0	0	0	0	300	300	300	300	300	300	300	300	250	200	100
profit	-50	-500	-100	-100	-50	-50	280	280	280	280	280	280	280	280	230	180	80
NPV=	-143.7																

- same total expenditure (£1070 million) and income (£2950 million)
- but delay of two years during construction
- delay in the income stream
- financial disaster

Decision tree analysis + Monte Carlo simulation output

- Monte Carlo simulation provides estimates of probabilities of : optimistic, medium and pessimistic schedules
- approximate each schedule and the consequences, e.g. sales
- construct decision tree:



Generic sources of project network risk

- uncertainty:
  - critical activities’ durations
  - availabilities of resources
- impact:
  - many parallel near critical paths
  - highly interconnected
  - adopting latest start dates
- in general, projects often have several near critical paths:
  - if any one path is late, the project is late
  - if any one path is early, the project will have to wait for others to be completed