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Introduction to Risk Analysis

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Contents

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Learning Outcomes

- Gather, extract and analyse valuable information from data
- Structure and analyse business problems
- Make informed recommendations in the presence of uncertainty and risk
- Communicate quantitative analysis and recommendations effectively
- Use modern decision support tools effectively

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Software Installation

1. Windows users

- https://schoolwiki.london.edu/index.php?title=Install_Decision_Tools_software and follow installation instructions from step 2 onwards.

2. macOS

- Install a Windows virtual machine, setup instructions online at https://schoolwiki.london.edu/images/d/d4/VMware_Palisade_Tool_for_Apple_%28MAC%29.pdf

3. Windows or macOS users needing a remote lab computer

- If your Mac cannot support a Windows virtual machine or are unable to install the software, please email help@london.edu and ask for a remote lab computer to use @Risk

- **For support with any issues please email help@london.edu**

Contents

- Introduction
- Process of decision making
- Decision making in action
- Workshop

Why decision making?

- Fred Goodwin
  - RBS CEO between 2001 and 2009
  - Knighthood 2004
  - LBS Honorary Fellow 2008 for being a “true leader”
- Financial Services Authority:
  - RBS collapsed in 2008 because of poor decisions
- “Fred the Shred”
  - Stripped out of knighthood in 2012
- How could such a smart guy make such a poor decision?

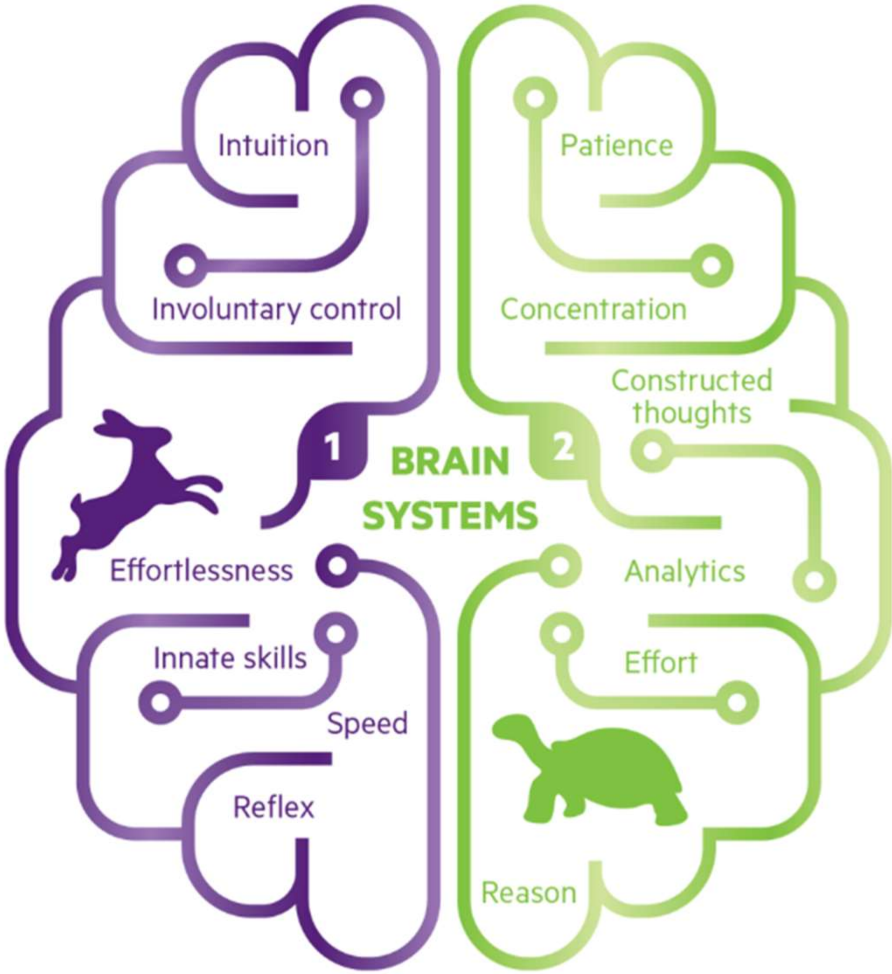
Intuition and analysis

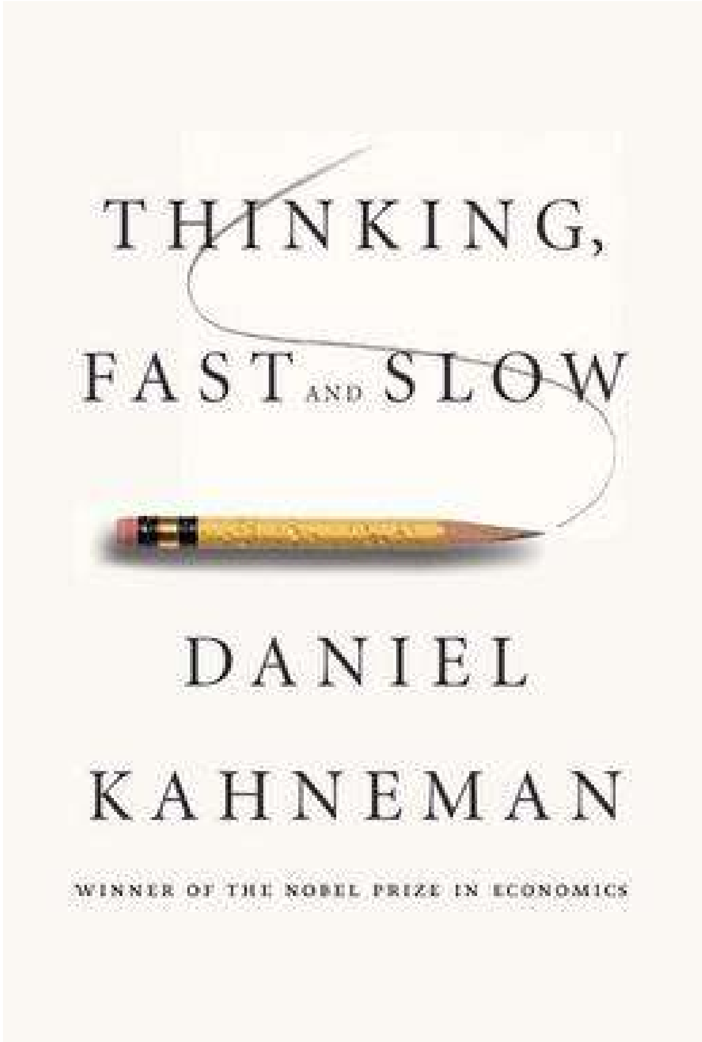
Why do people follow intuition? It's fast.

If people follow intuition that is close to their field, they do make good decisions.

System 1 – Fast Thinking: Intuition- heuristics- rule of thumb

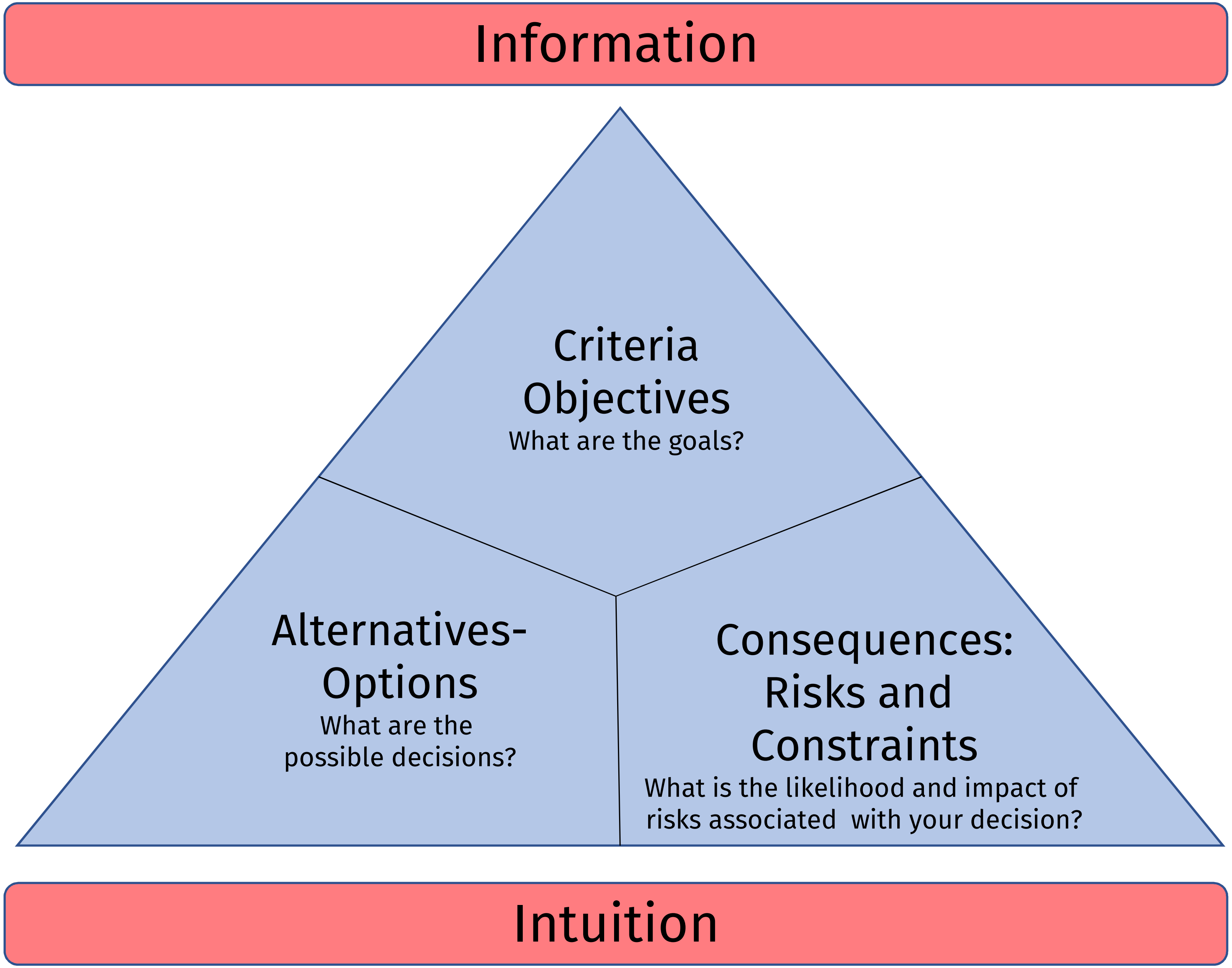
System 2 – Slow Thinking : Analytics- data- due diligence- facts





Source: https://bigarrowgroup.com/tortoise-hare-marketing

Process of Decision Making



Structuring a problem allows dealing with it systematically

- Criteria
- Alternatives
- Consequences

Decision Making

- **Decision Making**
  - What makes a good decision?
  - How can we structure investment decisions?
  - How can we create an environment that will lead to great decision making?

- **Risk**
  - What is risk? How can measure and assess it?
  - What is our attitude towards risk, and what should it be?
  - Which tools are available for analyzing risk?
  - What are the typical pitfalls when making investment decisions?

Contents

- Introduction
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Why do we need risk analysis?

- Naïve decision making ignores uncertainties and based on a single view of the future
    - Single point forecasts are dangerous
- Educated guesses, based on gut feeling
- Risk analysis: process to help you take calculated risks
    - Derive bounds for the range of possible outcomes
    - Sensitivity testing of the assumptions
    - Better perception of risks and their interaction
    - Anticipation and contingency planning
    - Overall reduction of risk exposure through hedging

Risk analysis helps you develop insights, knowledge and confidence for better decision making and risk management.

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Risk in Business

- Every business decision entails risk
  - Incomplete knowledge of future
  - Incorrect information
  - Uncertain outcome of decision

- Risk Analysis
  - Identifying risk
  - Analysing likelihood and impact of risk
  - Understanding risk

- Risk Management
  - Taking uncertainty into consideration in decision-making
  - Contingency planning: anticipate and cope with risk
  - Risk reduction: hedging – diversification
  - Determine the best business decision under risk

Project Evaluation

- Evaluating a business proposition
  - Does it make sense overall?
    - Market conditions
  - What is the outlook under a basic set of assumptions? (Base Case)
  - What are the risks involved?

Eagle Airlines

Small regional airline in south-eastern Australia: scheduled & chartered flights

Opportunity for Expansion - Piper Chieftain for sale @ $600,000
– 5 years
– 10 passengers
– operating costs $1,200/hour
– annual fixed costs: $160,000

Financial Data

- Charters: $1,900/hour, 40% of Eagle's flights
- Scheduled flights: $240/hour, 60% load factor
- 800 flight hours/year
- corporate tax rate: 33%
- Cost of capital: 15%

Eagle Airlines- Base Case Model

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	A	B	C	D	E	F	G
1	**Parameters**				**Uncertain Parameters**		*Base Value*
2	Number of Seats		10		Hours Flown		800
3	Tax Rate		33%		Charter Price/Hour		1900
4	Purchase Price		600,000		Ticket Price/Hour		240
5	After tax discount rate		15%		Load factor of scheduled flig		60%
6	Fixed Cost		160,000		Ratio of scheduled flights		60%
7	Remaining life		5		Operating Cost/hour		1200
8							
9	**Profit & Loss**						
10	Income from Scheduled		691,200				
11	Income from Chartered		608,000				
12	Operating costs		-960,000				
13	Fixed Costs		-160,000				
14	Profit before tax		179,200				
15	Depreciation		120,000				
16	Taxable Profit		59,200				
17	Tax		19,536				
18	Profit after tax		159,664				
19							
20	**Cash Flows**						
21	Year	0	1	2	3	4	5
22	CF	-600,000	159,664	159,664	159,664	159,664	159,664
23	NPV	-64,782					
24	IRR	10.3%					

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Expanding on the base case model

- Ignore uncertainty?
  - single-point forecasts are typically wrong
  - decisions based on them can be dangerous

- Step I: Scenario Analysis
  - range of results

- Step II: Sensitivity Analysis
  - observe changes in profit due to changes in assumptions
  - identify main uncertainty drivers

- Step III: Monte-Carlo Simulation
  - evaluate possible outcomes
  - determine expected result, range of results, probability of results (e.g. probability of break-even), downside risk, etc.

- Decision: make decisions in the face of uncertainty

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Scenario Analysis

"Scenarios are discrete internally consistent views of how the world will look in the future, which can be selected to bound the possible range of outcomes that might occur."
Michael Porter in ***Competitive Strategy***

"Shell flavour" of scenarios

Scenarios should present testing conditions for the business. The future will of course be different from all of these views/scenarios, but if the company is prepared to cope with any of them, it will be able to cope with the real world.

Do not assign probabilities to scenarios!

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Eagle Airlines – Scenario Analysis

Uncertain Parameters	*Base Value*	*Pessimistic*	*Optimistic*
Hours Flown	800	700	1000
Charter Price/Hour	1900	1600	2200
Ticket Price/Hour	240	200	300
Utilisation of Scheduled fligl	60%	50%	70%
Ratio of scheduled flights	60%	40%	70%
Operating Cost/hour	1200	1250	1150
Profit & Loss			
Income from Scheduled	691,200	280,000	1,470,000
Income from Chartered	608,000	672,000	660,000
Operating costs	-960,000	-875,000	-1,150,000
Fixed Costs	-160,000	-160,000	-160,000
Profit before tax	179,200	-83,000	820,000
Capital allowance	120,000	120,000	120,000
Taxable Profit	59,200	-203,000	700,000
Tax	19,536	-66,990	231,000
Profit after tax	159,664	-16,010	589,000
NPV	**-64,782**	**-653,668**	**1,374,419**

Three NPV Scenarios

Pessimistic : -653,668

Base: -64,782

Optimistic: 1,374,419

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Sensitivity analysis

Purpose

- Explore robustness of results to variations in model parameters
- Determine main uncertainty drivers

Methodology

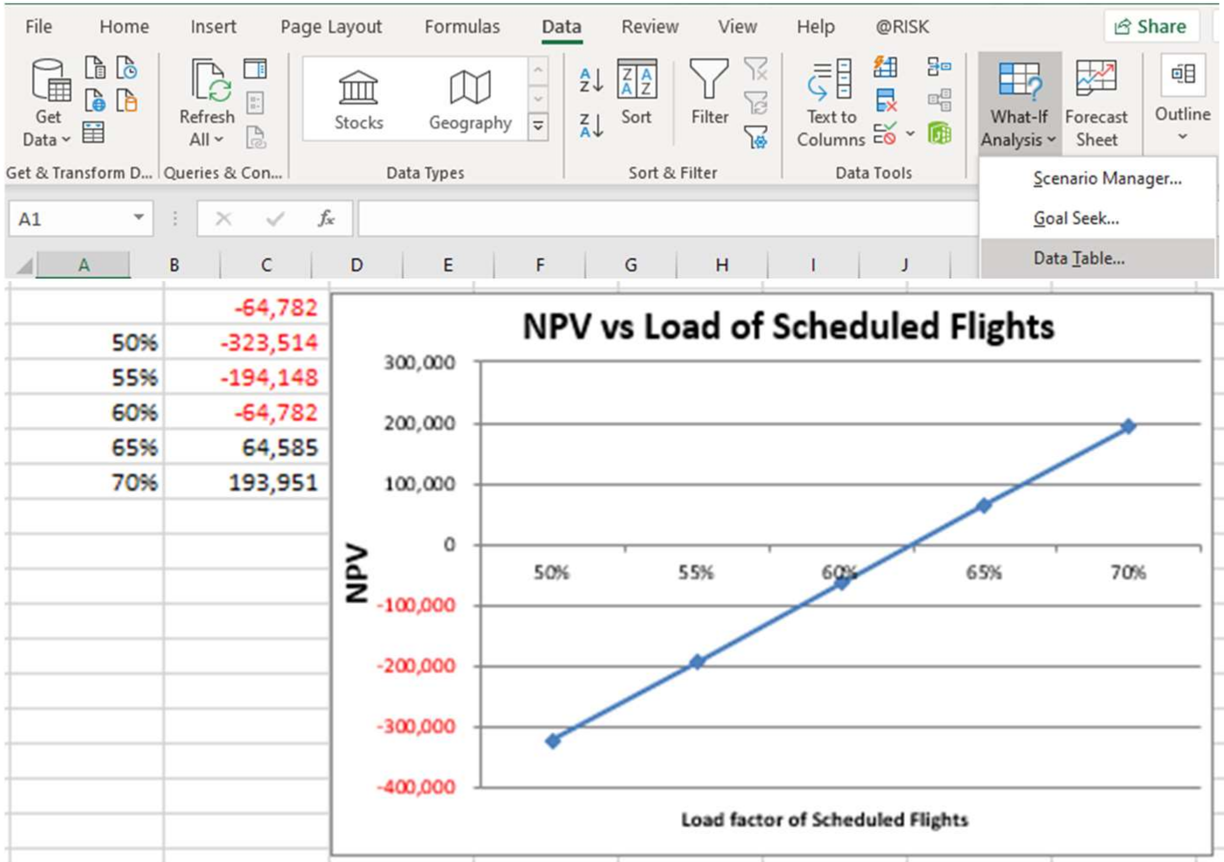
- Identify variables to which results are particularly sensitive and those to which they are relatively insensitive
- Gain an indication into range over which results might vary, thus assessing the risks

Tools

- What-if questions
- One- and two-way sensitivity analysis
- Tornado diagrams

What-if analysis: One way sensitivity

- What-if load factor (or capacity utilisation) of scheduled flights is, e.g., 65%
- Sensitivity Analysis using Data Table (*Data… What-If Analysis… Data Table*)

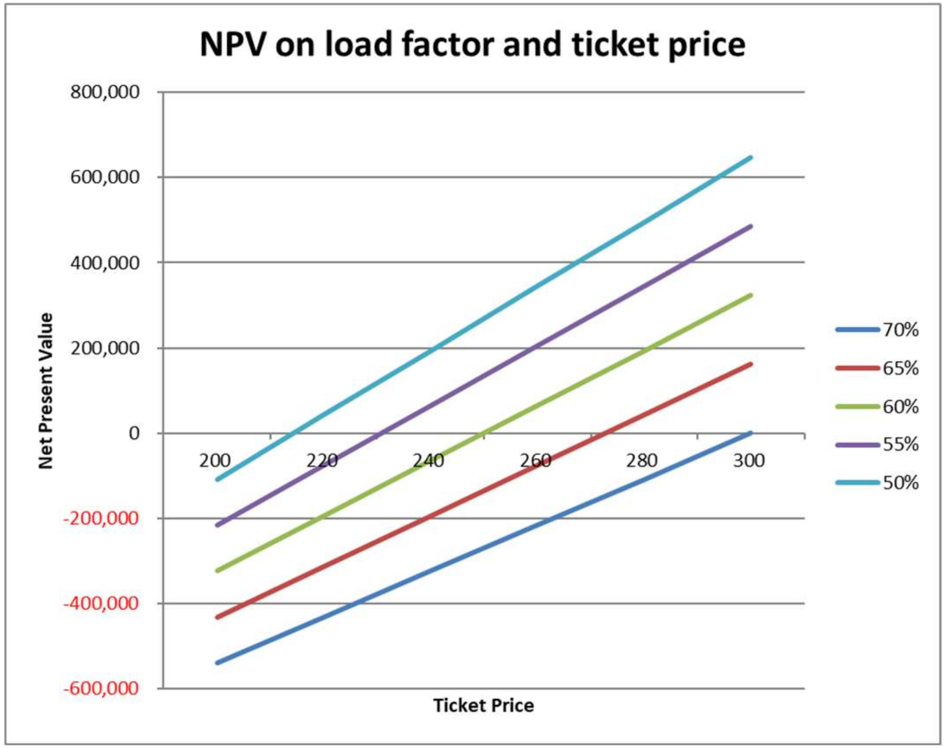


- Break-Even Analysis using *Solver* or *Goal Seek, utilisation = 62.5%*
- Tutorial on Datatables in *DataTables.xls*

What-if analysis: Two way sensitivity

- What-if capacity = 65% and ticket price = 220
- Two-Way Sensitivity Analysis using Data Tables

-64,782	200	220	240	260	280	300
50%	-539,125	-431,320	-323,514	-215,709	-107,904	-98
55%	-431,320	-312,734	-194,148	-75,562	43,024	161,610
60%	-323,514	-194,148	-64,782	64,585	193,951	323,318
65%	-215,709	-75,562	64,585	204,732	344,879	485,026
70%	-107,904	43,024	193,951	344,879	495,806	646,734



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Tornado diagrams (1/2)

Help us identify the impact of each uncertain parameter.

Change one parameter at a time from its optimistic to its pessimistic value while keeping the remaining parameters at their base value

Uncertain Parameters	*Pessimistic*	*Optimistic*	*Range*
Ticket Price/Hour	-323,514	323,318	646,832
Utilisation of Scheduled fligh	-323,514	193,951	517,465
Charter Price/Hour	-280,392	150,829	431,221
Hours Flown	-160,010	125,675	285,685
Ratio of charter flights	-147,432	100,520	247,952
Operating Cost/hour	-154,619	25,056	179,675

Tornado diagrams (2/2)

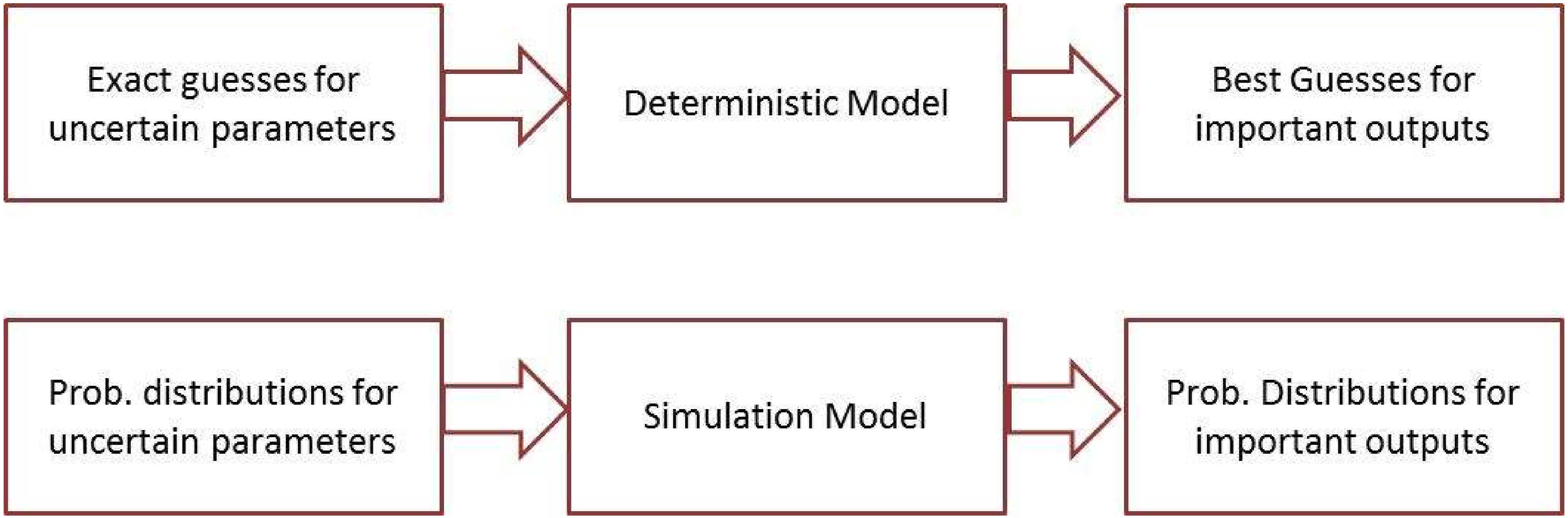
Helps us determine visually the main uncertainty drivers.

Tutorial on Tornado diagrams in *Tornado.xls*

Introduction to Simulation

- **A simulation model** is a computer model that explicitly incorporates uncertainty in one or more input variables.
- When you run a simulation, you allow these random input variables to take on various values, and you keep track of any resulting output variables of interest.
- The fundamental advantage of a simulation model is that it provides an entire distribution of results, not simply a single bottom-line result.
- Each different set of values for the uncertain quantities can be considered a scenario.
- Simulation allows the company to generate many scenarios, each leading to a particular NPV. In the end, it sees a whole distribution of NPVs, not a single best guess. The company can see what the NPV will be on average, and it can also see worst-case and best-case results.

Monte Carlo simulation



- The deterministic approach uses best guesses for uncertain inputs
- The simulation model models uncertainty explicitly with random inputs, and the end result is a probability distribution for NPV, rather than a fixed value

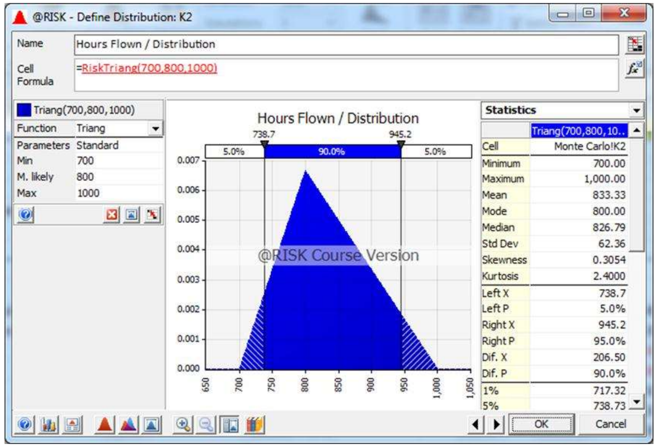
Monte Carlo sampling got its name from the code name of an American project on the atom bomb during World War II and not, as most believe, from the well known casino town in Monaco.

Modelling uncertainty in Eagle Airlines (1/3)

"Keith hoped to be able to fly 1,000 hours per year, but realised that 800 might be more realistic. If things get really hard, 700 hours was a possibility, although remote"

=RISKTRIANG(Min,MostLikely,Max)

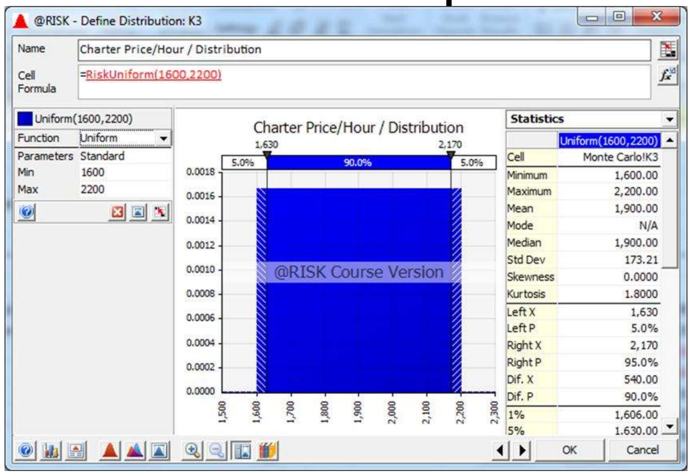
=RISKTRIANG(700, 800, 1000)



Charter price per hour: competitive pressures resulted in a charter price in the range between \$1,600 and \$2,200 per hour

=RISKUNIFORM(Min, Max)

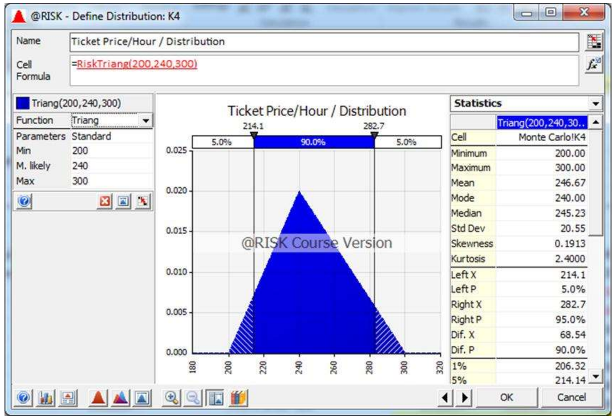
=RISKUNIFORM(1600, 2200)



Modelling uncertainty in Eagle Airlines (2/3)

Ticket price per hour for scheduled flights, which would probably have to be around $240 per person, but could range up to extremes of $200 or $300, depending on market conditions.

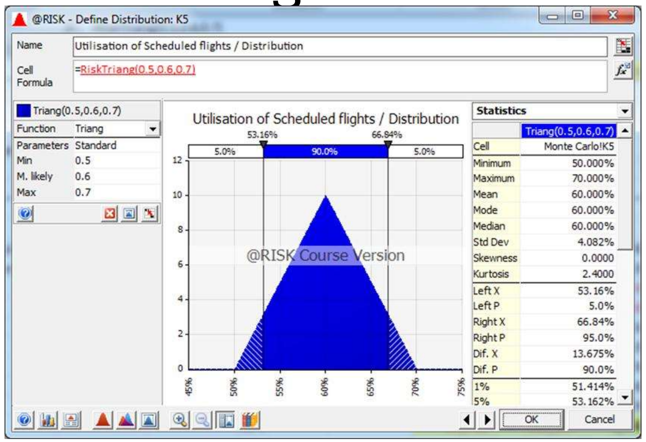
=RiskTriang(200,240,300)



Utilisation of the scheduled flights, which was currently around 60%, may turn out to be different, and range from lows of 50% to highs of 70%.

=RiskTriang(0.5,0.60,0.7)

However, the aeroplane utilisation rate will in part depend on the actual ticket price.



Modelling uncertainty in Eagle Airlines (3/3)

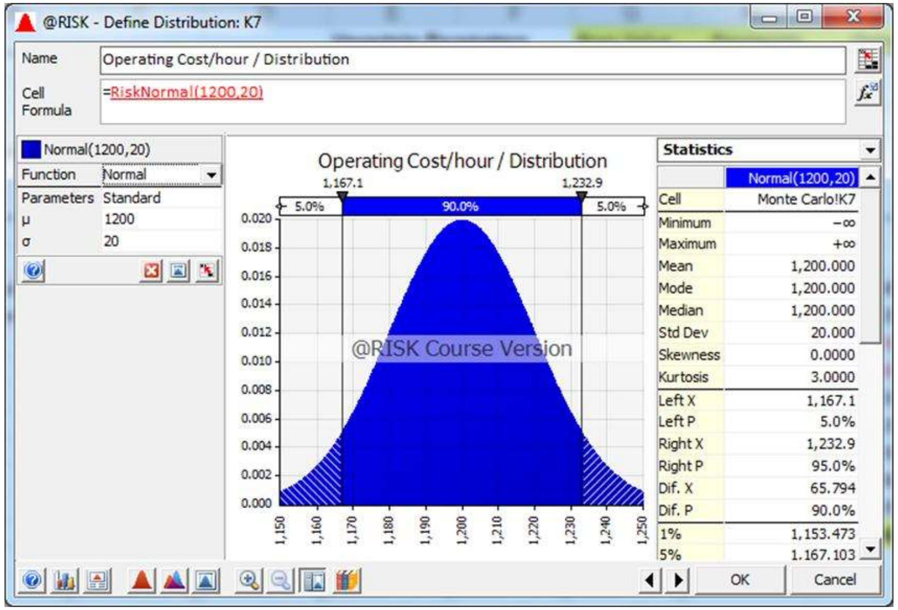
Although 60% was still Keith's best estimate for the proportion of scheduled flights, the proportion may decrease to 40% or increase to 70%

=RiskTriang(0.4,0.6,0.7)

"Keith's best estimate for operating costs was $1200; however, this could be wrong by $50 in either direction, mainly depending on fuel prices"

=RISKNORMAL(Mean,SD)

=RISKNORMAL(1200, 20)



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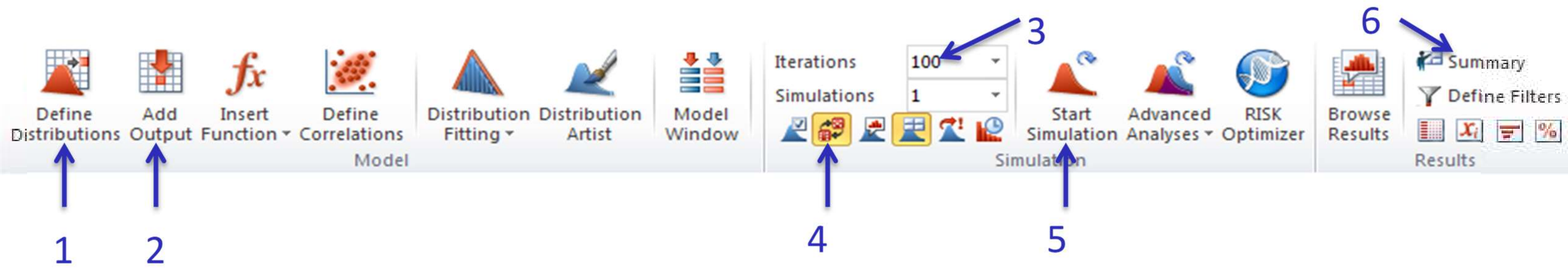
Using @*RISK* for Excel

- @RISK supports many probability distributions, e.g.,
  - RiskNormal(mean,SD)
  - RiskTriang(minimum, most likely, maximum)
  - RiskUniform(minimum, maximum)
  - RiskDUniform({value 1, value 2,..., value *n*})
  - RiskDiscrete({Event A, event B...event *K*},{ProbA, ProbB,..., ProbK})
  - RiskCumul(min,max,{value list},{probability list})
- Select Output Cell(s), e.g. NPV on Eagle Airlines
- Run the simulation
- View Results
  - Summary statistics
  - Graphs
  - Sensitivity Analysis
- Tutorial videos at http://www.palisade.com/videos/

@RISK for Excel toolbar



1. Define distributions for uncertainties
2. Define the output or objective you want to keep track of, NPV in Eagle Airlines
3. Set the number of iterations for the simulation
4. Enable manual [F9] simulations
5. Start simulation
6. Go to summary window to explore the results

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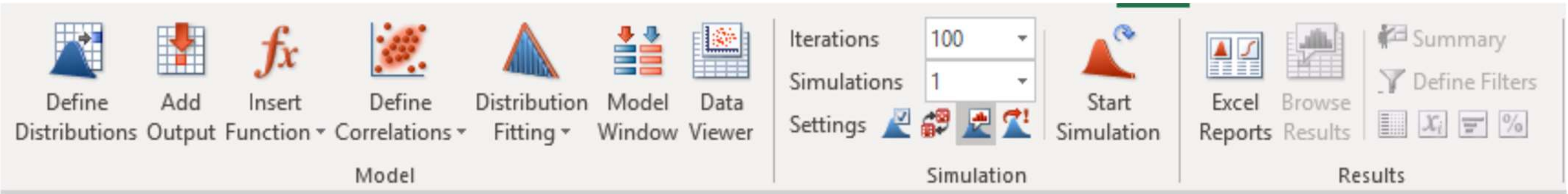
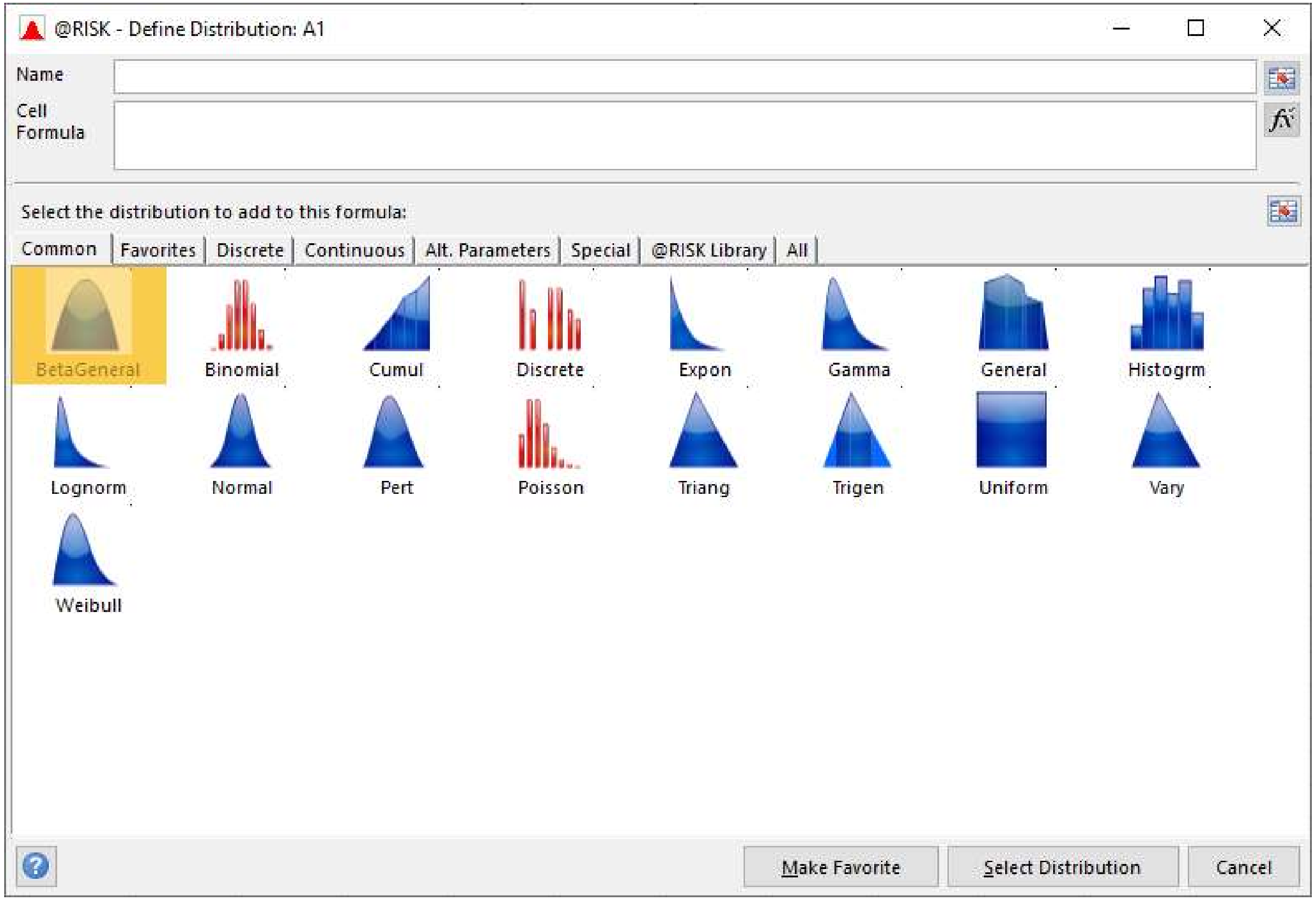
Using @*RISK* to define distributions

Use *Define Distributions*





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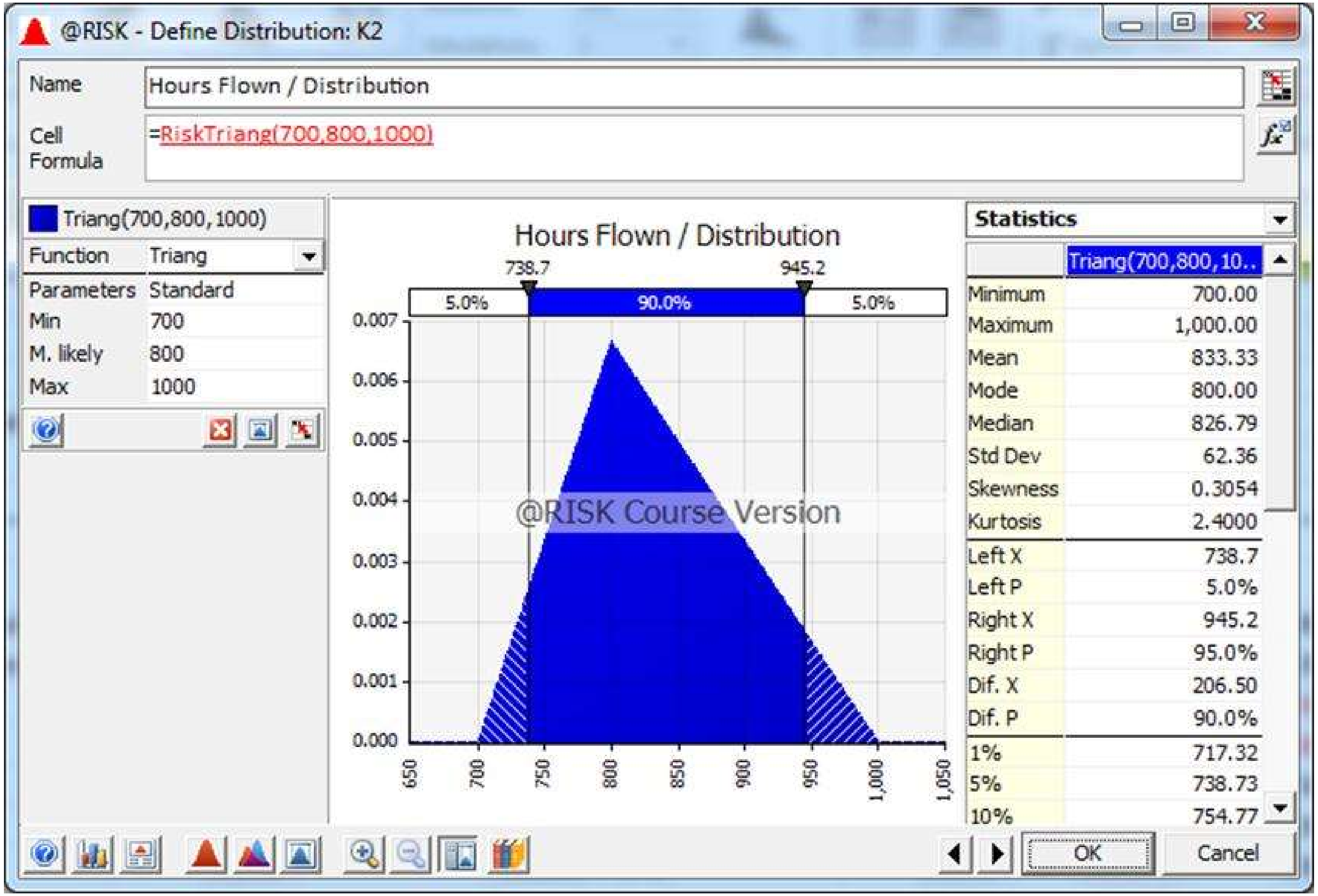
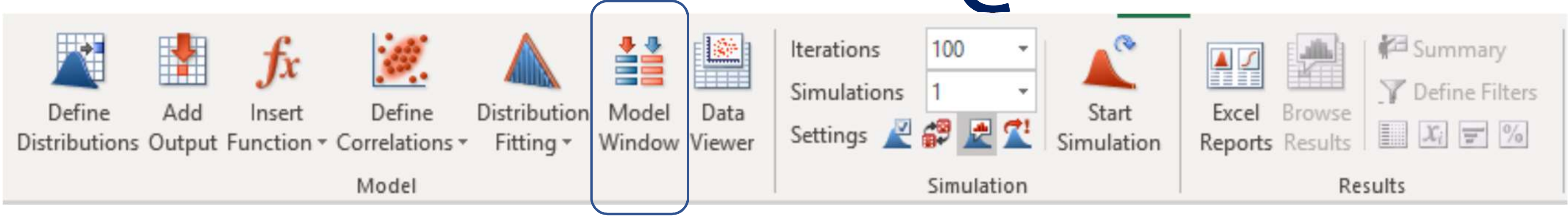
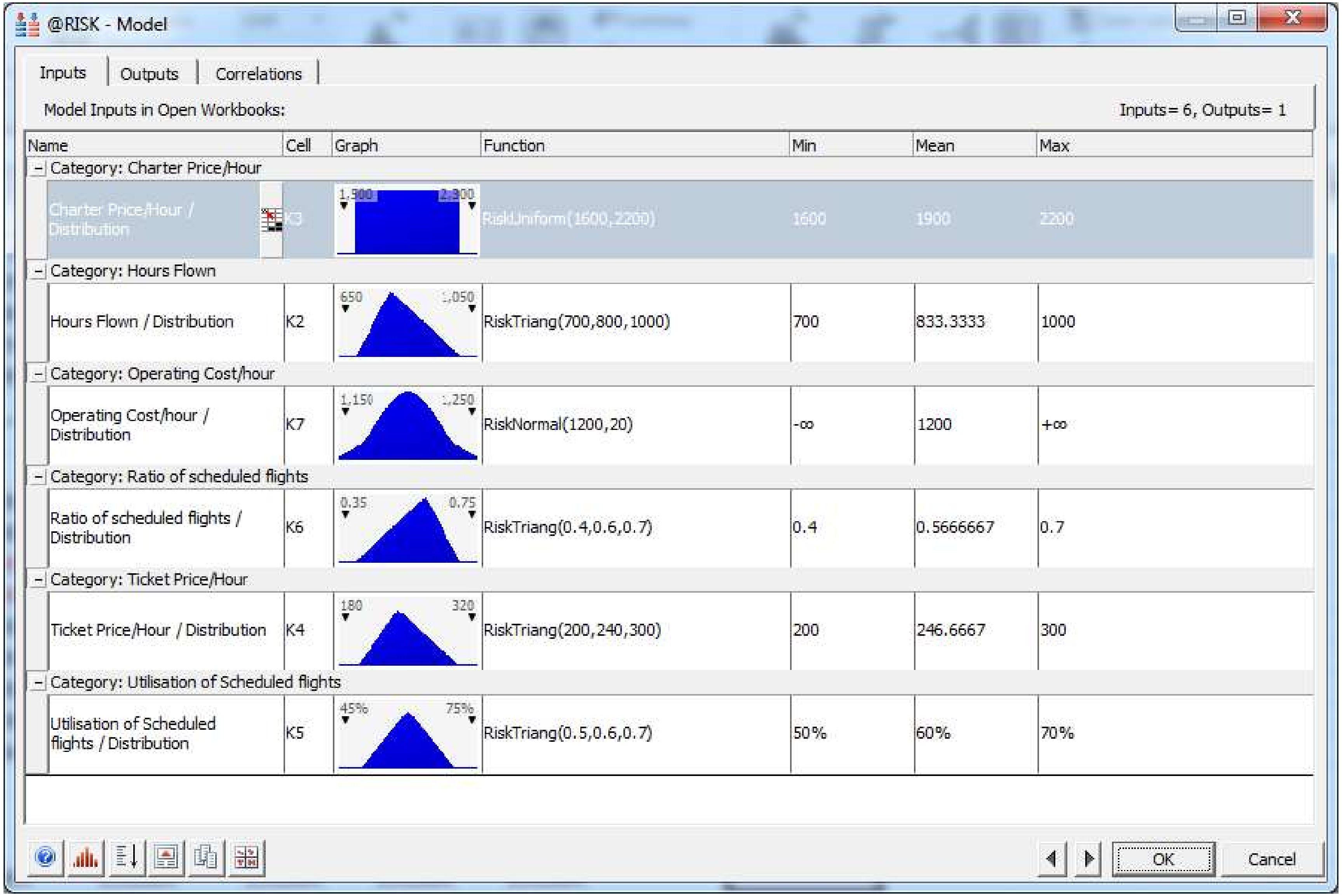
Using *@RISK* to define distributions



Or, input manually, by typing ***=RiskTriang(700,800,1000)***

@RISK model window




@RISK - Model

Inputs | Outputs | Correlations

Model Inputs in Open Workbooks:

Inputs= 6, Outputs= 1

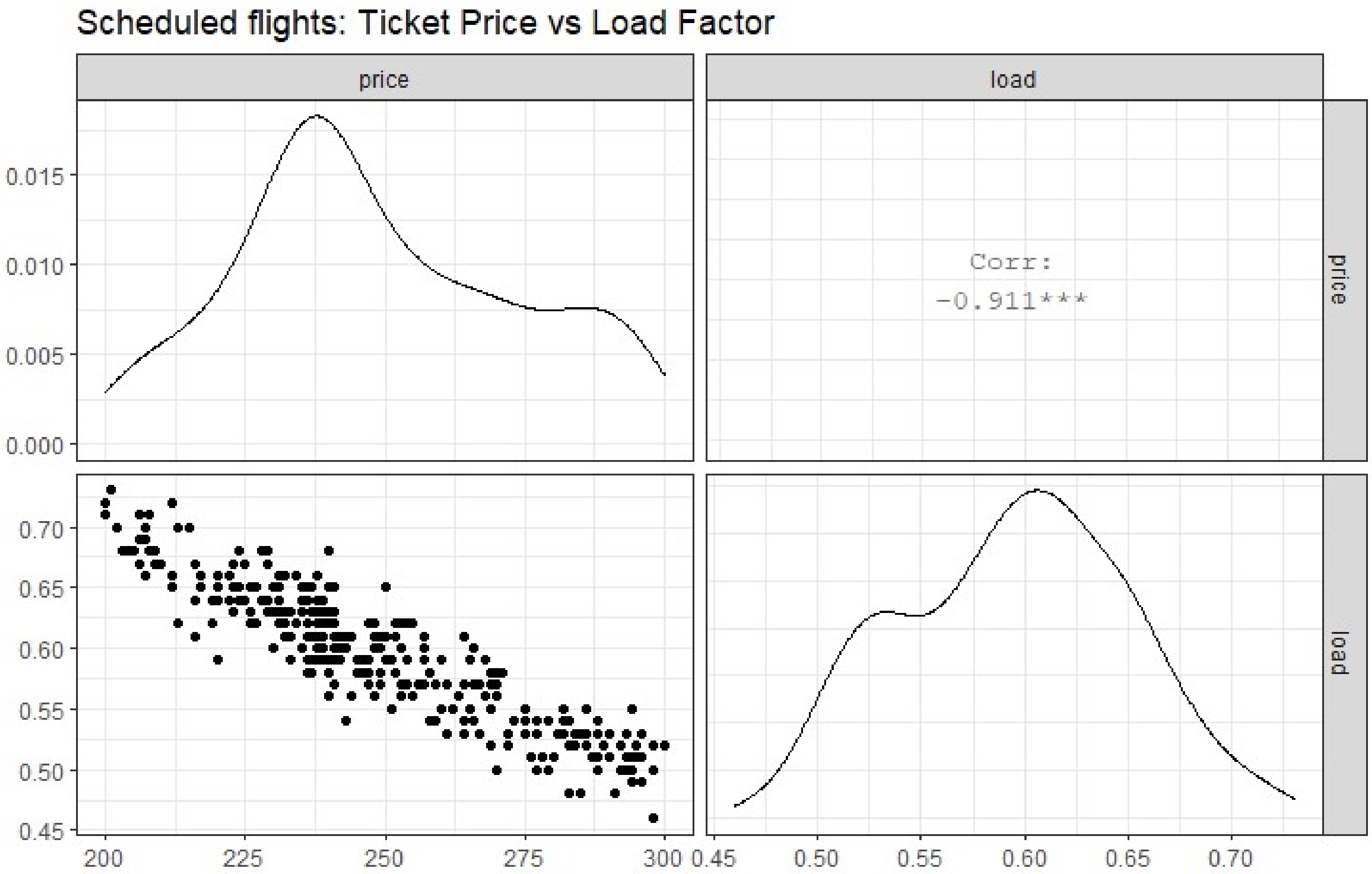
Name	Cell	Graph	Function	Min	Mean	Max
Category: Charter Price/Hour						
Charter Price/Hour / Distribution	K3	1,500 2,300	RiskUniform(1600,2200)	1600	1900	2200
Category: Hours Flown						
Hours Flown / Distribution	K2	650 1,050	RiskTriang(700,800,1000)	700	833.3333	1000
Category: Operating Cost/hour						
Operating Cost/hour / Distribution	K7	1,150 1,250	RiskNormal(1200,20)	-∞	1200	+∞
Category: Ratio of scheduled flights						
Ratio of scheduled flights / Distribution	K6	0.35 0.75	RiskTriang(0.4,0.6,0.7)	0.4	0.5666667	0.7
Category: Ticket Price/Hour						
Ticket Price/Hour / Distribution	K4	180 320	RiskTriang(200,240,300)	200	246.6667	300
Category: Utilisation of Scheduled flights						
Utilisation of Scheduled flights / Distribution	K5	45% 75%	RiskTriang(0.5,0.6,0.7)	50%	60%	70%

OK Cancel

Effects of correlated input variables

- Until now, all random numbers generated with @*RISK* functions have been probabilistically independent. @RISK enables you to build correlation into a model.
- Sometimes, however, independence is unrealistic. In such cases, the random numbers should be correlated in some way.
- As an example, you might expect load factor of an airplane to be negatively correlated with ticket prices; if ticket prices go up, you expect load factor to go down and vice versa.
- @RISK enables you to build in this correlated behavior with the RISKCORRMAT function, or you can define correlations through the @RISK *Model Window*
- Alternatively, you could estimate a regression line between the two variables. You sample for one of the variables and use the equation with random errors to generate the other one.

Effects of correlated input variables




```
> model1 <- lm(load ~ price, data = load_factor)
> mosaic::msummary(model1)
             Estimate  Std. Error t value             Pr(>|t|)
(Intercept)  1.09401303  0.01316285   83.11 <0.0000000000000002 ***
price       -0.00200769  0.00005268  -38.11 <0.0000000000000002 ***

Residual standard error: 0.02276 on 298 degrees of freedom
Multiple R-squared:  0.8298,	Adjusted R-squared:  0.8292
F-statistic:  1452 on 1 and 298 DF,  p-value: < 0.00000000000000022
```

Modelling correlated variables

However, the aeroplane utilisation rate will in part depend on the actual ticket price.

1. Use Regression Model: Load Factor (Y) on ticket price (X)
   - Load Factor = 1.094 – 0.002 * (ticket price) *+ error*
   - R^2 = 83%
   - *Regression SE = 0.02276 (2.28%) (zero mean, normally distributed)*
   - Load Factor = 1.094 – 0.002 * (ticket price) + *RiskNormal(0, **0.02276**)*

```
> model1 <- lm(load ~ price, data = load_factor)
> mosaic::msummary(model1)
              Estimate  Std. Error t value             Pr(>|t|)
(Intercept)  1.09401303  0.01316285   83.11 <0.0000000000000002 ***
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```
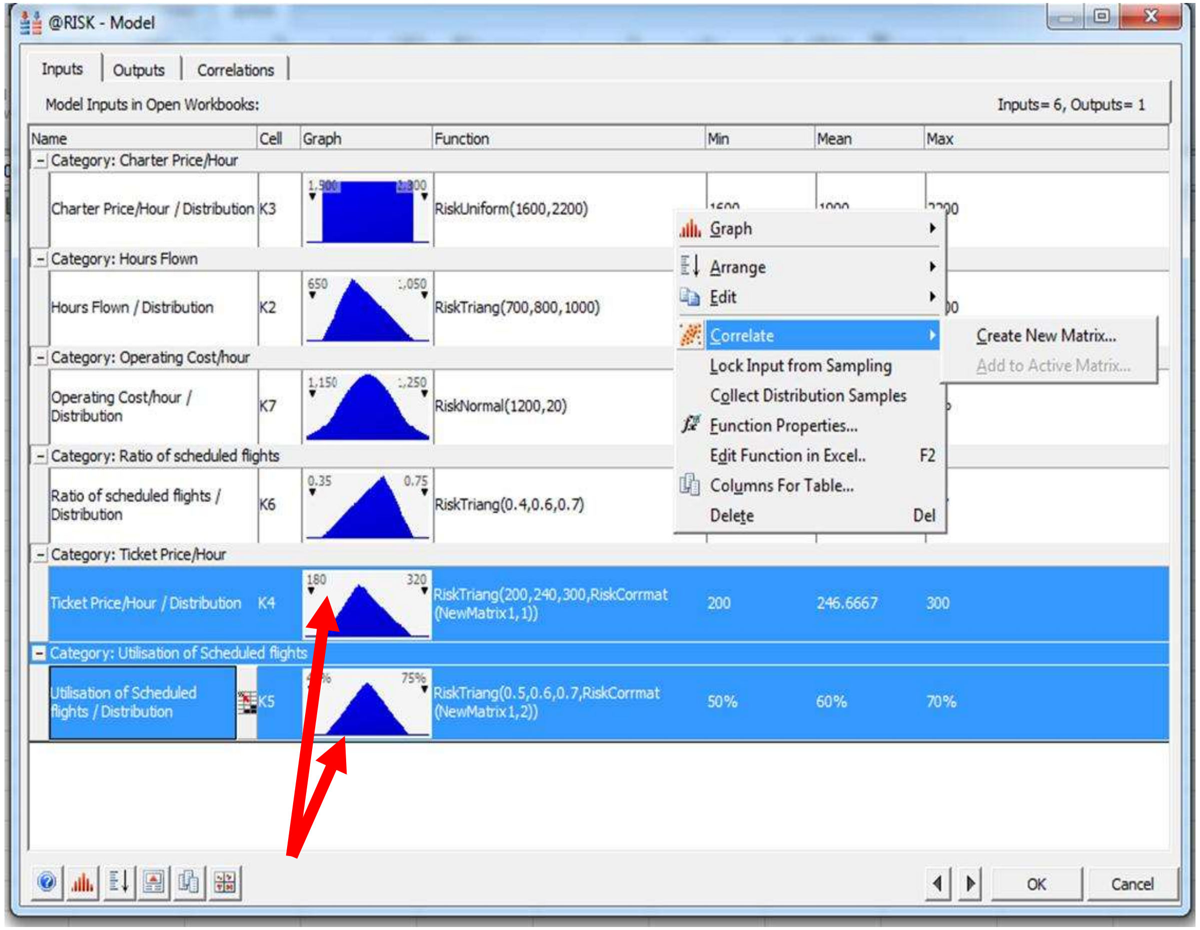
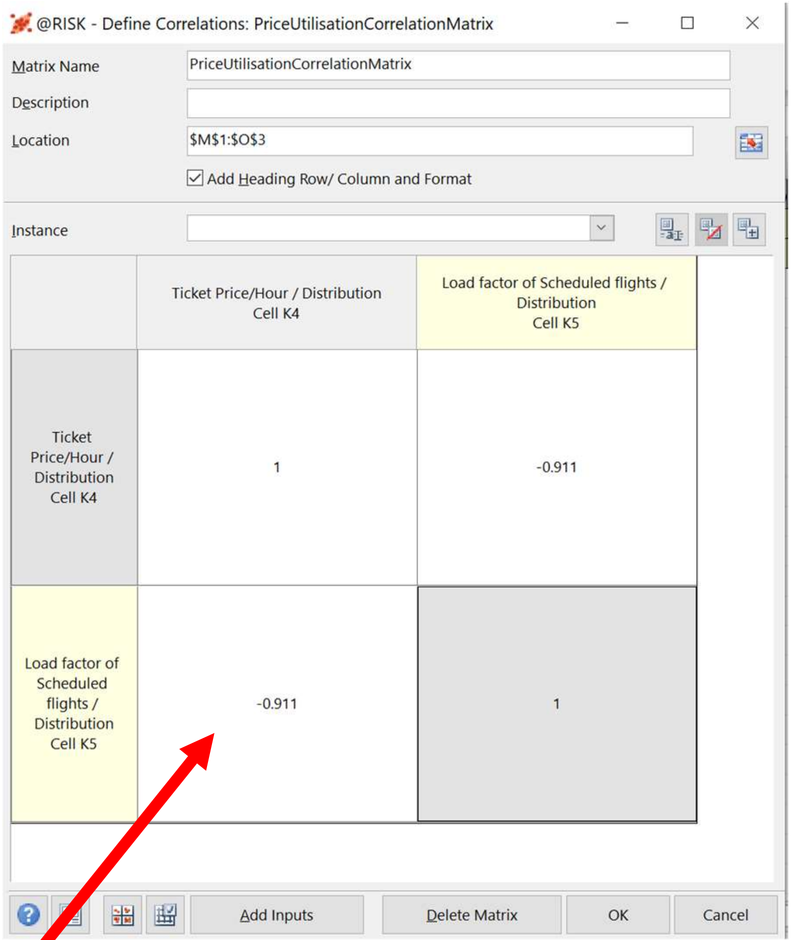

2. Use Correlations through @RISK
   - Load factor and ticket price are negatively correlated
   - Correlation coefficient = -0.911

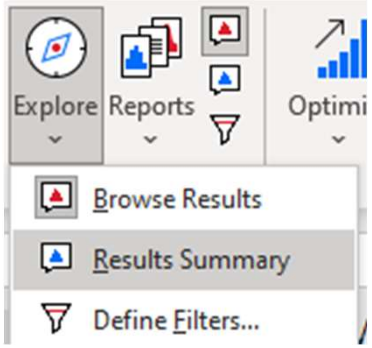
Correlation matrices in @RISK





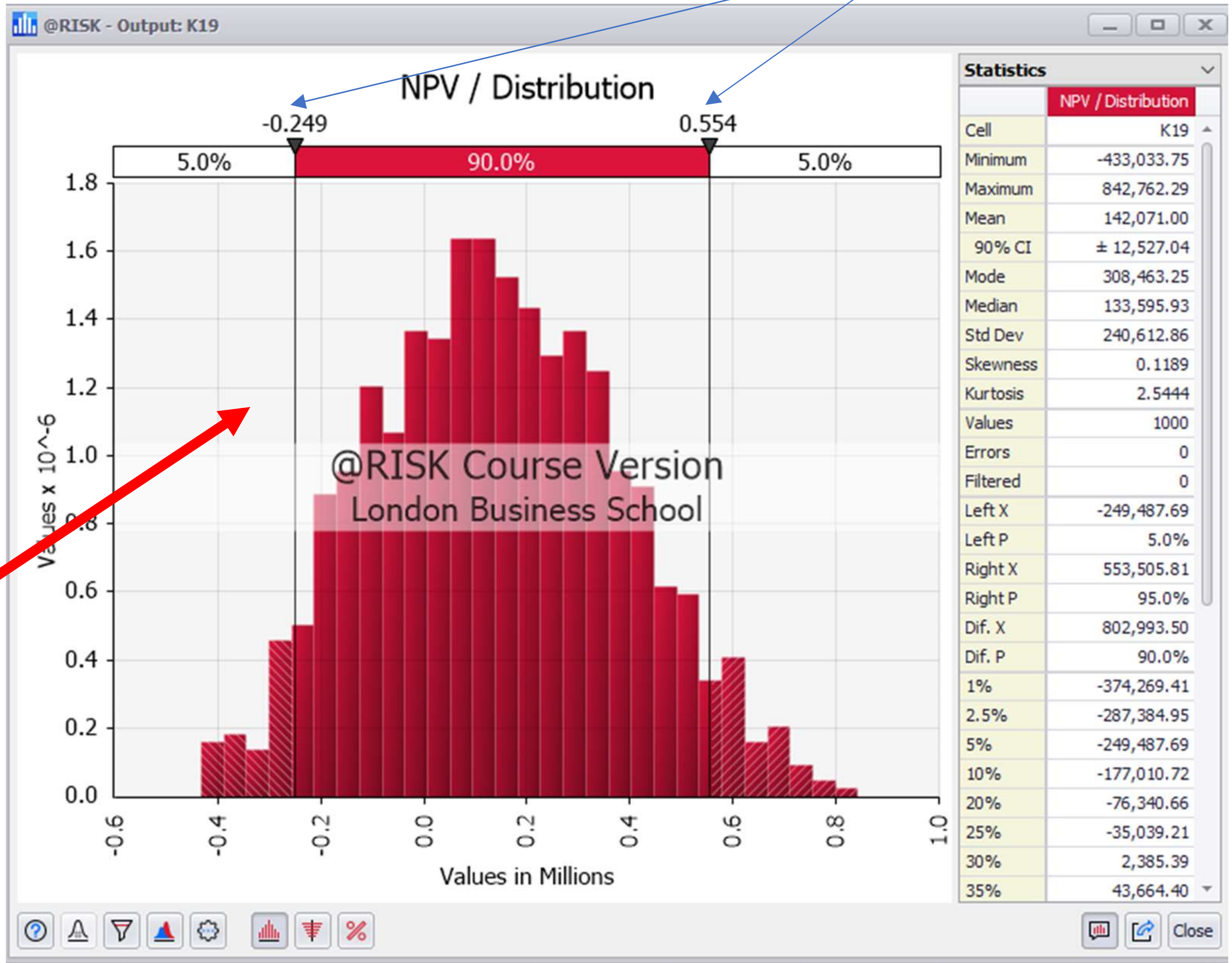
Select ticket price and utilisation
Right click and select
"Correlate -> Create new matrix"

Enter correlation coefficient



Browse Results - Summary

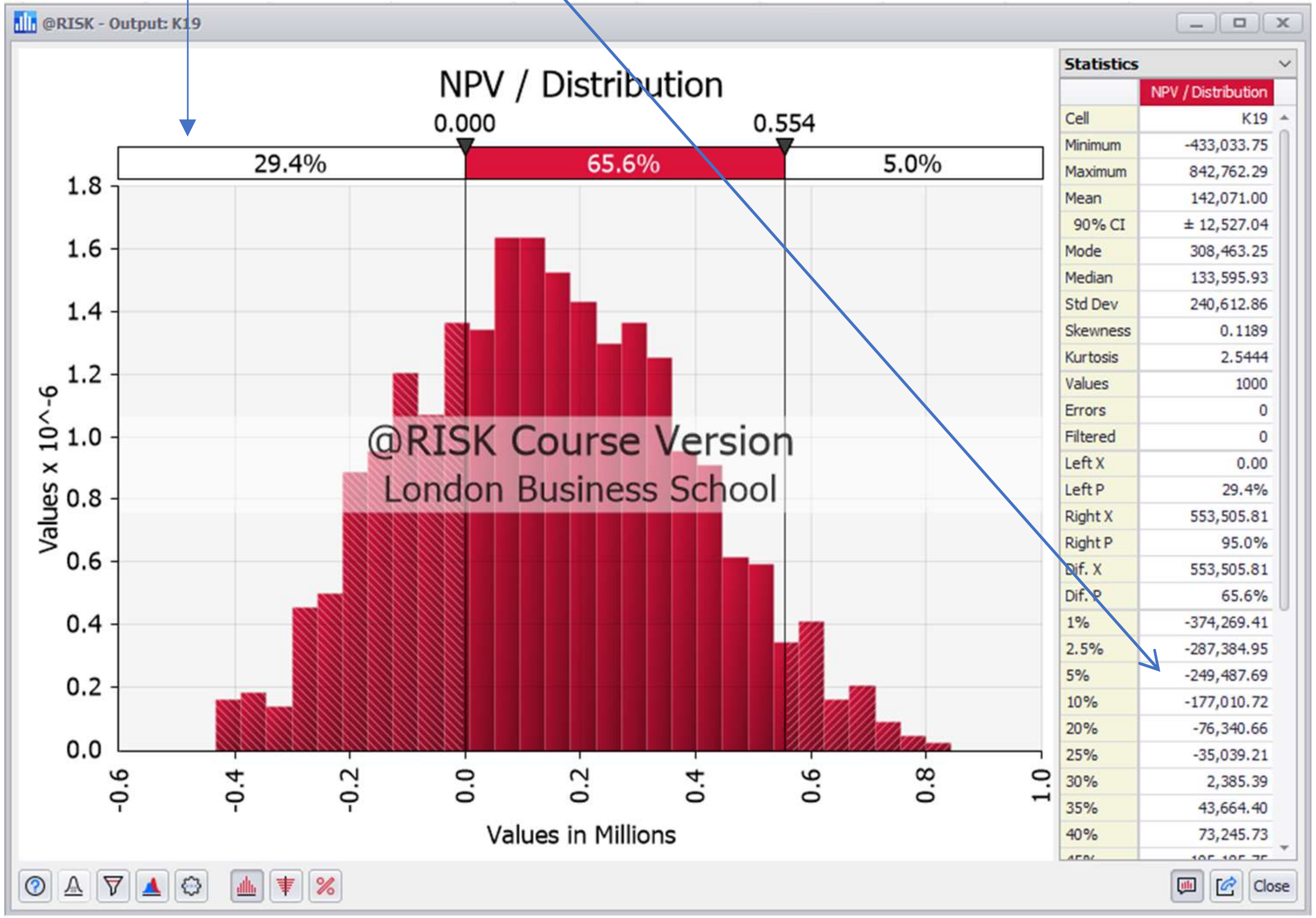
90% chance NPV will be between: [-249K, 554K]



Slide vertical lines to compute probabilities; by default you get the mid 90% interval

@RISK Results

- Expected NPV = $133.6K, SD= 240K,
  - May differ from result using expected values of parameters
- Range = [$-433K, $843K]
  - Compare with scenario results [-654K, 1,374K]
- 90% confidence profit will be between: [-249K, 554K]
- Probability (NPV<0) = 29.4%
- Project's VaR (5th percentile) = -250K



Recap Risk Analysis

Value Model

- Identify relevant data
- Build model that is easy to extend-modify

Decision Elements

- **Objective**: What do we want?
- **Uncertainties**: what worries us ?
- **Decisions**: what to do?

Impact Evaluation

- **Scenarios**: Range of results
- **Sensitivity Analysis:** 1- and 2-way data tables
- **Tornado diagram**: identify main uncertainty drivers

Likelihood Evaluation

- Model uncertainty (using distributions)
- Evaluate different possible outcomes
- Expected result (average)
- Risk (range, SD, distribution, downside risk, break-even probability, etc..)

Make decision

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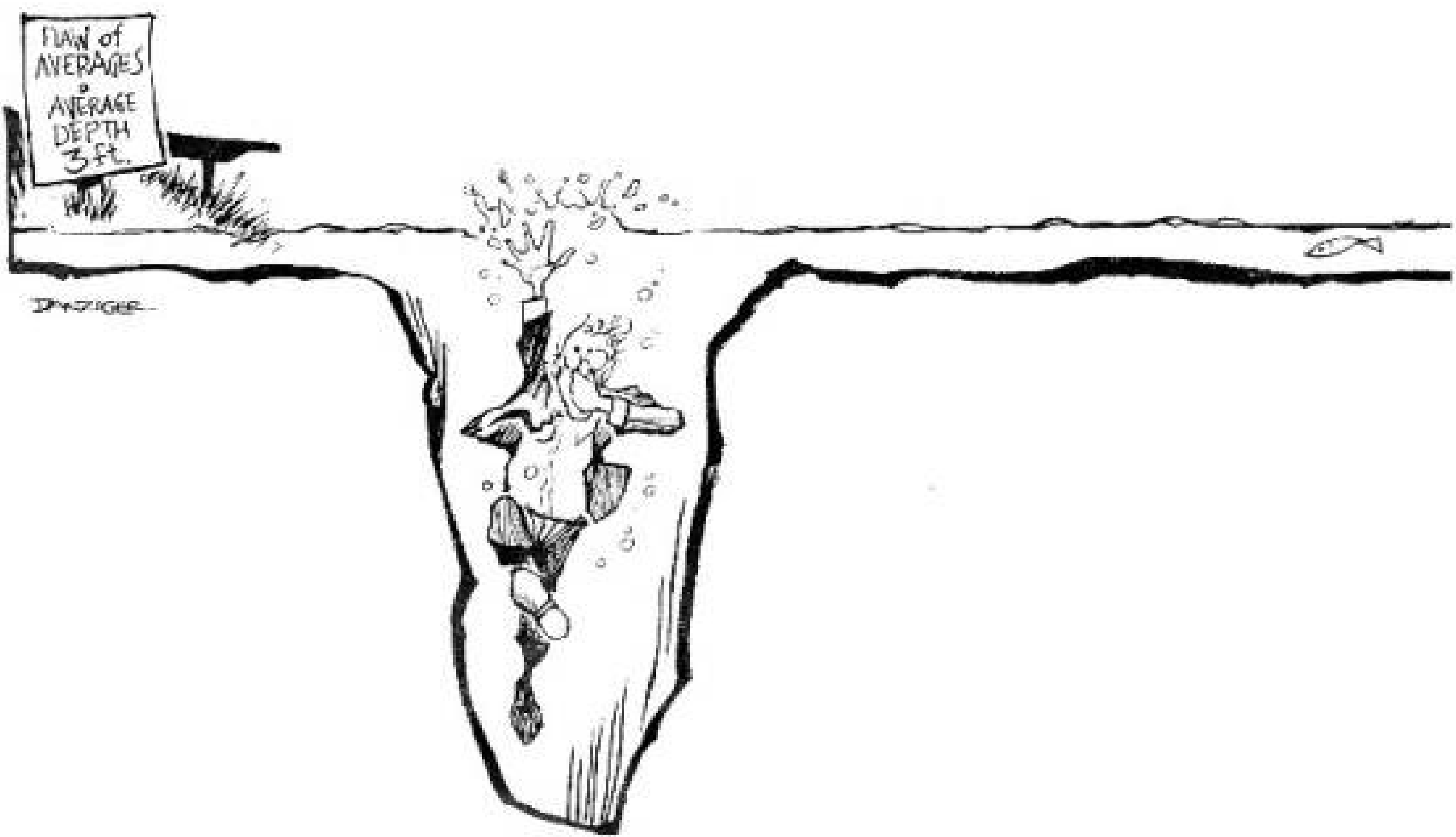
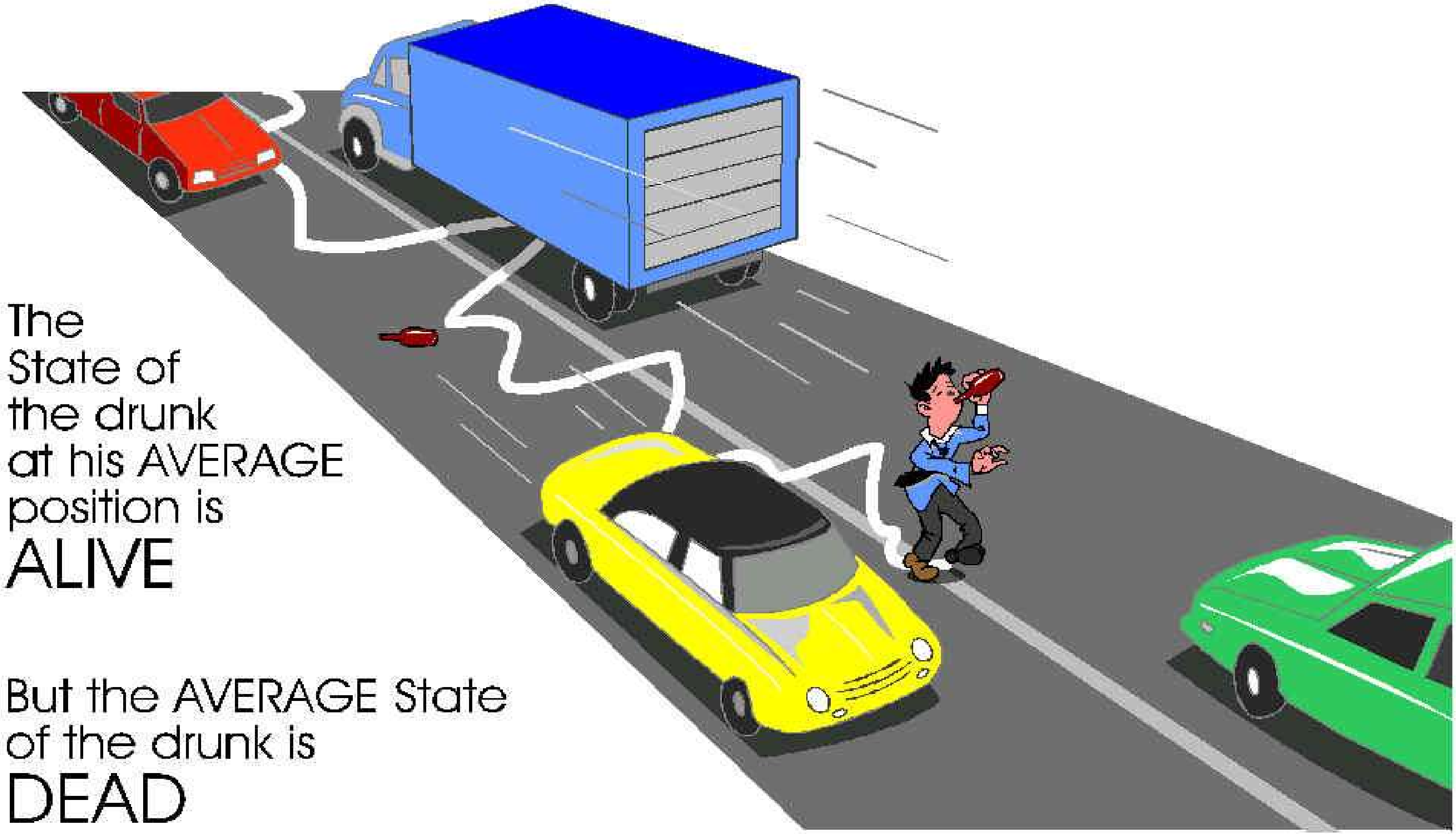
The flaw of averages (1/2)



The flaw of averages (2/2)



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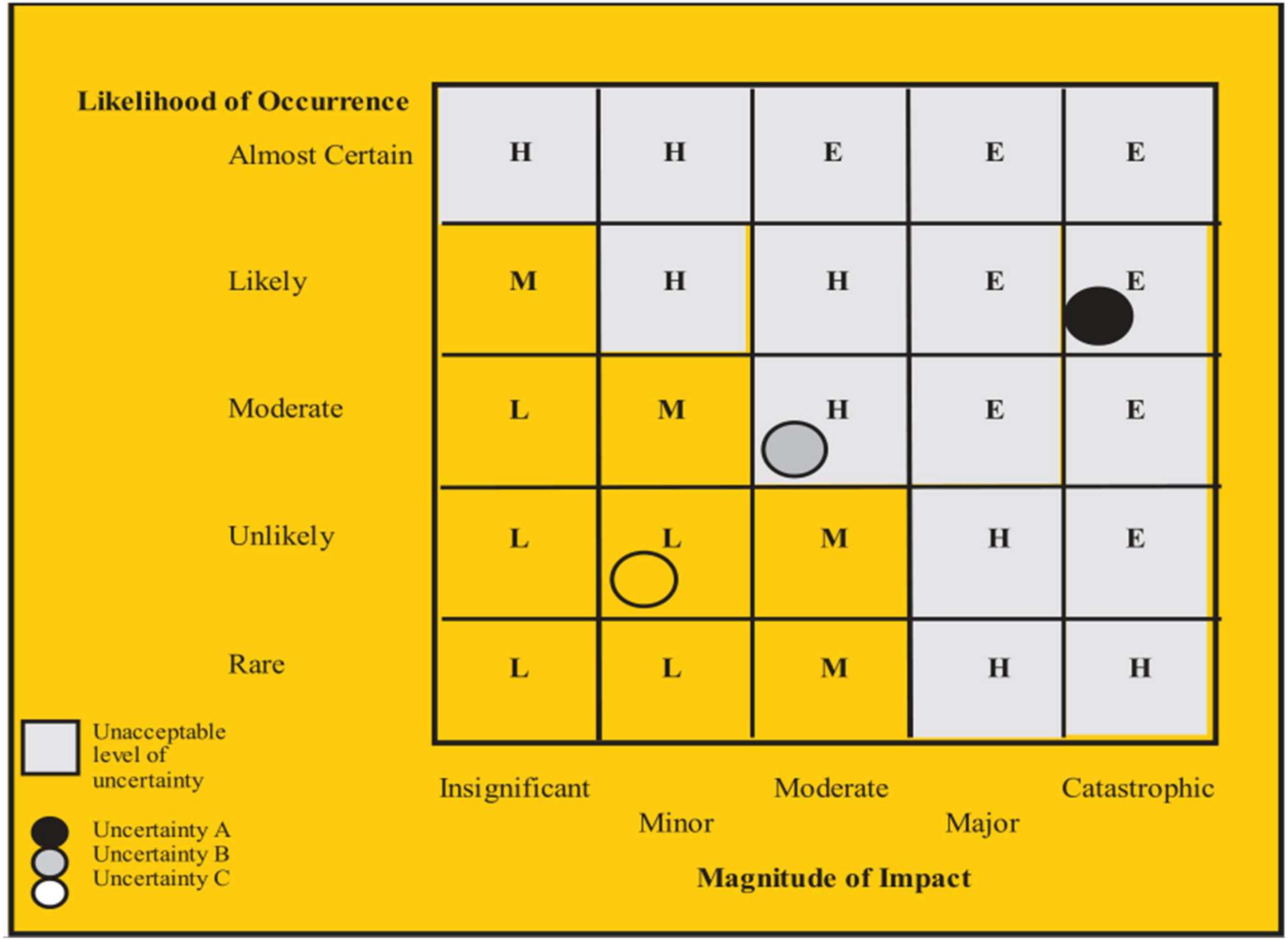
Key takeaways

- A decision model describes a real situation by extracting the salient features that affect decision-making
- Risk consists of two parts: likelihood (chance of occurring) and impact. Risk analysis constitutes of constructing and analyzing the likelihood and impact of a situation.
- You learned about the "flaw of averages": that using average values to base decisions on can be dangerous.
- To avoid making dangerous decisions, you can do three things:
  1. **Scenario Analysis:** Optimistic/Most Likely/Pessimistic scenarios to get a sense of the range of possible outcomes.
  2. **Sensitivity Analysis:** Sensitivity to outcomes (e.g. NPV) when we make small changes to inputs.
     - *What if* analysis refers to changing the value of an input one at a time
     - *One-* and *Two-way Sensitivity* analysis allows you to obtain the full range of sensitivities for one or two risk factors
     - *Tornado diagram* identifies main uncertainty drivers.
  3. **Simulation Analysis:** Comprehensive picture of uncertain outcomes, with all uncertainties playing a role. Provide uncertainties as input distributions, and generate a distribution for output variable of interest (NPV/profit/cost). Can incorporate correlations of risk factors

Likelihood and impact of risk



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Allowing for Risk in Spreadsheet Models

— A Tutorial on Risk Analysis with @Risk —

1. Novaduct New Product Appraisal

A simple example of launching a new product is employed to illustrate how risk analysis is undertaken with @Risk. The objective in Novaduct is to examine the robustness of decisions based on Net Present Value (NPV) analysis, when some of the assumptions change. First, the cash flows and resultant NPV are calculated in a small spreadsheet model, 'Nova'. Next, the uncertainty about certain key assumptions is modelled explicitly by deciding on suitable probability distributions. To start, the relevant details of the new product launch and the associated spreadsheet model are set out in the next paragraphs.

1.1 Details of Novaduct's New Product

Novaduct's management is trying to decide whether or not to launch a new novelty product, which is expected to have a market for the next five years. The following information about the product has been gathered:

1. The expected market size is 8,000,000 units in the first year with 2% growth per annum thereafter;
2. A 15% market share is anticipated in the first year, growing by 0.3% per year afterwards;
3. In the first year, the price is likely to be £7, growing by 6% annually thereafter;
4. The expected variable cost per unit is £5 increasing by 3% per annum;
5. Fixed costs are expected to start at £2,000,000 and to grow annually at 3% as well;
6. An initial investment of £2,500,000 is planned. A discount rate of 15% is usually taken in calculating the Net Present Value for projects of this kind.

Nova_Template.xlsx

	A	B	C	D	E	F	G
1	NOVADUCT SPREADSHEET FOR FIVE YEARS (cashflow in thousands)						
2		YEAR	1	2	3	4	5
3	MARKET		8000	8160	8323	8490	8659
4	PRICE		7.0	7.4	7.9	8.3	8.8
5	V COST		5.0	5.2	5.3	5.5	5.6
6	SALES (MS)		1200	1248	1298	1350	1403
7	NET REVENUE		2400	2834	3325	3879	4503
8	FIXED COSTS		-2000	-2060	-2122	-2185	-2251
9	CASHFLOW	-2500	400	774	1203	1693	2252
10							
11							
12	ASSUMPTIONS				RESULTS		
13	Discount Rate	15%			NPV	1312	
14	Prod Cost	5	103.0%		IRR	30%	
15	Price	7	106.0%				
16	Market Share	15%		BaseCase	Pess	ML	Opt
17	MS Incr	0.3%		MS Incr	-0.2%	0.3%	0.8%
18	MktGrowth	102.0%		MktGrowth	90.0%	102.0%	108.0%
19				NPV	-1483	1312	3520
20				IRR	-19%	30%	48%

Novaduct Workshop

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