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Expert Elicitation of a Maximum Duration using Risk Scenarios

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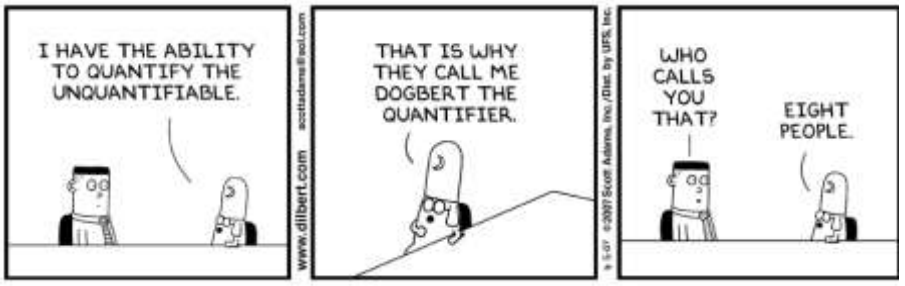
A Day in the Life of a Cost Analyst …



How Does A Cost Analyst REALLY Quantify the Unquantifiable?

A. Use common estimating methods: analogy, parametric & build-up
B. Use subject matter expert opinion
C. Incorporate cost risk & uncertainty analysis techniques
D. Yell out a number with conviction (like Dogbert the Quantifier)
E. Have the estimate "magically" equal what's in your budget
F. Combination of A, B and/or C

Slide 2

Estimating Minimum & Maximum Values

Perhaps the most common method of uncertainty analysis used today is where the FIRST step is to elicit Minimum & Maximum values directly from an expert based upon her Most-Likely value.

The 2 scenario-based methods presented herein take an alternative approach where the FIRST step is to elicit "risk scenarios" that enable an expert to describe risks & risk intensities that occur in *typical*, *optimistic* and *pessimistic* scenarios.

By having such scenarios already described, we now have (i) a justification for what risk factors contribute to the uncertainty and (ii) a means to estimate to what extent each risk factor "drives" the uncertainty in order to estimate Minimum & Maximum values.

Slide 3

Outline

- Purpose of Presentation
- Background
  - The Uncertainty Spectrum & Expert Judgment Elicitation
  - Five Expert Elicitation (EE) Phases
- Case Study: Estimate Morning Commute Time
  - Establish Framework of Interview Session
  - Create Objective Hierarchy
  - Brainstorm Risk Factors then Create "Risk Reference Table"
    - Includes descriptions of each Risk Factor
  - Method 1: Scenario-Based Ratios (SBR) Method
  - Method 2: Scenario-Based Values (SBV) Method
  - Suggested use of SBR and SBV Methods in Practice
- Conclusion & Potential Improvements / Future Work

Slide 4

Purpose of Presentation

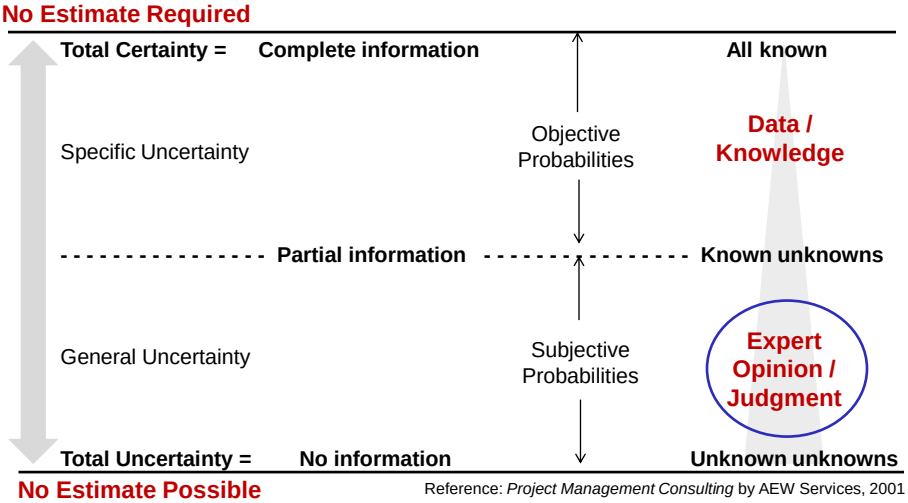
Demonstrate two expert elicitation methods that ...

1. **Model expert's inputs as a triangular distribution**
   - Two methods that use risk scenarios (derived from an objective hierarchy)
     - Method 1 (existing): Scenario-Based Ratios (SBR) Method
     - Method 2 (new): Scenario-Based Values (SBV) Method
   - Not too complex to be impractical; not too simple to be too subjective
2. **Estimate each risk factor's contribution to uncertainty**
   - e.g., "Bad weather" contributes 25% or 22 minutes to duration uncertainty
3. **Incorporate techniques to account for expert bias**
   - Facilitates interview process with use of visual aids
   - Uses SBV method's outputs to calibrate SBR method's outputs
4. **Are structured in a way to justify expert inputs**
   - Using "risk reference table", expert gives rationale for values she provides under for each scenario

As with most subjective methods, there are many ways to do this.

Slide 5

The Uncertainty Spectrum



Reference: *Project Management Consulting* by AEW Services, 2001

Expert judgment should only be used when there is (i) lack of time for collection & analysis of historical data, (ii) lack of available historical data or (iii) the design is incomplete

Slide 6

Expert Judgment Definition

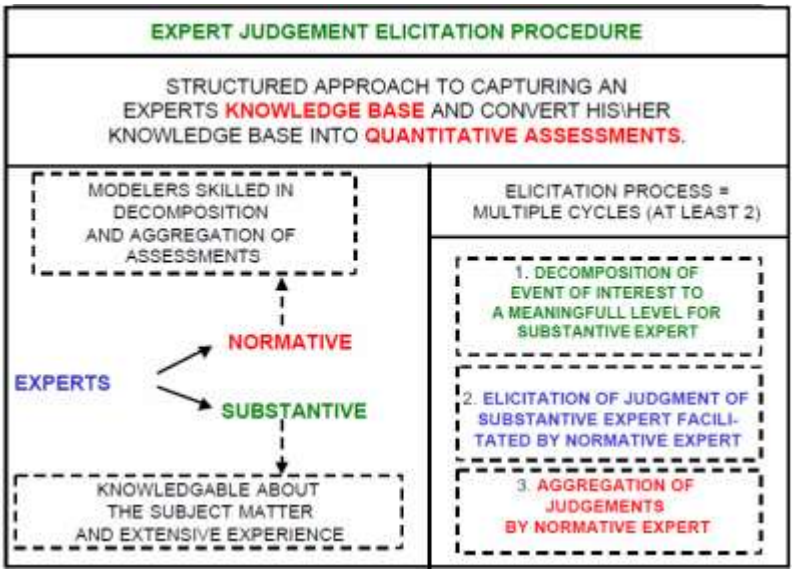
Contrary to popular belief, this Dilbert Cartoon does NOT give the best definition of Expert "Judgment" ☺

Try this one instead …

Expert Judgment (for estimating) are value estimates developed solely on the basis of a person's experience & knowledge of the process or product being estimated.

Slide 7

Expert Judgment Elicitation (EE) Procedure



Source: Making Hard Decisions, An Introduction to Decision Analysis by R.T. Clemen

Slide 8

Expert Elicitation (EE) Phases

Expert Elicitation consists of five phases:

(note that Phases 4 & 5 are iterative)

1. Motivating the expert
2. Structuring objective, assumptions & process
3. Training (conditioning) the expert
4. Assessing (encoding) expert's responses
   - Q&A – Expert's experienced-based opinion is elicited
   - Quantitative results w/ documented rationale
5. Verifying encoded values & documentation

Our example that follows covers only phases 1, 2 & 4

Slide 9

Example: Estimate Commute Time

- **Why this example?**
  - Fairly easy to find a subject matter expert
  - It is a parameter that is measurable
  - Most experts can estimate a most likely time
  - Factors that drive uncertainty can be readily identified
  - People general care about their morning commute time!

Assume only Given a Most-Likely Commute = 55 minutes

Slide 10

Establish Framework of Interview Session

1. Motivating the expert

- Explain the importance & reasons for collecting the data
- Explore stake in decision & potential for motivational bias

2. Structuring objective, assumptions & process

- Must be explicit about what you want to know & why you need to know it
  - *Clearly define variable & avoid ambiguity and explain data values that are required (e.g. hours, dollars, %, etc)*

You should have worked with SME to develop the Objective and up to 5 Major Assumptions in the table below

Objective: Develop uncertainty distribution associated with time (minutes) it will take for your morning commute starting 1 October 2014.

Assumption 1: Your commute estimate includes only MORNING driving time
Assumption 2: The commute will be analogous to the one you've been doing
Assumption 3 Period of commute will be from 1 Oct 2015 thru 30 Sep 2016
Assumption 4 Do not try to account for extremely rare & unusual scenarios
Assumption 5: Unless you prefer otherwise, time will be measured in minutes

Slide 11

Create Objective Hierarchy

Q: To minimize commute time, what is your primary objective?

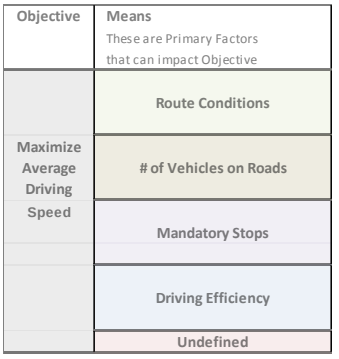
A: Maximize average driving speed

Q: What are primary factors that can impact driving speed?

A: Route Conditions, # of Vehicles on Roads, Mandatory Stops & Driving Efficiency

Q: Is it possible that other factors can impact driving speed?

A: Yes … (but SME cannot specify them at the moment)



The utility of this Objective Hierarchy is to aid the Expert in:

(a) Establishing a Framework from which to elicit most risk factors,

(b) Describing the relative importance of each risk factor with respect to means & objective, and

(c) Creating specific risk scenarios

Slide 12

Brainstorm Risk Factors

Unlike Dilbert, Risks affecting the Objective can be Specified, Described and Well Understood by All

Slide 13

Brainstorm Risk Factors

SME & Interviewer brainstorm risk factors using Objective Hierarchy as a guide:

Objective	Means These are Primary Factors that can impact Objective
Maximize Average Driving Speed	Route Conditions
	# of Vehicles on Roads
	Mandatory Stops
	Driving Efficiency
	Undefined

Q: What are some factors that could degrade route conditions?

A: Weather, Road Construction, and Accidents

Q: What influences the # of vehicles on the road in any given morning?

A: Departure time, Day of the Work Week, and Time of Season (incl. Holiday Season)

Q: What is meant by Mandatory Stops?

A: By law, need to stop for Red Lights, Emergency Vehicles and School Bus Signals

Q: What can reduce Driving Efficiency?

A: Picking the "Slow Lane", Talking on the Cell Phone and Driving Below Speed Limit

Slide 14

Create "Risk Reference Table"

The Risk Factors are then Mapped to the Objective Hierarchy.

Then the SME and Interviewer work together to describe risk factors.

Objective	Means These are Primary Factors that can impact Objective	Risk Factors These are Causal Factors that can impact Means	Description (can include examples) Subject Matter Expert's (SME's) top-level description of each Barrier / Risk
Maximize Average Driving Speed	Route Conditions	Weather	Rain, snow or icy conditions. Drive into direct sun.
		Accidents	Vehicle accidents on either side of highway.
		Road Construction	Lane closures, bridge work, etc.
	# of Vehicles on Roads	Departure Time	SME departure time varies from 6:00AM to 9:00AM
		Day of Work Week	Driving densities seem to vary with day of week
		Season & Holidays	Summer vs. Fall, Holiday weekends
	Mandatory Stops	Red Lights	Approx 8 traffic intersections; some with long lights
		Emergency Vehicles	Incl. police, firetrucks, ambulances & secret service
		School Bus Signals	School buses stopping to pick up / drop off
	Driving Efficiency	Pick Slow Lane	Just check out opening scene of "Office Space" :)
		Talking on Cellphone	On rare occasion, will call someone during commute
		Driving below Speed Limit	Can be due to less work pressure or not feeling well
	Undefined	Undefined	It's possible for SME to exclude some risk factors

This is the most time-intensive part of interview process

It will serve as the reference for the Methods that follow

Slide 15

Scenario-Based Ratios (SBR) Method [1]

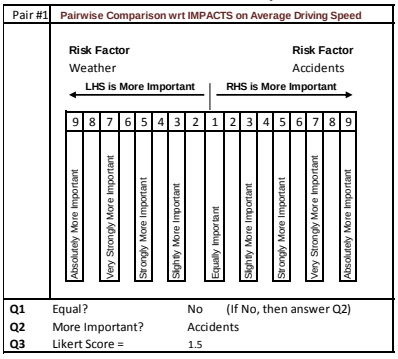
Q: What are the top 6 risk factors that impact your commute time?

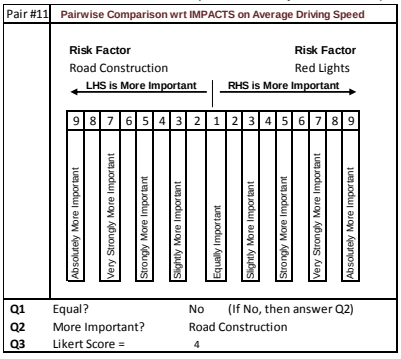
A: Top 3 are … #1. **Accidents**, #2. **Weather** and #3. **Road Construction**

Next 3 are … #4. **Departure Time**, #5. **Red Lights** and #6. **Seasons & Holidays**

Through the use of a simple Pairwise Comparison technique, the Expert can provide relative importance of each risk factor

Because 6 Risk Factors = 15 pairs, use of Visual Aids is recommended (*see examples below*):





1. A version of a paper by LaserLight Networks, Inc, "Estimating Cost Uncertainty when only Baseline Cost is Available." Their paper is based upon "A Quantification Structure for Assessing Risk-Impact Drivers," R.L Abramson and S.A. Book, 1990

Slide 16

SBR Method: Pairwise Comparison Results

Pairwise comparison of risk factors results in the following raw values:

Raw P/W Weighting	Weather	Accidents	Road Construction	Departure Time	Red Lights	Season & Holidays
Weather	1	2/3	1 1/2	2	4	8
Accidents	1 1/2	1	2	2 1/2	6	9
Road Construction	2/3	1/2	1	2	4	7
Departure Time	1/2	2/5	1/2	1	2	5
Red Lights	1/4	1/6	1/4	1/2	1	2
Season & Holidays	1/8	1/9	1/7	1/5	1/2	1
Sum	4.0	2.8	5.4	8.2	17.5	32.0
Rank	2	1	3	4	5	6

The raw values are normalized to a 100% scale, then summed to Weights per Risk Factor:

Normalized Matrix	Weather	Accidents	Road Construction	Departure Time	Red Lights	Season & Holidays	Weights
Weather	0.247	0.234	0.278	0.244	0.229	0.250	0.2471
Accidents	0.371	0.352	0.371	0.305	0.343	0.281	0.3371
Road Construction	0.165	0.176	0.185	0.244	0.229	0.219	0.2029
Departure Time	0.124	0.141	0.093	0.122	0.114	0.156	0.1249
Red Lights	0.062	0.059	0.046	0.061	0.057	0.063	0.0579
Season & Holidays	0.031	0.039	0.026	0.024	0.029	0.031	0.0301
Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000

→ Accidents have the biggest impact (34%) on commute time uncertainty

If Expert is not comfortable with calculated Weights, need to revisit (a) selection of her top 6 risk factors and/or (b) expert-provided Pairwise Comparisons

Slide 17

SBR Method: Intensity Scale & Expert Inputs

Create Intensity Scale for 6 risk factors that impact commute time

Intensity Scale	Weather	Accidents	Road Construction	Departure Time	Red Lights	Season & Holidays	*Value*	*Normalized*
Low	Perfect	None	None	< 7:00AM	No lights	Never	1	0.061
Medium-Low	Some wind	Evacuated car on side of road	Shoulder work at 1 location	7:15AM	1 light	Rarely	1.5	0.091
Medium	Some rain	1 accident on shoulder	Shoulder work at 2 locations	7:30AM	2 lights	Half of commutes	2	0.121
Medium-High	Rain & Wind	2 accidents on shoulder	1 of 3 lane closures	8:00AM	3 lights	More than half of commutes	3	0.182
High	Rain & Snow	Accident shutting 1 lane	2 of 3 lane closures	8:15AM	4 lights	>75% of commutes	4	0.242
Very High	Snow & Wind	Accident shutting 2 lanes	Temporary road closure	8:30AM	> 4 lights	Nearly Always	5	0.303

Expert provides "intensity" levels for each risk factor in each scenario

Scenario Intensities	Weather	Accidents	Road Construction	Departure Time	Red Lights	Season & Holidays
Most Likely Intensities	Medium-Low	Low	Medium-Low	Medium	Medium	Medium-Low
Optimistic Intensities	Low	Low	Low	Medium-Low	Medium-Low	Low
Pessimistic Intensities	Very High	Very High	High	High	High	High

→ Typical commute
→ Best case commute
→ Worst case commute

Slide 18

SBR Method: Intensity x Weight = Score

Using the intensity scale from previous slide, the following inputs …

Scenario Intensities	Weather	Accidents	Road Construction	Departure Time	Red Lights	Season & Holidays	
Most Likely Intensities	Medium-Low	Low	Medium-Low	Medium	Medium	Medium-Low	→ Typical commute
Optimistic Intensities	Low	Low	Low	Medium-Low	Medium-Low	Low	→ Best case commute
Pessimistic Intensities	Very High	Very High	High	High	High	High	→ Worst case commute

… are replaced with respective normalized values from intensity scale, then multiplied by respective risk factor weights (ref. slide 13) to produce a "Score" for each Scenario …

	Risk Factor Weights:						
	0.2471	*0.3371*	*0.2029*	*0.1249*	*0.0579*	*0.0301*	SCORE
Scenario Intensities	Weather	Accidents	Road Construction	Departure Time	Red Lights	Season & Holidays	Sum Product
Most Likely Intensities	0.091	0.061	0.091	0.121	0.121	0.091	0.0862
Optimistic Intensities	0.061	0.061	0.061	0.091	0.091	0.061	0.0661
Pessimistic Intensities	0.303	0.303	0.242	0.242	0.242	0.242	0.2778

Slide 19

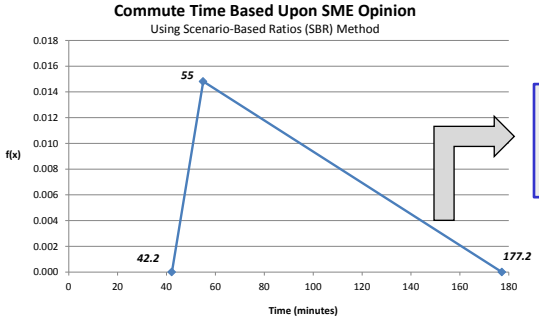
SBR Method: Ratios to Get Min & Max

Use Scores from the 3 scenarios to calculate Ratios wrt Most Likely Score

- Optimistic Score / Most-Likely Score = 0.0661 / 0.0862 = 0.7671
- Pessimistic Score / Most-Likely Score = 0.2778 / 0.0862 = 3.2218

Given a Most Likely Commute of 55 minutes, apply these Ratios to get:

- Minimum Commute Time = 0.7671 x 55 = 42.2 minutes
- Maximum Commute Time = 3.2218 x 55 = 177.2 minutes



If Expert is not comfortable with Min & Max values, need to revisit (a) Intensity scale content and/or (b) expert-provided Intensities

Slide 20

SBR Method: Risk Factor Contributions

Using weights (slide 13), "Accidents" contribute most to dispersion (46 minutes)

Risk Factor	Weights
Weather	0.2471
Accidents	0.3371
Road Construction	0.2029
Departure Time	0.1249
Red Lights	0.0579
Season & Holidays	0.0301
SUM	1.000

% of Total
25%
34%
20%
12%
6%
3%
100%

Impact
33
46
27
17
8
4
135.0

Time Impact due to Realization of Given Risk

Total minutes from Minimum to Maximum

But this is not accounting for impact of "undefined" risk factor.

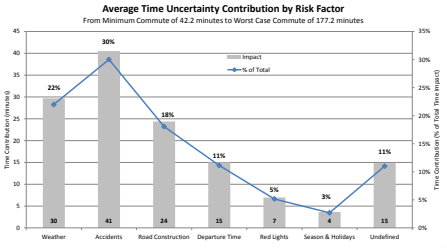
Therefore, Interviewer must ask the Expert:

Q: Suppose you knew the state of all 6 risk factors just prior to your commute. On average, within a spread of how many minutes could you estimate your commute time?

A: About 15 minutes

Risk Factor	Impact
Weather	30
Accidents	41
Road Construction	24
Departure Time	15
Red Lights	7
Season & Holidays	4
Undefined	15
SUM	135.0

% of Total
22%
30%
18%
11%
5%
3%
11%
100%



Slide 21

Scenario-Based Values (SBV) Method

Using the **Risk Reference Table** (Slide 15) …

1. Get Expert to talk about risks she experiences during "typical" commute scenario.
   Then ask her to provide time impacts associated with each risk she experiences.
   - **Result: 6 discrete time impacts associated with each of 6 risk factors**

2. Get Expert to talk about risks she experiences during a worst case commute scenario (Worst Case #1).
   Then ask her to provide time impacts associated with each risk she experiences.
   Helpful Hint: Use her "Most Likely" results as a reference.
   - **Result: 9 discrete time impacts associated with each of 9 risk factors**

3. Get Expert to talk about risks she experiences during another worst case commute scenario (Worst Case #2).
   Then ask her to provide time impacts associated with each risk she experiences.
   Helpful Hint: Use "Worst Case #1" results as a reference.
   - **Result: 11 discrete time impacts associated with each of 11 risk factors**

4. Sum up **Time Impacts** of Each Scenario

5. Use Step 4 results to Determine **Minimum** and **Maximum** commute times.
   - For **Minimum**, the Sum is subtracted from the Most-Likely commute time.
   - For **Maximum**, the Sum is added to the Most-Likely commute time.

6. Select the **Higher Maximum** value of the Two Worst Case Scenarios.

7. Display **Triangular Distribution** associated with Minimum, Most-Likely and Maximum values.
8. Display **contribution of risk factors** to uncertainty (in minutes and %).

9. Iterate back through Steps 1 - 8 as necessary based upon Expert's feedback on output.

Slide 22

SBV Method: Most-Likely Scenario

6 risk factors impact most-likely commute time

Given by Expert: Most-Likely Commute Time = 55 minutes
Assume you drive same route in morning; no MAJOR detours & no random stops (e.g. to pick up a coffee)
Assume you are NOT driving in extreme (dangerous) weather.
Assume you will turnaround or "stop" commute if foresee extreme time (e.g. more than 3 hour commute).
You should also do your best to account for correlated effects among risk factors within this scenario.

Objective	Means These are Primary Factors that can impact Objective	Risk Factors These are Causal Factors that can impact Means	Most Likely or Typical Scenario What SME experiences on a typical morning commute	Most Likely Impact SME guess on on time added to Most Likely (in minutes)	Most Likely Rank Top risks impacting Objective
Maximize Average Driving Speed	Route Conditions	Weather	Dry conditions w/direct sun, Occasional rain	2	3
		Accidents	No accidents on a typical commute	0	
		Road Construction	Occasional shoulder work	3	2
	# of Vehicles on Roads	Departure Time	Depart near start of rush hour (7:30 - 7:45am)	5	1
		Day of Work Week	(Not applicable)	0	
		Season & Holidays	(Not applicable)	0	
	Mandatory Stops	Red Lights	Typically 'catch' 2 "long" red lights	3	2
		Emergency Vehicles	Typcially no emergency vehicles en route	0	
		School Bus Signals	Typically no stops needed for school bus	0	
	Driving Efficiency	Pick Slow Lane	Minor issues (Several lanes are "equally" bad)	1	4
		Talking on Cellphone	No calls in morning	0	
		Driving below Speed Limit	Drive with flow of traffic	0	
	Undefined	Undefined	Undefined	1	4
			Impact versus MIN commute time =	**15**	**minutes**
			Subtract from MOST LIKELY commute =	**55**	**minutes**
			MINIMUM commute time =	**40**	**minutes**

"Undefined" – Expert acknowledges that there could be other known and unknown factors

Slide 23

SBV Method: Worst Case Scenario I

9 risk factors impact commute time for this worst case scenario

Given by Expert: Most-Likely Commute Time = 55 minutes
Assume you drive same route in morning; no MAJOR detours & no random stops (e.g. to pick up a coffee)
Assume you are NOT driving in extreme (dangerous) weather.
Assume you will turnaround or "stop" commute if foresee extreme time (e.g. more than 3 hour commute).
You should also do your best to account for correlated effects among risk factors within this scenario.

Objective	Means These are Primary Factors that can impact Objective	Risk Factors These are Causal Factors that can impact Means	Worst Case Scenario 1 What SME believes is a feasible worst case morning commute	Worst Case Impact SME guess on on time added to Most Likely (in minutes)	Worst Case Rank Top risks impacting Objective
Maximize Average Driving Speed	Route Conditions	Weather	Drove in heavy rain; likely led to accident	15	2
		Accidents	Severe accident that shut 2 lanes	50	1
		Road Construction	Lane closures on bridge due to accident	0	
	# of Vehicles on Roads	Departure Time	Depart during rush hour peak (8:30am)	10	3
		Day of Work Week	More traffic on Tuesdays & Wednesdays	4	6
		Season & Holidays	Shopping traffic (mid-Nov)	5	5
	Mandatory Stops	Red Lights	Caught' 4 red lights en route	8	4
		Emergency Vehicles	Had to pull over for 2 emergency vehicles	2	7
		School Bus Signals	Bus pick-ups are prior to rush hour	0	
	Driving Efficiency	Pick Slow Lane	Can be stuck in a lane behind metro bus	2	7
		Talking on Cellphone	If accident, typically will make phone call	0	
		Driving below Speed Limit	Already driving slowly from Route Conditions	0	
	Undefined	Undefined	Undefined	5	5
			Impact versus Most Likely commute time =	**101**	**minutes**
			Add to MOST LIKELY commute =	**55**	**minutes**
			MAXIMUM commute time =	**156**	**minutes**

"Undefined" – Expert acknowledges that there could be other known and unknown factors

Slide 24

SBV Method: Worst Case Scenario 2

11 risk factors impact most-likely commute time

Given by Expert: Most-Likely Commute Time = 55 minutes
Assume you drive same route in morning; no MAJOR detours & no random stops (e.g. to pick up a coffee)
Assume you are NOT driving in extreme (dangerous) weather.
Assume you will turnaround or "stop" commute if foresee extreme time (e.g. more than 3 hour commute).
You should also do your best to account for correlated effects among risk factors within this scenario.

Objective	Means These are Primary Factors that can impact Objective	Risk Factors These are Causal Factors that can impact Means	Worst Case Scenario 2 What SME believes is a feasible worst case morning commute	Worst Case Impact SME guess on on time added to Most Likely (in minutes)	Worst Case Rank Top risks impacting Objective
Maximize Average Driving Speed	Route Conditions	Weather	Drove in light snow	20	2
		Accidents	Witnessed 2 accidents on side of road	35	1
		Road Construction	Lane closures unrelated to accidents	15	3
	# of Vehicles on Roads	Departure Time	Departed during rush hour peak (8:30am)	10	4
		Day of Work Week	More traffic on Tuesdays & Wednesdays	4	7
		Season & Holidays	Shopping traffic (mid-Nov)	5	6
	Mandatory Stops	Red Lights	Caught' 4 red lights en route	8	5
		Emergency Vehicles	Salt trucks caused additional slow down	2	8
		School Bus Signals	Bus pick-ups are prior to rush hour	0	
	Driving Efficiency	Pick Slow Lane	Can be stuck in a lane behind metro bus	2	8
		Talking on Cellphone	Could do a phone call unrelated to risks	2	8
		Driving below Speed Limit	Already driving slowly from Route Conditions	0	
	Undefined	Undefined	Undefined	5	6
			Impact versus Most Likely commute time =	108	minutes
			Subtract from MOST LIKELY commute of	55	minutes
			MAXIMUM commute time =	163	minutes

"Undefined" – Expert acknowledges that there could be other known and unknown factors

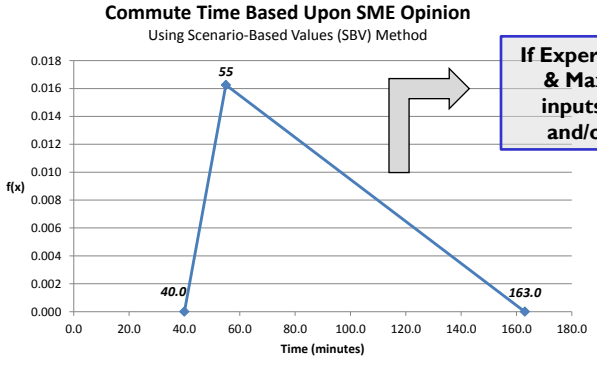
This is higher than Max from Worst Case Scenario 1

Slide 25

SBV Method: Min, Most-Likely and Max

Given a Most Likely Commute of 55 minutes, estimated:

- Minimum Commute Time = 55 – 15 = 40 minutes
- Maximum Commute Time = 55 + 108 = 163 minutes



If Expert is not comfortable with Min & Max values, need to revisit her inputs to (a) most-likely scenario and/or (b) worst-case scenarios.

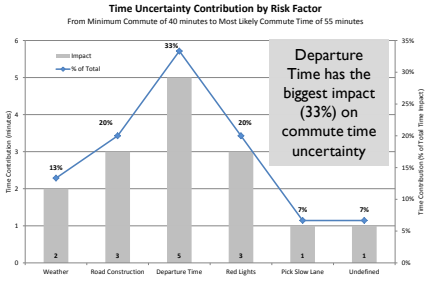
Can use these Min and Max values to calibrate SBR results

Slide 26

SBV Method: Risk Factor Contributions

Time Contribution:
from Minimum to Most Likely (in minutes)

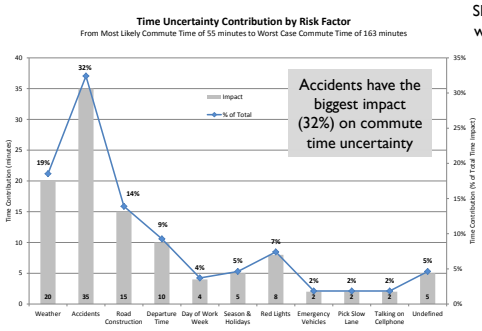
Risk Factor	Impact	% of Total
Weather	2	13%
Road Construction	3	20%
Departure Time	5	33%
Red Lights	3	20%
Pick Slow Lane	1	7%
Undefined	1	7%
SUM	15.0	100%



SBV Method provides a more detailed look (vs. SBR Method) at what drives the uncertainty

Time Contribution:
from Most Likely to Maximum (in minutes)

Risk Factor	Impact	% of Total
Weather	20	19%
Accidents	35	32%
Road Construction	15	14%
Departure Time	10	9%
Day of Work Week	4	4%
Season & Holidays	5	5%
Red Lights	8	7%
Emergency Vehicles	2	2%
Pick Slow Lane	2	2%
Talking on Cellphone	2	2%
Undefined	5	5%
SUM	108.0	100%



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Suggested Use of SBR & SBV Methods in Practice

The most critical effort is to create a "Risk Reference Table"

- And it will only serve schedule / cost elements that share these risks & objective
- Can take >2 hours to set up each, but can be used again for other estimates

SBR Method takes a little time to set-up, primarily because Intensity Scale is customized to specific risk factors

- After which the Expert can efficiently select Intensities for each activity or CER (that could be affected by specific risk factors)
- The Pairwise Comparison only needs to be completed one time to get Weights

SBV Method takes less time to set-up, but the discussion, iterations & documentation for Most-Likely and Maximum scenarios can be time consuming (> 1 hour per WBS item)

- SBV Method may be more useful for schedule / cost elements that have "large-share" most-likely values (with no specified uncertainty)

SBV Method could be used to calibrate results of SBR Method

- Example: After applying SBR Method to 10 WBS elements, apply SBV Method on 1 or 2 of these WBS that have largest "spread." Then calibrate Ratios using SBV results.

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Conclusion

- **Demonstrated two expert elicitation methods that modeled expert's inputs as a triangular distribution**
  - Started with only one numeric value: Most-Likely Commute = 55 minutes
  - Method 1 (existing): Scenario-Based Ratios (SBR) Method
  - Method 2 (new): Scenario-Based Values (SBV) Method
- **Each method focused <u>first</u> on describing Risk Scenarios**
  - A "Risk Reference Table" was created from which the expert described
    - relative importance and intensity of each risk factor (SBR Method), or
    - how each risk impacts ideal commute time (SBV Method)
- **Each method measured risk factor impacts on uncertainty**
  - e.g., "Accidents" contributes 34% or 41 minutes to duration uncertainty
- **Incorporated techniques to account for expert bias**
  - Facilitates interview process with use of visual aids
  - Recommends using SBV method outputs to calibrate SBR method outputs
- **Are structured in a way to justify expert inputs**

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Potential Improvements / Future Work

- Develop standardized NASA system objective hierarchies
  - Example: One for Satellites, One for Rockets, One for Aircraft, etc.
- Develop risk factor "sets" for each objective hierarchy
  - Example: A satellite objective hierarchy may have 3 sets depending on estimate type
- Improve method of weighting risk factors
- Improve intensity tables that depict expert judgment
  - Example: Make less subjective using pairwise comparison method
- Develop step-by-step templates for SBR & SBV methods
  - Example: Something along the lines of a 1040 EZ form
- Provide criteria when to elicit mean or median (vs mode)
- Incorporate methods to combine expert judgments
- Demonstrate how elements of SBR and SBV methods can augment output of data-driven CERs

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Questions?

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