Integrated Cost-Schedule Risk Analysis Improves Cost Contingency Calculation ICEAA 2017 Workshop Portland OR June 6 – 9, 2017 David T. Hulett, Ph.D., FAACE Hulett & Associates, LLC David.hulett@projectrisk / www.projectrisk.com (310) 476-7699



Summary

- Purpose of the Quantitative Risk Analysis
- Model uncertainty for duration and cost
- Model project-specific risks using Risk Drivers
- Compare P-80 for cost and schedule to the Joint Confidence Level (JCL-80) as promise dates and costs
- Prioritize the risks @ P-80 and days saved
- Mitigate risks partially, recording mitigation costs



Abstract

- The main benefits of integrated cost-schedule risk analysis are improvement of the estimates of cost contingency and identification of the main risks to cost for mitigation purposes.
- The main focus is on estimating the cost contingency needed and identifying risks to cost, which may be independent of schedule or indirectly due to schedule risk.
- New simulation software including iterative risk prioritization will be used to illustrate these points.



Purpose of Quantitative Risk Analysis

- Answer 3 questions:
 - How likely is the project to <u>meet its schedule and</u> <u>cost goals</u> on the current plan?
 - How much schedule and cost contingency is needed to <u>achieve the a desired level of certainty</u> <u>of hitting both schedule and cost targets</u>
 - Which risks are causing potential overrun of schedule and cost, <u>including indirect schedule-</u> <u>driven cost</u>, and are thus high priority for risk mitigation?



Example Schedule: Offshore Gas Production Platform Project

Activi	ty ID	Activity Name	Original Duration	Start	Finish	Q4	2017 Q1 Q2 Q3	Q4 Q	2018 1 Q2 Q3 Q	201 4 Q1 Q2	9 Q3 Q4	2020 Q1 Q2 Q3	Q4 Q	2021 1 Q2 Q3	20 Q4 Q1 Q2
- 1	Total		1190d	01-Jan-17	04-Apr-20							🛶 🗸 04-Api	r-20, To	tal	
-	Gas Plat	form-7 Offshore Gas Pr	1190d	01-Jan-17	04-Apr-20							🛶 04-Apr	r-20, Ga	s Platform	-7 Offshore G
E	Gas Plat	form-7.1 Milestones and Ham	1190d	01-Jan-17	04-Apr-20							🛶 🗸 04-Api	r-20, Ga	s Platform	-7.1 Milestone
	A1030	Project Management Hammock	1190d	01-Jan-17	04-Apr-20	⊢ ⊧						Projec	t Mana	gement H	ammock
	A1020	First Gas	0d		04-Apr-20							First G	as		
	A1010	Project Sanction	0d		19-Jul-17		📇 F	Project S	anction						
	A1000	Project Start	0d	01-Jan-17*			Project Sta	art							
6	Gas Plat	form-7.2 Decision Making	100d	11-Apr-17	19-Jul-17		**** 1	9-Jul-17	Gas Platform	m-7.2 Decis	ion Mak	king			
	B1000	Approval Process	100d	11-Apr-17	19-Jul-17		A 1111	Approva	Process						
6	Gas Plat	form-7.3 Engineering	700d	01-Jan-17	01-Dec-18					▼ 01-Dec-1	8, Gas F	Platform+7.3 E	Inginee	ring	
	C950	FEED	200d	20-Jul-17	04-Feb-18		1 L 1 + 🗰		FEED						
	C900	Concept Engineering	100d	01-Jan-17	10-Apr-17	l lea	Conce	ept Engii	neering						
	C1010	Detailed Engineering	300d	05-Feb-18	01-Dec-18					Detailed	Enginee	erin <mark>g</mark>			
6	Gas Plat	form-7.4 Procurement	580d	05-Feb-18	07-Sep-19						07-	Sep-19, Gas I	Platform	n-7.4 Proc	urement
	D1010	Procurement of Other Equipment	250d	02-Dec-18	08-Aug-19					-	Proc	urement of Ot	her Equ	uipment	
	D1000	Procurement of LLE	580d	05-Feb-18	07-Sep-19						📫 Pro	curement of L	LE:		
E	Gas Plat	form-7.5 Fabrication	340d	02-Dec-18	06-Nov-19						•••• •	06-Nov-19, Ga	as Platf	orm-7.5 F	abrication
	E1030	Fabricate CPP Jacket	250d	02-Dec-18	08-Aug-19				•		Fabr	icate CPP Ja	cket		
	E1025	Install LLE Equipment	40d	28-Sep-19	06-Nov-19						*-	install LLE Eq	uipmen	ıt 💠	
	E1020	Fabricate CPP Topsides	300d	02-Dec-18	27-Sep-19						F ε	abri <mark>cate CPP</mark> '	Topsid	es	
	E1010	Fabricate Drilling Jacket	200d	02-Dec-18	19-Jun-19				•		Faprica	ate Drilling Ja	cket		
	E1000	Fabricate Drilling Topsides	200d	02-Dec-18	19-Jun-19				•		Faprica	ate Drilling To	psides		
6	Gas Plat	form-7.6 Drilling	100d	04-Aug-19	11-Nov-19						T	11-Nov-19, G	as Platf	orm-7.6 D	rilling
	F1000	Drilling for First Gas Only	100d	04-Aug-19	11-Nov-19							Drilling for Fire	st Gas (Dnly	
E	Gas Plat	form-7.7 Installation	170d	20-Jun-19	06-Dec-19	LU.						/ 06-Dec-19, (Gas Pla	tform-7.7	Installation
	G1030	Install CPP Topsides	30d	07-Nov-19	06-Dec-19						1 - 1	Install CPP 1	Fopside	es	
	G1020	Install CPP Jacket	20d	09-Aug-19	28-Aug-19						-🖸 Insta	all CPP Jacke	et		
	G1010	Install Drilling Topsides	25d	10-Jul-19	03-Aug-19						🚽 Insta	II Drilling Top:	sides		
	G1000	Install Drilling Platform Jacket	20d	20-Jun-19	09-Jul-19					· · · · · · · · · · · · · · · · · · ·	Install	Drilling Platfo	rm Jac	ket	
E	Gas Plat	form-7.8 HUC	120d	07-Dec-19	04-Apr-20							🔫 04-Apr	r-20, Ga	s Platform	-7.8 HUC
	H1000	Hook UP and Commissioning	120d	07-Dec-19	04-Apr-20						-	Hook	UP and	Commiss	ioning



Import to Integrated Cost-Schedule Risk Analysis Software

UID	Task III	Start Date	End Date	Duration	Cost	A 2016	2017			2018		_	2019			2	2020			2021				
						23 Q4	Q1	Q2 Q3	3 Q4	4 Q1	Q2	Q3 Q4	Q1	Q2	Q3	Q4 Q	Q1 Q	2 Q3	Q4	Q1	Q2 Q	23 Q4		
Gas Pla	Offshore Gas Production Platfori	01/01/2017	04/04/2020	1,190	\$1.697M		_											Offshore	Gas Prod	duction I	Platform		39-month	
Gas Pla	Milestones and Hammocks	01/01/2017	04/04/2020	1,190	\$80,000		-									_	_	Milestone	is and Ha	mmock	s		oo monen	
A1010	Project Sanction		07/19/2017	0	\$0			•	Proje	ct Sanction													¢1 7 hillior	h
A1020	First Gas		04/04/2020	0	\$0		-										-	First Gas						•
A1030	Project Management Ham	01/01/2017	04/04/2020	1,190	\$80,000		-	1111	1111	11111	1111	1111	1111	1111	1111	2000		Project N	lanageme	ent Ham	mock		Ducient	
A1000	Project Start	01/01/2017		0	\$0		Proje	ct Start								_							Project	
Gas Pla	V Decision Making	04/11/2017	07/19/2017	100	\$8,000				Decisi	ion Making													 •	
B1000	Approval Process	04/11/2017	07/19/2017	100	\$8,000		C		- K Ap	proval Pro	cess													
Gas Pla	▼ Engineering	01/01/2017	12/01/2018	700	\$256,000		-		1 - F				Engin	neering										
C950	FEED	07/20/2017	02/04/2018	200	\$80,000			4			R FEED													
C1010	Detailed Engineering	02/05/2018	12/01/2018	300	\$160,000					-			ך 🛛 🗠	etailed E	ingineerin	1g								
C900	Concept Engineering	01/01/2017	04/10/2017	100	\$16,000		-	Cor	incept Er	ngineering								1						
Gas Pla	▼ Procurement	02/05/2018	09/07/2019	580	\$350,000					_						Produrer	ment							
D1000	Procurement of LLE	02/05/2018	09/07/2019	580	\$250,000					-	-					K Procu	urement	of LLE						
D1010	Procurement of Other Equ	12/02/2018	08/08/2019	250	\$100,000								-	-		Procure	ement of	Other Equ	ipment					
Gas Pla	Fabrication	12/02/2018	11/06/2019	340	\$836,000								-			Fab	brication							
E1000	Fabricate Drilling Topsides	12/02/2018	06/19/2019	200	\$180,000								-		Fa 🔟	bricate Dr	rilling To	osides						
E1010	Fabricate Drilling Jacket	12/02/2018	06/19/2019	200	\$140,000								+		- 🔣 Fa	bricate Dr	rilling Ja	cket						
E1020	Fabricate CPP Topsides	12/02/2018	09/27/2019	300	\$320,000								-	_		🔣 Fab	oricate C	PP Topsid	es					
E1030	Fabricate CPP Jacket	12/02/2018	08/08/2019	250	\$164,000								-			K Fabricat	te CPP)	acket						
E1025	Install LLE Equipment	09/28/2019	11/06/2019	40	\$32,000										9		Install L	E Equipm	ent					
Gas Pla	▼ Drilling	08/04/2019	11/11/2019	100	\$80,000										-	Dri	illing							
F1000	Drilling for First Gas Only	08/04/2019	11/11/2019	100	\$80,000										-		Drilling	for First G	as Only					
Gas Pla	▼ Installation	06/20/2019	12/06/2019	170	\$47,200											-	Installati	on						
G1000	Install Drilling Platform Ja	06/20/2019	07/09/2019	20	\$8,000									Ģ		Instal Dri	illing Pla	form Jack	et					
G1010	Install Drilling Topsides	07/10/2019	08/03/2019	25	\$13,600											Install D	Drilling T	opsides						
G1020	Install CPP Jacket	08/09/2019	08/28/2019	20	\$9,600										G0-	E Install	CPP Ja	cket						
G1030	Install CPP Topsides	11/07/2019	12/06/2019	30	\$16,000											-0-1	Insta	CPP Top	sides					
Gas Pla	T HUC	12/07/2019	04/04/2020	120	\$40,000											-	-	HUC						
H1000	Hook UP and Commission	12/07/2019	04/04/2020	120	\$40,000											¢۲	_	K Hook	UP and C	Commiss	ioning for	First Gas		

Using Booz Allen Hamilton Polaris[©]

http://www.boozallen.com/consulting/products/polaris



Uncertainty

- Inherent variability
- Estimating Error
- Estimating Bias if it exists
- These must be taken into account in the Risk Analysis



Adding Uncertainty to Activity Durations and Resource Quantities by Reference Ranges

- Uncertainty in schedule duration is similar to "<u>common cause</u>" variation related to six sigma process control concepts developed by Walter Shewhart and championed by Edwards Demming
- "Common cause variability is a source of variation caused by unknown factors that result in a <u>steady but random distribution</u> <u>of output</u> around the average of the data Common cause variation is also called random variation, noise, <u>non-controllable</u> <u>variation</u> ... " (<u>http://www.isixsigma.com/dictionary/commoncause-variation/</u>)



Apply Uncertainty to Activity Durations by Reference Ranges

Tem	plate	d U	ncertainty Editor	
Ten	nplat	es 🗌	O Add C Remove	
Prior	ity		Filter	Schedule Uncertainty
	1	\bigtriangledown	Engineering -	Triangular - Min:0.9 Likely:1.05 Max:1.2
	2	\bigtriangledown	Procurement 👻 🥌	Triangular - Min:0.95 Likely:1.05 Max:1.2
	3	\bigtriangledown	Fabrication 💌 🥌	Triangular - Min:0.85 Likely:1.1 Max:1.3
	4	\bigtriangledown	Drilling 💌 🥏	Triangular - Min:0.8 Likely:1.1 Max:1.3
	5	\bigtriangledown	Installation 💌 🥌	Triangular - Min:0.9 Likely:1.1 Max:1.3
	6		HUC 💌	Triangular - Min:0.9 Likely:1.1 Max:1.4

These represent uncertainty parameters for the entire activity class (engineering, procurement, fabrication...). To achieve that while using the specified ranges on each activity within the class, these uncertainty values must be correlated 100%



Resource usage Uncertainty Ranges

R	esou	rces 😳 Add 🔵 Remov	e Apply to All		Utilizations	Add C Remove Appl
	UID	Resource	Туре	Max	Category	Rate per unit or day
	R-3	Fabrication	Time Dependent	1	Fabrication 🤤	Triangular - Min:600 Likely:800 Max:1,200
	R-4	Installation	Time Dependent	1	Installation	Triangular - Min:700 Likely:900 Max:1,400
	R-6	Hook Up and Commissioning	Time Dependent	1	нис 🤤	Triangular - Min:600 Likely:800 Max:1,200
	R-1	Time-Dependent	Time Dependent	1	Time-Dependent 🤤	Triangular - Min:700 Likely:800 Max:1,400
E	R-5	Drilling	Time Dependent	1	Drilling	Triangular - Min:750 Likely:850 Max:1,500
	R-15	Procurement	Time Independent	1	Procurement	Triangular - Min:90 Likely:110 Max:180
	R-7	Engineering	Time Dependent	1	Engineering	Triangular - Min:700 Likely:850 Max:1,400
æ	R-10	Approval	Time Dependent	1	Approval 🤤	Triangular - Min:750 Likely:800 Max:1,500



Effect of Uncertainty on Finish Date



Deterministic Finish Date 4/4/20

P-80 Finish Date 8/31/20

Effect ~ 5 months



Effect of Uncertainty on Project Cost



Baseline = \$1.69 billion
P-80 cost = \$2.32 billion
Over cost = \$630 million or 37%



Scatterplot: Effect of Uncertainty on Durations and Resources





Correlation Finish Date – Cost calculated at 49%. Upward slope reflects effect of uncertain durations on cost

Project-Specific Risks

- Risks identified, so potentially mitigated
- Risks quantified with probability, impact, activities affected
- Risk Driver Method of representing these risks



Add Project-Specific Risks

- Risk is similar to "special causes" in six sigma
- "... special cause variation is caused by <u>known</u> <u>factors that result in a non-random distribution of</u> <u>output</u>...Special cause variation is a shift in output caused by a specific factor such as environmental conditions or process input parameters. It can be accounted for directly and <u>potentially removed</u>..." (<u>http://www.isixsigma.com/dictionary/variationspecial-cause/</u>)
- Hence, pre-mitigated risks are the subject of risk mitigation workshops



Risk Drivers (1)

- Each identified risk has a probability that it will occur with some effect on time or cost
 - Cost of labor (time-dependent) resources will increase proportionately with the activity duration
- If the risk occurs it affects activities' durations and costs
 - If time-dependent resources (labor, rented equipment) it will vary the daily burn rate
 - If time-independent resources (equipment to be installed, material) it will affect the entire cost directly



Risk Drivers (2)

- A risk may affect multiple activities
- Activities may be affected by multiple risks
- If a risk driver occurs it has a multiplicative effect on the durations of the activities it affects
 - Multiplier < 1.0 \rightarrow shorter duration, opportunity
 - Multiplier > 1.0 \rightarrow longer duration, threat
- Multiplier <u>for each iteration</u> is chosen at random from input distribution (usually 3-point estimate, triangle)



100% Likely Risk Driver's Effect on Design Duration



With a 100% likely risk the probability distribution of the activity's duration looks like a triangle. Not any different from placing a triangle directly on the activity



Risk Driver with Risk at < 100% likelihood

Risk Driv	er Ed	litor					
Enabled 🗹	UID	Risk Driver Name	Probability	Description	Notes		
V	1	Engineering company productivity may differ from planned	100%		0		
V	2	Construction Contractor may or may not be familiar with the technology	40%				
1	3	Testing may reveal issues that need to be resolved	65%		0		
	4	Organization's quality controls may not be sufficient to avoid issues in Delivered Product	50%		0		
Risk Driv	/er In	npact Editor		Tasks 🗿	Add Semove	Trippoular Mini@ 0 Likeluut 1 Mayri 4	Duration Factor
Task					In Parallel	mangular - Minto.9 Likely:1.1 Max:1.4	Cont Forday
B1010 - Build	1						Cost Factor
C1010 - Build	2					None - Original Value: 1	
-							

With this risk, the Construction Contractor may or may not be familiar with the technology, the probability is 40% and the risk impact if it happens is .9, 1.1 and 1.4. It is applied to the two Build activities



With a 40% Likelihood, the "Spike" in the Distribution Contains 60% of the Probability



Here is where the Risk Driver method gets interesting. It can create distributions that reflect:

- Probability of occurring
- Impact if it does occur
 Cannot represent these
 two factors with simple
 triangular distributions
 applied to the durations
 directly



Using Risk Drivers Method

	Driver			Selected Risk Scenario: Basel	ine 💌 Ed	it	
Risk Dri	ver E	ditor					
Enabled 🗹	UID	Risk Driver Name		Risk Drivers with		Description	Probability Notes
	1	Bids may be Abusive I	eading to delayed approval	RISK DITVETS WITH			70%
	2	Engineering may be co	emplicated by using offshore design firm	nrobability			60%
\checkmark	3	Suppliers of installed e	equipment may be busy	probability			50%
\checkmark	4	Fabrication yards may	experience lower Productivity than planned				65%
	5	The subsea geological	conditions may be different than expected				70%
\checkmark	6	Installation may be de	layed due to coordination problems				60%
	7	Fabrication and installa	tion problems may be revealed during HUC				35.76
	8	The organization has o	ther priority projects so personnel and funding may be un	available			50%
1010 - Deta 1000 - Proc	ailed Engir curement	neering of LLE			N.	one - Original Voluer 1	1
1010 - Flot	ricate Drilli	ing Topsides	Activities to				
.000 - Fabr .010 - Fabr	ricate Drilli ricate Drilli	ing Topsides ing Jacket	Activities to				
000 - Fabr 010 - Fabr 020 - Fabr	icate Drilli icate Drilli icate CPP	ing Topsides ing Jacket Topsides	Activities to which Driver is				
1010 - Frak 1000 - Fabr 1010 - Fabr 1020 - Fabr 1030 - Fabr	ricate Drilli ricate Drilli ricate CPP ricate CPP	ing Topsides ing Jacket Topsides Jacket	Activities to which Driver is			Risk Dr	ivers' impact
1010 - Fabr 1010 - Fabr 1020 - Fabr 1030 - Fabr 1030 - Drilli	ricate Drilli ricate Drilli ricate CPP ricate CPP ricate CPP	ing Topsides ing Jacket Topsides Jacket st Gas Only Solutions Jacket	Activities to which Driver is assigned			Risk Dr	ivers' impact
000 - Fabr 010 - Fabr 020 - Fabr 030 - Fabr 000 - Drilli	ricate Drilli ricate Drilli ricate CPP ricate CPP ricate CPP ring for First call Drilling	ing Topsides ing Jacket Topsides Jacket st Gas Only platform Jacket	Activities to which Driver is assigned			Risk Dr	<mark>ivers' impact</mark>
1010 - Fabr 1010 - Fabr 1020 - Fabr 1030 - Fabr 1030 - Drilli 1000 - Inst 1010 - Inst	ricate Drilli ricate Drilli ricate CPP ricate CPP ricate CPP ricate CPP ricate CPP ricate CPP ricate CPP ricate CPP ricate CPP ricate CPP	ing Topsides ing Jacket Topsides Jacket st Gas Only Platform Jacket J Topsides	Activities to which Driver is assigned			Risk Dr	<mark>ivers' impact</mark>
000 - Fabr 010 - Fabr 020 - Fabr 020 - Fabr 000 - Drilli 1000 - Inst 1010 - Inst	ricate Drilli ricate Drilli ricate CPP ricate CPP ricate CPP ricate CPP ricate CPP ricate CPP ricate CPP rall CPP To	ing Topsides ing Jacket Topsides Jacket Jacket St Gas Only Platform Jacket Topsides cket modes	Activities to which Driver is assigned			Risk Dr	<mark>ivers' impact</mark>
1000 - Fabr 1000 - Fabr 1020 - Fabr 1030 - Fabr 1000 - Drilli 1000 - Inst 1010 - Inst 1020 - Inst 1030 - Inst	icate Drilli icate Drilli icate CPP icate CPP ing for First call Drilling call Drilling call CPP Ja call CPP To k UP and	ing Topsides ing Jacket Topsides Jacket st Gas Only Platform Jacket j Topsides ccket opsides Commissioning for Firet G	Activities to which Driver is assigned			<mark>Risk Dr</mark>	<mark>ivers' impact</mark>
1000 - Fabr 1000 - Fabr 1000 - Fabr 1000 - Fabr 1000 - Drilli 51000 - Inst 51010 - Inst 51020 - Inst 51030 - Inst 1000 - Hoo	ricate Drilli ricate Drilli ricate CPP ricate CPP ricat	ing Topsides ing Jacket Topsides Jacket Jacket Jacket Jacket Jacket Jacket Jacket Jacket Jopsides ccket Lopsides Commissioning for First G commissioning for First G	Activities to which Driver is assigned			<mark>Risk Dr</mark>	<mark>ivers' impact</mark>



Risk Factors Model How Correlation Occurs Coefficients are Calculated (1)



Correlation = 100%

We are very bad at estimating correlation coefficients directly



Risk Factors Model How Correlation Occurs Coefficients are Calculated (2)



- Correlation is modeled as it is caused in the project
- Correlation coefficients are generated, not guessed
- Correlation drives the results correctly
- By modeling correlation we never get an inconsistent correlation coefficient matrix (C) 2017 Hulett & Associates, LLC

Project-Specific Risks as Risk Drivers that Cause Additional Variation in the Simulation

Risk Driv	ver E	ditor		Risk Drivers	🕒 Ad
Enabled 🗹	UID	Risk Driver Name		Description	Proba
	1	Bids may be Abusive leading to delayed approval			70%
	2	Engineering may be complicated by using offshore design firm			60%
	3	Suppliers of installed equipment may be busy			50%
	4	Fabrication yards may experience lower Productivity than planned			65%
	5	The subsea geological conditions may be different than expected			70%
	6	Installation may be delayed due to coordination problems			60%
	7	Fabrication and installation problems may be revealed during HUC			55%
	8	The organization has other priority projects so personnel and funding may	be unavailable		50%
Task			Parallel Triangular - Min:0.95 Lik	ely:1.1 Max:1.45	
Task B1000 - Appr	oval Proc	855	Parallel	ely:1.1 Max:1.45 Cost Factor)
Task B1000 - Appr C1010 - Deta	oval Prov	ess ieering	Parallel Triangular - Min:0.95 Lik	ely:1.1 Max:1.45 Cost Factor	
Task B1000 - Appr C1010 - Deta D1000 - Proc	oval Proc iled Engir urement	ess veering of LLE	Parallel Triangular - Min:0.95 Lik	ely:1.1 Max:1.45 Cost Factor ly:1 Max:1.15	
Task B1000 - Appr C1010 - Deta D1000 - Proc D1010 - Proc	oval Proc iled Engir urement urement	ress eering of LLE of Other Equipment	Parallel Triangular - Min:0.95 Lik	ely:1.1 Max:1.45 Cost Factor ly:1 Max:1.15	
Task B1000 - Appr C1010 - Deta D1000 - Proc D1010 - Proc E1000 - Fabri	oval Proc iled Engir urement urement cate Drill	ress leering of LLE of Other Equipment ng Topsides	Parallel Triangular - Min:0.95 Lik	ely:1.1 Max:1.45 Cost Factor ly:1 Max:1.15)
Task B1000 - Appr C1010 - Deta D1000 - Proc D1010 - Proc E1000 - Fabri E1010 - Fabri	oval Proc iled Engir urement urement cate Drill cate Drill	ess leering of LLE of Other Equipment ng Topsides ng Jacket	Parallel Triangular - Min:0.95 Lik	ely:1.1 Max:1.45 Cost Factor ly:1 Max:1.15)
Task B1000 - Appr C1010 - Deta D1000 - Proc D1010 - Proc E1000 - Fabri E1010 - Fabri E1020 - Fabri	oval Proc iled Engir urement urement cate Drill cate Drill cate CPP	ess eering of LLE of Other Equipment ng Topsides ng Jacket Topsides	Parallel Triangular - Min:0.95 Lik	ely:1.1 Max:1.45 Cost Factor ly:1 Max:1.15	
Task B1000 - Appr C1010 - Deta D1000 - Proc D1010 - Proc E1000 - Fabri E1010 - Fabri E1020 - Fabri E1030 - Fabri	oval Proc iled Engin urement urement cate Drill cate Drill cate CPP cate CPP	ess veering of LLE of Other Equipment ng Topsides ng Jacket Topsides Jacket	Parallel Triangular - Min:0.95 Like	ely:1.1 Max:1.45 Cost Factor ly:1 Max:1.15	
Task B1000 - Appr C1010 - Deta D1000 - Proc E1000 - Fabri E1010 - Fabri E1020 - Fabri E1030 - Fabri F1000 - Drillir	oval Proc iled Engir urement cate Drill cate Drill cate CPP cate CPP ng for Firs	eess eeering of LLE of Other Equipment ng Topsides ng Jacket Topsides Jacket t Gas Only	Parallel Triangular - Min:0.95 Lik Triangular - Min:0.9 Like	ely:1.1 Max:1.45 Cost Factor ly:1 Max:1.15)

The highlighted risk driver is an organizational risk that affects all activities' duration as well as daily expenditure rate (for time-dependent labor resources)



What End Date and Cost should be put forward?



P-80 finish date is 5/14/21 adding another 8 ½ months to the project over uncertainty P-80 cost is \$2.96 billion, adding another \$638 million to the project from uncertainty.



Use the Time – Cost Scatterplot to Estimate Targets to meet BOTH Objectives

- The histograms / cumulative distribution functions estimate finish date and cost to <u>meet each target individually</u>
- To meet BOTH targets, use the scatterplot
- Meeting both targets requires a more conservative (later date, more cost) estimate
- How much more time and cost depends on their correlation



The P-80 Cost and Schedule together do not Provide 80% Joint Success



Approximating the P-80 date and cost as closely as possible with the software yields only abut a 73% probability of joint success



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The Joint Confidence Level (JCL-80) values provide 80% Joint Success



Values are approximate since there are many combinations of date and cost that yield a JCL-80 and we cannot just choose where the project will end up. Also, the software is not infinitely calibrated

JCL-80 compared with P-80 Results

P-80 and Joint Confidence Level (JCL-8	30) Results with Risks and Uncertainty
Base	eline
Finish Date	4/4/2020
Budgeted Cost (billions)	\$1.70
Risk Analy	sis Results
Sche	dule
P-80	5/14/2021
JCL-80 (point chosen)	8/31/2021
Difference	3.1 Months
Co	ost
P-80	2.957
JCL-80 (point chosen)	3.178
Difference	0.221 \$Billion



Effect of Including Schedule Risk in a Cost Risk Analysis

- Direct impacts on cost risk are from
 - Traditional cost risks (e.g., metrics such as quantities, unit prices...)
 - Affect labor burn rate, material total cost
 - Effect of uncertainty, estimating error, bias
- Indirect impacts on cost risk from schedule combine
 - Schedule uncertainty, estimating error, bias
 - Risks that affect schedule duration of activities with labortype (e.g., labor, rented equipment...)
 - Indirect costs modeled on schedule hammocks
- Some cost contingency should be held for schedule overruns



In this Example Schedule Risk and Uncertainty Contributes One-Third of the Cost Contingency

So	urces of Cost R	isk	
Causes of Cost Risk	P-80 Cost (\$bill)	Contribution (% of Base)	P-80 End Date
Add Risks on Schedule	2.957	8%	5/14/2021
Add Schedule Uncertainty	2.827	16%	2/15/2021
Traditional Cost Risk Items	2.547	50%	4/4/2020
Base Case (deterministic no Risk)	1.697	100%	
Total Cost Contingency All Risk	and		
Uncertainty		74%	



Iterative Approach to Prioritizing the Risk

- Purpose, discover which risks contribute the most days or total cost at the P-80 level if they were fully mitigated
 - Use Monte Carlo simulation to identify the most important risk, the one that save the most days or dollars at the P-80
 - Continue until all risks contributions have been calculated



Improve on the Traditional Tornado Sensitivity Approach

- Traditional tornado is usually based on the activities, not the risks
- Even when based on the risk, the traditional tornado is based on correlation but that is a concept at the mean of the distributions and we are at the P-80
- Tornado may provide counterintuitive results if the risk is not 100% likely, as many are not
- The correlation concept cannot be used easily to see if the improvement in schedule or cost is worth the cost of the mitigation
- We use this approach to prioritize risks for mitigation



Picture of Prioritized Risks Selected by their Days Saved at P-80

	Iterativ	e Approach	to Prioritiz	ing Risks (Bas	ed on Day	ys Saved at	P-80)	
Risk #	1	2	3	4	5	6	7	8
Priority Level (Iteration #)	Abusive Bids	Offshore design firm	Suppliers Busy	Fab productivity	Geology unknown	Coordinati on during Installation	Problems at HUC	Resources may go to other projects
1	Х	Х	Х	X	Х	Х	X	1
2	Х	Х	Х	2	Х	Х	Х	
3	Х	3	Х		Х	Х	Х	
4	Х		Х		Х	Х	4	
5	Х		5		Х	Х		
6	Х				Х	6		
7	7				Х			
8					8			



Risks Prioritized to the P-80 Level for Schedule Measured in "Days Saved"

Risk Prioritization at 80%								🕑 Predict F
View: Tornado v Show: Schedule	v f	Filter by Top: 8	*					Schedule Impact
8 - The organization has other priority projects so personnel and funding may be unavailable								
2 - Engineering may be complicated by using offshore design firm		_						
4 - Fabrication yards may experience lower Productivity than planned								
3 - Suppliers of installed equipment may be busy								
7 - Fabrication and installation problems may be revealed during HUC								
1 - Bids may be Abusive leading to delayed approval								
6 - Installation may be delayed due to coordination problems								
5 - The subsea geological conditions may be different than expected								
	0	20	40	60 Oth Percentile Sch	80 edule Impact (Pase	100 eline = 0)	120	140



Risks Prioritized to the P-80 Level for Cost Measured in "Cost Saved"

tisk Prioritization at 80%								🕑 Predict
View: Tornado 💌 Show: Cost		Filter by Top: 8	÷					Cost Impact
4 - Fabrication yards may experience lower Productivity than planned							4	
8 - The organization has other priority projects so personnel and funding may be unavailable								
3 - Suppliers of installed equipment may be busy								
- Engineering may be complicated by ing offshore design firm								
5 - The subsea geological conditions may be different than expected								
 Installation may be delayed due to pordination problems 								
 Fabrication and installation roblems may be revealed during HUC 								
1 - Bids may be Abusive leading to delayed approval								
	\$0	\$40,000	\$80,000	\$120,000 0th Percentile Co	\$160,000 st Impact (Basel	\$200,000 ine = \$2.962M)	\$240,000	\$280,000



Saving Days will also Reduce Cost Contingency but the Priority Order is not Exactly the Same

Compare The order of Priority for the Risks if the Focus is on Cost or Time										
UID	Name	Days Saved		UID	Name	Cost Saved				
8	The organization has other priority projects so personnel and funding may be unavailable	146		4	Fabrication yards may experience lower Productivity than planned	\$296,329				
2	Engineering may be complicated by using offshore design firm	41		8	The organization has other priority projects so personnel and funding may be unavailable	\$166,342				
4	Fabrication yards may experience lower Productivity than planned	21		3	Suppliers of installed equipment may be busy	\$75,391				
3	Suppliers of installed equipment may be busy	28		2	Engineering may be complicated by using offshore design firm	\$47,607				
7	Fabrication and installation problems may be revealed during HUC	9		5	The subsea geological conditions may be different than expected	\$28,480				
1	Bids may be Abusive leading to delayed approval	9		6	Installation may be delayed due to coordination problems	\$15,930				
6	Installation may be delayed due to coordination problems	3		7	Fabrication and installation problems may be revealed during HUC	\$9,626				
5	The subsea geological conditions may be different than expected	0		1	Bids may be Abusive leading to delayed approval	\$3,313				



Risk Mitigation Workshop

- Risks can be mitigated but usually not completely
- Mitigation actions are:
 - New, not known to the interviewees, different from yesterday
 - Committed to by management so funded, staffed, monitored and reported on
- Once agreed to, estimate the owner, cost and timing of the mitigation
- Estimate the improvement to risk parameters



Mitigation Workshop Strategy and Simple Mitigation Scenario

- Prioritize the risks according to days saved
- Recognize that as schedule risk is addressed, the indirect effect on cost risk will be good
- Each risk mitigation has a cost and that cost will be added, so cost risk will represent two conflicting forces
- Simple mitigation scenario,
 - Cut probability for each of the risks in half
 - Add \$40 thousand to mitigate each of the 8 project specific risk for a total mitigation cost of \$320 million



Compare Pre- and Post-Mitigation Schedule





Compare Pre- and Post-Mitigation Cost





Review

- Purpose of the Quantitative Risk Analysis
- Model uncertainty for duration and cost
- Model project-specific risks using Risk Drivers
- Compare P-80 for cost and schedule to the Joint Confidence Level (JCL-80) as promise dates and costs
- Prioritize the risks @ P-80 and days saved
- Mitigate risks partially, recording mitigation costs



Integrated Cost-Schedule Risk Analysis Improves Cost Contingency Calculation ICEAA 2017 Workshop Portland OR June 6 – 9, 2017 David T. Hulett, Ph.D., FAACE Hulett & Associates, LLC David.hulett@projectrisk / www.projectrisk.com (310) 476-7699

