

**System Dynamics in Construction** 



### Project Simulation: Rethinking the "Expected Completion Date"

**Erich Alexander Voigt** Construction Dynamics Solutions L.L.C.

Alan K. Graham 4Sight Solutions, Inc.



#### The "Expected Project Completion Date": A Critical Input for Effective Project Management



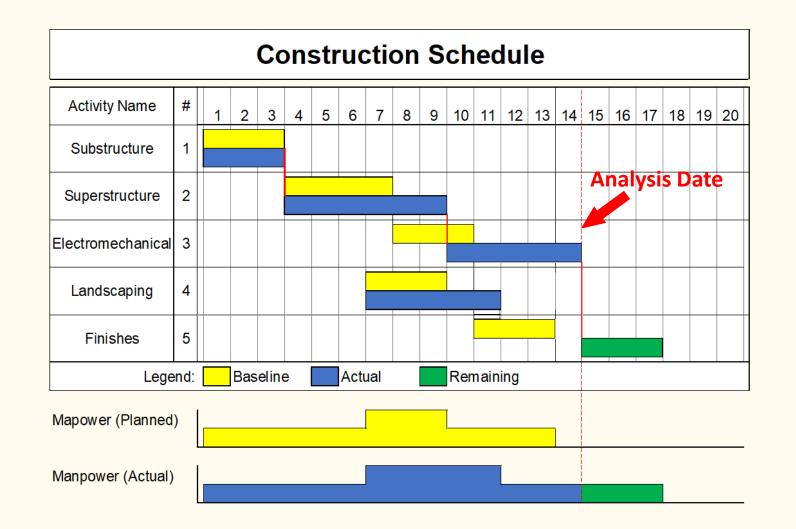
- In construction, completing projects on time is often critical:
  - Even a few months' delay can lead to severe penalties ("Liquidated Damages")
- The "Expected Time to Completion" is a critical piece of information for project managers.
- Construction schedules are managed with tools based on CPM (the "Critical Path Method")

Schedule Monthly U	Jpdate (D.D. FEB-2016)		Finish	BL Project Start				206							
ID	Activity Name	Start			BL Project Finish	Remaining Duration									
							cb	Mar	Apr	May	Jun	Jul	Aug	Sep	
C-LND-0-ROD-MSG-1700		05-Sep-16	11-Sep-16	09-Dec-15	10-Dec-15	5								Roa	
C-LND-0-ROD-LSC-1710		05-Sep-16	19-Sep-16	08-Dec-15	12-Dec-15	8									Road #
C-LND-0-ROD-KRB-1690	Road #5/13/16/17- (FAST)- Kerbs & Guardrails	06-Sep-16	20-Sep-16	08-Dec-15	12-Dec-15	8						<u> </u>			Road Sed-16
Road# 18 (FAST)		30-Jun-16	11-Sep-16	31-May-15	20-Aug-15	59						30- Jun-16	FAST Mileston		Sep-16
FAST Milestone M-FAST-1040	FAST TN26-TN31 - (FAST Revised Milestone)	30-Jun-16	30-Jun-16 30-Jun-16	31-May-15	31-May-15 31-May-15	0					÷		6-TN31 - (FAS		Miesto
Earthworks	PAST TN26-TN31 - (PAST Revised Milesione)	02-Jul-16	06-Aug-16	01-Jun-15	13-Jul-15	28							06-Aug-1		
C-LND-0-ROD-PRP-2490	Road # 18 - (FAST)- Area Preparation & Clearing	02-Jul-16	26-Jul-16	01-Jun-15 01-Jun-15	13-Jul-15 22-Jun-15	19							Road # 18 - (F		
C-LND-F-ERW-EXV-2730		23-Jul-16	31-Jul-16	23-Jun-15	01-Jul-15	8							Road # 18 - (F		
C-LND-0-ROD-FIL-2510	Road # 18 - (FAST) - Excavation	26-Jul-16	06-Aug-16	02-Jul-15	13-Jul-15	10						-			
Civil Works	Road # 16 - (PAST)- Pilling	26-Jul-16	31-Aug-16	02-Jul-15	11-Aug-15	32					÷		Road # 1	8 - (FAST) 31-Aug-	)- heing
C-LND-0-ROD-SGC-2530	Road # 18 - (FAST)- Subgrade Course	26-Jul-16	06-Aug-16	02-Jul-15 02-Jul-15	13-Jul-15	10						1	Band # 1	8 - (FAST)	
C-LND-0-ROD-SBC-2540		07-Aug-16	15-Aug-16	14-Jul-15	26-Jul-15	8						-		# 18 - (FAST)	
C-LND-0-ROD-SLP-2520	Road # 18 - (FAST)- Subbase Course Road # 18 - (FAST)- Slope Protection	09-Aug-16	17-Aug-16	20-Jul-15	28-Jul-15	8								d # 18 - (FA	
C-LND-0-ROD-BSC-2550		18-Aug-16	27-Aug-16	29-Jul-15	06-Aug-15	8									
C-LND-0-ROD-BSC-2550 C-LND-0-ROD-BNC-2560		28-Aug-16	27-Aug-16 29-Aug-16	08-Aug-15	09-Aug-15	2					+	-+		Road # 18	
C-LND-0-ROD-BNC-2580 C-LND-0-ROD-WRC-2570					11-Aug-15	2								Road # 1	
	0 Road # 18 - (FAST)- Wearing Course	30-Aug-16	31-Aug-16	10-Aug-15									1	Road # 1	
Mechanical Works	Road # 18 - (FAST)- Drainage Works	01-Sep-16 01-Sep-16	07-Sep-16 07-Sep-16	12-Aug-15 12-Aug-15	18-Aug-15 18-Aug-15	6									
Electrical Works	Road # 10 * (FNOT)* brailage works	28-Aug-16	03-Sep-16	08-Aug-15	13-Aug-15	6								V 03-Sep	d#18- n-16 Fi
C-LND-0-ROD-LGT-2590	Road # 18 - (FAST)- Lighting Installation	28-Aug-16	03-Sep-16 03-Sep-16	08-Aug-15	13-Aug-15	6					÷		· · · · · · · · · · · · · · · · · · ·	Road #	
Finishing Works	road # 10 - (rPor) - Egnarg maaaaaan	03-Sep-16	11-Sep-16	13-Aug-15	20-Aug-15	8								11-	
C-LND-0-ROD-KRB-2600	Road # 18 - (FAST)- Kerbs & Guardrails	03-Sep-16	06-Sep-16	13-Aug-15	17-Aug-15	4								_	1# 18 -
C-LND-0-ROD-MSG-2610		04-Sep-16	07-Sep-16	15-Aug-15	18-Aug-15	4							-	Road	
C-LND-0-ROD-LSC-2620		06-Sep-16	11-Sep-16	17-Aug-15	20-Aug-15	5								Road	
Road# 19 (FAST)	Hold # 10 - (PAOT)- Hard California	30-Jun-16	04-Sep-16	31-May-15	02-Aug-15	53					÷	·	÷	- Ros	p-16, R
FAST Milestone		30-Jun-16	30-Jun-16	31-May-15	31-May-15	0						¥ 30-Jun-16,	EAST Mileston	Þ	
M-FAST-1050	FAST TN26-TN31 - (FAST Revised Milestone)		30-Jun-16		31-May-15	0						FAST TN2	6 TN31 - (FAS	Revised M	Midstor
Earthworks		02-Jul-16	03-Aug-16	01-Jun-15	30-Jun-15	26						-	03-Aug-16	Earthwork	rks
C-LND-0-ROD-PRP-2500	Road # 19 - (FAST)- Area Preparation & Clearing	02-Jul-16	24-Jul-16	01-Jun-15	20-Jun-15	17							Road # 19 - (F	AST)- Area	a Pinoa
C-LND-F-ERW-EXV-2740	Road # 19 - (FAST)- Excavation	25-Jul-16	28-Jul-16	21-Jun-15	24-Jun-15	4					1		Road # 19 - (		
C-LND-0-ROD-FIL-2520	Road # 19 - (FAST)- Filling	30-Jul-16	03-Aug-16	25-Jun-15	30-Jun-15	5						-	Road # 19		
Civil Works		04-Aug-16	25-Aug-16	01-Jul-15	23-Jul-15	19								25-Aug-16,	
C-LND-0-ROD-SGC-2540	Road # 19 - (FAST)- Subgrade Course	04-Aug-16	09-Aug-16	01-Jul-15	06-Jul-15	5							Road #	19 - (FAST	T)- Sub
C-LND-0-ROD-SBC-2550	Road # 19 - (FAST)- Subbase Course	10-Aug-16	14-Aug-16	07-Jul-15	11-Jul-15	4								# 19 - (FA	
C-LND-0-ROD-SLP-2530	Road # 19 - (FAST)- Slope Protection	11-Aug-16	16-Aug-16	09-Jul-15	13-Jul-15	5					1	1		d#19-(FA	
C-LND-0-ROD-BSC-2560	Road # 19 - (FAST)- Base Course	17-Aug-16	21-Aug-16	14-Jul-15	21-Jul-15	4								ad # 19 - (	
C-LND-0-ROD-BNC-2570	Road # 19 - (FAST)- MC1 Spray and First Layer of Asphalt	22-Aug-16	23-Aug-16	22-Jul-15	22-Jul-15	2								oad # 19 -	
C-LND-0-ROD-WRC-258		24-Aug-16	25-Aug-16	23-Jul-15	23-Jul-15	2								Road # 19	
Mechanical Works		27-Aug-16	29-Aug-16	25-Jul-15	27-Jul-15	3							÷ 🐨	29-Aug-1	16, Mec
	Road # 19 - (FAST)- Drainage Works	27-Aug-16	29-Aug-16	25-Jul-15	27-Jul-15	3						1	1	Road # 1	19 - (FA
Electrical Works		22-Aug-16	24-Aug-16	22-Jul-15	25-Jul-15	3								4-Aug-16,	
C-LND-0-ROD-LGT-2600	Road # 19 - (FAST)- Lighting Installation	22-Aug-16	24-Aug-16	22-Jul-15	25-Jul-15	3						1	1 📕 🛉	Road # 19 -	(FAST
Finishing Works		28-Aug-16	04-Sep-16	26-Jul-15	02-Aug-15	7								V 04-Sep	p-16, F
C-LND-0-ROD-MSG-2620	Road # 19 - (FAST)- Marking & Signage Works	29-Aug-16	30-Aug-16	27-Jul-15	28-Jul-15	2						1	1	Road # 1	19 - (FA
C-LND-0-ROD-KRB-2610	Road # 19 - (FAST)- Kerbs & Guardrails	28-Aug-16	30-Aug-16	26-Jul-15	28-Jul-15	3					1	1		Road # 1	19 - (FA
C-LND-0-ROD-LSC-2630	Road # 19 - (FAST)- Hard Landscaping	31-Aug-16	04-Sep-16	29-Jul-15	02-Aug-15	4							÷ 1		# 19 - (
Surface Parking Areas		06-Jul-15 A	12-Apr-16	06-Aug-15	30-Dec-15	38		-	🔻 12-Ap	-16, Surface	Parking Area	IS.			
										-					
Primary Baseline	Remaining Work			Page 15 of 19		1.5.5	1.1.1.1	1000	22.2	1000	1111	11111	11111		



#### The Critical Path Method: Future expectations are based on "The Plan"





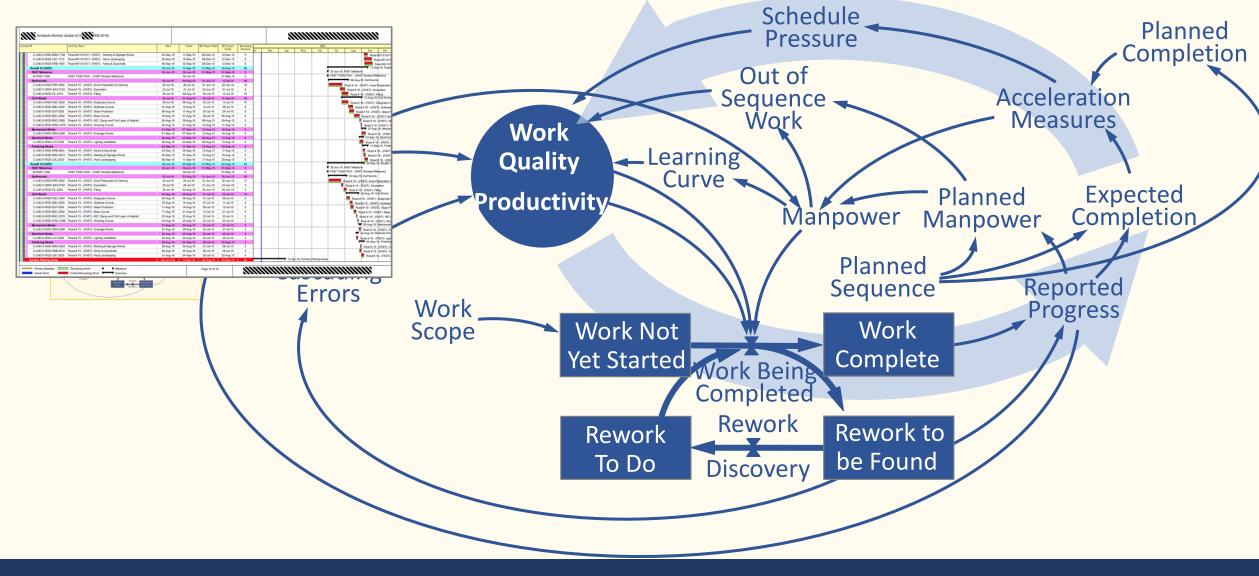


4SIGHT SOLUTIONS

- In 1976, Pugh Roberts Associates developed the first project simulation model, to support a disruption and delay claim against the US Navy.
- Since then, SD models based on the same causal framework (known as "the Rework Cycle") have been used to support decision-making in hundreds of major projects in many industries.
- SD models have also been used to provide expert evidence to support at least 50 major delay and disruption claims, in all continents.
  - The magnitude of these claims has ranged between \$10 million and \$5-6 billion.



### SD models capture the critical role of the Expected Completion Date



4SIGHT SOLUTIONS





#### Conventional formulations for the Expected Completion Date (ECD):

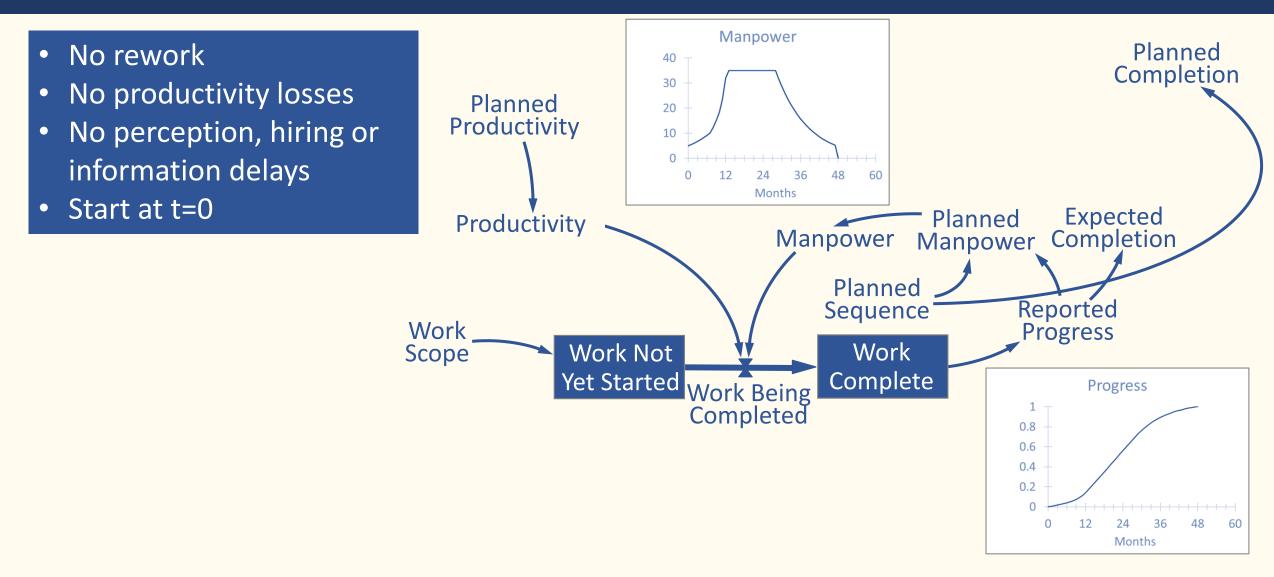
- 1. Progress extrapolation:
  - Expected Completion Date(t) = t/Progress(t)
- 2. Manpower based:
  - Expected Completion Date(t) = time +  $\frac{Person*Months Remaining(t)}{Average Future Manpower(t)}$  =

$$= time + \frac{Work \, Scope*(1 - Progress(t))}{Manpower(t)*Productivity(t)}$$

- These formulations usually require ad hoc adjustments:
  - Initially models tend to use planned dates, then shifting to these formulations as progress is made.



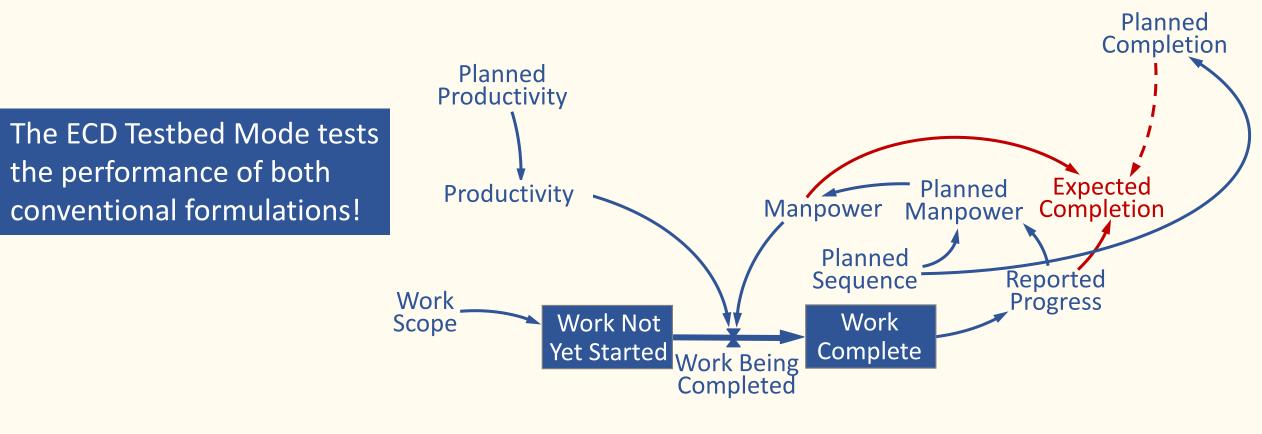
#### How well has SD estimated completion dates? The ECD Testbed Simulation Model



(❀)= 4SIGHT SOLUTIONS



## The ECD Testbed Simulation Model contains two conventional formulations



€ 4SIGHT SOLUTIONS

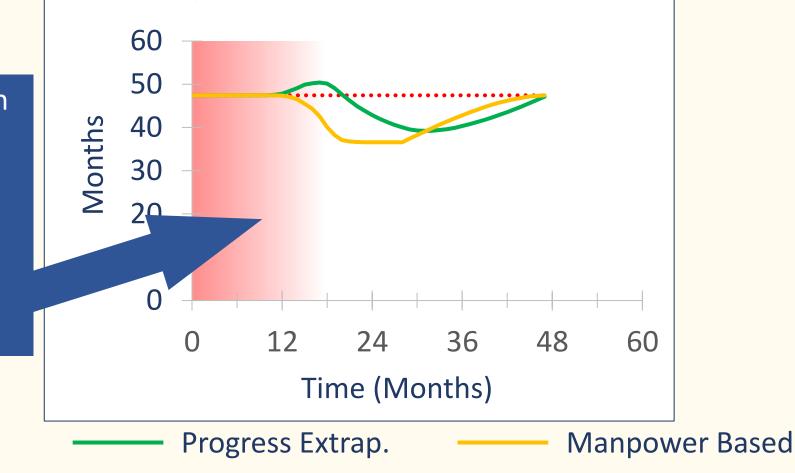
Construction Dynamics Solutions

# Conventional ECD formulations generate inherent bias



The conventional approach starts using the planned completion date, and then shifts to the progress / manpower formulations as the project gets closer to completion.

Actual



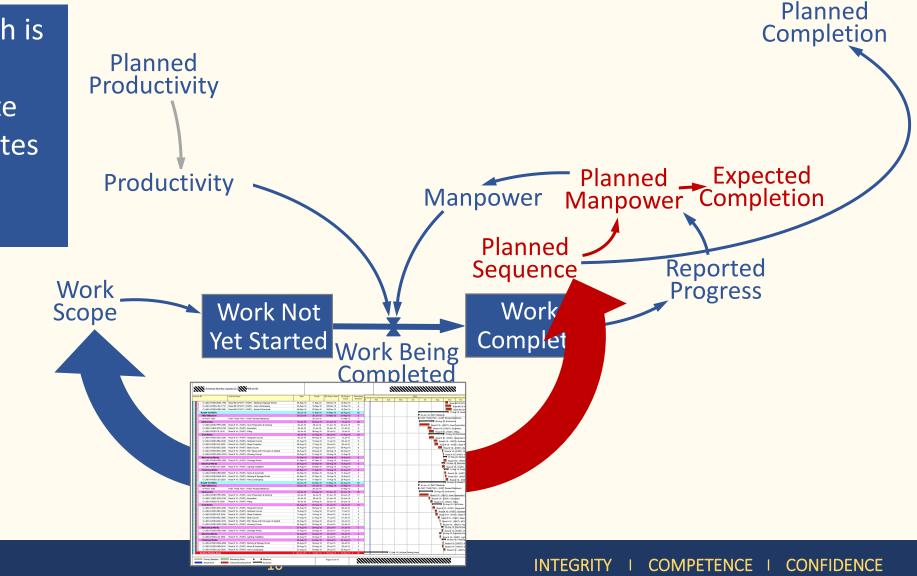
**Expected Completion Date** 

. . . . . . . . . . . .



### A Plan-Based formulation makes fuller use of the information available

The Plan-Based approach is able to use detailed planning data to simulate expected completion dates – just as actual project managers do.



€ 4SIGHT SOLUTIONS

© Construction Dynamics Solutions 2024





Work Completion Rate = 
$$\frac{\Delta Work \ Completed}{\Delta t}$$
 = Manpower \* Pdy

 $\Rightarrow \Delta t = \frac{Work\ Scope\ *\Delta x}{Manpower(x)\ *Pdy}, \qquad where\ x \cong "Actual\ Progress" \in [0,1]$ 

$$\Rightarrow Time\ Spent(x) \cong \int_0^x dt = \int_0^x \frac{Work\ Scope\ *\ dx}{Manpower(x)\ *\ Pdy(x)}$$

 $\Rightarrow Planned Time Spent(x) = \int_0^x \frac{Work Scope * dx}{Planned Manpower(x) * Planned Pdy(x)}$ 



# The Plan-Based formulation passes the test with flying colours!



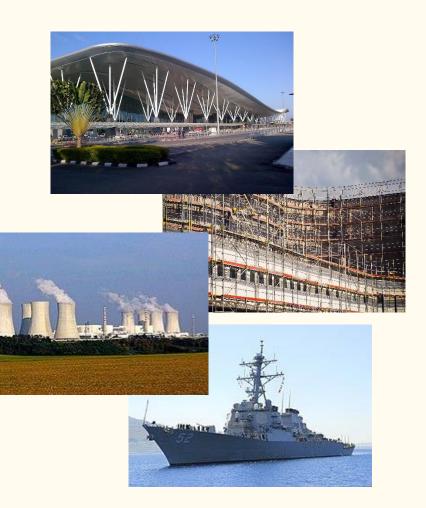


- The new formulation avoids biases suffered by previous formulations when planned manpower levels are not constant over time.
- It uses the same inputs actually used by project managers when estimating completion dates.
- Building upon this foundation, the formulation can be easily enhanced to account for productivity losses, schedule buffers, etc.



#### The Plan-Based ECD formulation, in practice

- The Plan-Based schedule formulation has already been used in eight delay and disruption claims, and in one retrospective research application (simulating the construction of destroyers at a US shipyard.)
- It has delivered good fits to recorded project behavior, without the need for *ad hoc* adjustments.
- By mimicking the actual decision-making process followed in construction projects, this formulation has proven to be more defensible in adversarial situations.



4SIGHT SOLUTIONS



Thank you!



### Project Simulation: Rethinking the "Expected Completion Date"

Erich Alexander Voigt alex.voigt@constructiondynamics.global

Alan K. Graham alan.graham@4sight-solutions.com