

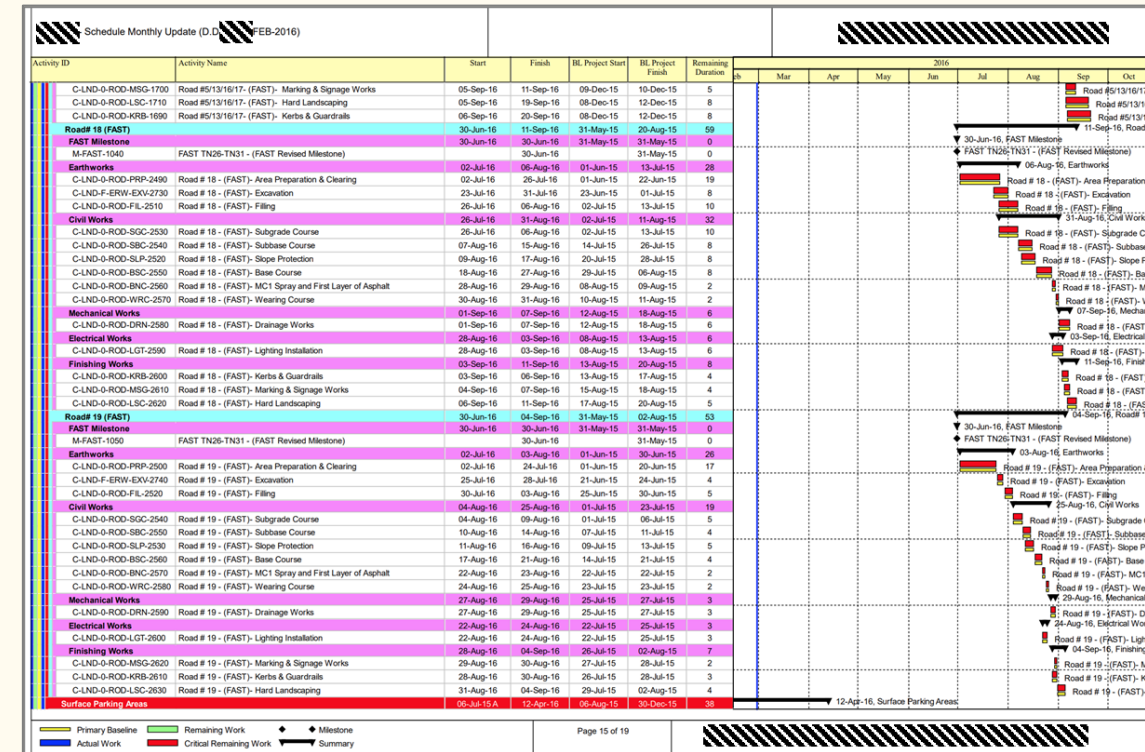
Project Simulation: Rethinking the “Expected Completion Date”

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

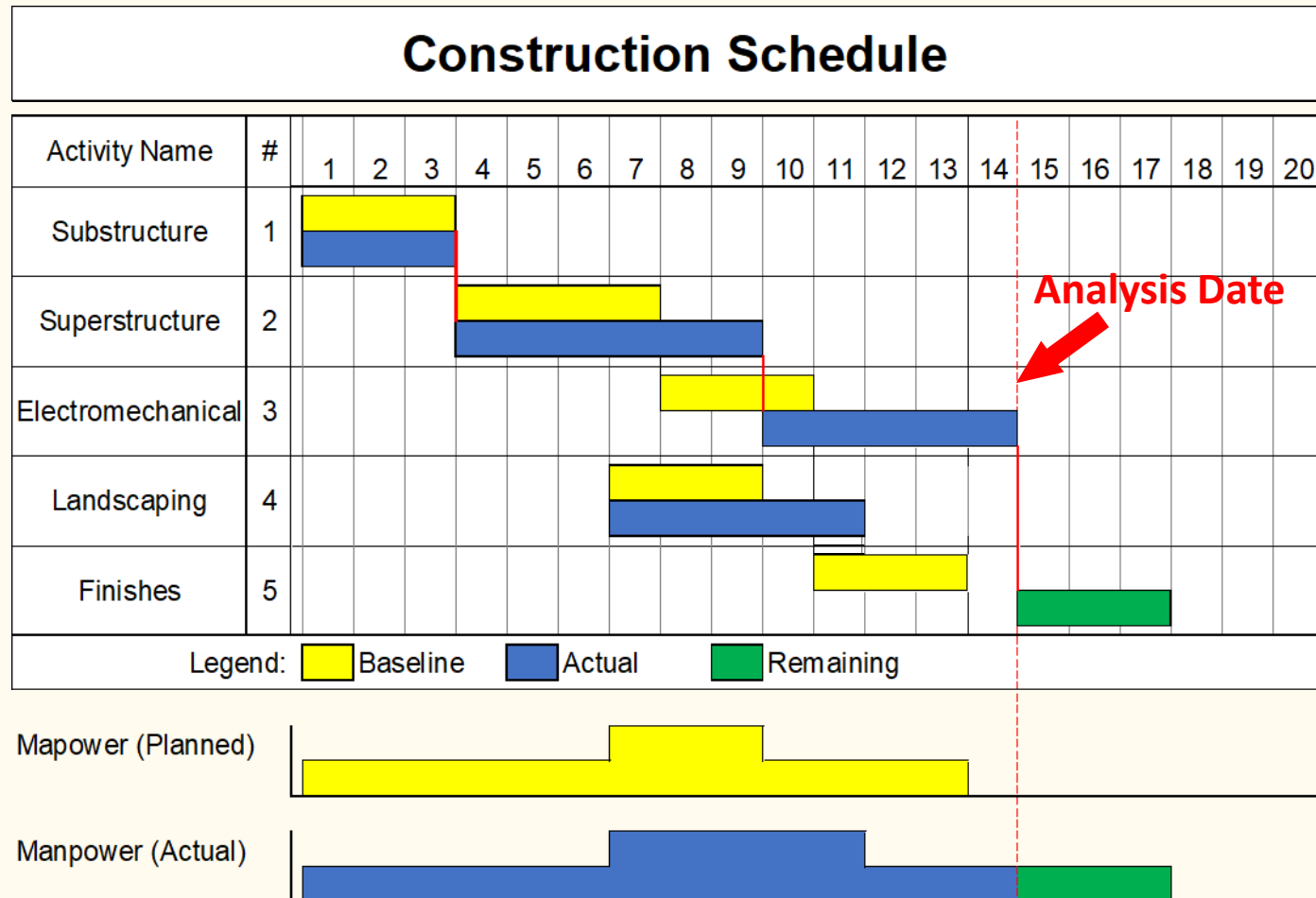
Alan K. Graham
4Sight Solutions, Inc.

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”)



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



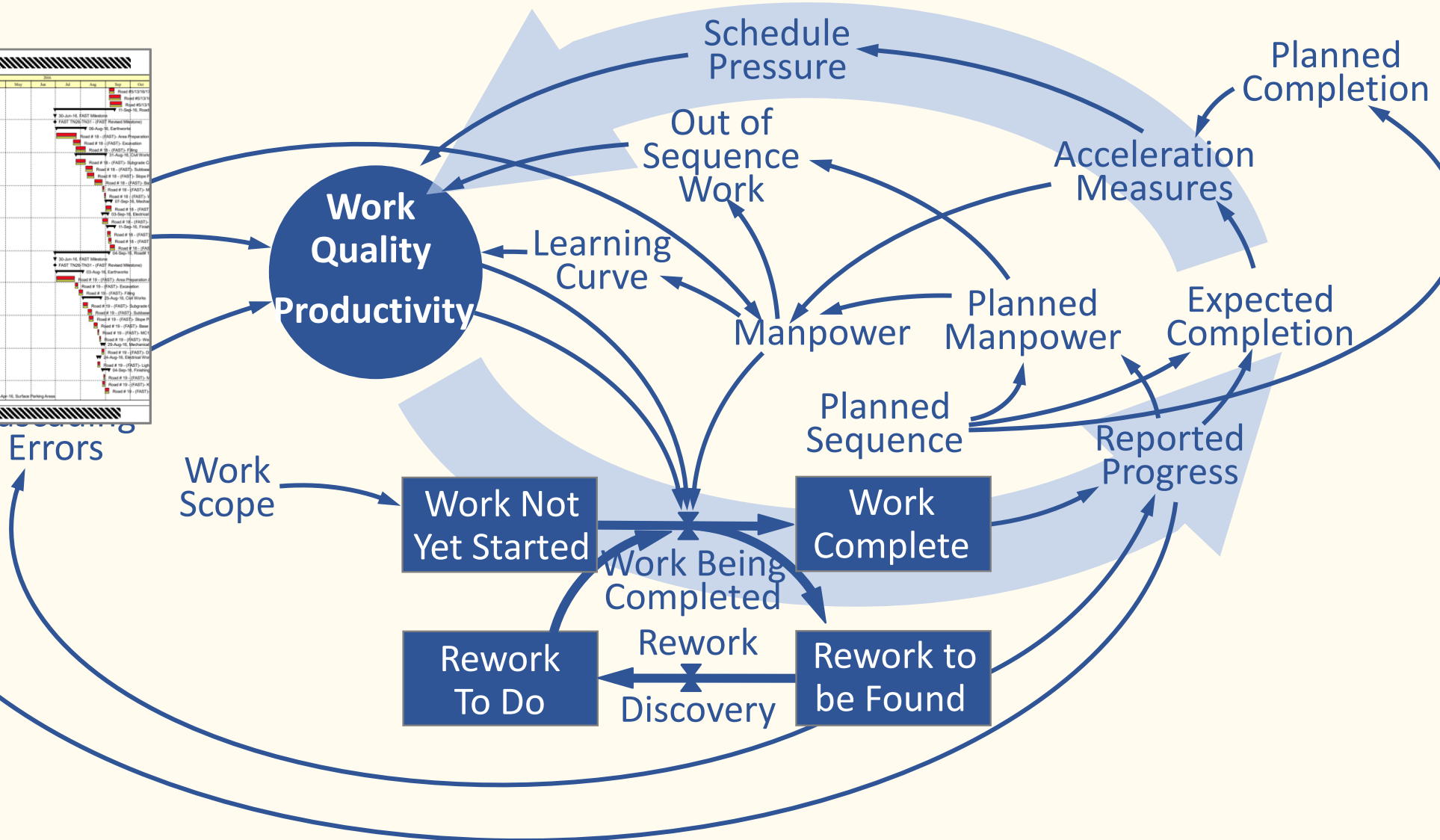
System Dynamics in construction: A continuous focus of activity for 50 years!

- 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

Schedule Monthly Update (09-2016)

Activity ID	Activity Name	Start	Finish	Pl. Start	Pl. Finish	Remaining Duration
CLND-0-RD-MSG-1700	Road #19 (FAST) - Marking & Signage Works	05-Sep-15	11-Sep-15	09-Dec-15	10-Dec-15	5
CLND-0-RD-LSC-1710	Road #19 (FAST) - Fuel Lendering	05-Sep-15	10-Sep-15	08-Dec-15	12-Dec-15	8
CLND-0-RD-SS-1600	Road #19 (FAST) - Storm & Gutterwork	05-Sep-15	20-Sep-15	08-Dec-15	12-Dec-15	8
FAST Release		30-Jun-16	15-Sep-16	30-May-16	30-Aug-16	59
FAST Release		30-Jun-16	30-Jun-16	30-Jun-16	30-Jun-16	0
FAST Release		30-Jun-16	30-Jun-16	30-Jun-16	30-Jun-16	0
CLND-0-RD-PPP-2400	Road #19 (FAST) - Area Preparation & Clearing	02-Jul-16	20-Jul-16	21-Jan-16	22-Jan-16	19
CLND-0-RD-ELN-2020	Road #19 (FAST) - Slope Protection	20-Jul-16	21-Jul-16	21-Jul-16	01-Aug-16	8
CLND-0-RD-FL-2010	Road #19 (FAST) - Filing	20-Jul-16	06-Aug-16	02-Jul-16	13-Jul-16	19
FAST Release		30-Jun-16	30-Jun-16	30-Jun-16	30-Jun-16	0
CLND-0-RD-SGC-2030	Road #19 (FAST) - Subgrade Course	20-Jul-16	08-Aug-16	02-Jul-16	13-Jul-16	19
CLND-0-RD-SBC-2040	Road #19 (FAST) - Subbase Course	07-Aug-16	13-Aug-16	14-Jul-16	20-Jul-16	8
CLND-0-RD-SL-2020	Road #19 (FAST) - Slope Protection	08-Aug-16	13-Aug-16	20-Jul-16	20-Jul-16	8
CLND-0-RD-BSC-2050	Road #19 (FAST) - Base Course	18-Aug-16	27-Aug-16	20-Jul-16	08-Aug-16	9
CLND-0-RD-SPC-2060	Road #19 (FAST) - Hot Spray and First Layer of Asphalt	24-Aug-16	29-Aug-16	08-Aug-16	09-Aug-16	2
CLND-0-RD-WRC-2070	Road #19 (FAST) - Sweeping Course	30-Aug-16	31-Aug-16	10-Aug-16	11-Aug-16	2
FAST Release		30-Jun-16	30-Jun-16	30-Jun-16	30-Jun-16	0
CLND-0-RD-CMN-2080	Road #19 (FAST) - Change Works	02-Sep-16	07-Sep-16	12-Aug-16	18-Aug-16	6
CLND-0-RD-LC1-2090	Road #19 (FAST) - Lighting Installation	28-Aug-16	03-Sep-16	08-Aug-16	13-Aug-16	6
CLND-0-RD-ATB-2000	Road #19 (FAST) - Storm & Gutterwork	03-Sep-16	08-Sep-16	13-Aug-16	17-Aug-16	4
CLND-0-RD-MSI-2010	Road #19 (FAST) - Marking & Signage Works	08-Sep-16	07-Oct-16	15-Aug-16	16-Aug-16	4
CLND-0-RD-LC2-2020	Road #19 (FAST) - Landscaping	08-Sep-16	15-Sep-16	17-Aug-16	20-Aug-16	4
FAST Release		30-Jun-16	30-Jun-16	30-Jun-16	30-Jun-16	0
FAST Release		30-Jun-16	30-Jun-16	30-Jun-16	30-Jun-16	0
CLND-0-RD-PPP-2000	Road #19 (FAST) - Area Preparation & Clearing	02-Jul-16	21-Jul-16	21-Jan-16	20-Jan-16	17
CLND-0-RD-ELN-2020	Road #19 (FAST) - Slope Protection	20-Jul-16	21-Jul-16	21-Jul-16	01-Aug-16	8
CLND-0-RD-FL-2020	Road #19 (FAST) - Filing	20-Jul-16	06-Aug-16	25-Jul-16	30-Jul-16	9
FAST Release		30-Jun-16	30-Jun-16	30-Jun-16	30-Jun-16	0
CLND-0-RD-SGC-2030	Road #19 (FAST) - Subgrade Course	04-Aug-16	09-Aug-16	01-Jul-16	06-Jul-16	5
CLND-0-RD-SBC-2040	Road #19 (FAST) - Subbase Course	10-Aug-16	14-Aug-16	07-Jul-16	11-Jul-16	4
CLND-0-RD-SL-2020	Road #19 (FAST) - Slope Protection	11-Aug-16	15-Aug-16	08-Jul-16	13-Jul-16	5
CLND-0-RD-BSC-2050	Road #19 (FAST) - Base Course	17-Aug-16	21-Aug-16	14-Jul-16	21-Jul-16	4
CLND-0-RD-SPC-2060	Road #19 (FAST) - Hot Spray and First Layer of Asphalt	20-Aug-16	24-Aug-16	20-Jul-16	20-Jul-16	2
CLND-0-RD-WRC-2070	Road #19 (FAST) - Sweeping Course	24-Aug-16	25-Aug-16	23-Jul-16	23-Jul-16	2
FAST Release		30-Jun-16	30-Jun-16	30-Jun-16	30-Jun-16	0
CLND-0-RD-CMN-2080	Road #19 (FAST) - Change Works	27-Aug-16	28-Aug-16	27-Jul-16	27-Jul-16	3
CLND-0-RD-LC1-2090	Road #19 (FAST) - Lighting Installation	22-Aug-16	24-Aug-16	22-Jul-16	20-Jul-16	3
CLND-0-RD-ATB-2000	Road #19 (FAST) - Storm & Gutterwork	03-Sep-16	08-Sep-16	08-Aug-16	08-Aug-16	7
CLND-0-RD-MSI-2010	Road #19 (FAST) - Marking & Signage Works	28-Aug-16	30-Aug-16	27-Jul-16	28-Jul-16	2
CLND-0-RD-LC2-2020	Road #19 (FAST) - Landscaping	28-Aug-16	30-Aug-16	25-Jul-16	25-Jul-16	3
CLND-0-RD-SGC-2030	Road #19 (FAST) - Subgrade Course	07-Sep-16	08-Sep-16	02-Aug-16	02-Aug-16	4



SD formulations for the Expected Completion Date are necessarily based on approximations

Conventional formulations for the Expected Completion Date (ECD):

1. Progress extrapolation:

- $Expected\ Completion\ Date(t) = t / Progress(t)$

2. Manpower based:

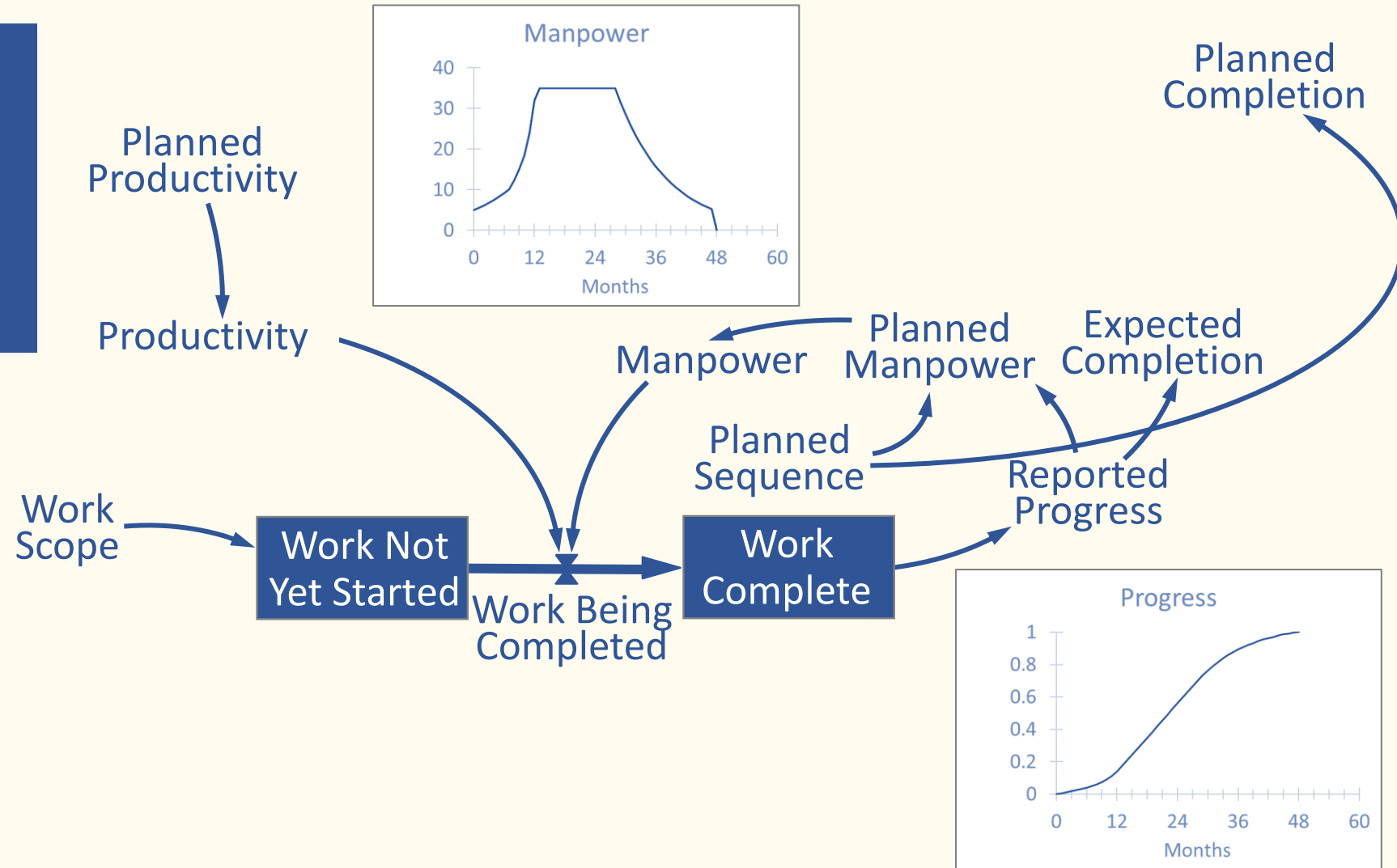
- $Expected\ Completion\ Date(t) = time + \frac{Person * Months\ Remaining(t)}{Average\ Future\ Manpower(t)} =$
 $= time + \frac{Work\ Scope * (1 - Progress(t))}{Manpower(t) * Productivity(t)}$

- These formulations usually require ad hoc adjustments:

- Initially models tend to use planned dates, then shifting to these formulations as progress is made.

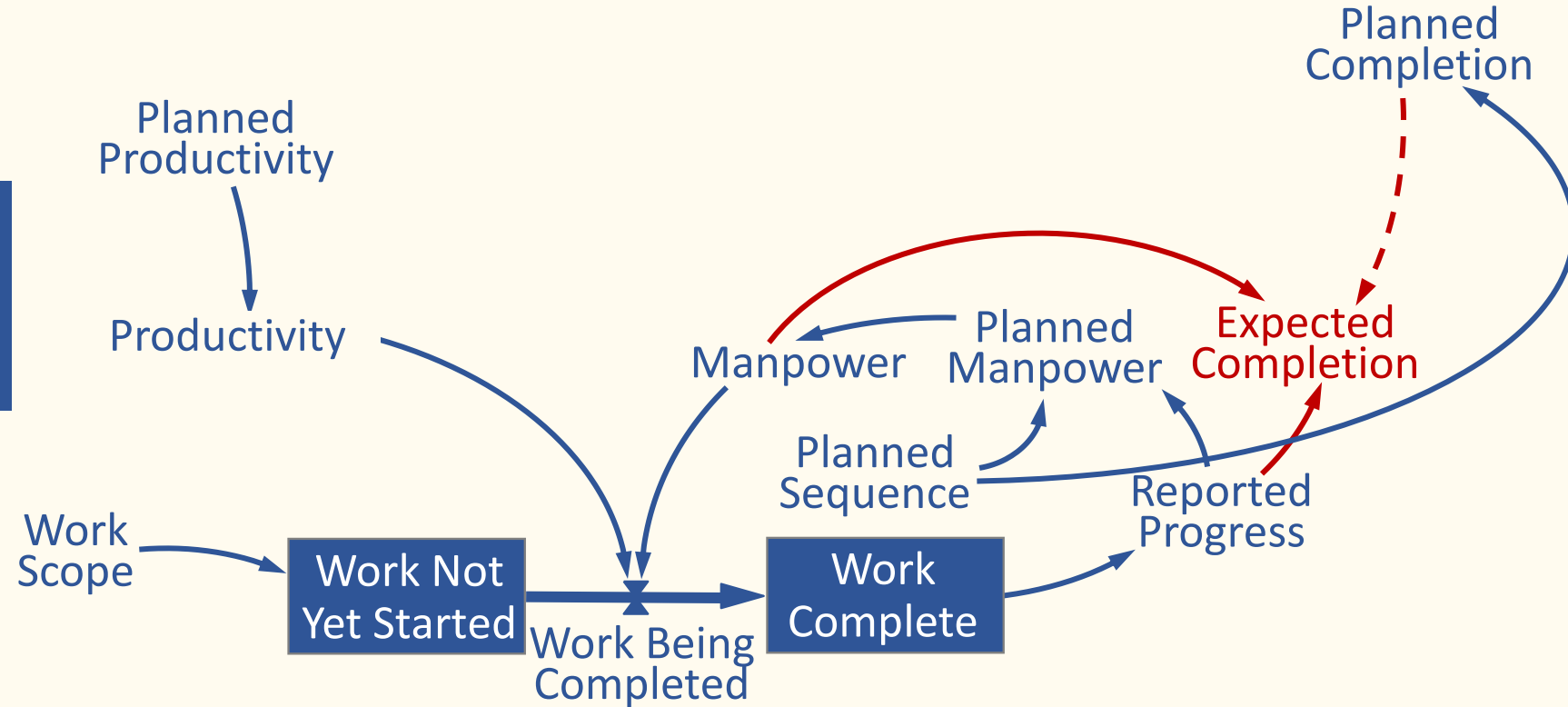
How well has SD estimated completion dates? The ECD Testbed Simulation Model

- No rework
- No productivity losses
- No perception, hiring or information delays
- Start at t=0



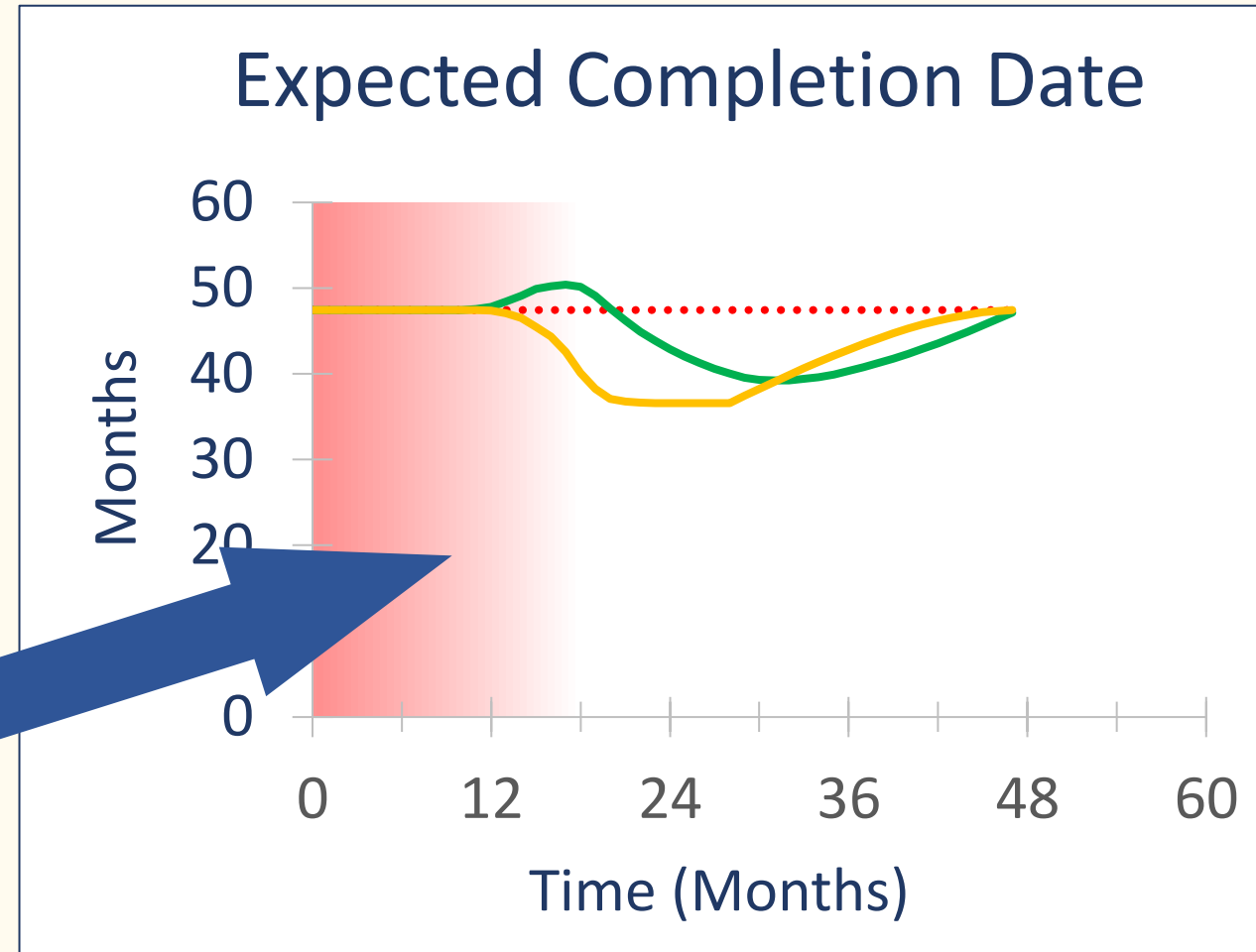
The ECD Testbed Simulation Model contains two conventional formulations

The ECD Testbed Mode tests
the performance of both
conventional formulations!



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.



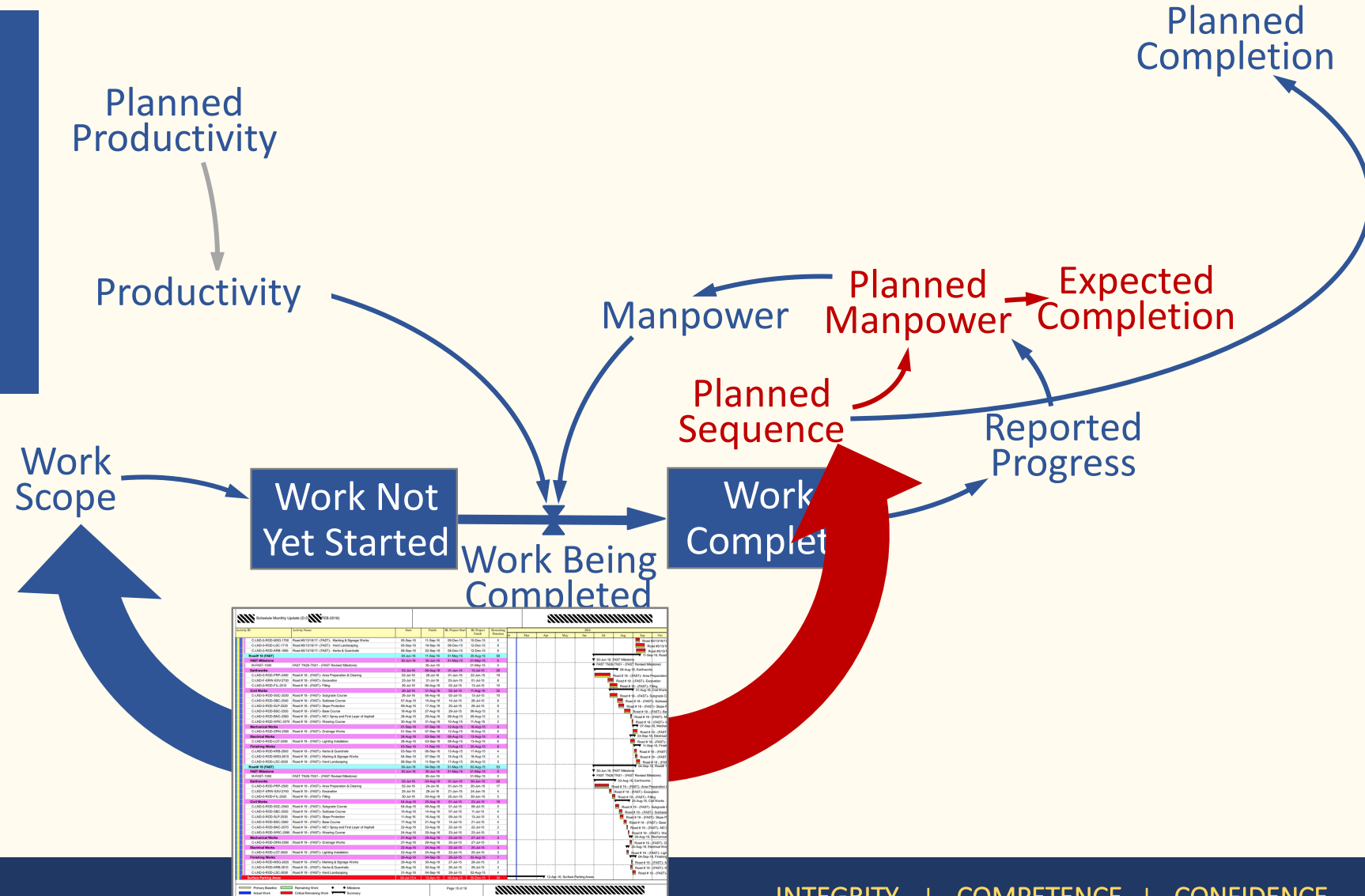
..... Actual

— Progress Extrap.

— Manpower Based

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.



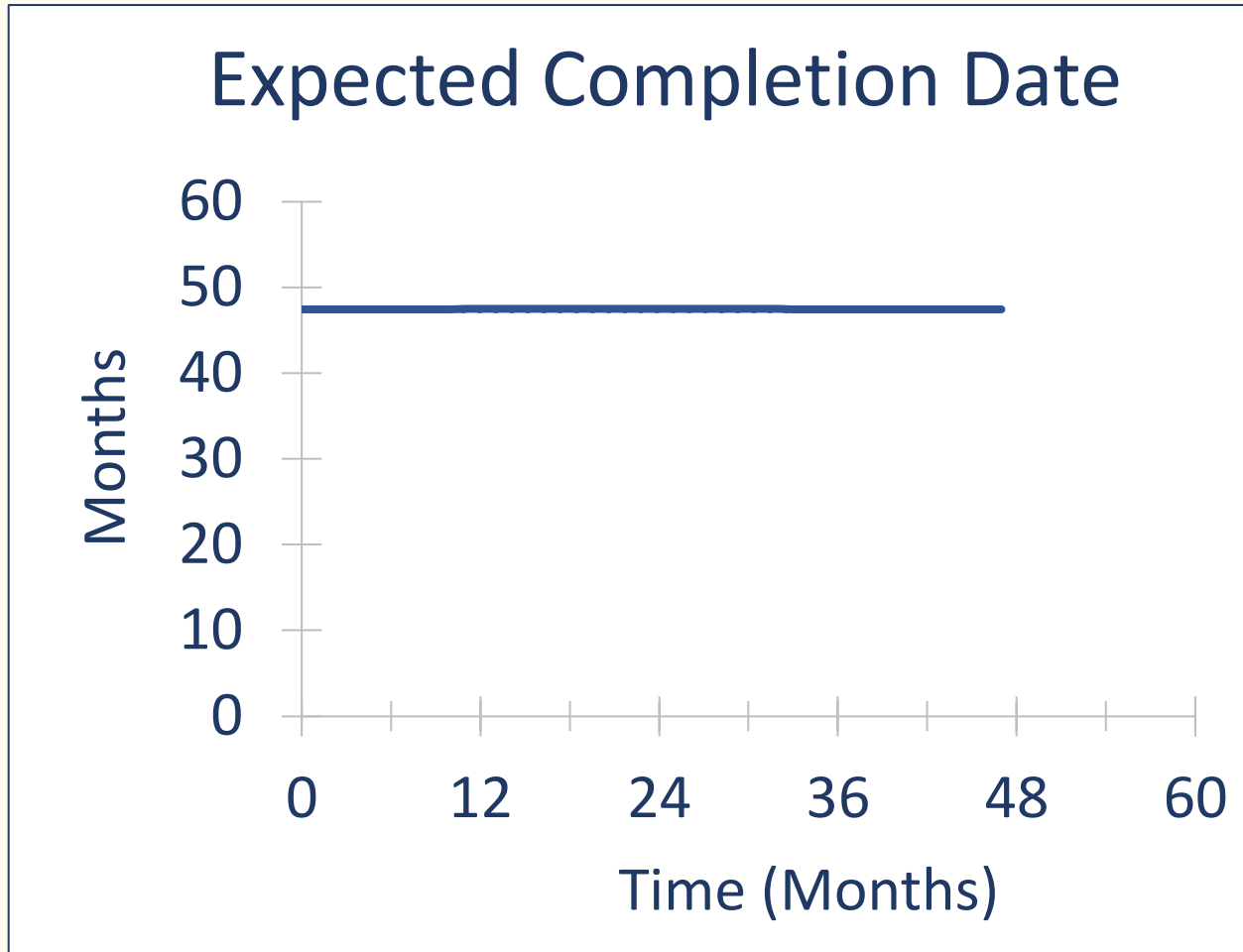
$$\text{Work Completion Rate} = \frac{\Delta \text{Work Completed}}{\Delta t} = \text{Manpower} * Pdy$$

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

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

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

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



..... Actual — Plan-based

- 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 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.



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Erich Alexander Voigt
alex.voigt@constructiondynamics.global

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alan.graham@4sight-solutions.com