Advanced Earned Value Management: Extending Program Management Theory Through Value Centric Turbulence Flow Methods

Raymond Jones
Professor of Practice in Program Management
Naval Postgraduate School
619-335-0872

The Problem

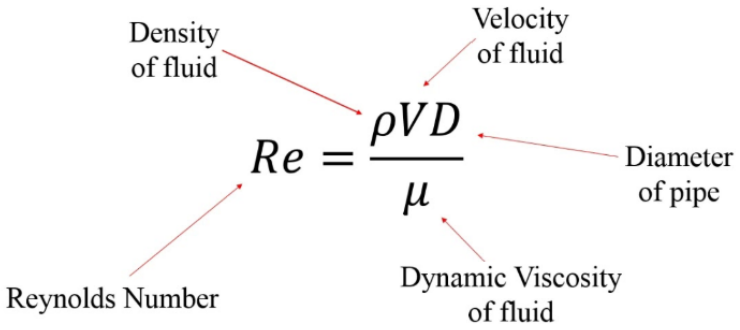
The problem is that current program management measurement and control methods do not provide adequate forecasting clarity for complex acquisition programs to understand how the decisions impact program volatility and value during the control phase of the program lifecycle.

Purpose and Research Question

The purpose of this research is to improve performance forecasting of acquisition development programs through a physics-based approach using Reynolds Number as a leading indicator of program volatility.

Turbulent flow is a fluid motion where particle trajectories varying randomly in time. Turbulence is a property of the flow rather than a physical characteristic of the fluid. Turbulence increases uncertainly within a fluid environment reducing the ability to predict the fluid environment's state over time.

Research Question: Is it possible to forecast acquisition program performance using turbulence flow theory, i.e., the Reynolds-averaged Navier–Stokes (RANS) equations?

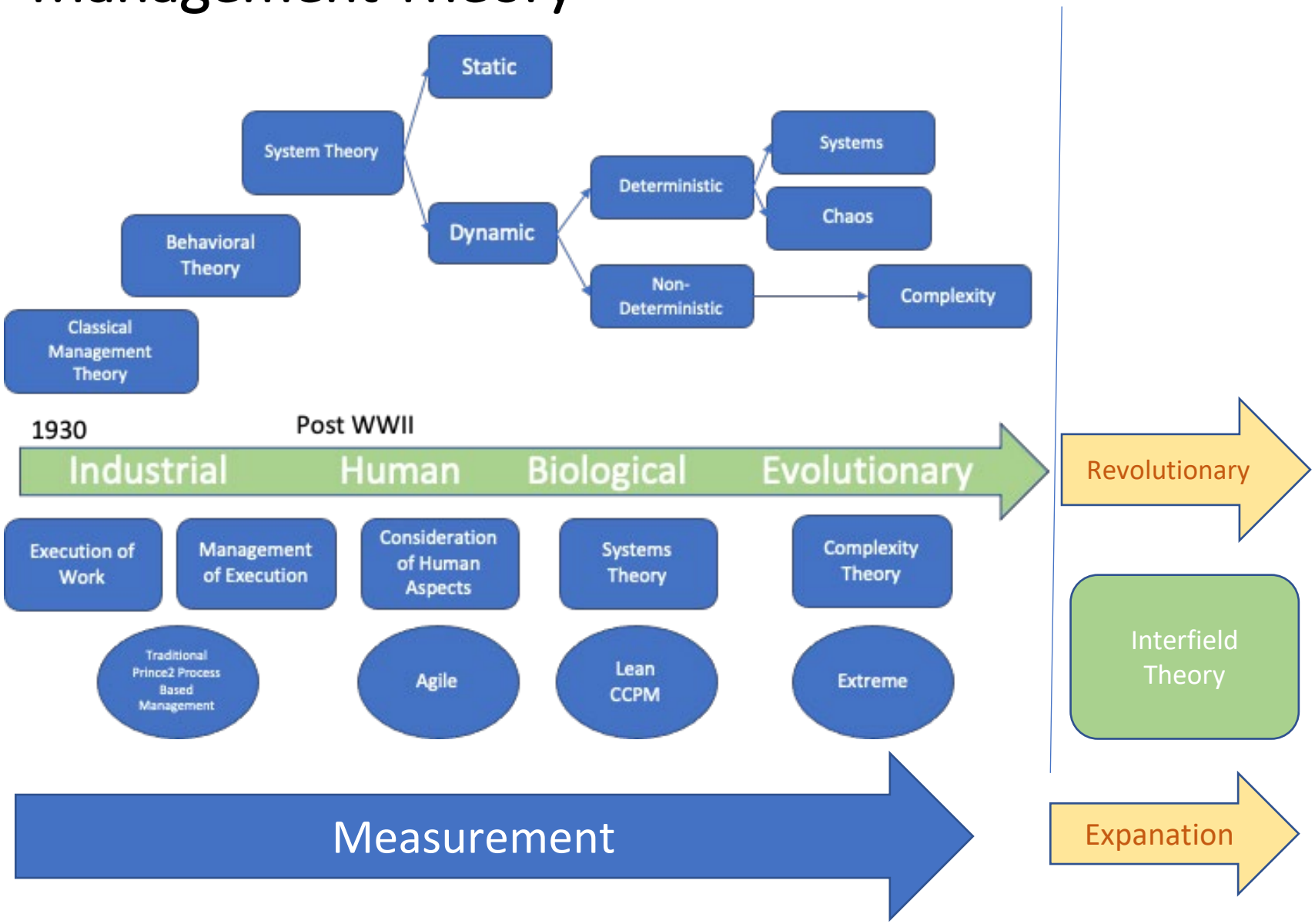


Why is this important…

- This is important because current measurement methods used by program managers are inadequate for predicting the performance of complex programs resulting in increasing program volatility and significant program delay and cost overruns.

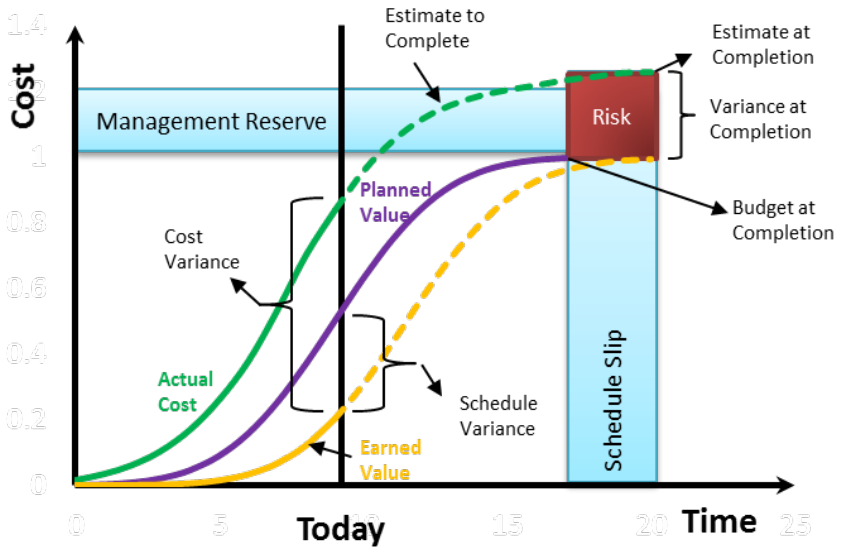
Hypothesis: Physics based approaches, such as fluid dynamics can improve program management performance forecasting providing better insight into how decisions impact program volatility.

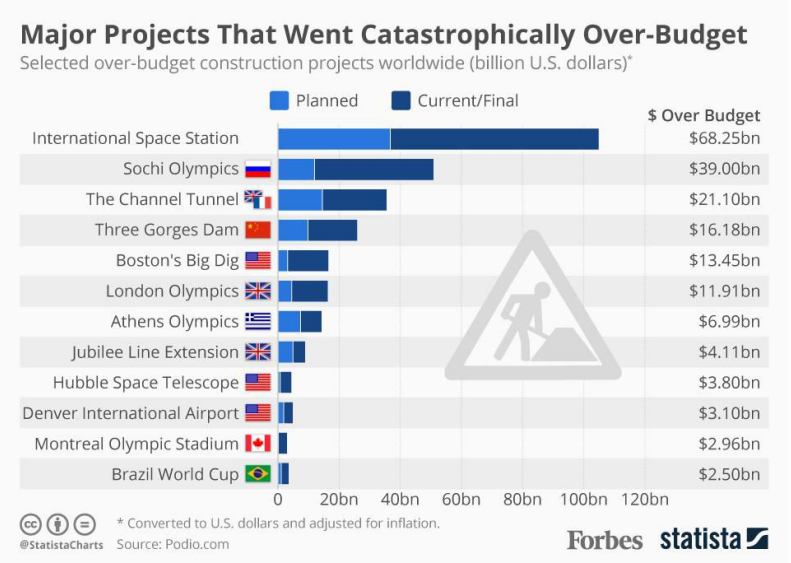
Evolution of Management and Program Management Theory



Current Management Control Methods

- **Earned Value Management** (EVM) helps project **managers** to measure project performance. It is a systematic project **management** process used to find variances in projects based on the comparison of worked performed and work **planned relative to program cost and schedule** (PMBOK Sixth Ed).





Current project management control methods such as earned value management rely on cost as the primary performance indicator providing lagging and coincident indicators with little predictive value.

$$Re = \frac{(\overline{V} \cdot D \cdot \rho)}{\eta} \quad \frac{\text{Inertia}}{\text{Viscosity}}$$

$$C_D = \frac{2F_D}{\rho A V^2}$$

Define Variables

Reynolds Number - The Reynolds number helps predict flow patterns in different fluid flow situations. At low Reynolds numbers, flows tend to be dominated by laminar flow, while at high Reynolds numbers flows tend to be turbulent. Reynolds number is a measure of volatility.

Drag Coefficient - the drag coefficient is a dimensionless quantity that is used to quantify the drag or resistance of an object in a fluid environment. It is used in the drag equation in which a lower drag coefficient indicates the object will have less fluid-dynamic drag. Analogous to ROK, where decreasing ROK represents increasing drag on "knowledge fluid".

Independent Variables

- Velocity
- Distance
- Density
- Viscosity
- Force
- Area

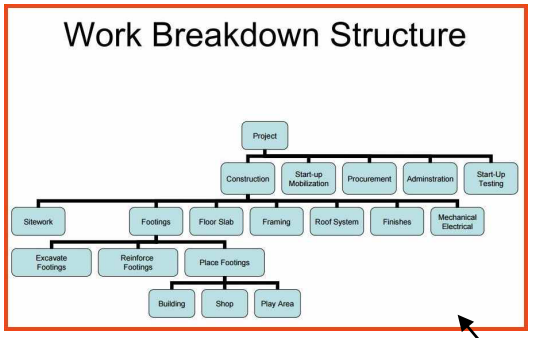
Align key program activity Variables to Re and Cd variables:

- CPI/SPI
- EAC
- BAC
- Schedule
- WBS
- LLA Key categories

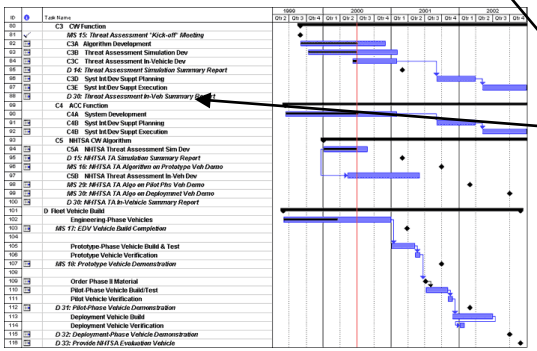
Dependent Variables

- Reynolds Number
- Drag Coefficient

Method
EVM Knowledge Value Mapping



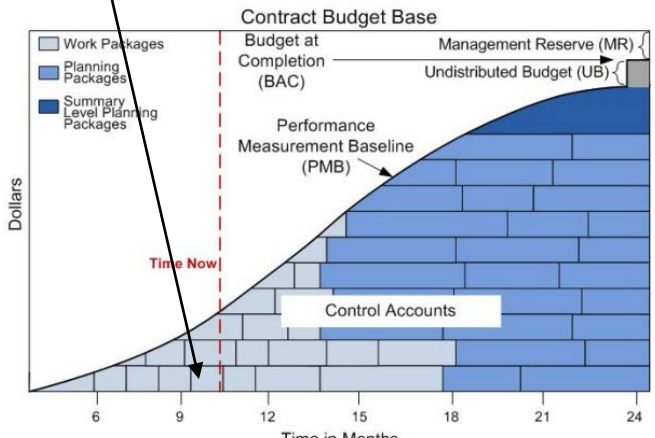
- ❑ Each task within the WBS represents an output at the sub organizational level
- ❑ The amount of knowledge embedded in each task is represented by the time necessary for the average person to complete the task
- ❑ On average, learning time is proportionate to the amount of knowledge learned.
- ❑ Variance from the in the initial estimate represents a decrease in knowledge resulting from unanticipated variables
- ❑ The amount of knowledge embedded in each task is represented by the time necessary for the average person to complete the task
- ❑ As each unit of knowledge is completed, KV increases



Work Breakdown Structure

L1	L2	L3	L4	L5	L6	L7	L8	WBS #	Description
								1	Airborne and Maritime/Fixed Station (AMF)
1	1							1.1	AMF Joint Tactical Radio System PMP
1	1	1						1.1.1	Subsystem 1 (JTR)
1	1	1	1					1.1.1.1	Development Stations
1	1	1	2					1.1.1.2	JTR-M Unique
1	1	1	2	5				1.1.1.2.5	JTR M Subsystem Systems Engineering / Program Management
1	1	1	2	5	1			1.1.1.2.5.1	JTR-M Program Management
1	1	1	2	5	2			1.1.1.2.5.2	JTR-M Systems Engineering
1	1	1	2	6				1.1.1.2.6	HW1100 INFOSEC/Processor, Red, Dual
1	1	1	2	6	1			1.1.1.2.6.1	Pre-EDM HW1100 INFOSEC/Processor, Red, Dual
1	1	1	2	6	2			1.1.1.2.6.2	EDM HW1100 INFOSEC/Processor, Red, Dual

Increasing Value



Method

EVM/KV Mapping

- This is a quantitative study that will use program data from earned value management (EVM) and selected acquisition reports (SAR) and correlate these data with turbulent flow variables in order to better predict acquisition program performance.
  - ❑Compare earned value data (Cost Performance Index/Schedule Performance Index) with work breakdown structure (WBS) data to estimate knowledge value (KV) at all levels of WBS.
  - ❑Each task within the WBS represents a unit of knowledge.
  - ❑As each unit of knowledge is completed KV increases
  - ❑The speed with which KV increases represents the knowledge velocity (KVe) within the WBS.
  - ❑KV represents the property of the “fluid” environment within the acquisition program

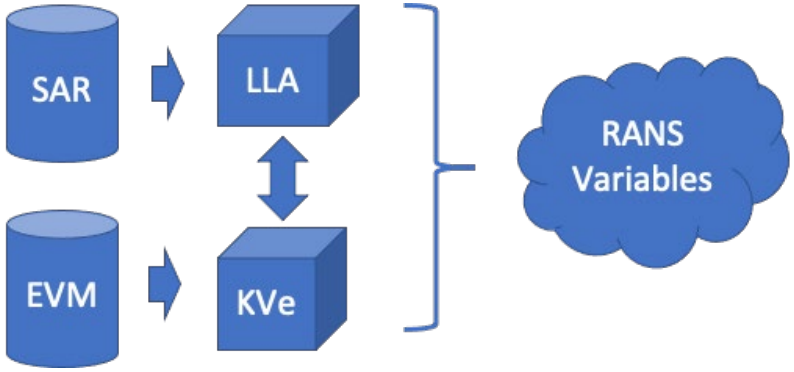
Work Breakdown Structure

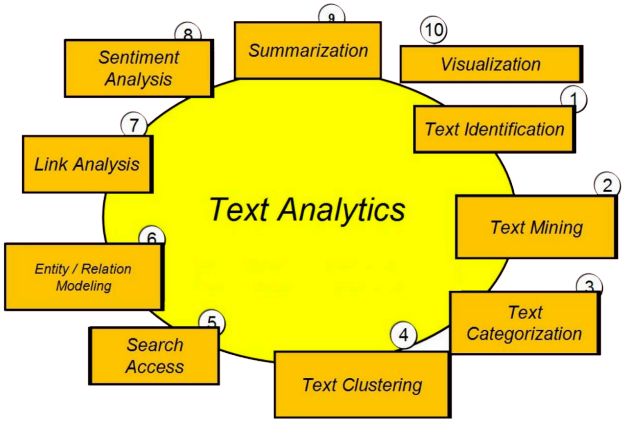
L 1	L 2	L3	L4	L5	L6	L7	L8	WBS #	Description
								1	Airborne and Maritime/Fixed Station (AMF)
1	1							1.1	AMF Joint Tactical Radio System PMP
1	1	1						1.1.1	Subsystem 1 (JTR)
1	1	1	1					1.1.1.1	Development Stations
1	1	1	2					1.1.1.2	JTR-M Unique
1	1	1	2	5				1.1.1.2.5	JTR M Subsystem Systems Engineering / Program Management
1	1	1	2	5	1			1.1.1.2.5.1	JTR-M Program Management
1	1	1	2	5	2			1.1.1.2.5.2	JTR-M Systems Engineering
1	1	1	2	6				1.1.1.2.6	HW1100 INFOSEC/Processor, Red, Dual
1	1	1	2	6	1			1.1.1.2.6.1	Pre-EDM HW1100 INFOSEC/Processor, Red, Dual
1	1	1	2	6	2			1.1.1.2.6.2	EDM HW1100 INFOSEC/Processor, Red, Dual

Method

Conduct LLA

- Conduct a lexical link analysis (LLA) of SAR data to reveal key activities during each EVM reporting period in order to better understand the underlying factors that are influencing KVe.
- Categorize key events identified during LLA in order to assess their relationship to KVe and potential for consideration as RANS variable.



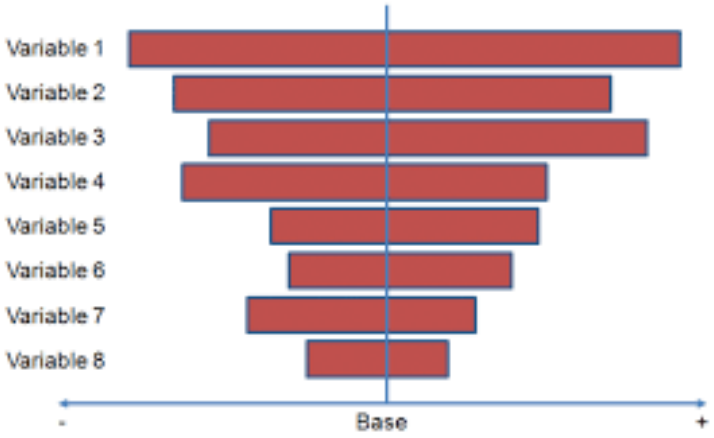


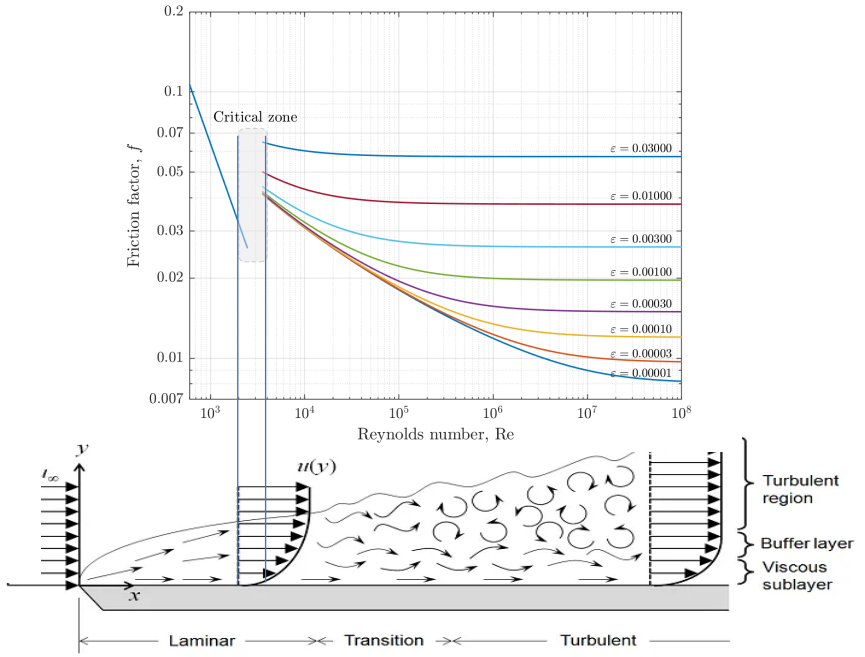
Lexical Link Analysis (LLA) is a form of text mining in which word meanings represented in **lexical** terms (e.g., word pairs) are treated as if they are in a community of a word network. LLA can provide automated awareness for analyzing text data and reveal previously unknown, data-driven themed connections.

Method

Define Causal Relationships

- ❑Correlate programmatic and LLA variables with Reynolds Number and Drag Coefficient variables
- ❑Assess relationship between independent and dependent variables across representative program development lifecycle.
- ❑Create library of RE/Cd plots and conduct ANOVA of multiple program programs
- ❑Conduct sensitivity analysis





Sample Notional Data

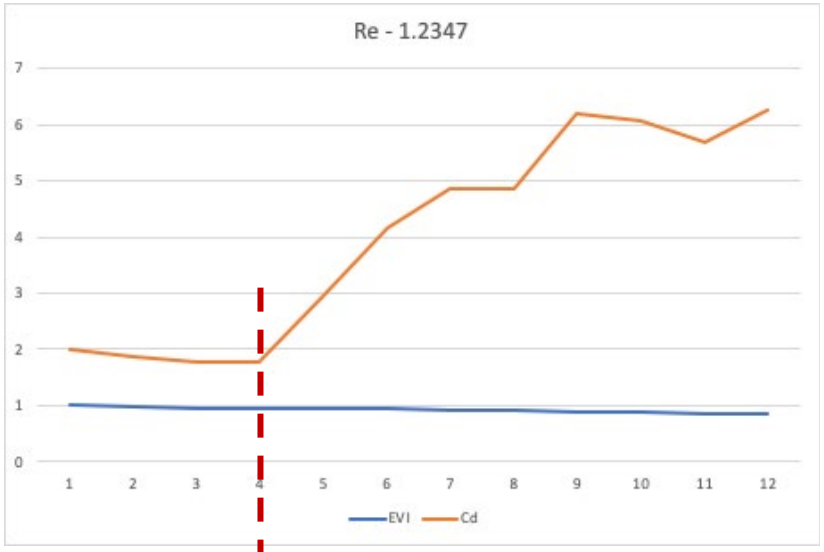
PoP	SPI	CPI	EVI	ROK (Percent)	BAC	EAC	LVI	Re	Cd
1	1	1	1	1	1	1	1	1	2
2	0.99	0.98	0.9702	0.902439024	1	1	1.1	1.29494784	1.86880113
3	0.98	0.98	0.9604	0.87804878	1	1.1	1.1	1.23474437	1.78174532
4	0.98	0.98	0.9604	0.87804878	1	1.1	1.1	1.23474437	1.78174532
5	0.97	0.97	0.9409	0.829268293	1	1.5	2	1.81617101	2.93658103
6	0.97	0.97	0.9409	0.780487805	1	1.5	3	2.89452255	4.14576145
7	0.96	0.95	0.912	0.731707317	1	1.6	4	4.10783446	4.86874537
8	0.96	0.95	0.912	0.731707317	1	1.6	4	4.10783446	4.86874537
9	0.96	0.94	0.9024	0.634146341	1	1.8	6	6.45492322	6.19682042
10	0.94	0.95	0.893	0.634146341	1	1.8	6	6.59153157	6.06839239
11	0.94	0.92	0.8648	0.634146341	1	2	6	6.32558071	5.69117708
12	0.93	0.92	0.8556	0.609756098	1	2	7	7.8409799	6.24921893

LLA volatility Indicators (LVI)			
Subcontract performance (SP)			
Budget (B)			
GFP			
Admin distractions (AD)			
Personnel (P)			
Technical (T)			
Contract Issues (CI)			
Independent Variables			
Velocity	EVI*ROK		
Distance	EAC		
Density	1/LVI		
Viscosity	[F/A][1/EVI]		
Force	B		
Area	BAC		
Re	1/((EVI*ROK)*EAC*(1/LVI))/[F/A][1/EVI]		
Cd	(2*B)/(1/LVI)*BAC*((EVI*EVI)*ROK))		

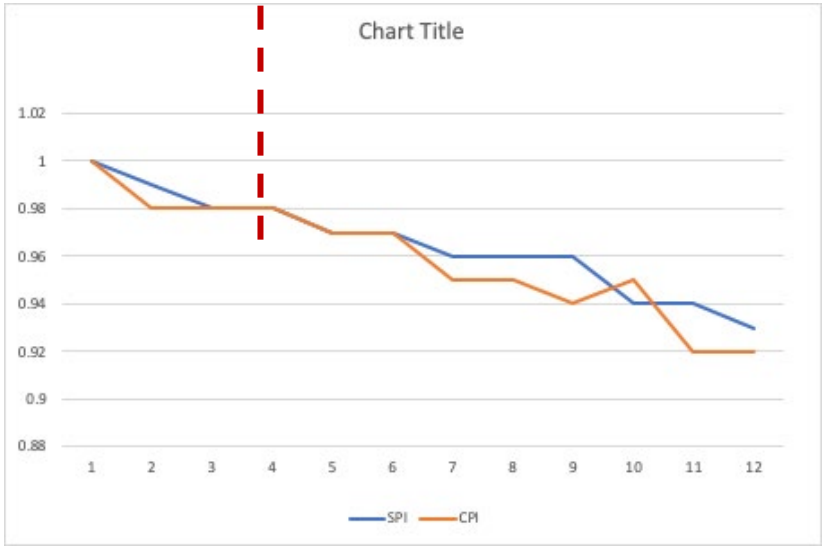
Uncertainty and Risk

Fluids Analogy

Turbulent Analogy v. EVM Approach



Fluid Analogy Data shows Rapid increase in drag at Re of 1.2347 during the fourth Reporting period for the program. Fluids Analogy.



Earned Value Data shows decreasing Performance begins at reporting period 6.

Backup

Literature Review

Classical Management Theory			
School	Scientific Management	Administrative Theory	
Theory	Scientific Management	Bureaucracy	Administration
Thought leaders	Frederick Winslow Taylor	Max Weber	Henri Fayol
Defining work	The Principles of Scientific Management	Die Protestantische Ethik und der Geist des Kapitalismus (The Protestant Ethic and the Spirit of Capitalism)	Administration industrielle et générale (General and industrial administration)

Literature Review

Behavioral Theory			
Theory	Behavioral Theory	Theory of Motivation	Theory X/Theory Y
Thought Leaders	Follet; Barnard	Maslow	McGregor
Defining Work	The New State (Follett); The Functions of the Executive (Barnard)	A Theory of Human Motivation	The Human Side of Enterprise

Literature Review

System Theory				
	Static	Dynamic		
		Deterministic		Non-deterministic
Theory	Systems Theory similar to industrial scientific management envisioned by Taylor	Systems Theory	Chaos Theory	Complexity Theory
Thought Leaders	Bertalanffy	Bertalanffy	Wheatley	Kauffman; Morin; Cilliers
Defining Work	General System Theory: Foundations, Development, Applications	General System Theory: Foundations, Development, Applications	Leadership and the New Science	The Origins of Order: Self-organization and Selection in Evolution (Kauffman); From the concept of system to the paradigm of complexity (Morin); Complexity and postmodernism. Understanding complex systems (Cilliers)

References

Classical Management Theory

- The Principles of Scientific Management; Frederick Winslow Taylor; Monograph; Harper & Brothers; 1911
  - Science for each element work, replaces rule-of-thumb method
  - Scientifically select, train, teach, and develop workers
  - Cooperation to ensure work done in accordance with the science
  - Division of the work/responsibility between management and workers. Management undertakes work for which they are better trained than the workers
- Die protestantische Ethik und der Geist des Kapitalismus (The Protestant Ethic and the Spirit of Capitalism); Karl Emil Maximilian "Max" Weber; 1905 (German); 1930
  - Distinct/separate areas of competence, set out in law/regulation
  - Hierarchy of office
  - Decisions based on written documents and written rules
  - Relationships and decisions are impersonal
  - Officials have extensive education in area of competence
  - Employment based on expertise and is full time
  - Fixed salaries
- Administration Industrielle et Générale" (General and industrial administration); Henri Fayol; 1916 (French); 1930
  - Forecast and plan
  - Organize
  - Command/direct
  - Coordinate
  - Control

References

Behavioral Theory

- The new state : group organization the solution of popular government; Mary Parker Follett ; Longmans; 1918
- The Functions of the Executive; Chester I. Barnard; Harvard University Press; 1938
  - Management is a dynamic process
  - Workers should be involved in decisions
  - Noncoercive power sharing (managers need buy-in of employees; power with vs. power over)
  - Employees motivated by social needs
  - Reciprocal relationships (peer forces are strong)
  - Win-win philosophy (employees respond to managers who help them satisfy needs)
  - Managers coordinate work fairly to improve efficiency
  - Authority of expertise (leads to matrix organization)
  - Conflict as opportunity to develop integrated solutions vs. compromising
  - Critical role of soft factors and informal processes
  - Relevance of theory is underpinned by the scientific Hawthorne studies

References

Behavioral Theory

- A Theory of Human Motivation; Abraham H. Maslow; Psychological Review, 50, 370-396; 1943
  - Hierarchy of needs
  - Needs never completely satisfied
  - Behavior motivated by need for satisfaction
  - Needs encompass physiological; safety; belonging; esteem; and self-actualization.
- The Human Side of Enterprise; Douglas Murray McGregor; 1960
  - Managers create situations where employees confirm manager s expectations (self-fulfilling prophecy)
  - People work for inner satisfaction not materialistic rewards (drives performance)

References

System Theory (Static)

- General System Theory: Foundations, Development, Applications; Ludwig Von Bertalanffy; George Braziller; 1968
  - Bounded in time and space
  - Exchanges information/material with environment limited and controlled
  - Processes that transform inputs to outputs
  - Self-correcting through feedback
  - Seeks equilibrium but can oscillate
  - View as industrial machine (Taylor)
  - Well defined processes
  - Division of labor limits required knowledge
  - Top down information flows

References

- **System Theory (Dynamic) - Deterministic**
  - Bounded in time and space
  - Exchanges information/material with environment limited and less controlled
  - Processes that transform inputs to outputs
  - Self-correcting through feedback
  - Seeks equilibrium but can oscillate
  - View as *biological system*
  - Well defined processes with focus on *controlling and managing change*
  - Communities of practice share relevant information
  - Matrix information flows
- **Chaos Theory – Deterministic**
  - Bounded in time and space
  - Exchanges information/material with environment measurable and least controlled
  - Processes that transform inputs to outputs
  - Self-correcting through feedback
  - Seeks equilibrium but can oscillate
  - View as living organism
  - Self-organizing (role of managers changes)
  - Everyone has access to all information needed to do their job (Knowledge Management; continuously educated workforce)
  - Everyone has access to anyone they need to do their job
  - Strong organization or purpose linkage (requires employee involvement)
  - Open information flows (changed communication methods)

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