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Schedule Adherence and Rework

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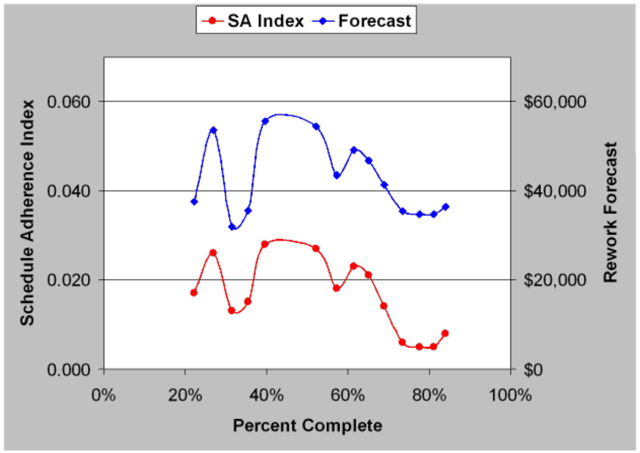

Abstract

- Rework has a negative impact on the likelihood of project success
- A significant portion of rework is caused by deviating from the project plan and its associated schedule
- The concept of schedule adherence provides an approach to increase project control and minimize the cost impact of rework

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Overview

- Background
- Schedule Adherence
- Derivation of Rework
- Computation Methods
- Notional & Real Examples
- Summary
- Final Remarks

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Background

- Schedule Adherence first recognized in 2004
- Desire since to understand its implications – i.e., the cost of rework
- Earned Schedule facilitates identifying constraints or impediments (C & I) and potential rework
- Minimizing C & I reduces workarounds and rework, maximizing performance

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Background

- Several causes of rework other than imperfect schedule adherence
  - Poor planning
  - Defective work
  - Poor requirements management
  - Schedule compression
  - Over zealous quality assurance
- Presentation is focused to rework from imperfect schedule adherence – only

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Background

- Possibly this discussion reminds those with background in quality and process improvement of the idea of “process discipline”
- ES provides the mechanism to identify and measure process performance discipline and forecast the waste – ***the cost of rework***

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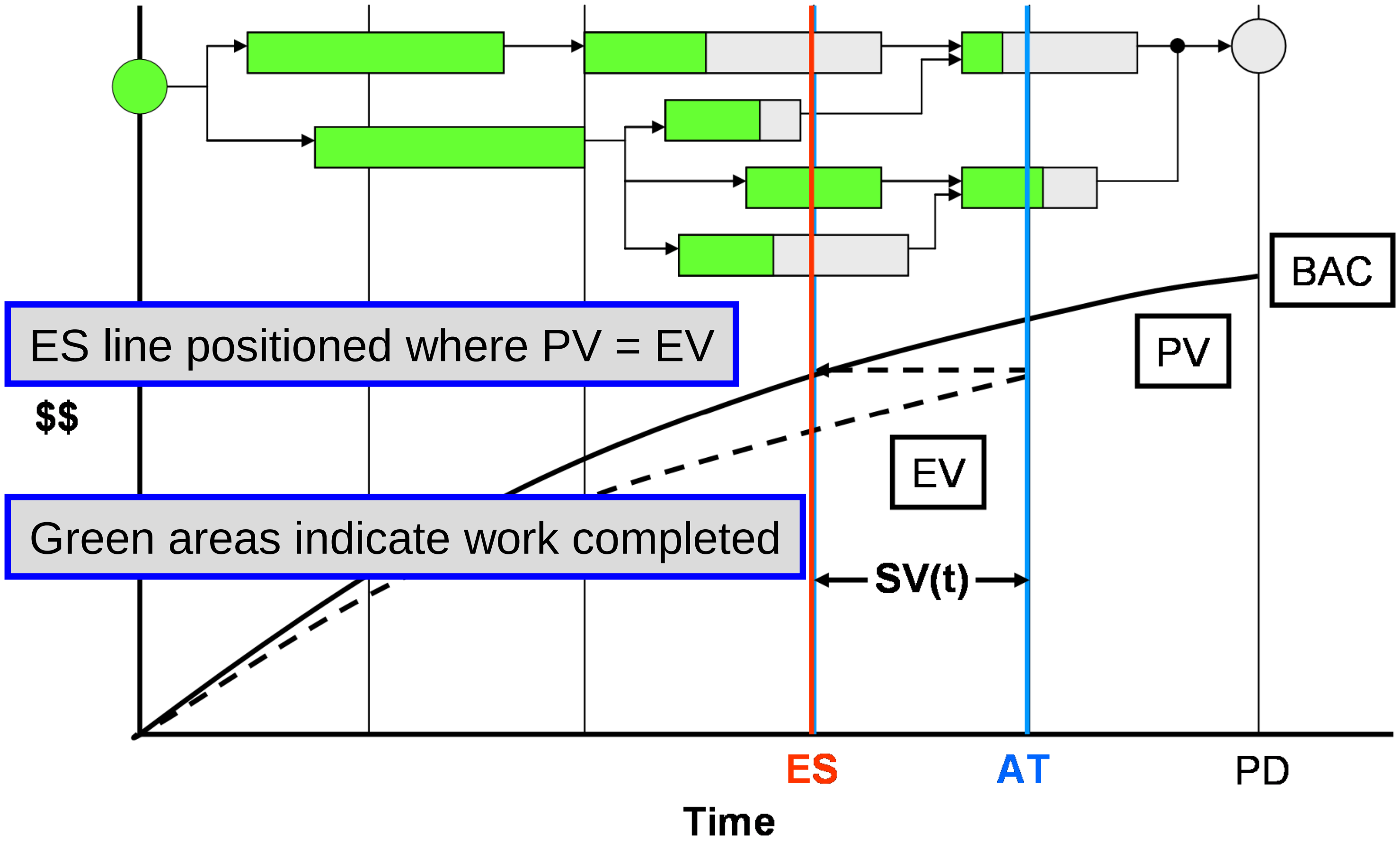
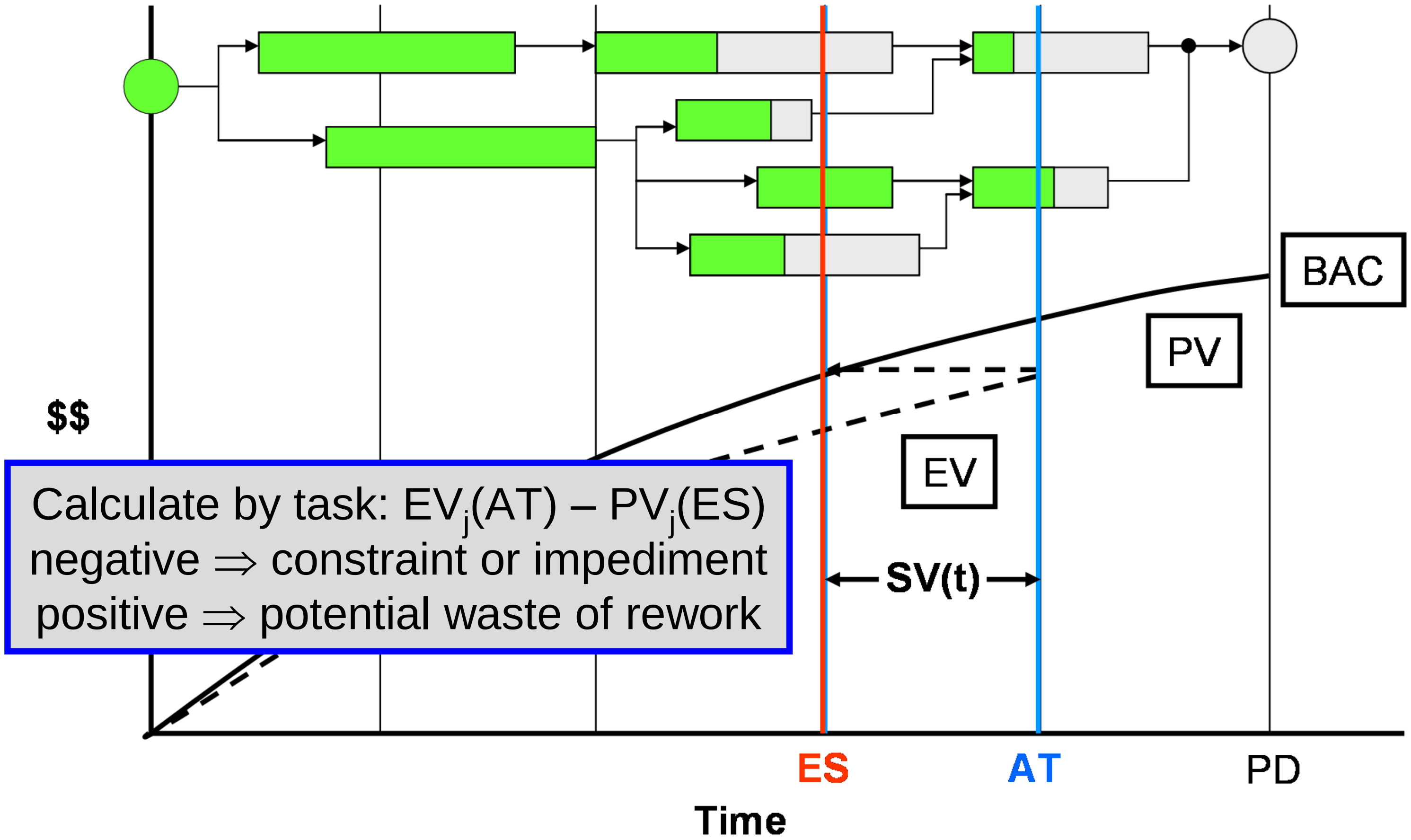
Schedule Adherence



Schedule Adherence



Calculate by task: $EV_j(AT) - PV_j(ES)$
negative ⇒ constraint or impediment
positive ⇒ potential waste of rework

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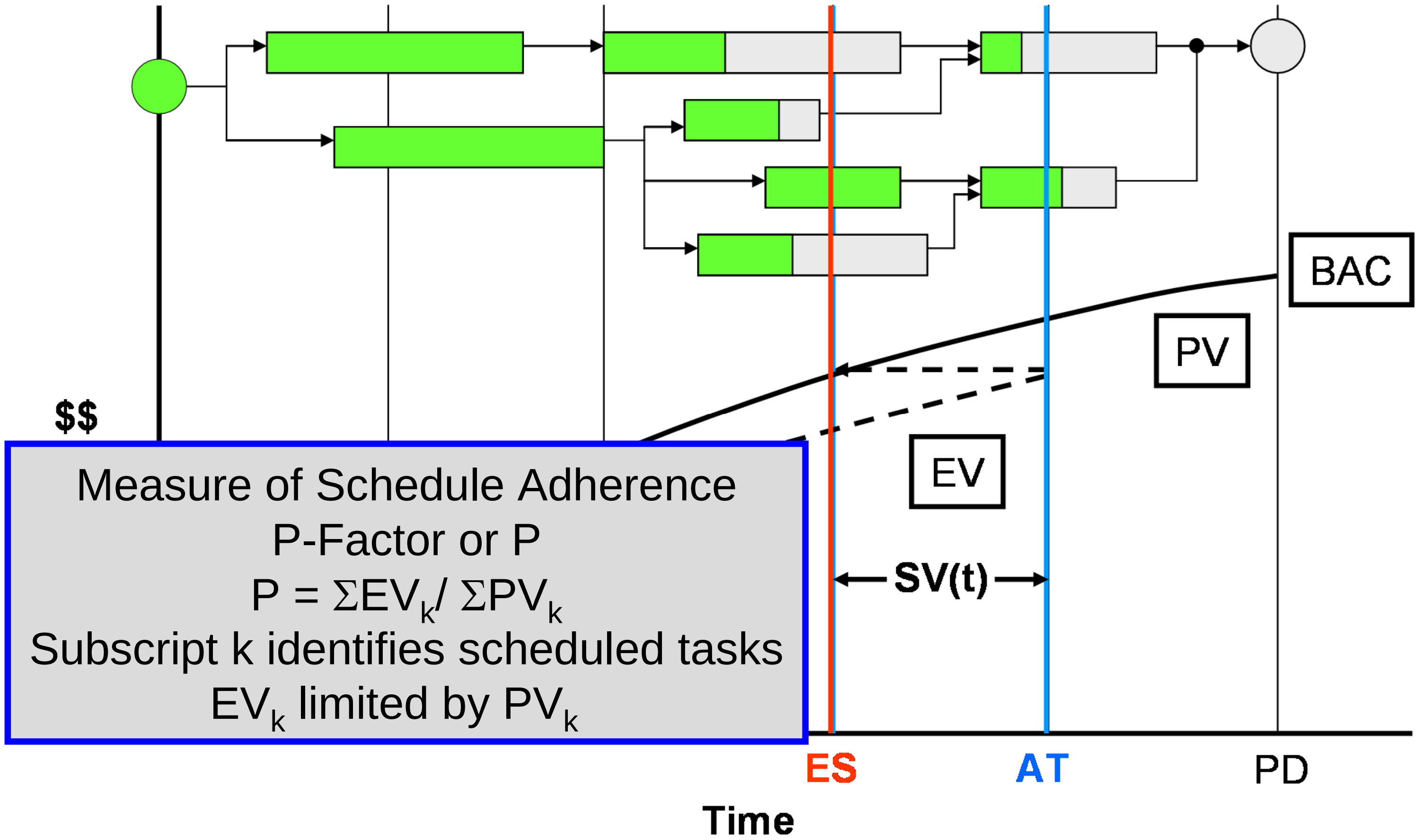
Schedule Adherence



Measure of Schedule Adherence

P-Factor or P

$P = \Sigma EV_k / \Sigma PV_k$

Subscript k identifies scheduled tasks

EV_k limited by PV_k

Schedule Adherence

- Characteristics of P-Factor
  - Cannot exceed 1.0
  - Equals 1.0 at project completion
  - $P = 0.0 \Rightarrow$ performance not conforming to schedule
  - $P = 1.0 \Rightarrow$ perfect conformance
  - $P < 1.0 \Rightarrow$ rework likely
  - $P \cong 1.0 \Rightarrow$ schedule is followed, milestones and interim products accomplished in proper sequence

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Schedule Adherence

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With the P-Factor, the PM has an indicator derived from ES which further enhances the description of project performance portrayed by EVM.

Derivation of Rework

- Fundamental relationships:
  - EV accrued = ΣEV_j @ AT = ΣPV_k @ ES
  - EV earned in concordance with the schedule:

    EV(p) = ΣEV_k @ AT = P • EV

    ...where $EV_k \leq PV_k$ and $P = \Sigma EV_k / \Sigma PV_k$
  - EV earned not in agreement with the schedule:

    EV(r) = EV – EV(p) = (1 – P) • EV
- From earlier discussion, we know a portion of EV(r) is unusable and requires rework

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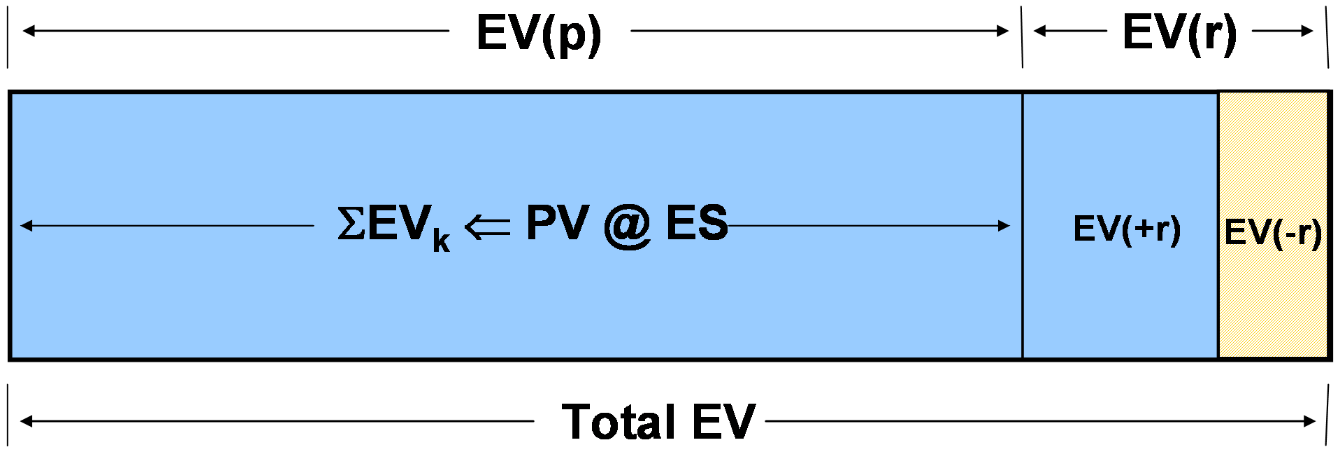
Derivation of Rework



- Rework fraction: f(r) = EV(-r)/EV(r)
- Usable fraction: f(p) = EV(+r)/EV(r)

where EV(r) = EV(-r) + EV(+r)

and f(r) + f(p) = 1

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Derivation of Rework

- Using the definitions we can describe rework, R, in terms of EV, P, and f(r):

$$R = EV(-r) = f(r) \bullet (1 - P) \bullet EV$$

- P and EV are obtainable from status data
- Project team's ability to interpret requirements increases with work accomplishment
- Conditions for f(r):
  - $f(r) = 1$ @ $C = 0$ and $f(r) = 0$ @ $C = 1$
  - Rework fraction decreases as EV increases
  - Rate of f(r) decrease becomes larger as EV $\Rightarrow$ 1

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Derivation of Rework

- Proposed equation for f(r) which meets conditions:

$$f(r) = 1 - C^n \bullet e^{(-m \bullet (1 - C))}$$

where C = fraction complete (EV/BAC)

e = natural number (2.718…)

^ = signifies exponent follows

- Exponents m and n are used to shape the f(r) curve. Values presently used: m = 0.5, n = 1.0
- Using the values the general equation for R is:

$$R = (1 - C \bullet e^{(-0.5 \bullet (1 - C))}) \bullet (1 - P) \bullet EV$$

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Computation Methods

- The value computed for R represents the cost of rework forecast for the remainder of the project due to the present value of P
- Although of some interest, P is not particularly useful for PMs
- Regardless of effort invested to improve, P increases as project progresses and concludes at 1.0 at completion
- Thus, R does not yield trend information, nor can it lead to a forecast of total cost of rework

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Computation Methods

- R can be transformed to a useful indicator by dividing by the work remaining (BAC – EV):

  $$SAI = R/(BAC - EV)$$

  where SAI = Schedule Adherence Index
- SAI is useful for detecting trends …thus a management tool for gauging actions taken
  - SAI increasing with EV $\Rightarrow$ SA worsening
  - SAI decreasing with EV $\Rightarrow$ SA improving

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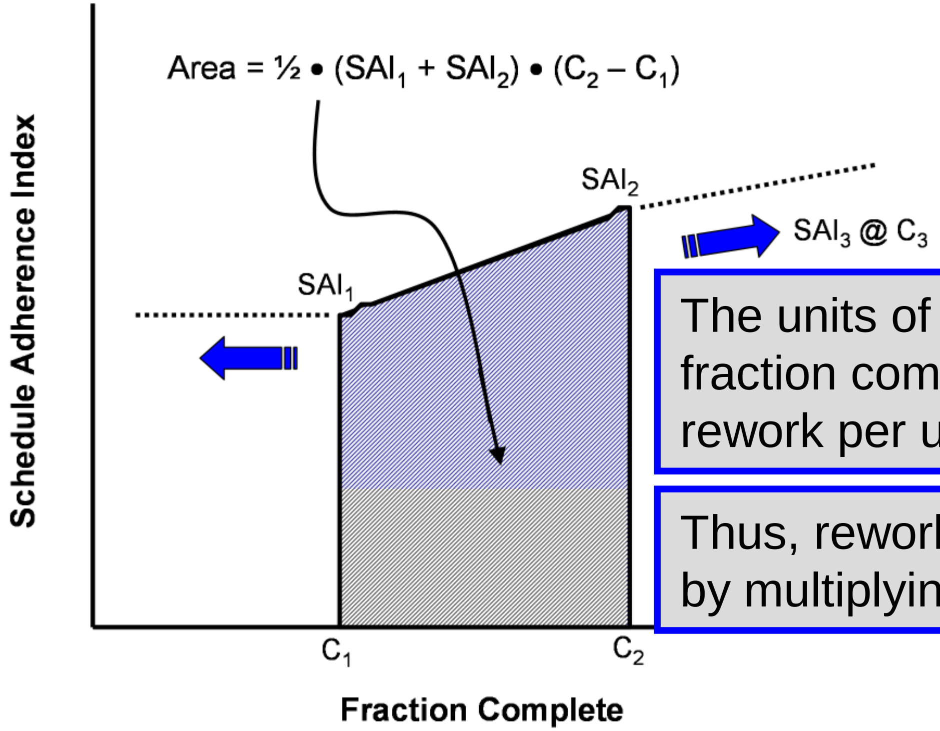
Computation Methods

- Having SAI facilitates the calculation of rework within a performance period



The units of the area is fraction complete times cost of rework per unit of budget

Thus, rework cost is computed by multiplying the area by BAC

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Computation Methods

- To obtain the rework cost for periods (n):

$$R_p(n) = BAC \bullet [½ \bullet (SAI_n + SAI_{n-1}) \bullet (C_n - C_{n-1})]$$

For n = 0 and N: SAI = 0.0

- The cumulative accrual is the sum of the periodic values:

$$R_{cum} = \Sigma\, R_p(n)$$

- The formula for total rework forecast is:

$$R_{tot} = R_{cum} + SAI \bullet (BAC - EV)$$

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Computation Methods

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- To clarify what R_{tot} represents, it is the forecast of actual cost for rework from imperfect execution of the schedule
- From experience, rework cost is closely aligned with planned cost
- Generally, rework does not experience the execution inefficiencies incurred in the initial performance of the tasks

Notional Data Example

Status Point	1	2	3	4	5	6
EV	$14	$37	$58	$82	$97	$113
P	0.082	0.208	0.247	0.337	0.371	0.431

Status Point	7	8	9	10	11	
EV	$125	$137	$157	$177	$185	
P	0.520	0.650	0.822	0.955	1.000	

- P values are very poor and do not exceed 0.8 until nearly 85% complete …normally P is greater than 0.8 by 20% complete
- Because P is poor we should expect rework to be large with respect to BAC

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Notional Data Example

Status Point	1	2	3	4	5	6
Percent Complete	7.6%	20.0%	31.4%	44.3%	52.4%	61.1%
SA Index	0.072	0.171	0.267	0.351	0.407	0.444
Rework Forecast	$13	$29	$42	$51	$57	$60

Status Point	7	8	9	10	11
Percent Complete	67.6%	74.1%	84.9%	95.7%	100.0%
SA Index	0.425	0.350	0.213	0.064	0.000
Rework Forecast	$59	$54	$49	$47	$46

- SAI increases until ~60% complete and then improves as the project moves to completion
- Rework forecast rapidly increases until ~30% complete, then at a slower rate peaks at $60 when 61% is reached …from there forecast decreases slightly to finish at $46 or about 25% of BAC ($185)

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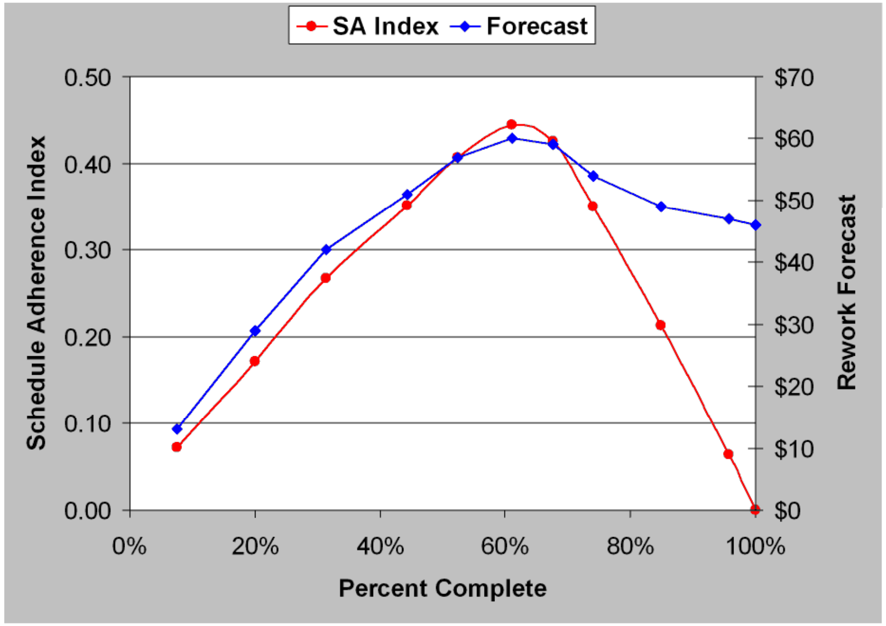
Notional Data Example



- SAI improves greatly after its peak value, but rework forecast improves only marginally
- Why? – there is less work remaining

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Real Data Example

Status Point	1	2	3	4	5
EV	$549,707	$668,776	$784,508	$881,288	$986,529
P	0.930	0.915	0.963	0.962	0.939
Status Point	6	7	8	9	10
EV	$1,299,880	$1,422,033	$1,526,842	$1,617,976	$1,716,130
P	0.957	0.975	0.970	0.975	0.984
Status Point	11	12	13	14	
EV	$1,826,991	$1,930,651	$2,015,852	$2,088,967	
P	0.994	0.995	0.996	0.993	

- P-Factor is high initially and increases to 0.995 by 75% complete
- CPI = 1.05 & SPI(t) = 0.98 – both are comparatively high
- Synergy between high values of P and high index values

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Real Data Example

Status Point	1	2	3	4	5
Percent Complete	22.1%	26.9%	31.5%	35.4%	39.6%
SA Index	0.017	0.026	0.013	0.015	0.028
Rework Forecast	$37,483	$53,697	$31,945	$35,577	$55,671

Status Point	6	7	8	9	10
Percent Complete	52.2%	57.2%	61.4%	65.0%	69.0%
SA Index	0.027	0.018	0.023	0.021	0.014
Rework Forecast	$54,401	$43,519	$49,221	$46,812	$41,443

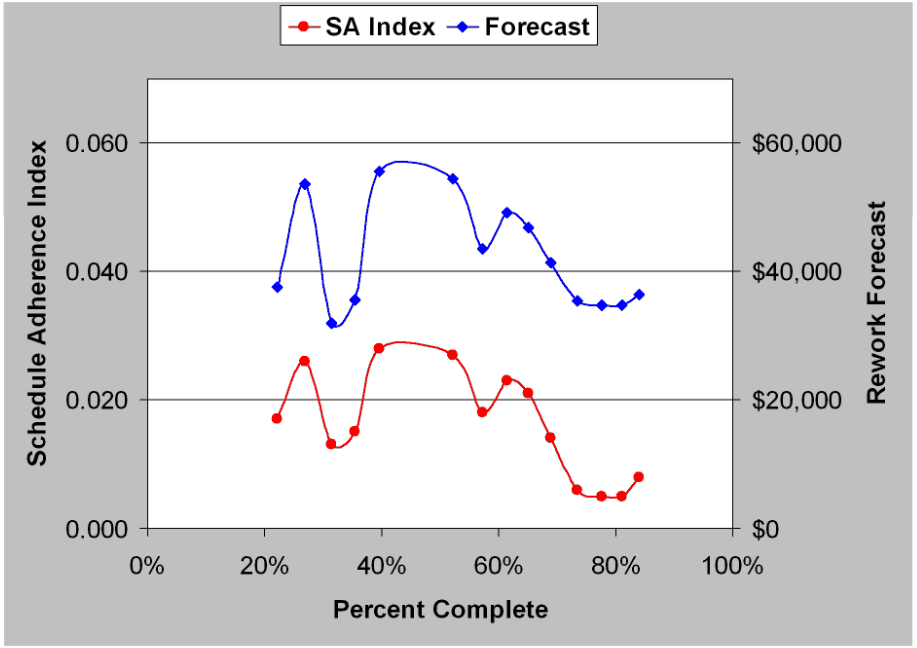
Status Point	11	12	13	14	
Percent Complete	73.4%	77.6%	81.0%	84.0%	
SA Index	0.006	0.005	0.005	0.008	
Rework Forecast	$35,349	$34,821	$34,754	$36,377	

- With P values very high, SAI values are extremely low, as expected

Real Data Example

- Other observations
  - SAI highest value = 0.028, lowest = 0.005
  - SAI values for real data as much as 89 times lower than for notional data
  - Average forecast value of rework = $42K or 1.7% of BAC ($2.5M)
  - Standard deviation of forecast values = $8300, thus high bound = $42K + 3 • $8.3K ≅ $67K

Real Data Example



- SAI & rework plots have negative trends showing improvement after 40% complete
- Assuming trend continues, rework will conclude at less than $40K, 1.6% of BAC

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Summary

- From the introduction of schedule adherence there has been a desire for the ability to forecast the cost of rework
- The forecast capability was long thought to be too complex for practical application
- The presentation has shown calculations are not that encumbering
- SAI was introduced and shown to be integral to computing the forecast rework

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Summary

- The application of SAI and rework forecasting was discussed for notional and real data
- SAI is proposed to be a viable PM tool for control of project performance, thereby enhancing the probability of a successful project
- Including SAI and R_{tot} at status reviews can be expected to heighten senior level attention to rework and process

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Final Remarks

- To encourage the application and uptake of the SAI and rework forecasting method a tool for trialing is available at the calculators page of the Earned Schedule website:

SA Index & Rework Calculator

The calculator produces values and graphs for the accrual and forecast of the total cost for rework, along with the value of the EV for work accomplished out of sequence. The calculator includes instructions and example data for trial use.

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References

- “Schedule Adherence: a useful measure for project management,” *The Measurable News*, 2009 Issue 3: 1, 9-15
- “Schedule Adherence and Rework,” *The Measurable News*, 2011 Issue 1: 9-14
- Earned Schedule Website: www.earnedschedule.com

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