“Forecasting Project Schedule Completion” by Using Earned Value Metrics

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Agenda

- Introduction
- Schedule performance indicators
- Schedule forecasting generic formula
- Method 1: Use of PV Rate (Planned Value Rate)
- Method 2: Use of ED (Earned Duration)
- Method 3: Use of ES (Earned Schedule)
- Discussion of different methods
- Forecasting at project level - Case Study
- Conclusion

Introduction

- Earned Value Management (EVM) as defined in the 2000 Edition of the PMBOK Guide:

  A method for integrating scope, schedule and resources, and for measuring project performance.

- Definition implies equal weight to both cost & schedule
- Reality is that most EVM metrics focus primarily on cost
- EVM was developed for cost measurement, not scheduling

- There is currently a trend to use performance indicators for predicting project duration.
- 3 methods are presented here.

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Schedule Variance (SV)

SV = Earned Value - Planned Value = EV - PV

Positive (+) variance: volume of work performed ahead of plan

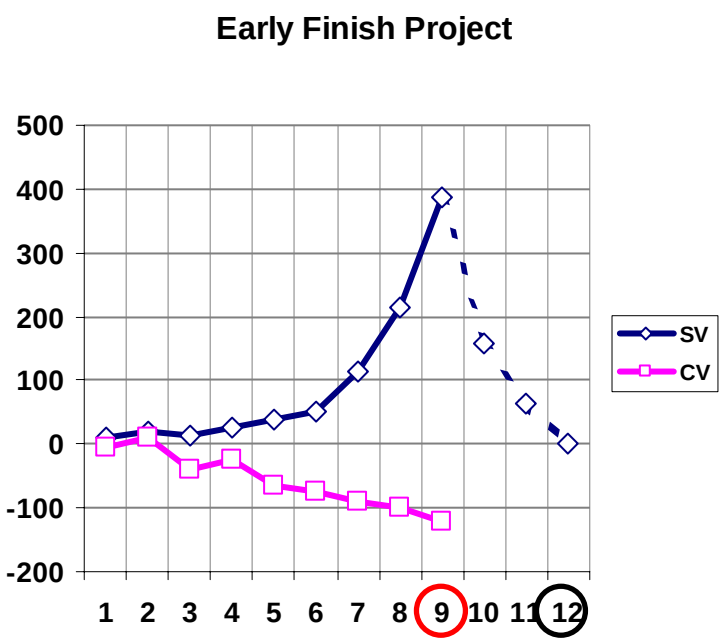
Negative (-) variance: volume of work performed behind plan

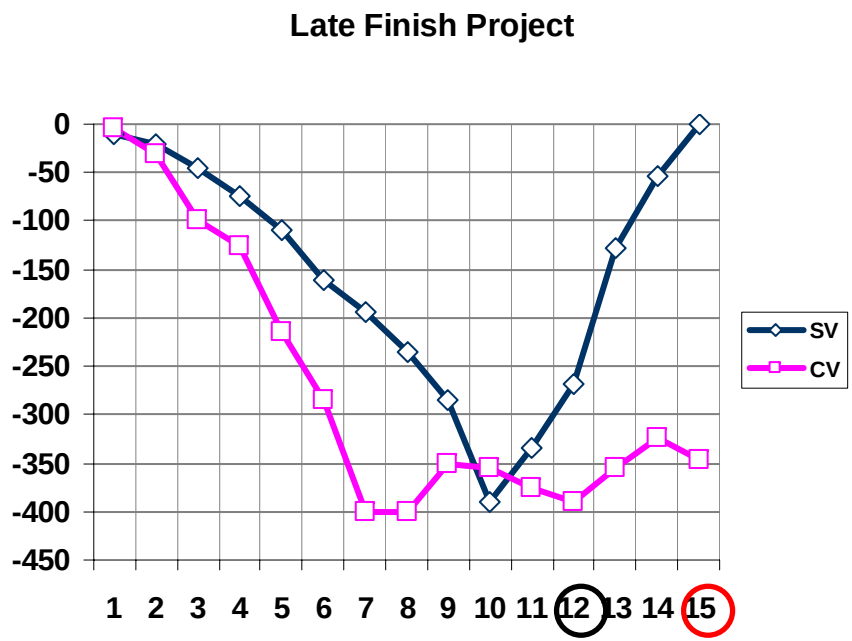
- SV does not measure time, it measures volume of work done versus planned on same basis (Euros)
- SV does not identfy work, requires “drill down” analysis
- “ + ” may be bad: work done not on critical path, offsetting tasks
- “ - ” may be good: work behind has float, offsetting tasks
- SV is zero at end of project, even when project is late

Suggestions for other name:

“Progress Variance” or “Accomplishment Variance”

Example - SV


Early Finish Project
500
400
300
200
100
0
-100
-200
1 2 3 4 5 6 7 8 9 10 11 12
SV
CV


Late Finish Project
0
-50
-100
-150
-200
-250
-300
-350
-400
-450
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
SV
CV

Schedule Performance Index (SPI)

SPI = Earned Value / Planned Value = EV / PV

SPI > 1: volume of work performed ahead of plan

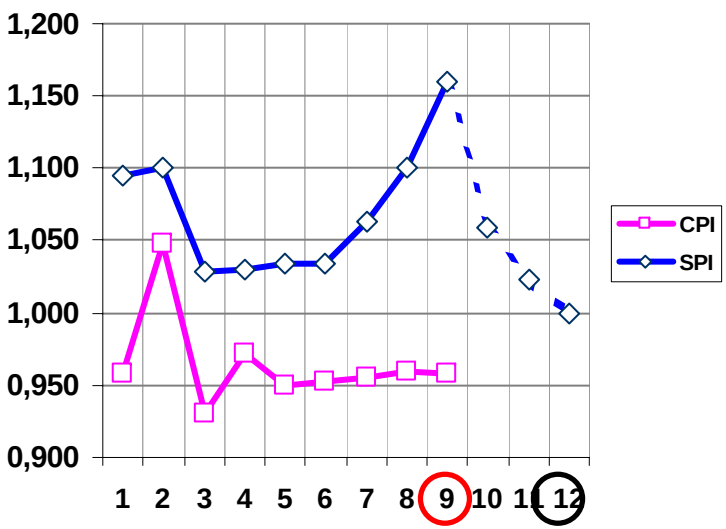
SPI = 1: volume of work perfomred according to plan

SPI < 1: volume of work performed behind plan

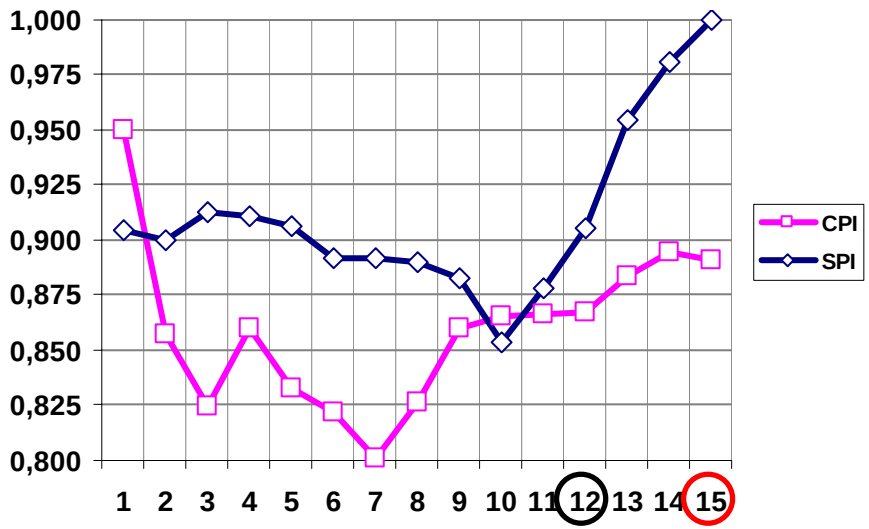
- SPI does not have a “dimension”
- SPI does not identfy work, requires “drill down” analysis
- “ >1 ” may be bad: work done not on critical path, offsetting tasks
- “ <1 ” may be good: work behind has float, offsetting tasks
- SPI equals 1 at end of project: even when project is late, the index shows a perfect schedule performance

Example - SPI

Early Finish Project



Late Finish Project



Discussion of schedule metrics

- Strenghts of SV & SPI:
  - provides a reliable early warning
  - Reflects cost/schedule integration

- Weaknesses of SV & SPI:
  - SV initially follows a trend, but moves towards 0, even if project is late
  - SPI initially follows a trend, but moves towards 1, even is project is late
  - SV & SPI does not indicate the real performance of the project

- At a certain point in time, the SV & SPI are no more reliable for forecasting purposes.
- This “grey area” occurs usually the last third of the project.

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Generic Formula

EDAC = Actual Duration + Estimated Duration Work Remaining
EDAC = AD + EDR

- EDAC = Estimated Duration at Completion
- AD = Actual Duration (time now)
- EDR = Estimated Duration of Remaining Work

- The EDR is the portion to “guess at best”
- The Estimated Duration of Work Remaining is influenced by the project environment
- 6 types are defined

Types of EDR Estimates (1)

- Case 1: new EDR estimate
  - occurs when original assumptions are no longer valid
  - a new estimate (new schedule) needs to be developped
  - forecasting formulas are useless in this case
- Case 2: EDAC as planned
  - project will be on schedule, even when prior performance is poor
  - f.e. “we’ll catch up during the testing phase”
  - can be dangereous,as unfixed problems don’t fix themselves
- Case 3: EDR substantially higher as planned
  - f.e. additional time is needed to fix various problems
  - estimate in general not quantified
  - more common as we believe

Types of EDR Estimates (2)

- Case 4: EDR as planned
  - past schedule problems will not occurr in the future
  - future progress will be according to plan
- Case 5: EDR will continue with current SPI trend
  - past problems will continue in the future
  - f.e. because of delaying corrective actions, is a realistic case
- Case 6: EDR will continue with current SCI trend
  - SCI = critical ratio = CPI * SPI
  - used when adherence to budget is critical to organization

Forecasting Methods

Case		Forecast Method		
		Anbari (*)	**Jacob (**)**	**Lipke (***)**
1	EDAC = new	re-schedule		
2	EDAC as originally planned	monitor schedule		
3	EDAC is very high	re-schedule		
4	EDR according to plan	EDACpv1	EDACed1	EDACes1
5	EDR will follow current SPI trend	EDACpv2	EDACed2	EDACes2
6	EDR will follow current SCI trend	EDACpv3	EDACed3	EDACes3
		Planned Value Rate	**Earned Duration**	**Earned Schedule**

EDAC = Estimated Duration at Completion

* *Earned Value Project Management Method and Extensions, Project Management Journal, Dec. 2003*

** *Forecasting Project Schedule Completion with EV Metrics, The Measurable News, Summer 2004*

*** *Further Developments in Earned Schedule, The Measurable News, Spring 2004*

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Method 1: PV Rate

PV Rate = BAC / TAC

- PV Rate = Planned Value Rate (€/month, €/week, ...)
- TAC = Time at Completion, number of periods (months, weeks, ...)
- BAC = Budget at Completion

TV = SV / PV Rate

- TV= Time Variance (months, weeks, ...)
- SV = Schedule Variance

Method 1: PV Rate

- EDR according to plan

  EDACpv1 = TAC - TV

- EDR with continued SPI performance

  EDACpv2 = TAC / SPI

- EDR with continued SCI performance

  EDACpv3 = TAC / SCI

Method 1: example

Scope: install 350 TFT Monitors, 50 monitors / week
TAC: 7 weeks
BAC: 35.000 € (100 € / monitor)

	W1	W2	W3	W4	W5	W6	W7
PV	5.000	10.000	15.000	20.000	25.000	30.000	35.000
AC	3.750	9.100	12.750				
EV	3.500	8.500	12.000				
SPI	0,70	0,85	0,80				
CPI	0,93	0,93	0,94				
SCI	0,65	0,79	0,75				

PV Rate = BAC / TAC = 35.000 / 7 = 5.000 € / week
TV = SV / PV Rate = (12.000 - 15.000) / 5.000 = -0,6 weeks

EDACpv1 = TAC - TV = 7 - (-0,6) = 7,6 weeks
EDACpv2 = TAC / SPI = 7 / 0,80 = 8,75 weeks
EDACpv3 = TAC / SCI = 7 / 0,75 = 9,33 weeks

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Method 2: ED Method

ED = AD * SPI

- ED = Earned Duration
- AD = Actual Duration
- SPI = Schedule Performance Index

EDAC = AD + (TAC - ED) / P.F.

- EDAC= Estimated Duration at Completion
- TAC = Time at Completion
- ED = Earned Duration
- P.F. = Performance factor (according to different cases)

Method 2: ED Method

- EDR according to plan (P.F. = 1)

  EDACed1 = AD + (TAC - ED) / 1
  = TAC + AD x (1 - SPI)

- EDR with continued SPI performance (P.F. = SPI)

  EDACed2 = AD + (TAC - ED) / SPI
  = TAC / SPI

- EDR with continued SCI performance
  - proposed in reference:

    EDACed3 = TAC / SCI

  - mathematically correct:

    EDACed3m = TAC / SCI + AD x (1-1/CPI)

Method 2: Extension

- Corrective action metric: TCSPI

TCSPI = (TAC - ED) / (TAC - AD)

- TCSPI = To Complete Schedule Performance Index
- a measure of the required performance needed to bring in the project on the planned time

TCSPI = (TAC - ED) / (EDAC - AD)

- TCSPI = To Complete Schedule Performance Index
- a measure of the required performance needed to bring in the project on the estimated EDAC time

Method 2: Extension

- What when work is not finished and planned duration is passed?
  - Mathematically: AD > PD and SPI < 1
  - TAC is being replaced by AD

EDACed1 = AD (2 - SPI)

EDACed2 = AD / SPI

EADCed3 = AD / SCI

EADCed3m = AD (1- 1/CPI + 1/SCI)

Method 2: example

Scope:	install 350 TFT Monitors, 50 monitors / week
TAC:	7 weeks
BAC:	35.000 € (100 € / monitor)

	W1	W2	W3	W4	W5	W6	W7
PV	5.000	10.000	15.000	20.000	25.000	30.000	35.000
AC	3.750	9.100	12.750				
EV	3.500	8.500	12.000				
SPI	0,70	0,85	0,80				
CPI	0,93	0,93	0,94				
SCI	0,65	0,79	0,75				

ED = AD x SPI = 3 x 0,8 = 2,4 weeks

EDACed1 = TAC + AD (1 - SPI) = 7 + 3 (1 - 0,80) = 7,6 weeks
EDACed2 = TAC / SPI = 7 / 0,80 = 8,75 weeks
EDACed3 = TAC / SCI = 7 / 0,75 = 9,33 weeks

EDACed3m = TAC / SCI + AD (1 - 1/CPI) = 9,14 weeks

Method 2: example

Scope: install 350 TFT Monitors, 50 monitors / week
TAC: 7 weeks
BAC: 35.000 € (100 € / monitor)

	W1	W2	W3	W4	W5	W6	W7
PV	5.000	10.000	15.000	20.000	25.000	30.000	35.000
AC	3.750	9.100	12.750				
EV	3.500	8.500	12.000				
SPI	0,70	0,85	0,80				
CPI	0,93	0,93	0,94				
SCI	0,65	0,79	0,75				

TCSPI = (TAC - ED) / (TAC - AD) = (7 - 2,4) / (7 - 3) = 1,15
TCSPI = (TAC - ED) / (EDACed1 - AD) = 1,00
TCSPI = (TAC - ED) / (EDACed2 - AD) = 0,80
TCSPI = (TAC - ED) / (EDACed3 - AD) = 0,73

TCSPI = (TAC - ED) / (EDACed3m - AD) = 0,75

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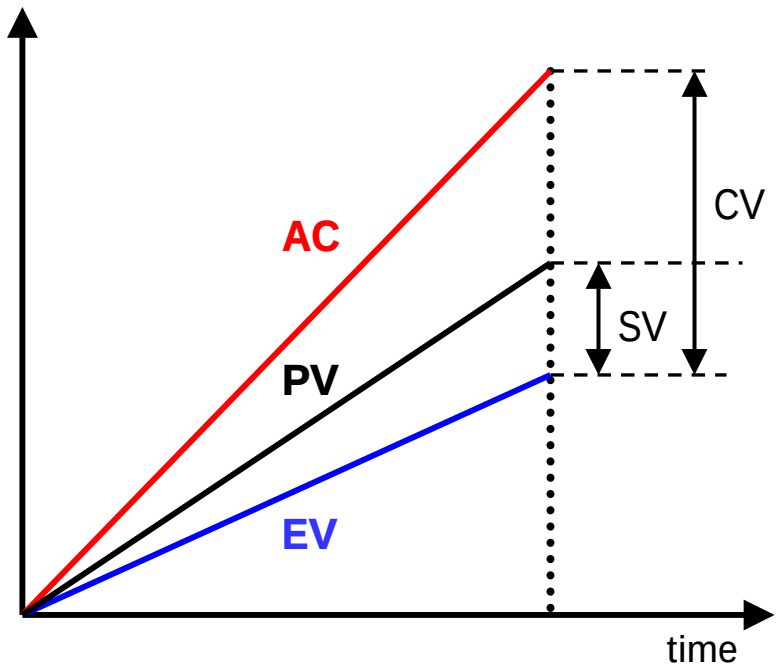
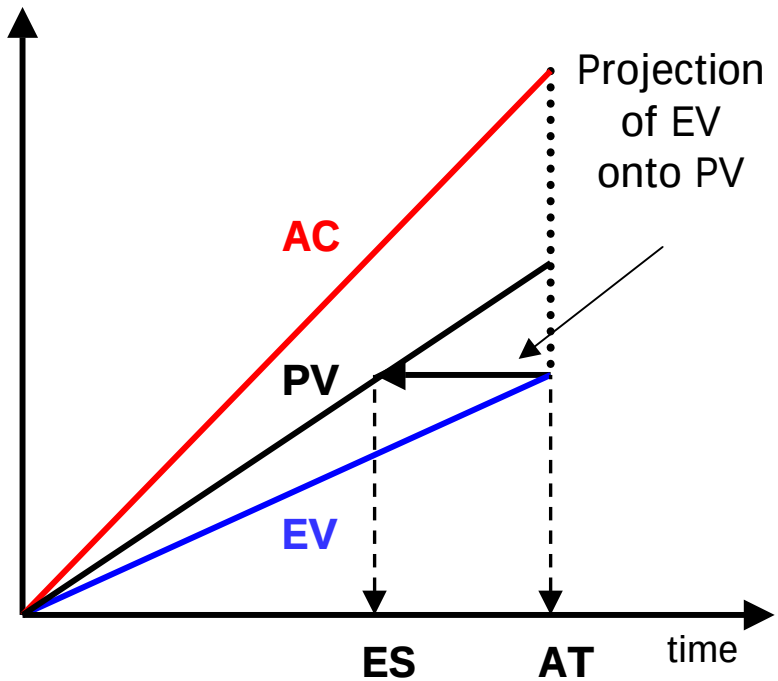
Method 3: Earned Schedule

- Idea of “Earned Schedule” is identical as “Earned Value”
- Instead of using cost for measuring schedule performance, we will use “time”
- “Earned Schedule” is determined by comparing Earned Value to the performance baseline (= planned value). The time associated with the Earned Value is found from the PV-curve.
- So we project the Earned Value onto the Planned Value curve

EV vs. ES - Graphical Display



Earned Value

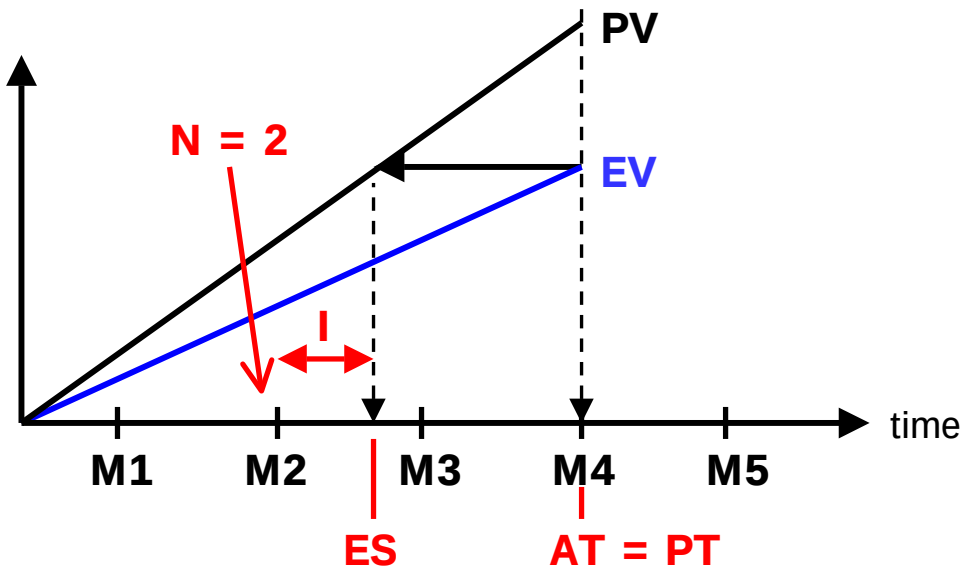


Earned Schedule

ES Calulation

$$ES = N + (EV - PV_N) / (PV_{N+1} - PV_N)$$

- ES = Earned Schedule
- N = time increment of PV that is less than current PV
- PV_N = Planned Value at time N
- PV_{N+1} = Planned Value at time N + 1



ES Derived Metrics

Derived metrics, similar to the “classical” Earned Value:

SV(t) = ES - AT

- “positive” = ahead of schedule
- “negative” = lagging

SPI(t) = ES / AT

- “>1” = ahead of schedule
- “>1” = lagging

EDAC = AT + Estimated Remaining Time to Completion
= AT + (TAC - ES) / P.F.

ES Forecasting

- EDR according to plan (P.F. = 1)

  EDACes1 = AD + (TAC - ES)

- EDR with continued SPI(t) performance

  EDACes2 = AD + (TAC - ES) / SPI(t)

- EDR with continued SPI performance

  EDACes3 = AD + (TAC - ES) / SCI(t)

- Corrective Action Metric

  TCSPI(t) = (TAC - ES) / (TAC - AT)

Method 3: example

Scope: install 350 TFT Monitors, 50 monitors / week
TAC: 7 weeks
BAC: 35.000 € (100 € / monitor)

	W1	W2	W3	W4	W5	W6	W7
PV	5.000	10.000	15.000	20.000	25.000	30.000	35.000
AC	3.750	9.100	12.750				
EV	3.500	8.500	12.000				
N	1	2	3	4	5	6	7
ES	0,70	1,70	2,40				
SPI(t)	0,70	0,85	0,80				
SCI(t)	0,65	0,79	0,75				

EDACes1 = AD + (TAC - ES) = 3 + (7 - 2,4) = 7,6 weeks
EDACes2 = AD + (TAC - ES) / SPI(t) = 8,75 weeks
EDACes3 = AD + (TAC - ES) / SCI(t) = 9,33 weeks

TCSPI(t) = (TAC - ES) / (TAC - AT) = (7 - 2,4) / (7 - 3) = 1,15

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Summary of Results

		Forecast Method		
Case		**Anbari (*)**	**Jacob (**)**	**Lipke (***)**
1	EDAC = new	re-schedule		
2	EDAC as originally planned	monitor schedule		
3	EDAC is very high	re-schedule		
4	EDR according to plan	7,60	7,60	7,60
5	EDR will follow current SPI trend	8,75	8,75	8,75
6	EDR will follow current SCI trend	9,33	9,33 (9,14)	9,33
		Planned Value Rate	**Earned Duration**	**Earned Schedule**

- All results are the same!
- Why?

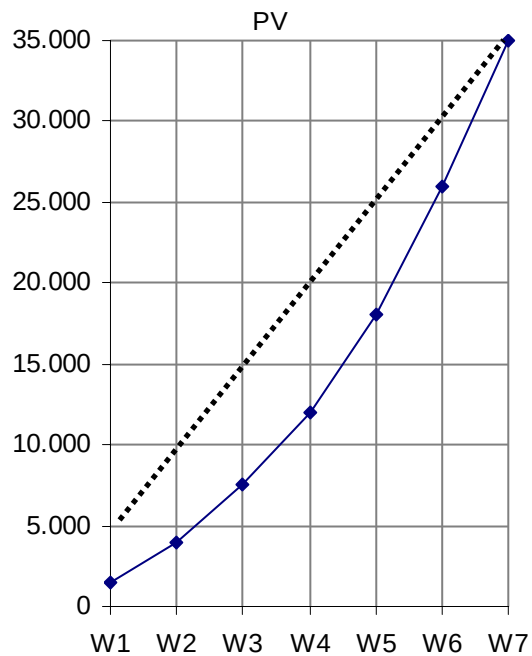
Why are Results the Same?

- All methods apply the same basic parameters (EV, PV, ...)
- All methods are based on sound analytical thought
- Formulas used in methods are linear, as well as the used PV in the example.
- If the PV is non-linear, differences between the methods could be introduced. These “errors” can be reduced by using smaller time increments (more reporting periods)

Non Linear PV Rate

Scope: install 350 TFT Monitors, including learning curve
TAC: 7 weeks
BAC: 35.000 € (100 € / monitor)

	W1	W2	W3	W4	W5	W6	W7
PV	1.500	4.000	7.500	12.000	18.000	26.000	35.000
AC	3.750	9.100	12.750				
EV	3.500	8.500	12.000				
SPI	2,33	2,13	1,60				
CPI	0,93	0,93	0,94				
SCI	2,18	1,98	1,51				
AT	1	2	3	4	5	6	7
ES	1,80	4,00	4,00				
SPI(t)	1,80	2,00	1,33				
SCI(t)	1,68	1,87	1,25				



Results - Non Linear PV - W3

Case		Forecast Method		
		Anbari (*)	**Jacob (**)**	**Lipke (***)**
1	EDAC = new	re-schedule		
2	EDAC as originally planned	monitor schedule		
3	EDAC is very high	re-schedule		
4	EDR according to plan	6,10	5,20	6,00
5	EDR will follow current SPI trend	4,38	4,38	5,25
6	EDR will follow current SCI trend	4,65	4,65	5,39
		Planned Value Rate	**Earned Duration**	**Earned Schedule**

Discussion

- Results are no longer identical, and depends on used method.
- The Earned Schedule method appears to forecast higher durations, compared with other methods.
- But most important:

  So far we applied the formulas to a single activity.

  How do the methods behave on higher WBS levels?

  Which method is the best?

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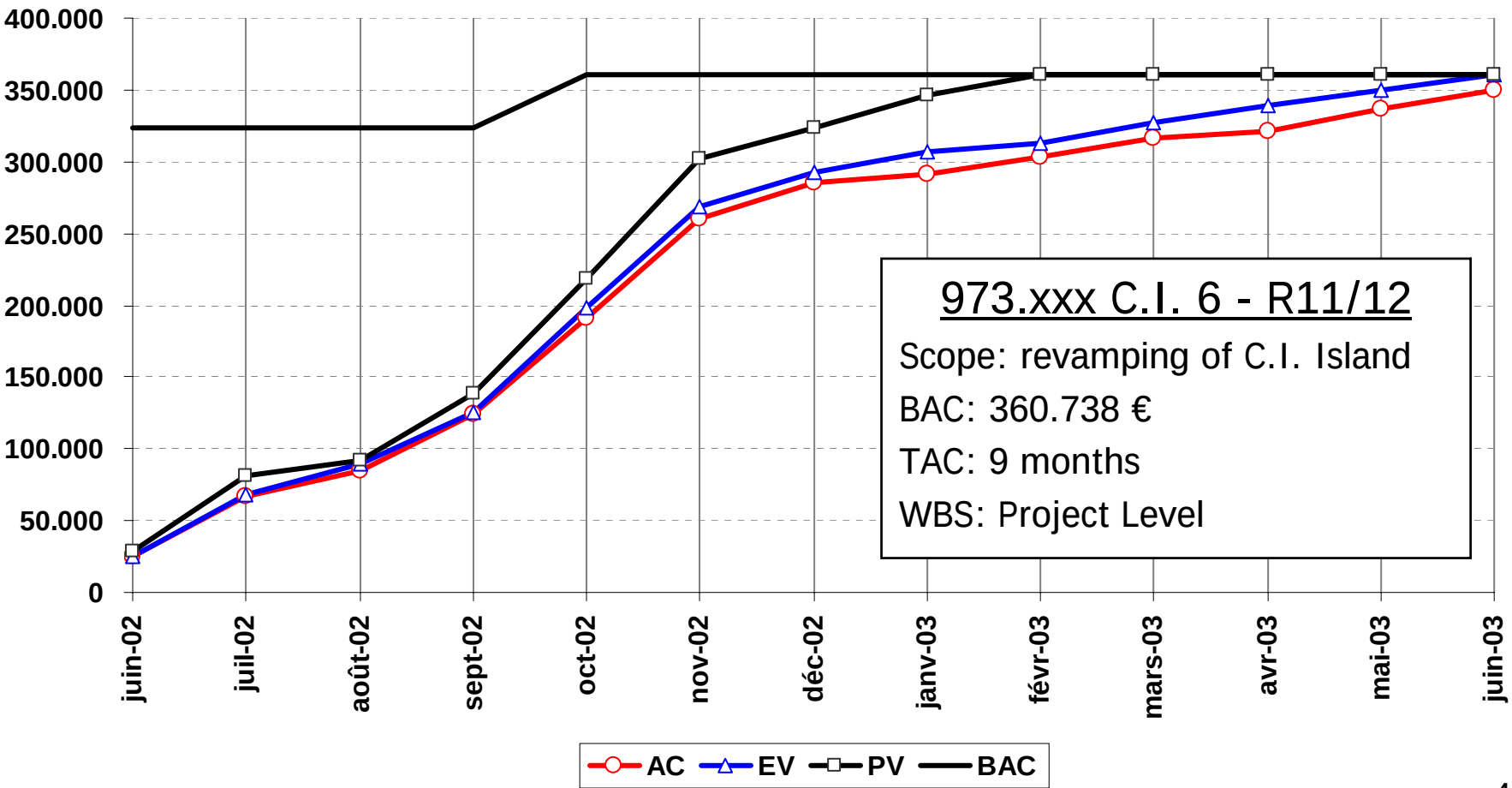
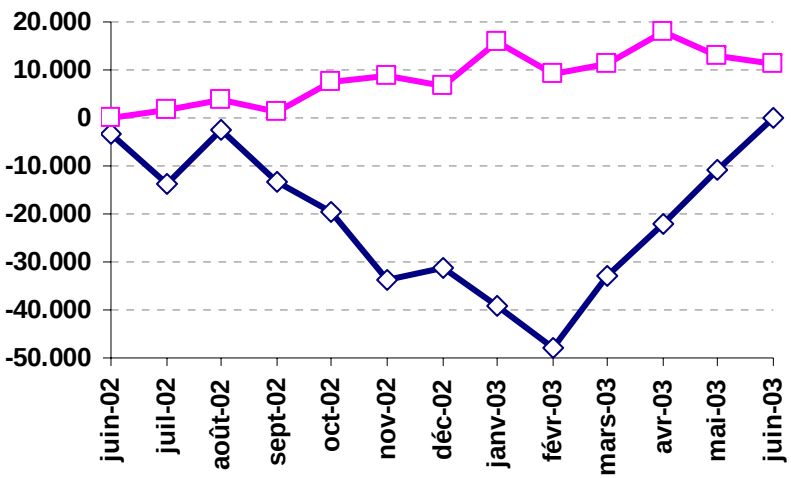
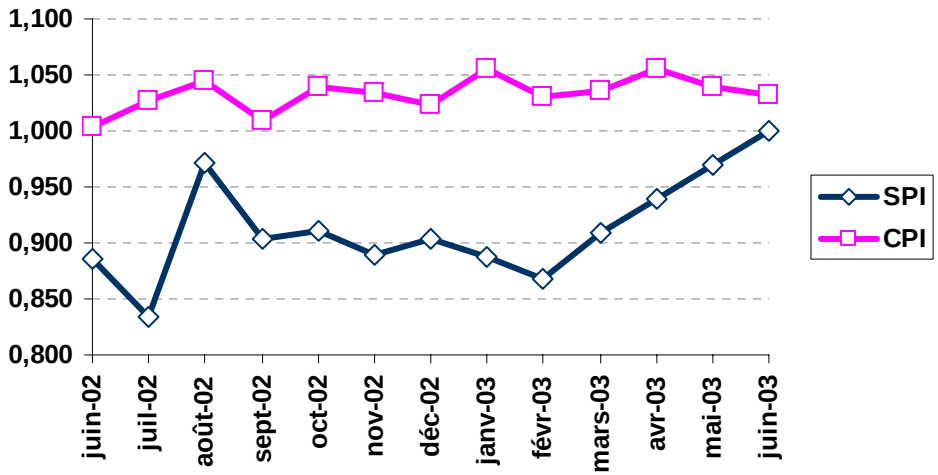
Case Study


400.000
350.000
300.000
250.000
200.000
150.000
100.000
50.000
0
juin-02
juil-02
août-02
sept-02
oct-02
nov-02
déc-02
janv-03
févr-03
mars-03
avr-03
mai-03
juin-03
AC
EV
PV
BAC
973.xxx C.I. 6 - R11/12
Scope: revamping of C.I. Island
BAC: 360.738 €
TAC: 9 months
WBS: Project Level

Case Study - EV Metrics

	juin-02	juil-02	août-02	sept-02	oct-02	nov-02	déc-02	janv-03	févr-03	mars-03	avr-03	mai-03	juin-03
AC	25.567	66.293	78.293	124.073	191.367	259.845	285.612	290.843	303.489	316.431	320.690	336.756	349.379
EV	25.645	68.074	89.135	125.244	198.754	268.763	292.469	306.725	312.864	327.694	338.672	349.861	360.738
PV	28.975	81.681	91.681	138.586	218.141	302.478	323.632	345.876	360.738	360.738	360.738	360.738	360.738
SV	-3.330	-13.607	-2.546	-13.342	-19.387	-33.715	-31.163	-39.151	-47.874	-33.044	-22.066	-10.877	0
SPI	0,89	0,83	0,97	0,90	0,91	0,89	0,90	0,89	0,87	0,91	0,94	0,97	1,00





Case Study - ES Calulation

	juin-02	juil-02	août-02	sept-02	oct-02	nov-02	déc-02	janv-03	févr-03	mars-03	avr-03	mai-03	juin-03
AC	25.567	66.293	78.293	124.073	191.367	259.845	285.612	290.843	303.489	316.431	320.690	336.756	349.379
EV	25.645	68.074	89.135	125.244	198.754	268.763	292.469	306.725	312.864	327.694	338.672	349.861	360.738
PV	28.975	81.681	91.681	138.586	218.141	302.478	323.632	345.876	360.738	360.738	360.738	360.738	360.738
SV	-3.330	-13.607	-2.546	-13.342	-19.387	-33.715	-31.163	-39.151	-47.874	-33.044	-22.066	-10.877	0
SPI	0,89	0,83	0,97	0,90	0,91	0,89	0,90	0,89	0,87	0,91	0,94	0,97	1,00

AT	1	2	3	4	5	6	7	8	9	10	11	12	13
ES	0,885	1,742	2,745	3,716	4,756	5,600	5,881	6,201	6,491	7,183	7,676	8,268	9,000
PT	1	2	3	4	5	6	7	8	9	9	9	9	9
SV(t)	-0,115	-0,258	-0,255	-0,284	-0,244	-0,400	-1,119	-1,799	-2,509	-2,817	-3,324	-3,732	-4,000
SPI(t)	0,89	0,87	0,92	0,93	0,95	0,93	0,84	0,78	0,72	0,72	0,70	0,69	0,69

Example ES Calculation (period 09/02, 4th period):

ES = 3 + (125.244 - 91.681) / (138.586 - 91.681) = 3,716 months

Example ES Calculation (period 01/03, 8th period):

ES = 6 + (306.725 - 302.478) / (323.632 - 302.478) = 6,201 months

Case Study - ES Calulation

	juin-02	juil-02	août-02	sept-02	oct-02	nov-02	déc-02	janv-03	févr-03	mars-03	avr-03	mai-03	juin-03
AT	1	2	3	4	5	6	7	8	9	10	11	12	13
ES	0,885	1,742	2,745	3,716	4,756	5,600	5,881	6,201	6,491	7,183	7,676	8,268	9,000
PT	1	2	3	4	5	6	7	8	9	9	9	9	9
SV(t)	-0,115	-0,258	-0,255	-0,284	-0,244	-0,400	-1,119	-1,799	-2,509	-2,817	-3,324	-3,732	-4,000
SPI(t)	0,89	0,87	0,92	0,93	0,95	0,93	0,84	0,78	0,72	0,72	0,70	0,69	0,69

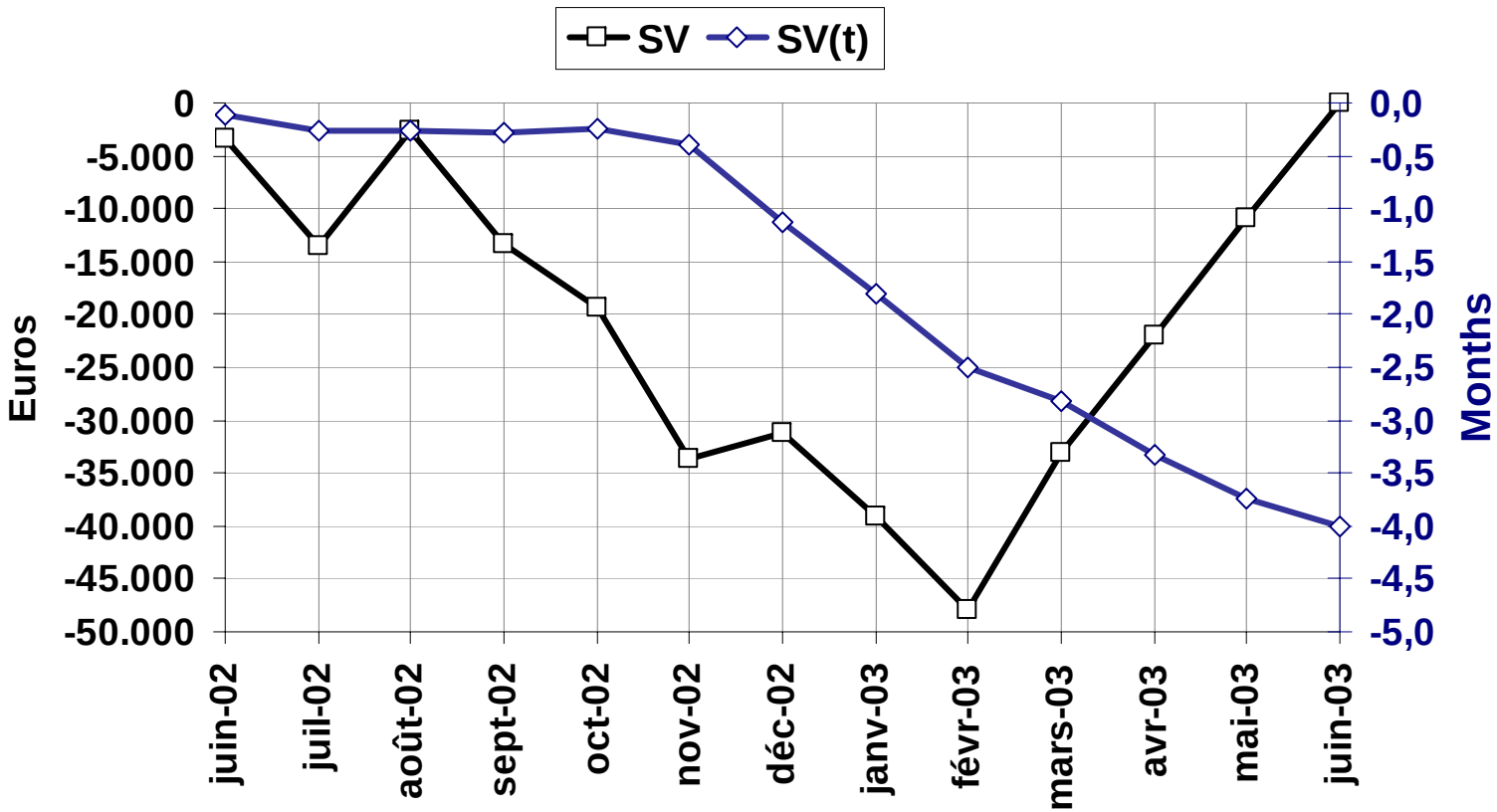
Example SPI(t) Calculation (period 12/02, 7th period):

- ⇨ SPI(t) = 5,881 / 7 = 0,84
- ⇨ Project is progressing at at a rate of 0,78 months for each month of actual time

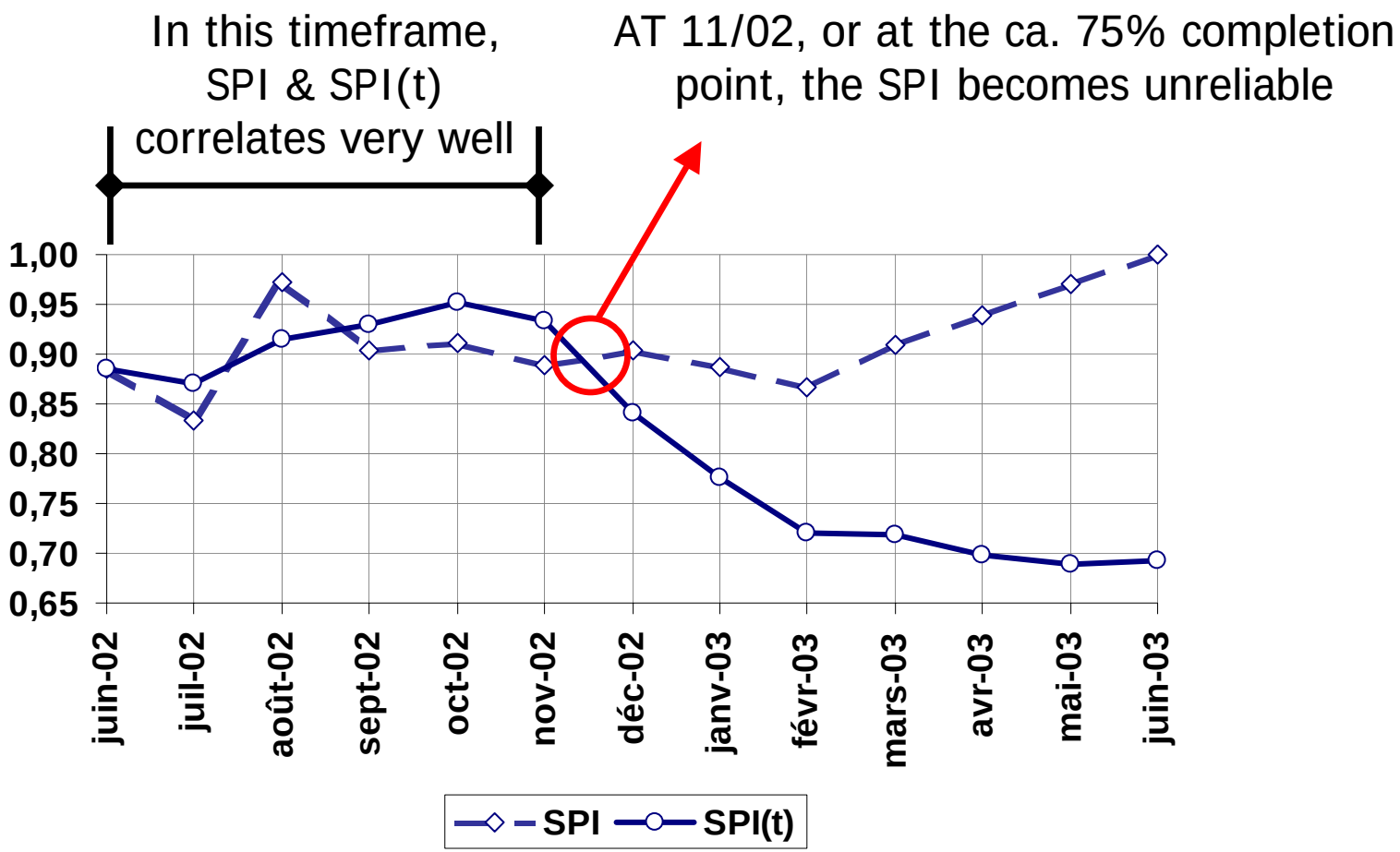
Example SV(t) Calculation (period 12/02, 7th period):

- ⇨ SV(t) = 5,881 - 7 = - 1,119
- ⇨ Project lags it expected performance by 1,119 months

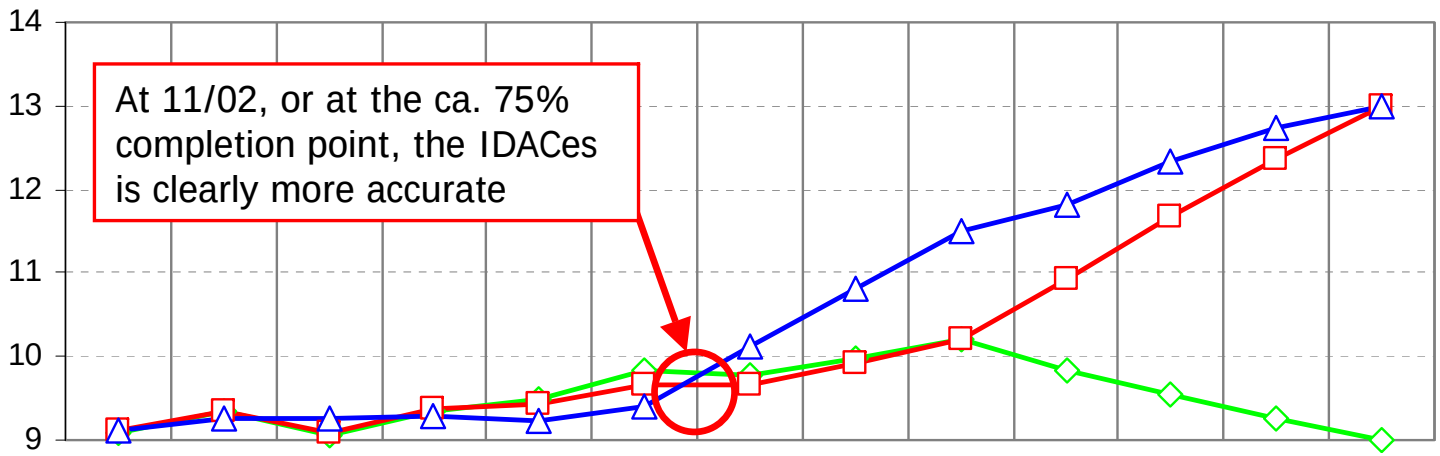
Case Study - SV vs. SV(t)



Case Study - SPI vs. SPI(t)



Case Study - EDAC P.F. = 1



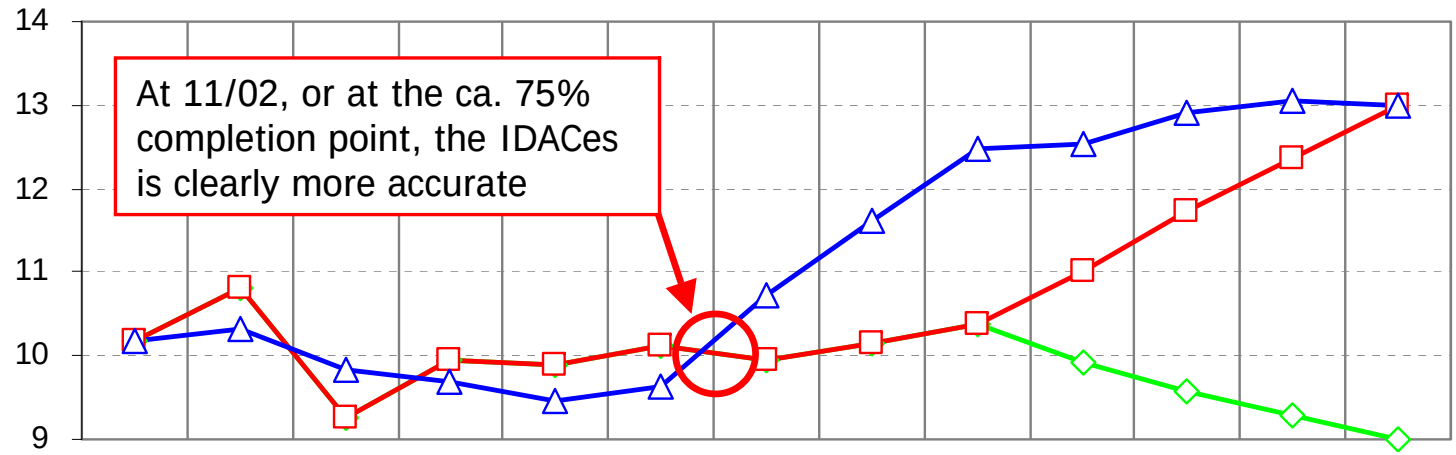
	06/02	07/02	08/02	09/02	10/02	11/02	12/02	01/03	02/03	03/03	04/03	05/03	06/03
EDACpv	9,08	9,34	9,06	9,33	9,48	9,84	9,78	9,98	10,19	9,82	9,55	9,27	9,00
EDACed	9,11	9,33	9,08	9,39	9,44	9,67	9,67	9,91	10,19	10,92	11,67	12,36	13,00
EDACes	9,11	9,26	9,25	9,28	9,24	9,40	10,12	10,80	11,51	11,82	12,32	12,73	13,00

PV Rate Method: correlates well at early stages, but is useless towards the end

ED Method: correlates well till 75% completion point

ES Method: predicts more accurate towards the final stages

Case Study - EDAC P.F. = SPI



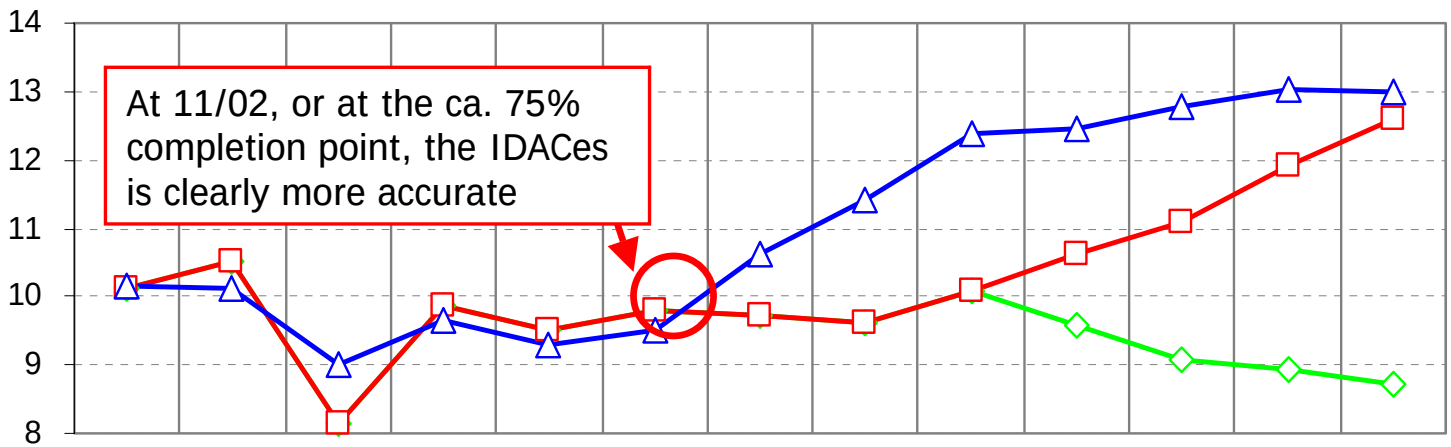
	06/02	07/02	08/02	09/02	10/02	11/02	12/02	01/03	02/03	03/03	04/03	05/03	06/03
EDACpv	10,17	10,80	9,26	9,96	9,88	10,13	9,96	10,15	10,38	9,91	9,59	9,28	9,00
EDACed	10,17	10,80	9,26	9,96	9,88	10,13	9,96	10,15	10,38	11,01	11,72	12,37	13,00
EDACes	10,17	10,33	9,83	9,69	9,46	9,64	10,71	11,61	12,48	12,53	12,90	13,06	13,00

PV Rate Method: correlates well at early stages, but is useless towards the end

ED Method: correlates well till 75% completion point

ES Method: predicts more accurate towards the final stages

Case Study - EDAC P.F. = SCI



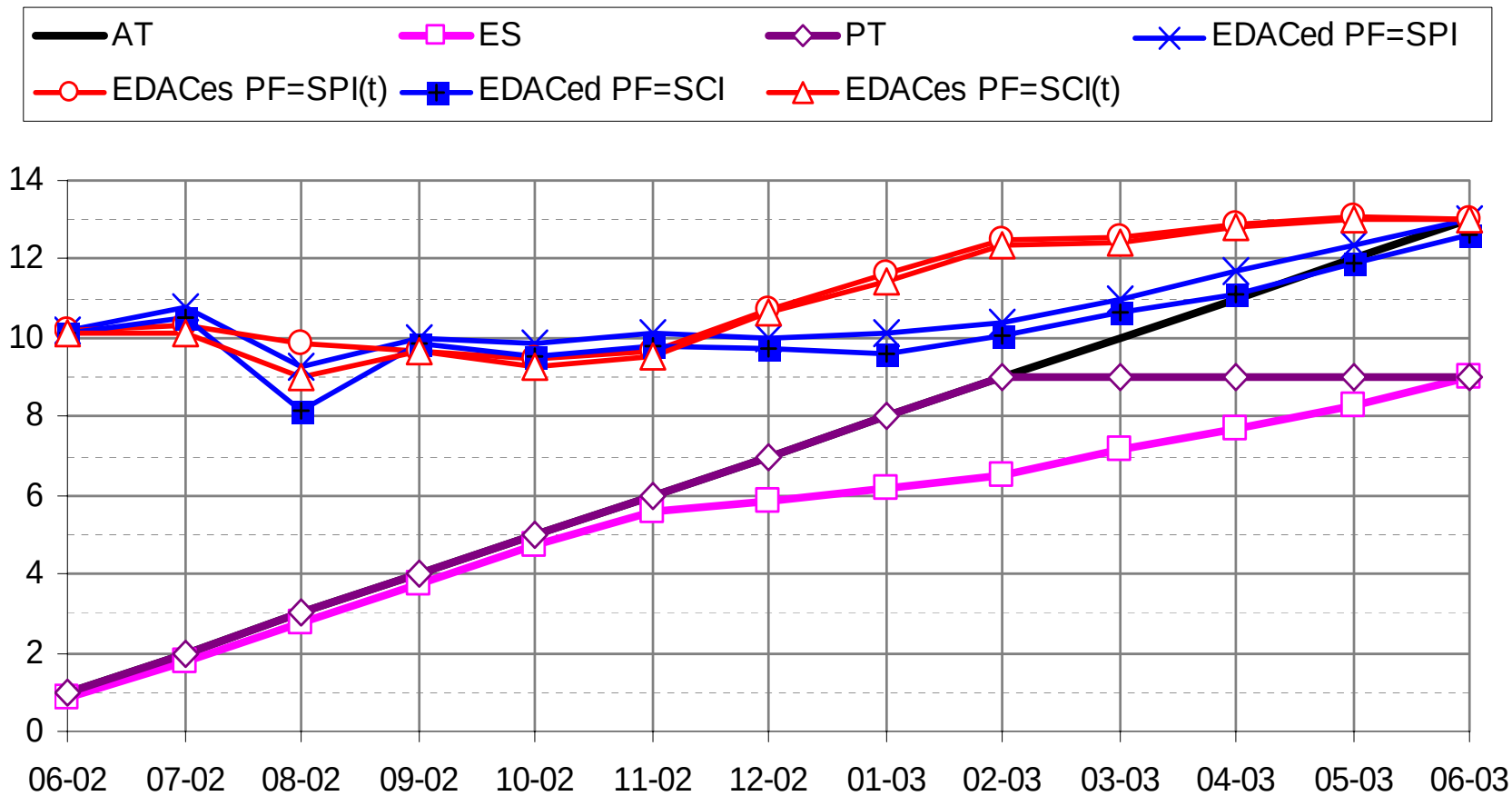
	06/02	07/02	08/02	09/02	10/02	11/02	12/02	01/03	02/03	03/03	04/03	05/03	06/03
EDACpv	10,14	10,52	8,13	9,87	9,51	9,79	9,73	9,62	10,07	9,57	9,08	8,93	8,72
EDACed	10,14	10,52	8,13	9,87	9,51	9,79	9,73	9,62	10,07	10,63	11,09	11,91	12,59
EDACes	10,14	10,12	9,00	9,64	9,30	9,52	10,62	11,42	12,37	12,44	12,80	13,02	13,00

PV Rate Method: correlates well at early stages, but is useless towards the end

ED Method: correlates well till 75% completion point

ES Method: predicts more accurate towards the final stages

Case Study - ED vs. ES

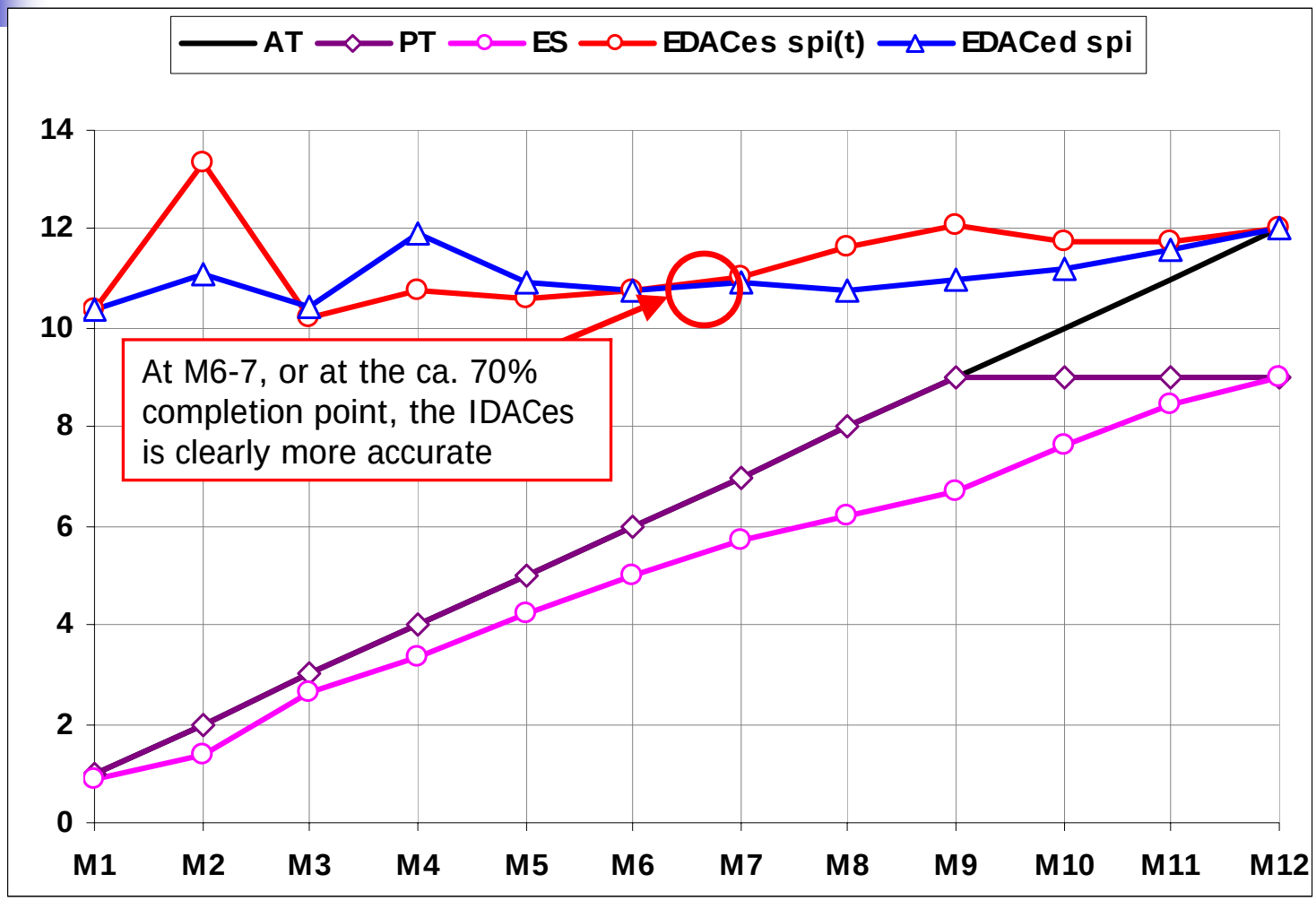


Discussion

- **During early and middle project stage**
  - All methods seems to correlate well
  - All methods produce same results within the same range

- **During late project stage**
  - The PV Rate method is useless and meaningless (at project level, the PV is non-linear, but follows a S-curve)
  - The ED method tends to underestimate the final duration (remember the strange SPI behaviour, the “grey area”)
  - The ES method produces the best forecast results

Other example (presentation 2)



Agenda

- Introduction
- Schedule performance indicators
- Schedule forecasting generic formula
- Method 1: Use of PV Rate (Planned Value Rate)
- Method 2: Use of ED (Earned Duration)
- Method 3: Use of ES (Earned Schedule)
- Discussion of different methods
- Forecasting at project level - Case Study
- Conclusion

Schedule Forecasting

- The use of EV metrics to forecast the schedule should happen at least on the overall project level (early warning signal):
  - for early and middle poject stages, each method can be used
  - for late project stage (mostly the most important period), the ES method produces clearly the best results
- When performance is poor, a “drill-down” into the lower WBS levels will help detect the troubled tasks
- If tasks are on the critical path, evaluation of the forecasted duration impact ca be made

- The use of “earned duration” and “earned schedule” metrics is NOT a replacement for scheduling tools such as PERT, CPM, Monte Carlo scheduling

Forecasting Methods

At early and middle stage	Forecast Method		
	PV Rate	**ED**	**ES**
EDR according to plan	TAC - TV	TAC + AD (1 - SPI)	AD + (TAC - ES)
EDR will follow current SPI trend	TAC / SPI	TAC / SPI	AD + (TAC - ES) / SPI(t)
EDR will follow current SCI trend	TAC / SCI	TAC / SCI	AD + (TAC - ES) / SPI(t)

At late stage	Forecast Method		
	PV Rate	**ED**	**ES**
EDR according to plan	---	---	AD + (TAC - ES)
EDR will follow current SPI trend	---	---	AD + (TAC - ES) / SPI(t)
EDR will follow current SCI trend	---	---	AD + (TAC - ES) / SPI(t)

Conclusion

- SPI & SV indicators are flawed and exhibit strange behaviour over the final third of the project, and are as a consequence not reliable.
- The use of the “Earned Schedule” method provides indicators SPI(t) & SV(t), which behave correctly during the project life.
- It has been demonstrated that the use of ES metrics provides a more reliable forecast for total project duration.
- Why not starting to use the “earned schedule method” as a standard procedure ?