IF TIME IS MONEY, ACCURACY PAYS DIVIDENDS!

AN OVERVIEW OF PAST AND FUTURE PROJECT MANAGEMENT RESEARCH

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Director, EVM Europe Association

Agenda

1. Intro
2. Past / Recent Work
3. Future Work
4. Relation with PMI Standards
5. Conclusion

The start

2001: when a project manager meets an academic

Sharing experiences about project controls www.evm-europe.eu

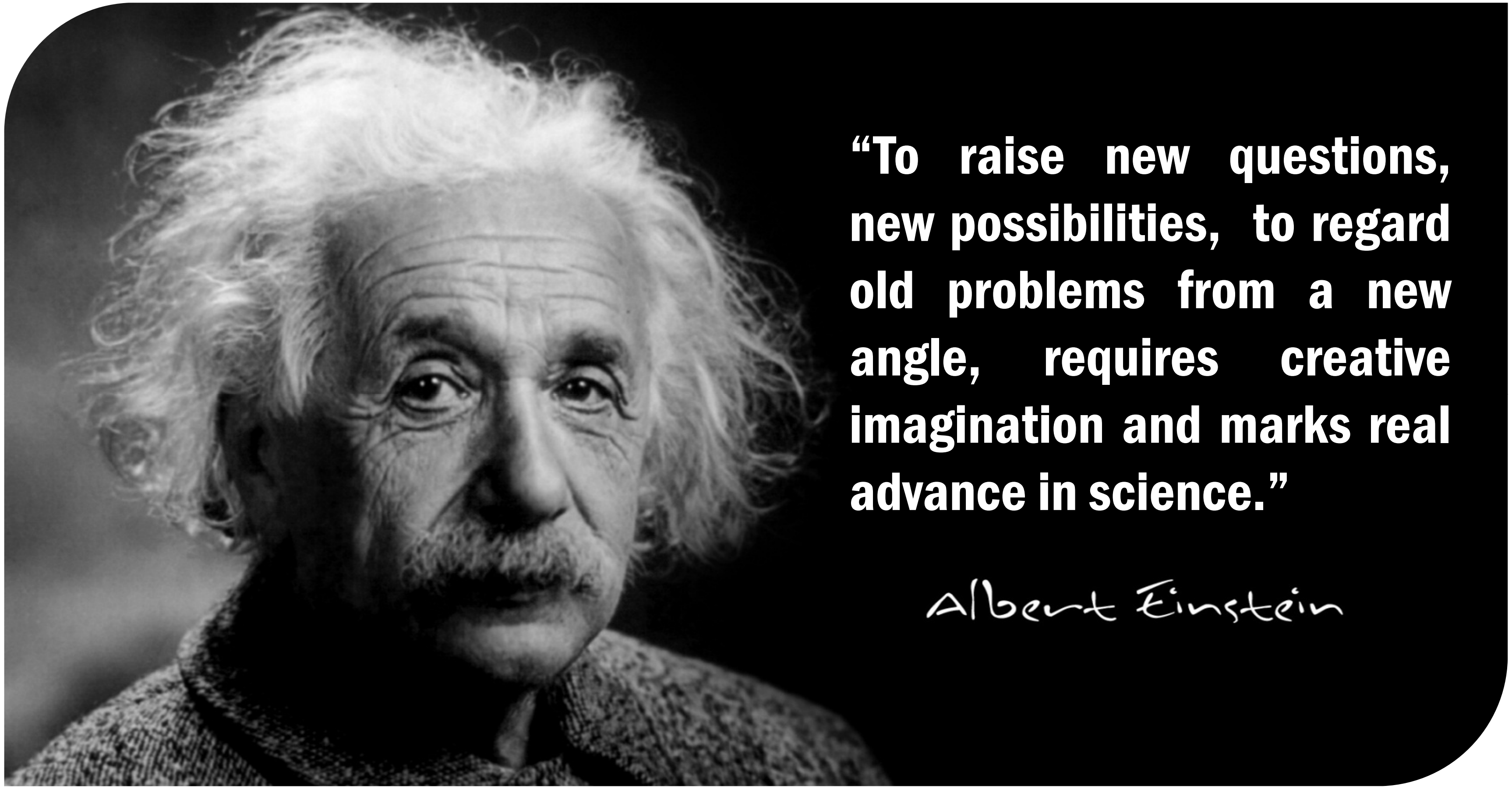
2009: creation of EVM Europe Association

Platform to share project control topics between professionals & academics www.evm-europe.eu

RESEARCH meets PRACTICE

Conferences to be organised with universities, business schools

What / why research?



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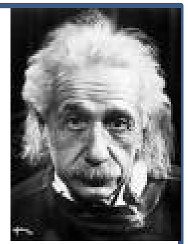


... to regard old problems ...

- CPM forecasting is optimistic (and difficult to do)
- EVM focus is cost, but claims to integrate both cost & schedule

... from a new angle ...

- The use of EV-based methods to augment the efficiency of schedule analysis & schedule forecasting

... requires creative imagination ...

- Investigate these methods by using academic state-of-the-art methodologies

... and marks real advance in science ...

- Does it lead to best practices?

Assumptions

- Awareness of the 10 PMBOK knowledge areas
  especially “project time management”

- Awareness of the 47 PMBOK process groups
  especially the montoring & controlling process group “control schedule”

- Basic knowledge of EVM, ES, SRA

Agenda

1. Intro

2. Past / Recent Work

- Study 1: Summarising EV-based duration forecasting methods
- Study 2: Measuring Time – A simulation study
- Study 3: Project control efficiency

3. Future Work

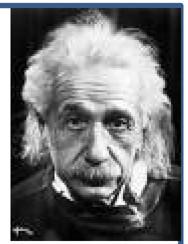
4. Relation with PMI Standards

5. Conclusion

Study 1: Summarising methods

Vandevoorde, S. and Vanhoucke, M., 2006, "A comparison of different project duration forecasting methods using earned value metrics", International Journal of Project Management, 24, 289-302.

Study 1



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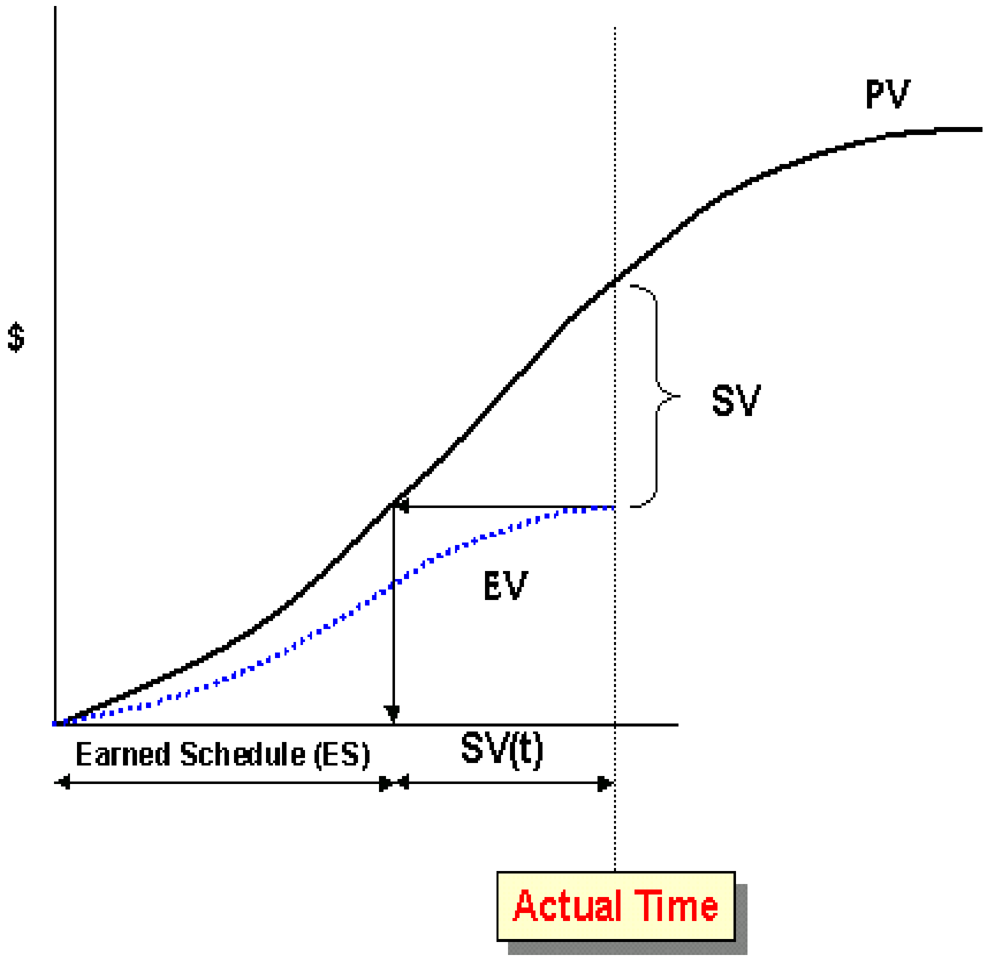
EV-based methods

Planned Value	Earned Duration	Earned Schedule
Anbari *Earned value method and extensions* *Project Management Journal 2003; 34*	*Jacob* *Forecasting project schedule completion with earned value metrics* *The Measurable News 2003 (March)*	*Lipke* *Schedule is different* *The Measurable News 2003 (March)*
TV = Time Variance TV = SV / PVrate	ED = Earned Duration ED = AD * SPI	ES = Earned Schedule SV(t) / SPI(t)
		www.earnedschedule.com

Schedule performance indicators



Find t such that EV ≥ PVn and EV < PVn+1

$$ES = N + \frac{(EV - PVn)}{(PVn+1 - PVn)}$$

	SV	SV(t)
Formula	EV - PV	ES - AT
Units	euros	time
Project end	always 0	real performance

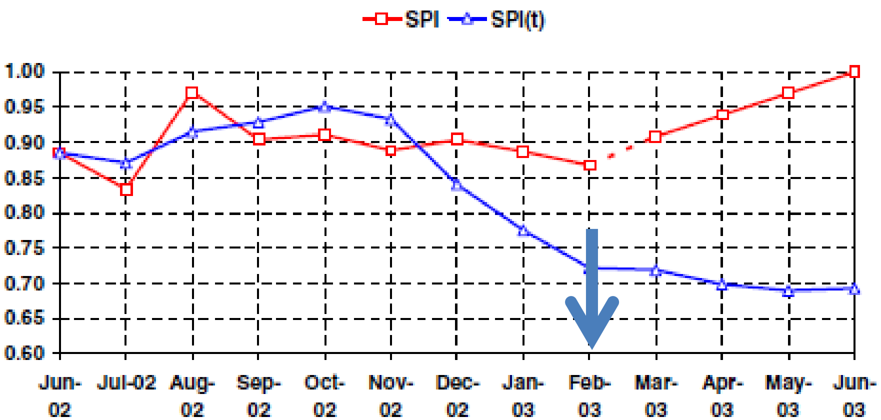
	SPI	SPI(t)
Formula	EV / PV	ES / AT
Units	none	none
Project end	always 1	real performance

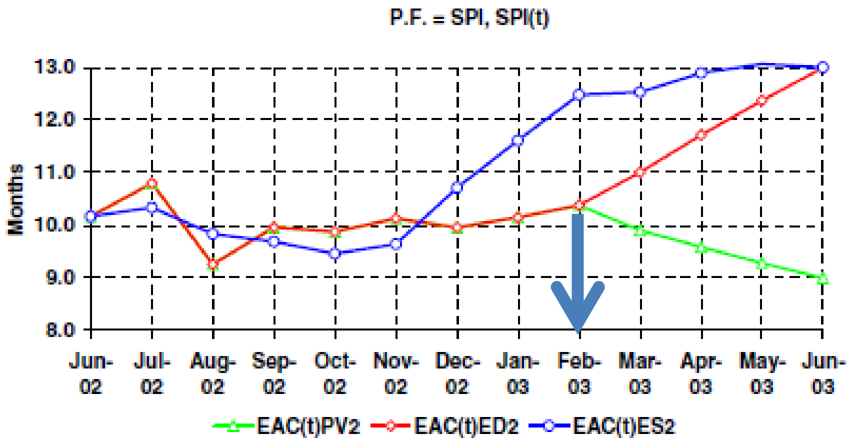
EV-based time forecasting methods

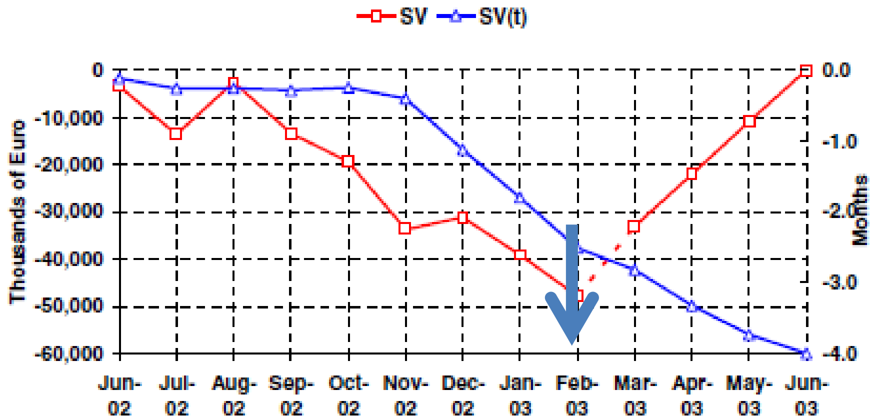
		Planned Value	Earned Duration	Earned Schedule
	Indicator	SV / SPI	SV / SPI	SV(t) / SPI(t)
	Generic time forecast formula: EAC(t) = AD + PDWR / P.F.			
Future expected performance	P.F. = 1	PV1 = PD – TV	ED1 = PD + AD * (1-SPI)	ES1 = AD + (PD – ES)
	P.F. = SPI/SPI(t)	PV2 = PD / SPI	ED2 = PD / SPI	ES2 = PD / SPI(t)
	P.F. = CSI/CSI(t)	PV3 = PD / SCI	ED3 = AD * (1 – 1/CPI + 1/SCI)	ES3 = AD + (PD – ES)/SCI(t)
		To Complete Performance Index		
		---	TCSPI = (PD – ED) / (PD – AD)	TCSPI(t) = (PD – ES) / (PD – AD)
			Note: if AD > PD then PD = AD	

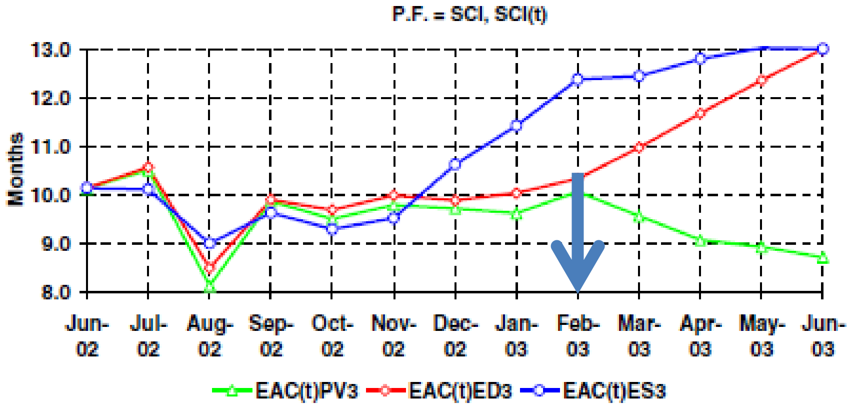
Forecast real life example

Project	Category	Budget at completion	Cost at completion	Planned duration	Actual duration
Revamp check in	Late finish cost under-run	€ 360,738	€ 349,379	9	13









IJPM Paper

- The 1st state of the art paper summarising duration forecasting methods by using EV/ES

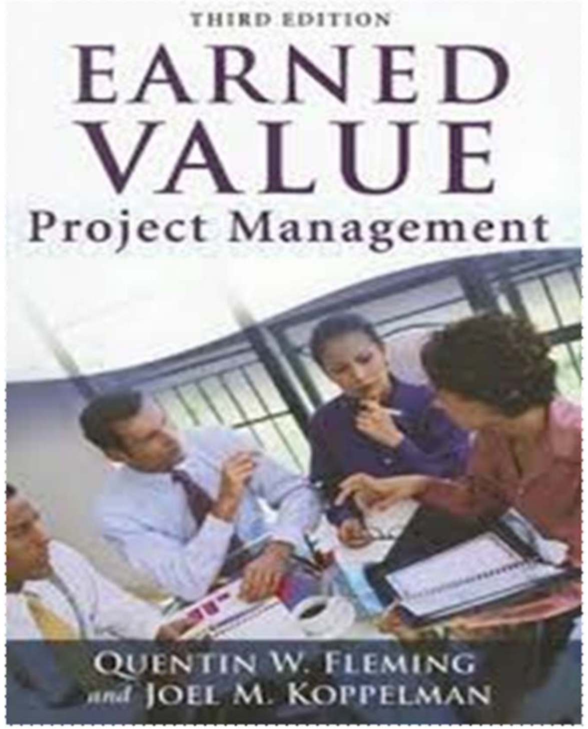
- Conclusion:

  Earned Schedule was the only method which showed satisfying and reliable results during the whole project duration.

- Recommendation:

  In order to generalise the results found in this study, we will test the three concepts on projects based on a full factorial simulation experiment, rather than relying on a (small) set of real life projects.

Critics – EVPM, 3th Ed., 2006



"There are some professionals in the field who feel that the earned value schedule position can be used to predict the final completion date for the project. The authors do not endorse this theory, nor have they ever read any scientific studies that support this position

TRUE

Earned Value Project Management,
3th Edition, 2006

Study 2: Measuring Time

Study 2: references

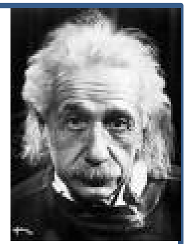
Vanhoucke, M. and Vandevoorde, S., 2007, "A simulation and evaluation of earned value metrics to forecast the project duration",
Journal of the Operational Research Society, 58, 1361–1374.

Vanhoucke, M. and Vandevoorde, S., 2007, "Measuring the accuracy of earned value/earned schedule forecasting predictors", The Measurable News, Winter, 26-30.

Vanhoucke, M., 2008, "Project tracking and control: can we measure the time?", Projects and Profits, August, 35-40.

Vanhoucke, M. and Vandevoorde, S., 2009, "Forecasting a project's duration under various topological structures", The Measurable News, Spring, 26-30.

Study 2



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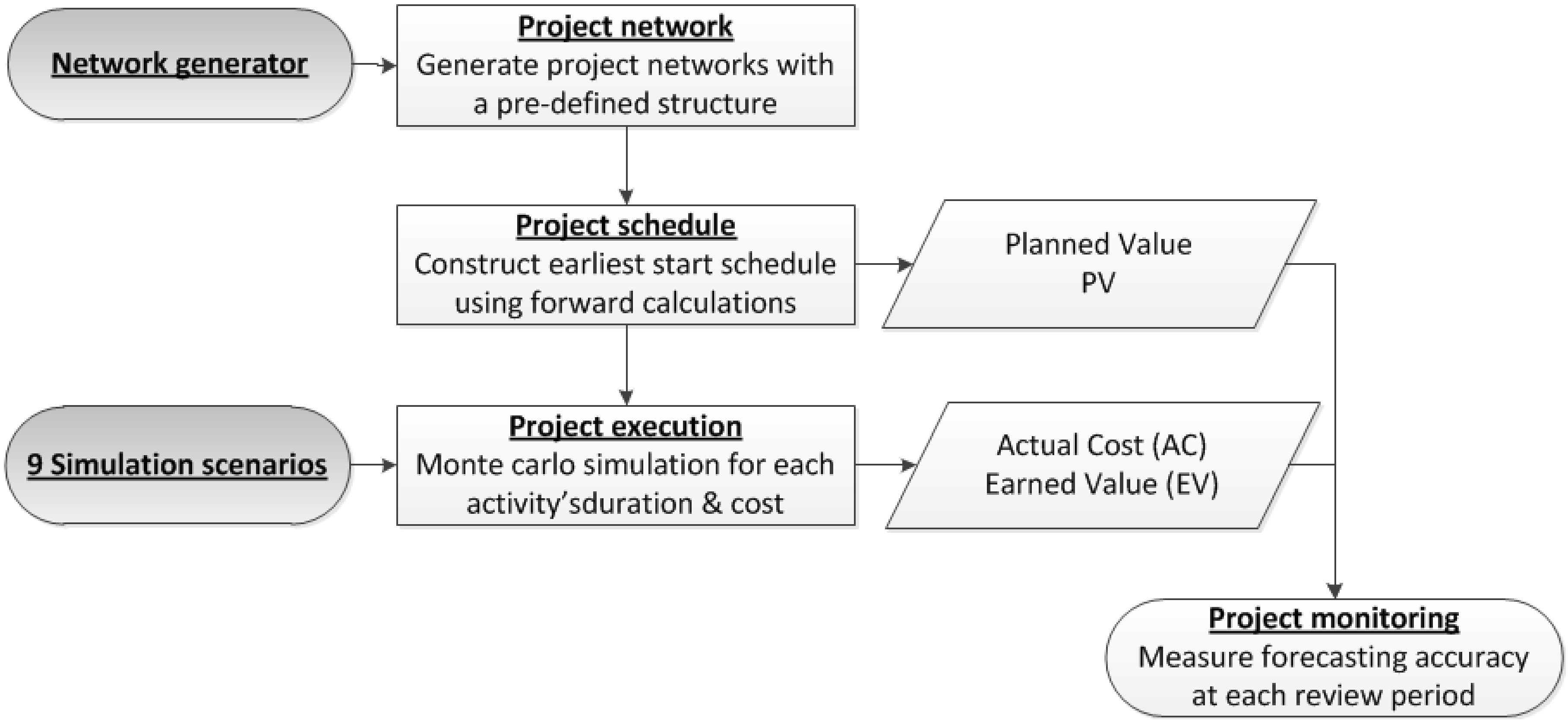
– Does it lead to best practices?

Test methodology



Create database : network generator

- Create a database of networks with a controlled topological structure by the use of a network generator.

- So we guarantee we have a very large set of networks that can and might occurr in practice

- To control the design of the networks topological indicators are used.

- *Based on: Vanhoucke, M., Coelho, J.S., Debels, D., Maenhout, B. and Tavares, L.V., 2008, "An evaluation of the adequacy of project network generators with systematically sampled networks", European Journal of Operational Research, 187, 511–524*

Network indicators

SP ∈ [0,1]: measures how closely the network lies to a parallel or serial network.

$$\text{SP} = 1 \; if \; n = 1$$

$$\text{SP} = \frac{m-1}{n-1} \; if \; n > 1$$

$$n = number\ of\ activities\ in\ network$$
$$\text{m} = number\ of\ activities\ along\ the\ longest\ path$$

AD ∈ [0,1]**:** measures the distribution of the activities along the network.

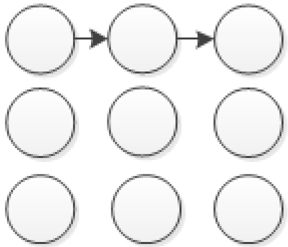
LA ∈ [0,1]: measures the length of each precedence relation between two activities.

TF ∈ [0,1]: measures the degrees of freedom for each activity. (topological float)

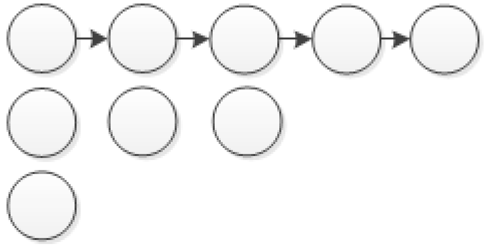
Serial / Parallel - Indicator

$SP = \frac{1-1}{9-1} = 0$

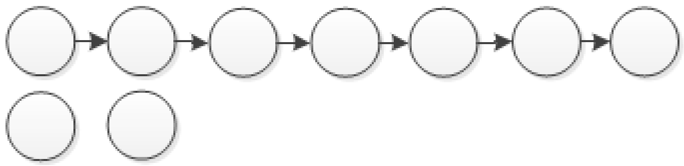
$SP = \frac{3-1}{9-1} = 0{,}25$



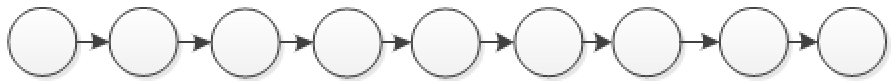
$SP = \frac{5-1}{9-1} = 0{,}5$



$SP = \frac{7-1}{9-1} = 0{,}75$



$SP = \frac{m-1}{n-1} = \frac{9-1}{9-1} = 1$

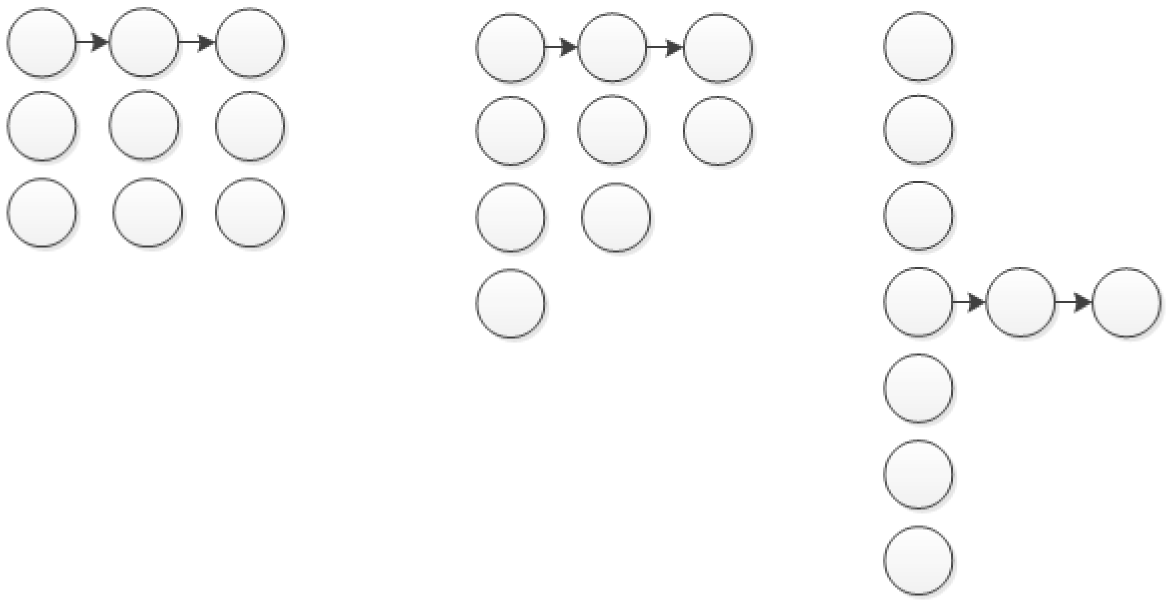


AD Indicator

$SP = 0{,}25$
$\mathrm{AD} = 0$

$SP = 0{,}25$
$\mathrm{AD} = 0{,}25$

$SP = 0{,}25$
$\mathrm{AD} = 1$

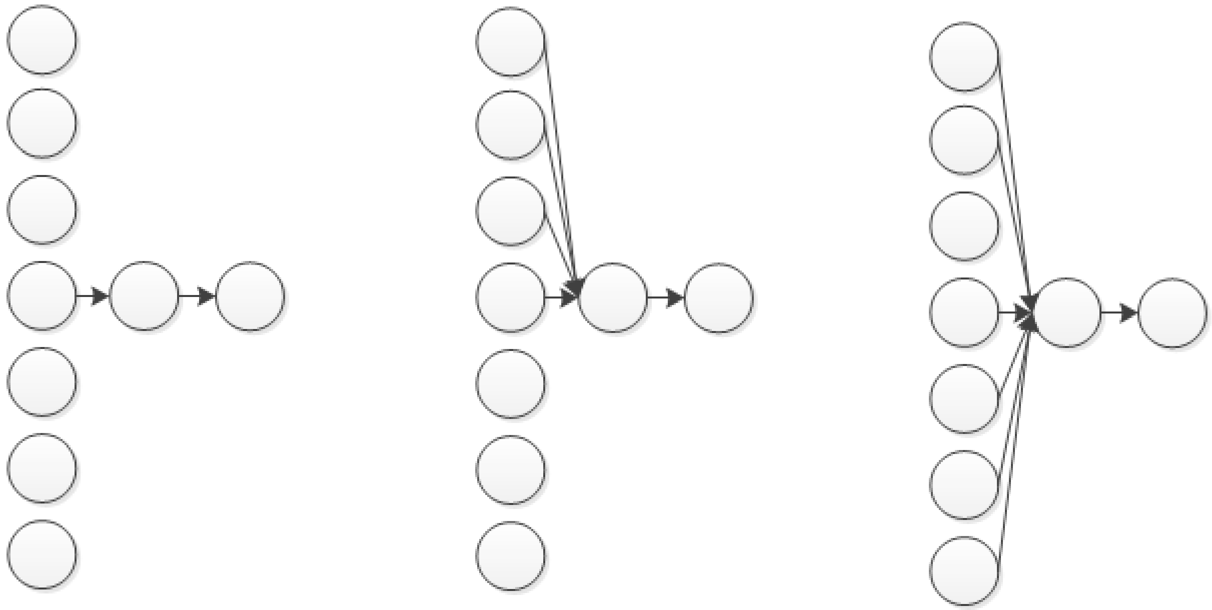


LA Indicator

$SP = 0{,}25$
$\mathrm{AD} = 1$
$\mathrm{LA} = 0$

$SP = 0{,}25$
$\mathrm{AD} = 1$
$\mathrm{LA} = 0{,}5$

$SP = 0{,}25$
$\mathrm{AD} = 1$
$\mathrm{LA} = 1$



Topological indicators in action

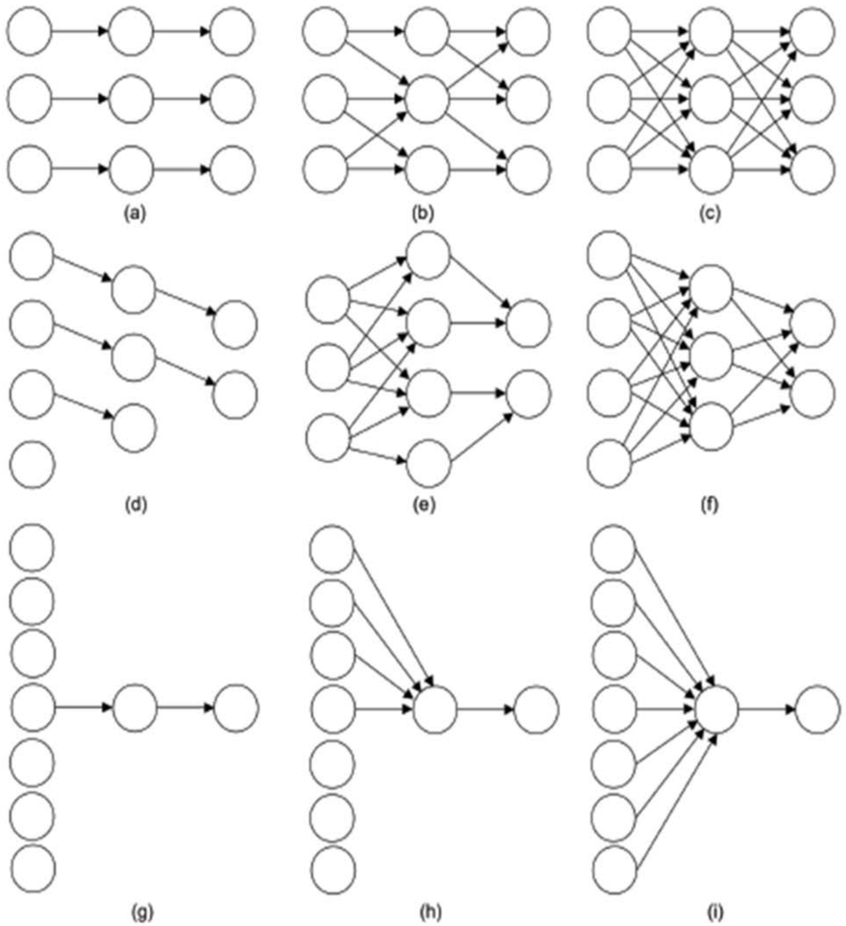
Project Network

Serial/Parallel (SP)

Activity Distribution (AD)

Length of Arcs (LA)

Topological Float (TF)



9 execution scenarios

NON CRITICAL ACTIVITIES	CRITICAL ACTIVITIES: EARLY	CRITICAL ACTIVITIES: ON TIME	CRITICAL ACTIVITIES: LATE
EARLY	1	4	7
ON TIME	2	5	8
LATE	3	6	9

9 execution scenarios

NON CRITICAL ACTIVITIES \ CRITICAL ACTIVITIES	EARLY	ON TIME	LATE
EARLY	1 RD < PD SPI(t) > 1	4 RD = PD SPI(t) > 1	7 RD > PD SPI(t) > 1
ON TIME	2 RD < PD SPI(t) > 1	5 RD = PD SPI(t) = 1	8 RD > PD SPI(t) < 1
LATE	3 RD < PD SPI(t) < 1	6 RD = PD SPI(t) < 1	9 RD > PD SPI(t) < 1

True scenarios

Misleading scenarios

False scenarios

Measuring accuracy

Mean percentage error:

$$\text{MPE} = \frac{1}{T}\sum_{rp=1}^{T}\frac{RD - EAC(t)^{rp}}{RD}$$

Mean absolute percentage error:

$$\text{MAPE} = \frac{1}{T}\sum_{rp=1}^{T}\frac{|RD - EAC(t)^{rp}|}{RD}$$

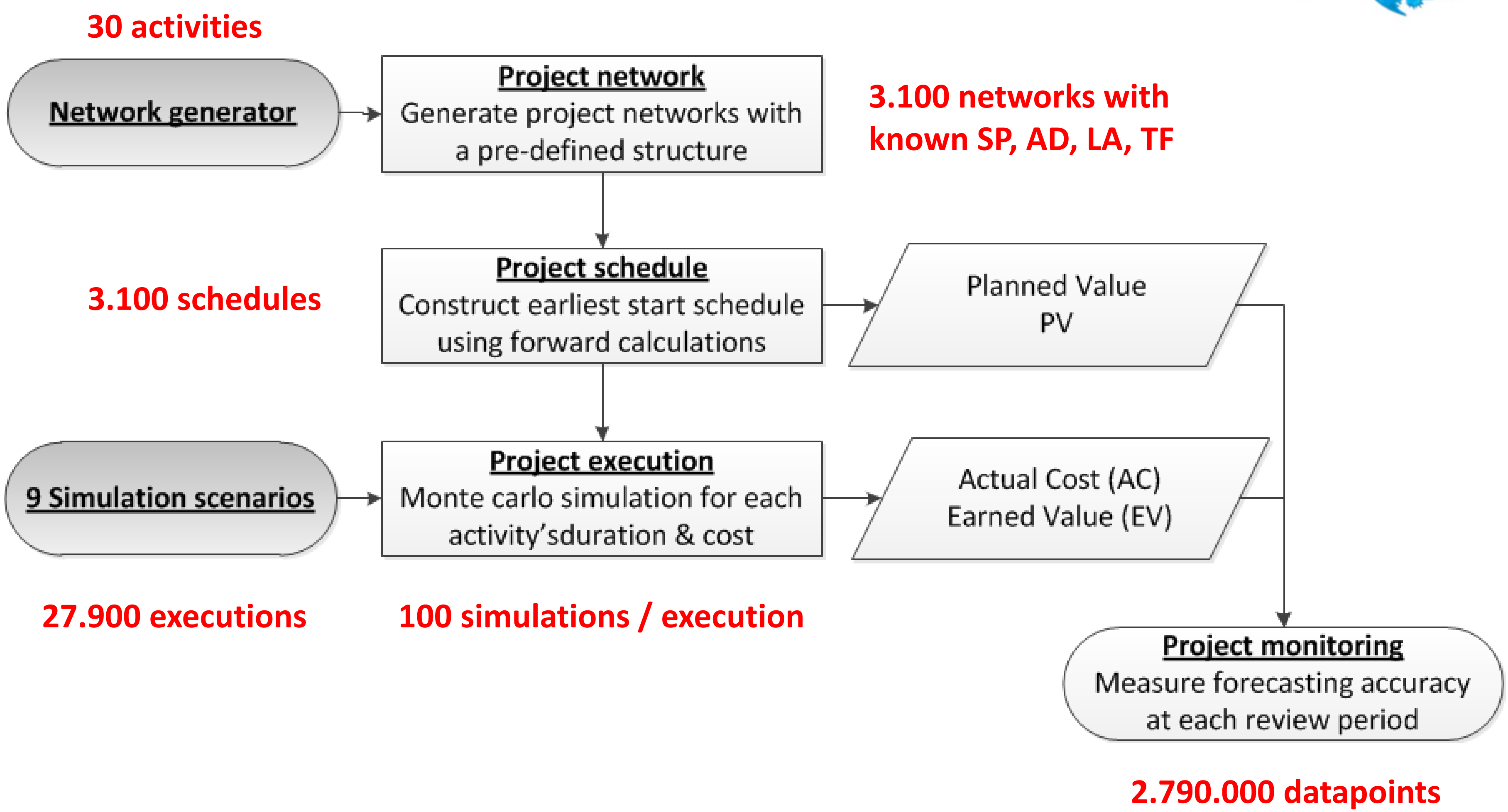
T = total number of reporting periods

rp = reporting period (= 1,2, …, T)

RD = real project duration

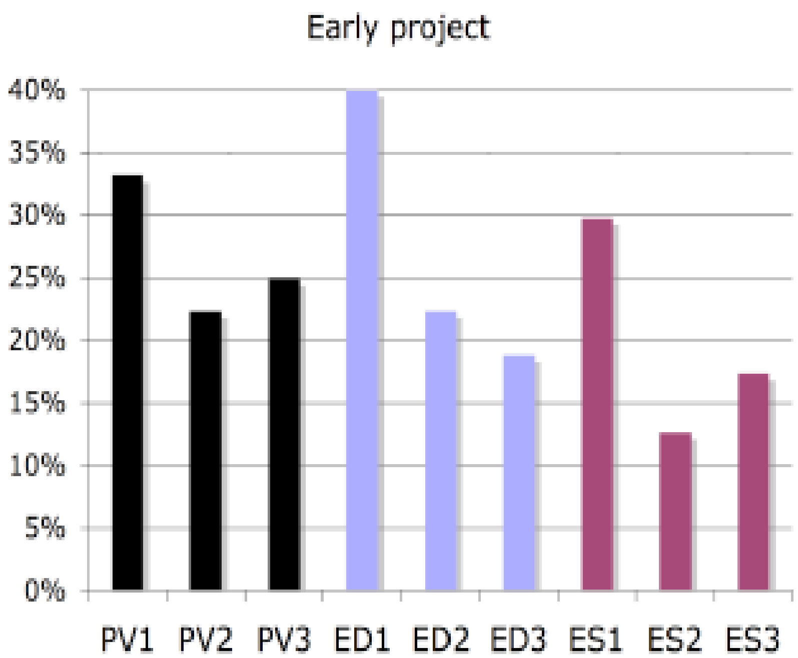
$EAC(t)^{rp}$ = project duration forecast at period rp

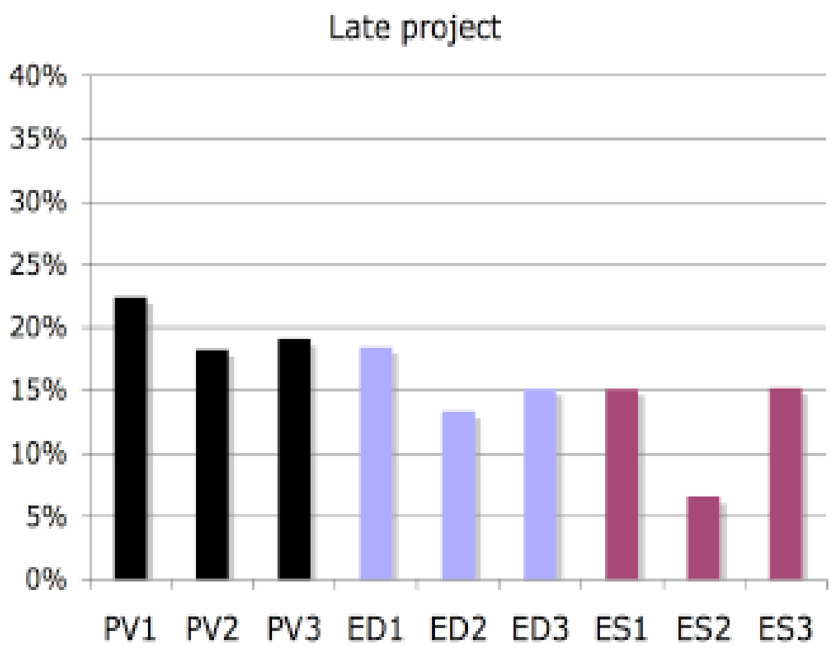
Test methodology



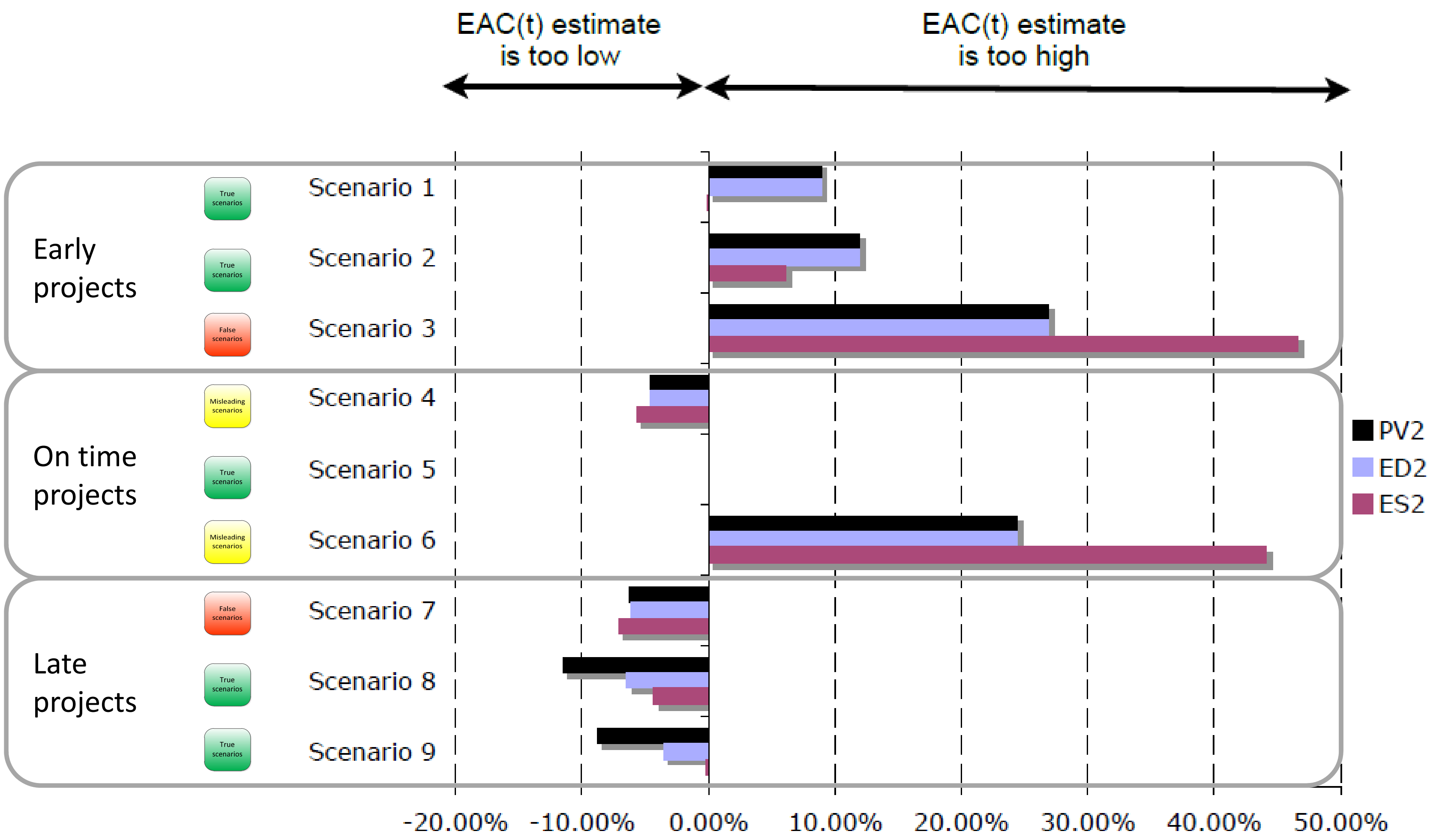
Research finding 1

The results reveal that the ES method outperforms, on the average, all other forecasting methods.





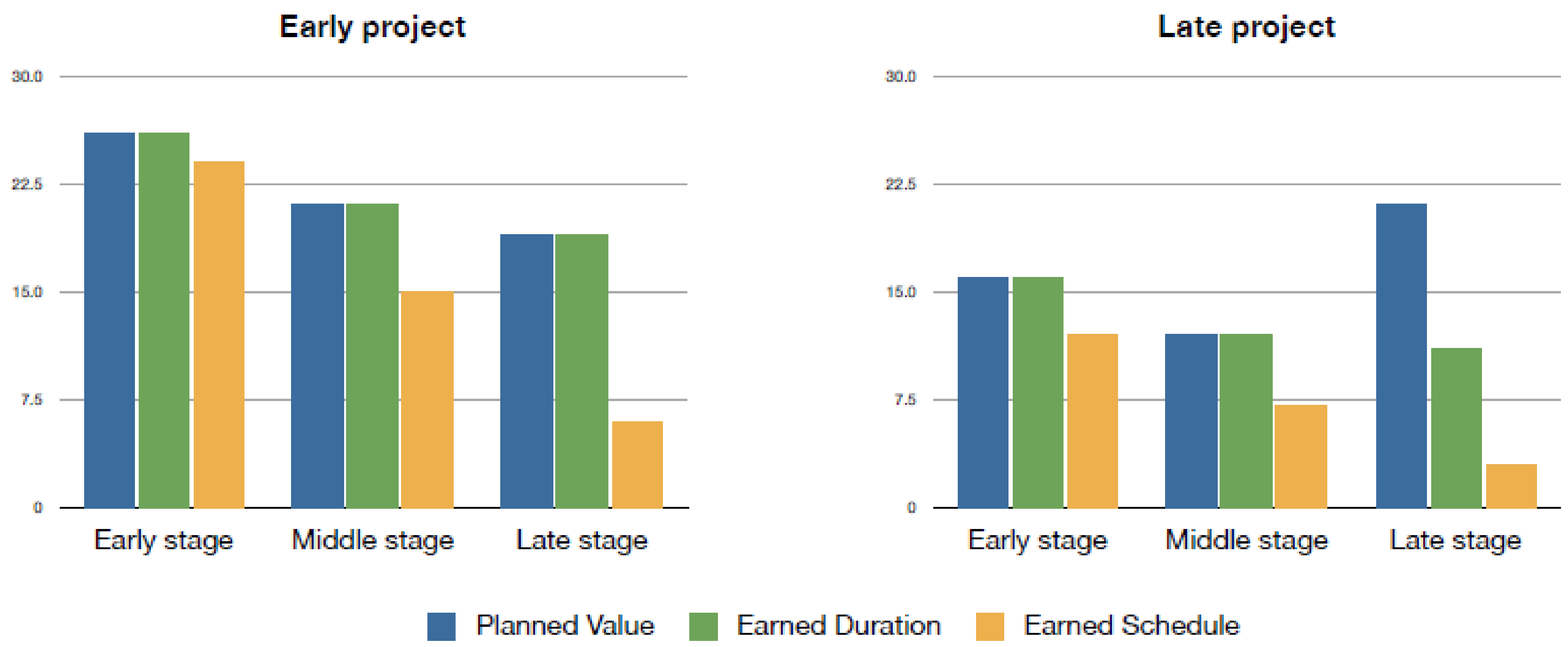
Research finding 1 by scenario



Research finding 2

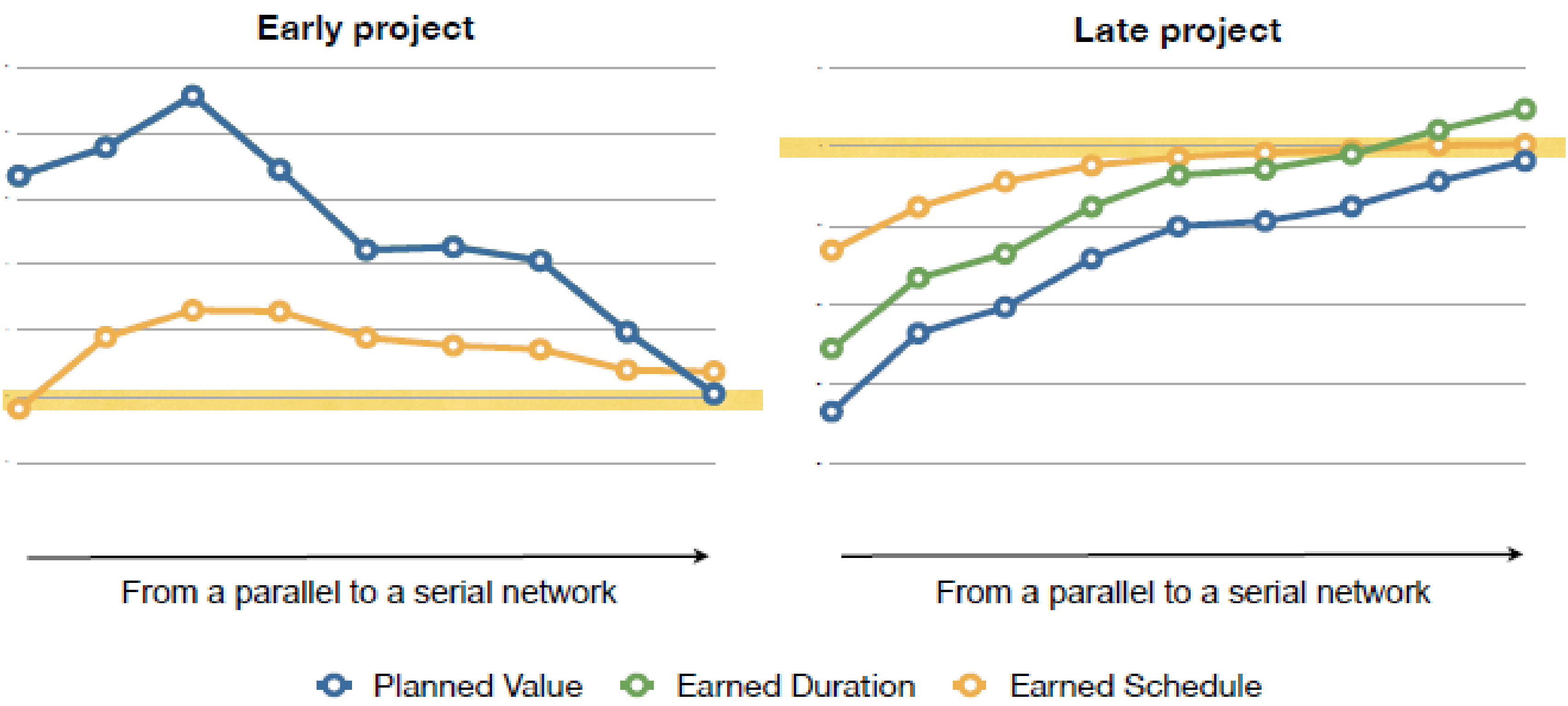
The earned schedule method outperforms the other methods at all stages during the project cycle,

SPI methods make the quirky mistake from ca. 60% completion



Research finding 3

The network structure as measured by the SP-indicator has a clear influence on the forecast accuracy.



Award winning research

PMI Belgium Chapter Event 12/06/2007
Research Collaboration Fund 5.000 €

IPMA Research Award 2008
“Measuring time”

Conclusion study 2

The results demonstrate the superiority of ES as a predictive tool.

The more serial networks, the better the accuracy of ES forecasts

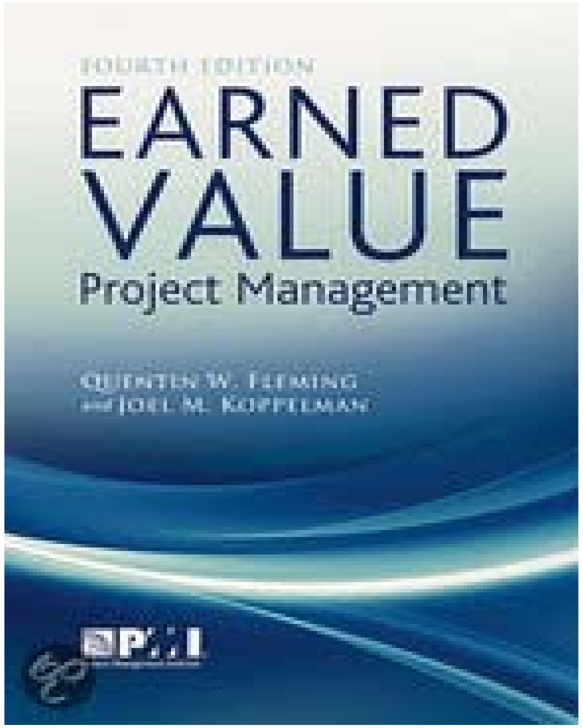
Table 1. Computational results for the four methods along the completion stage and network structure
Vanhoucke, 2008, IPMA

	Early stage			Middle stage			Late stage		
	P	S/P	S	P	S/P	S	P	S/P	S
PVM	12.30%	13.69%	14.07%	9.91%	9.88%	8.50%	12.08%	9.48%	7.32%
EDM	12.30%	13.69%	14.07%	9.91%	9.90%	8.51%	7.73%	5.52%	3.96%
ESM	10.40%	8.59%	8.22%	7.84%	4.96%	3.76%	4.05%	1.94%	1.31%
CPM	21.10%	14.86%	13.10%	10.81%	8.60%	7.40%	2.55%	2.40%	1.85%

Note 1. The completion stage is measured as the percentage completed EV/BAC with EV the Earned Value and BAC the Budget At Completion. Early, middle and late stages are defined as [0%,30%[, [30%,70%[, and [70%,100%] percentage completed, respectively.

Note 2. The Serial/Parallel degree of a project is measured by the I2 indicator presented by Vanhoucke et al. (2008).

Critics - EVPM, 4th Ed., 2010



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WRONG

Earned Value Project Management,
4th Edition, 2010

Study 3: Project control efficiency

Study 3: references

Vanhoucke, M., 2010, "Using activity sensitivity and network topology information to monitor project time performance",

Omega - International Journal of Management Science, 38, 359-370.

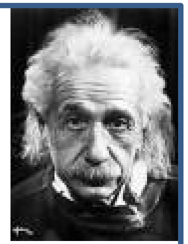
Vanhoucke, M., 2011, "On the dynamic use of project performance and schedule risk information during project tracking",

Omega - International Journal of Management Science, 39, 416-426.

Vanhoucke, M., 2012, "Measuring the efficiency of project control using fictitious and empirical project data",

International Journal of Project Management, 30, 252-263.

Study 3



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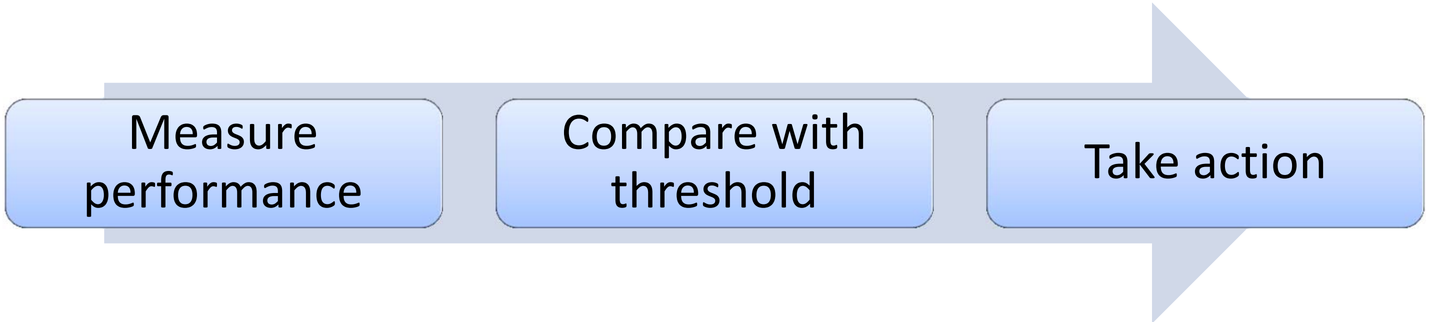
Project schedule control

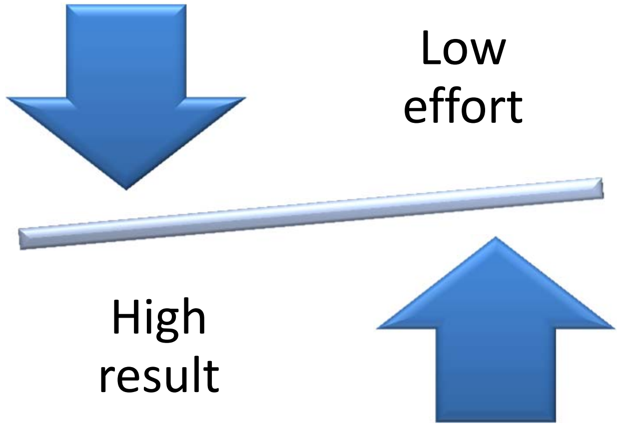
- Study 1 & 2:
  - analysing schedule forecasting capability
  - based on “finished projects data”

- This study 3:
  - analysing the EV/ES methods as a schedule control tool
  - testing the ability of EV/ES to trigger corrective actions

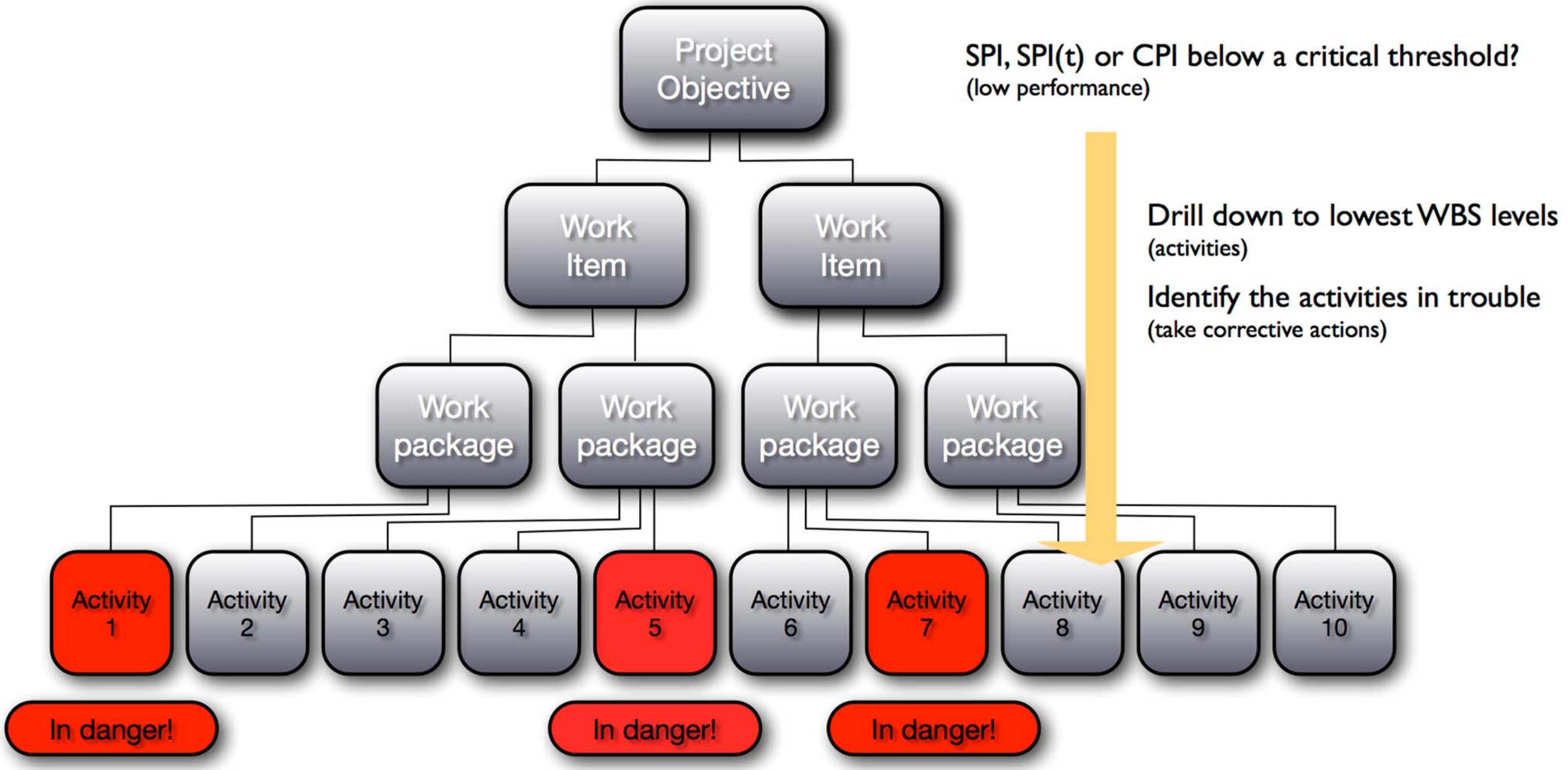
- Remark:
  - this is not a replacement for CPM schedule control tools

Project control: a balancing act

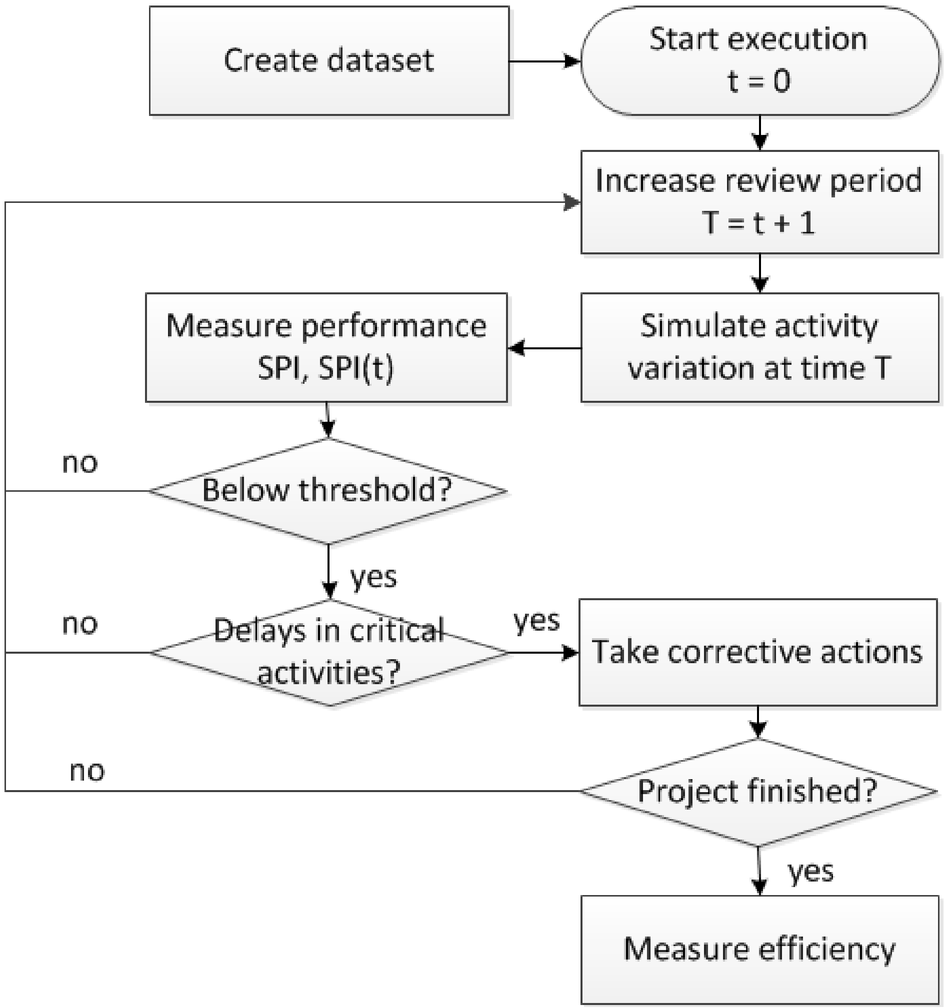




EV/ES: top down control



Test methodology: top down control



Corrective actions

- In general there are 3 classes of corrective actions

1. Activity crashing

   Reducing activity durations

2. Fast tracking

   Parallel execution of precedence related activities

3. Re-baselining parts of original schedule

   Considers often that some delay is accepted

Defining control efficiency

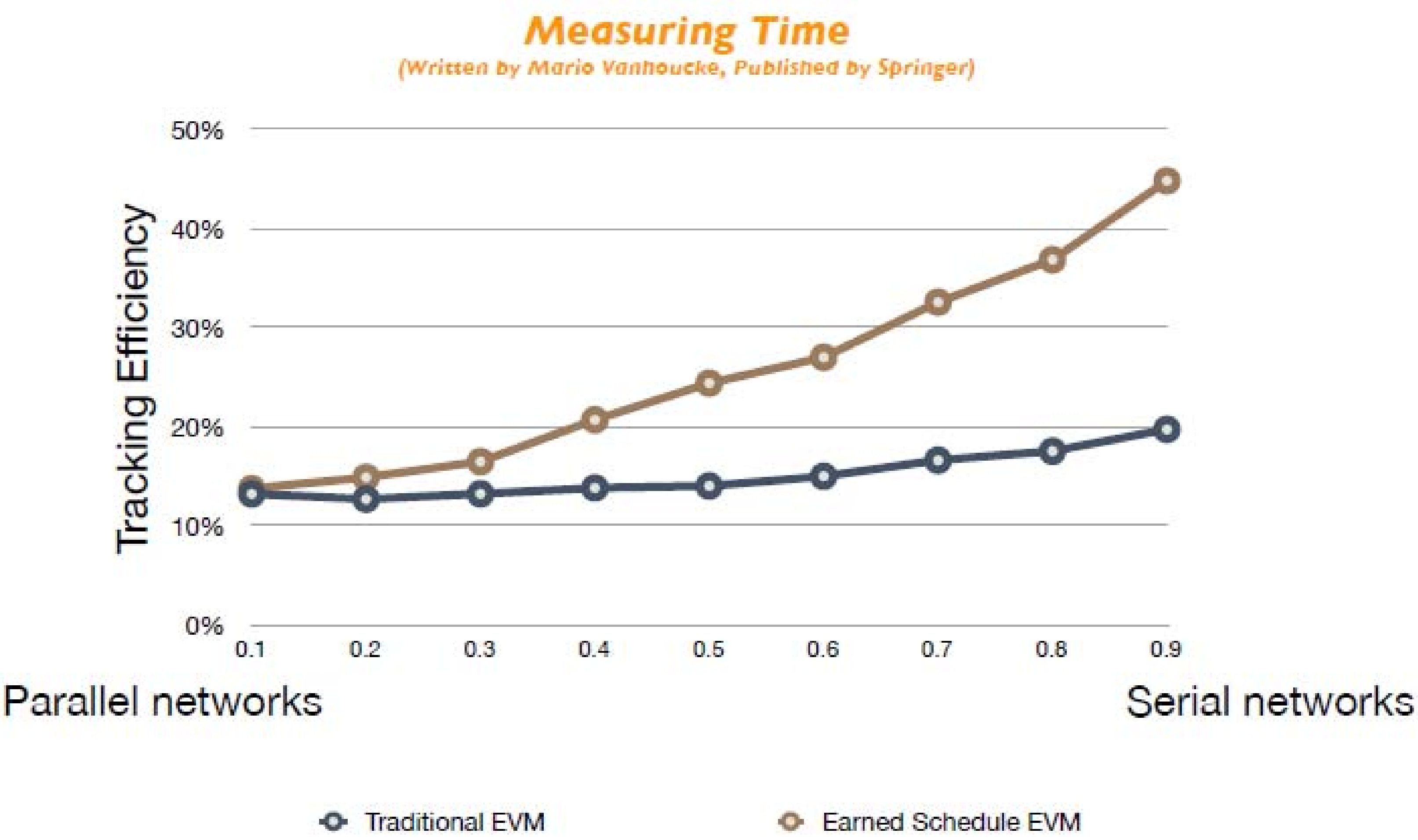
Control Efficiency = $\frac{Effect\ of\ actions\ taken}{Effort\ by\ PM} = \frac{RDno - RDyes}{NEA}$

RD^{no} = real project duration with no corrective action

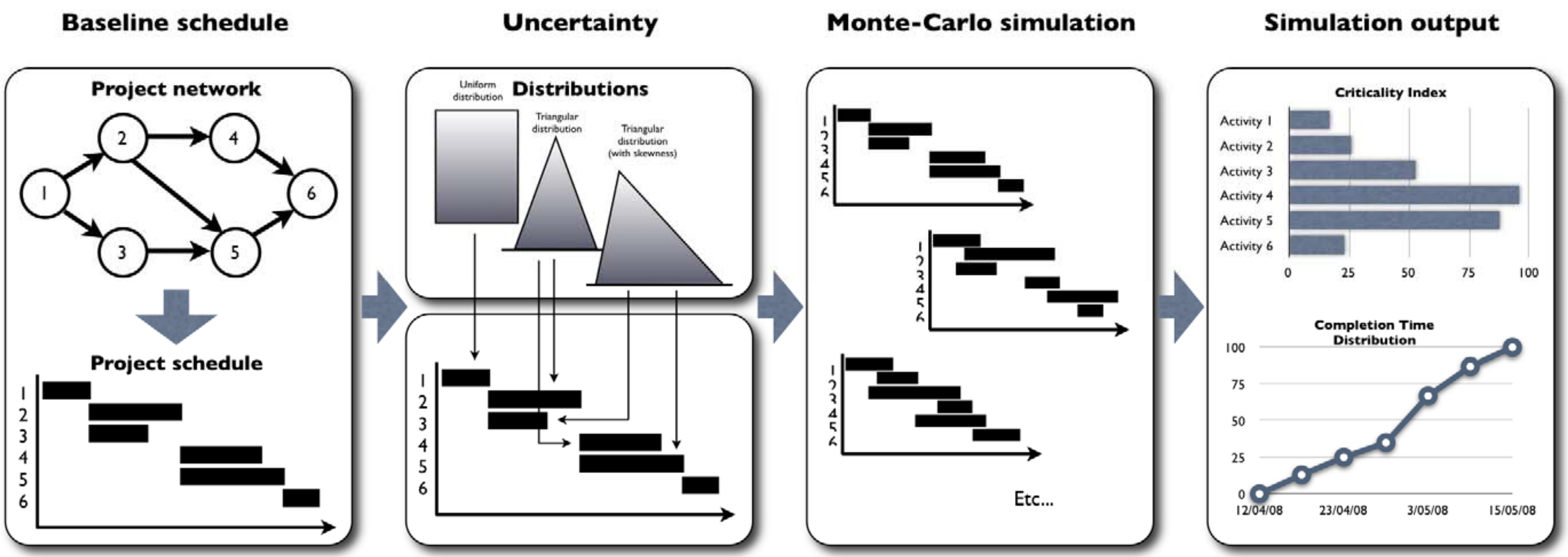
RD^{yes} = real project duration with corrective actions

NEA = number of evaluated activities

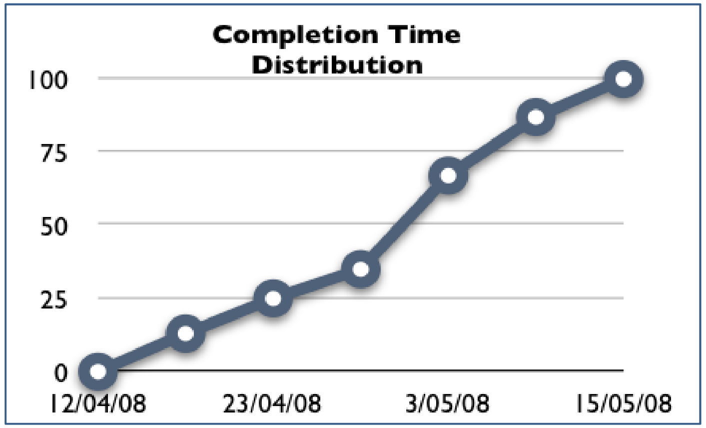
EV/ES: top down control



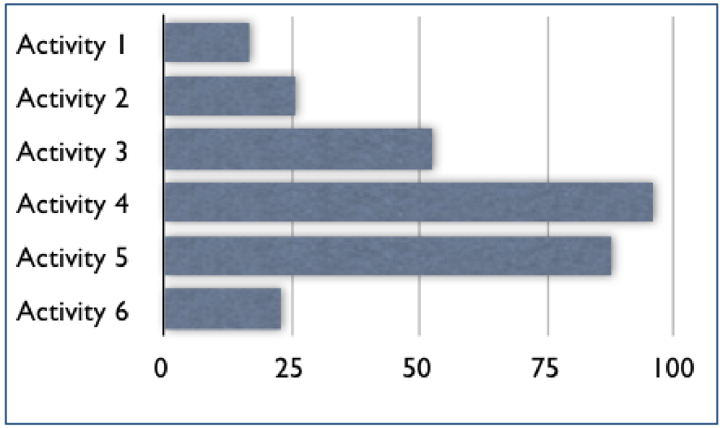
Schedule risk analysis



SRA: output



A probability distribution showing the likelyhood to achieve a defined end date.



CI : criticality index

SI: sensitivity index

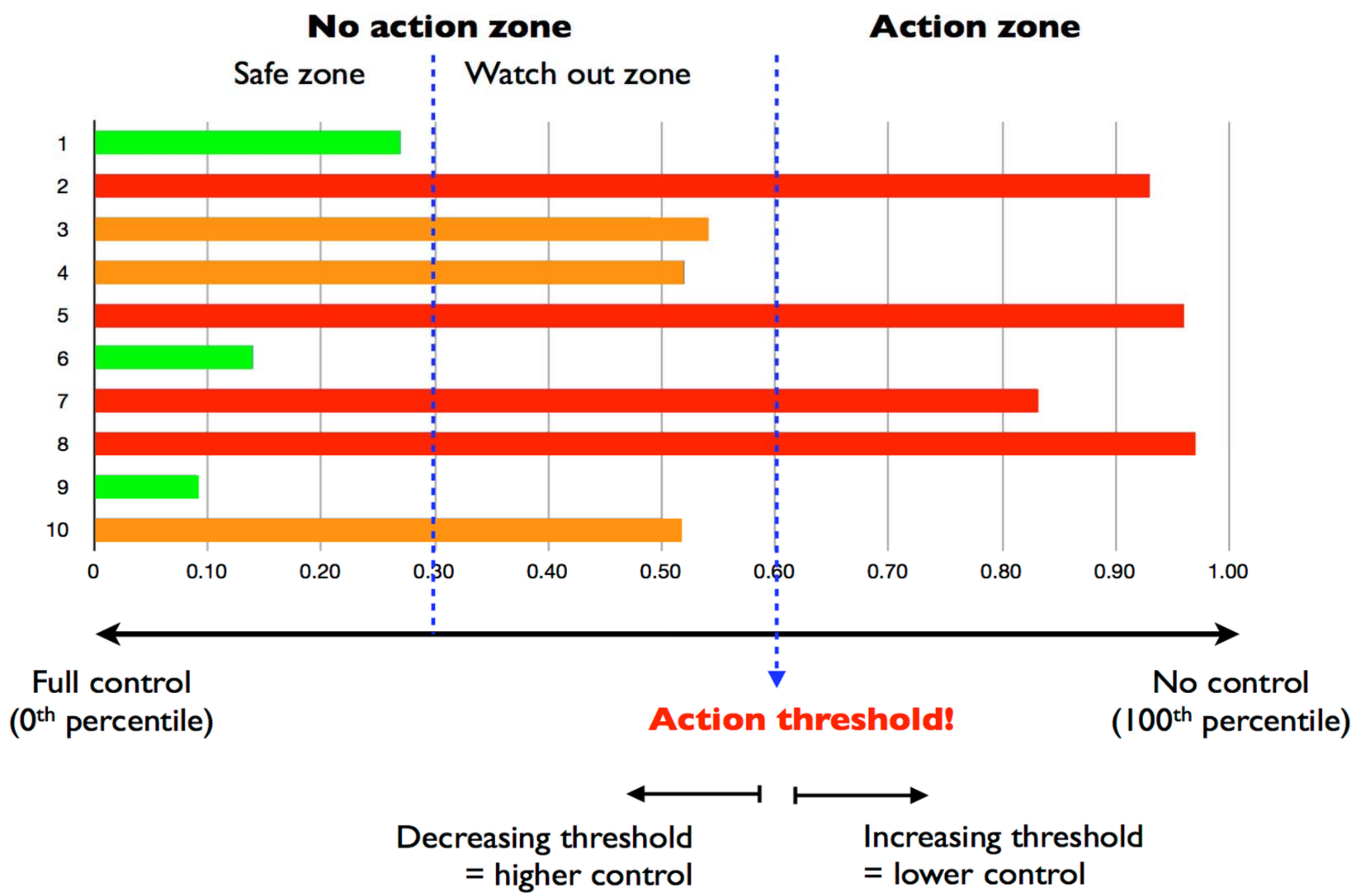
SSI: schedule sensitivity index

CRI(r): cruciality index (Pearson)

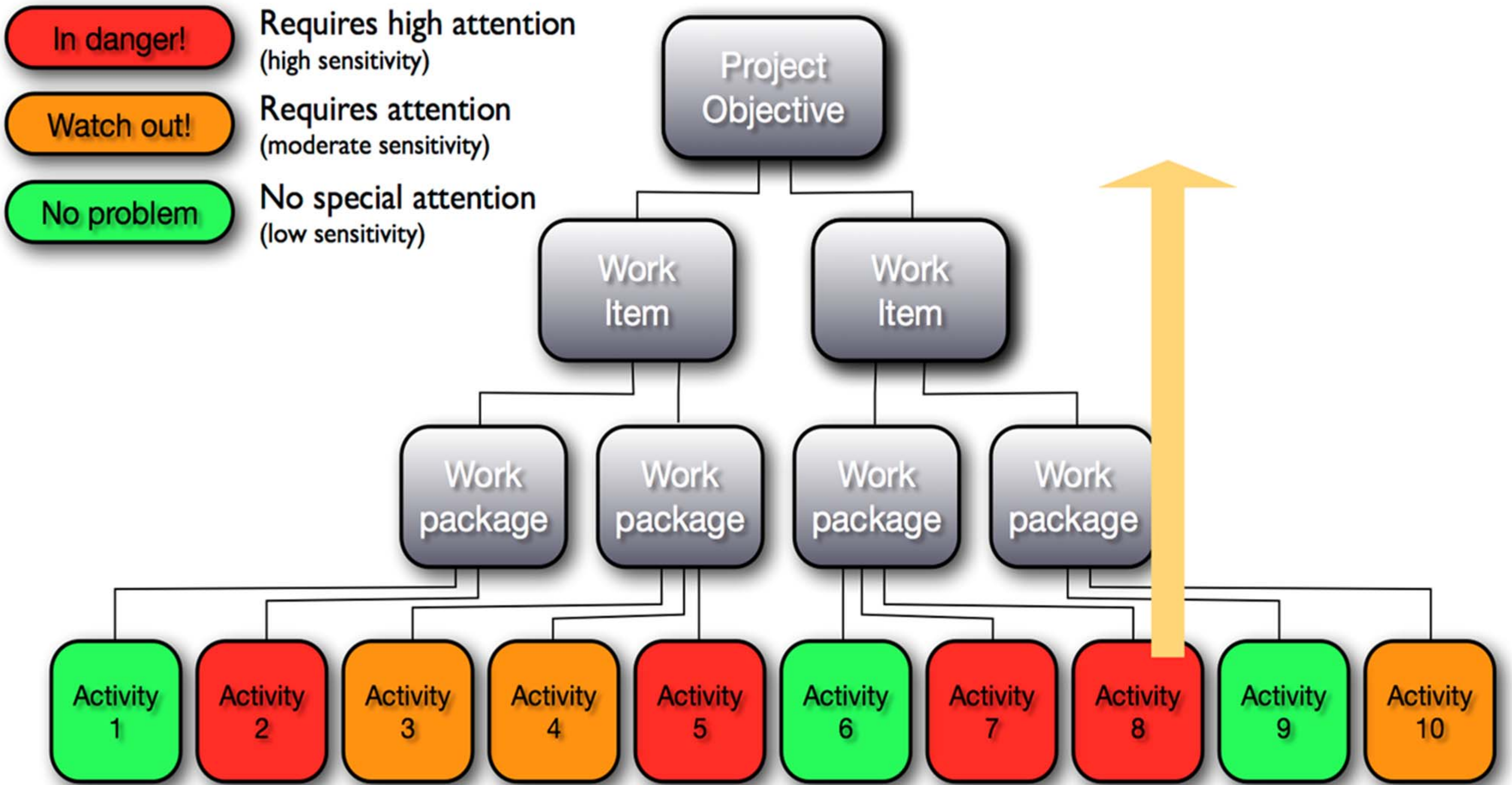
CRI(ρ): cruciality index (Spearman)

CRI(τ): cruciality index (Kendall)

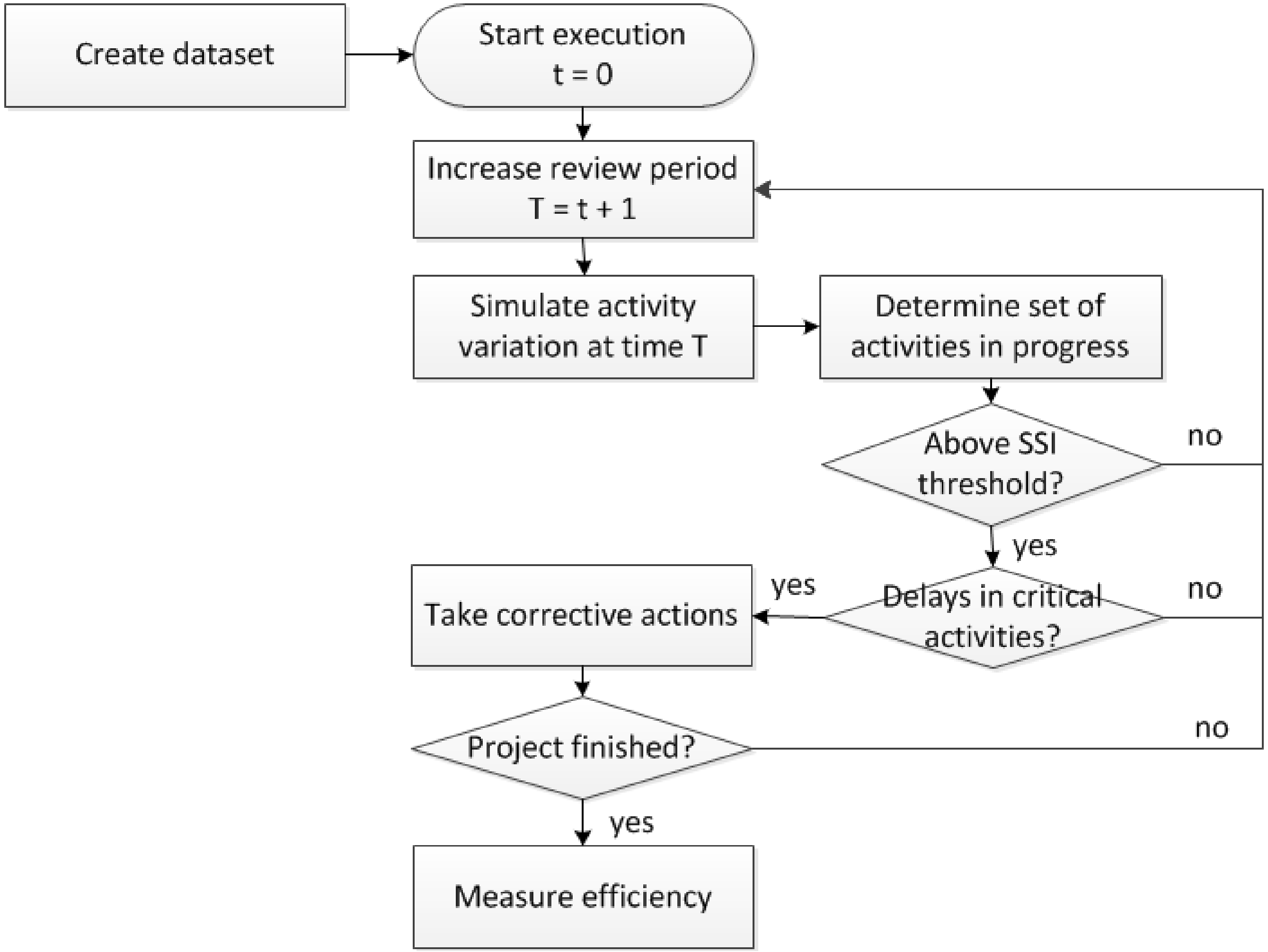
Bottom up control: SRA



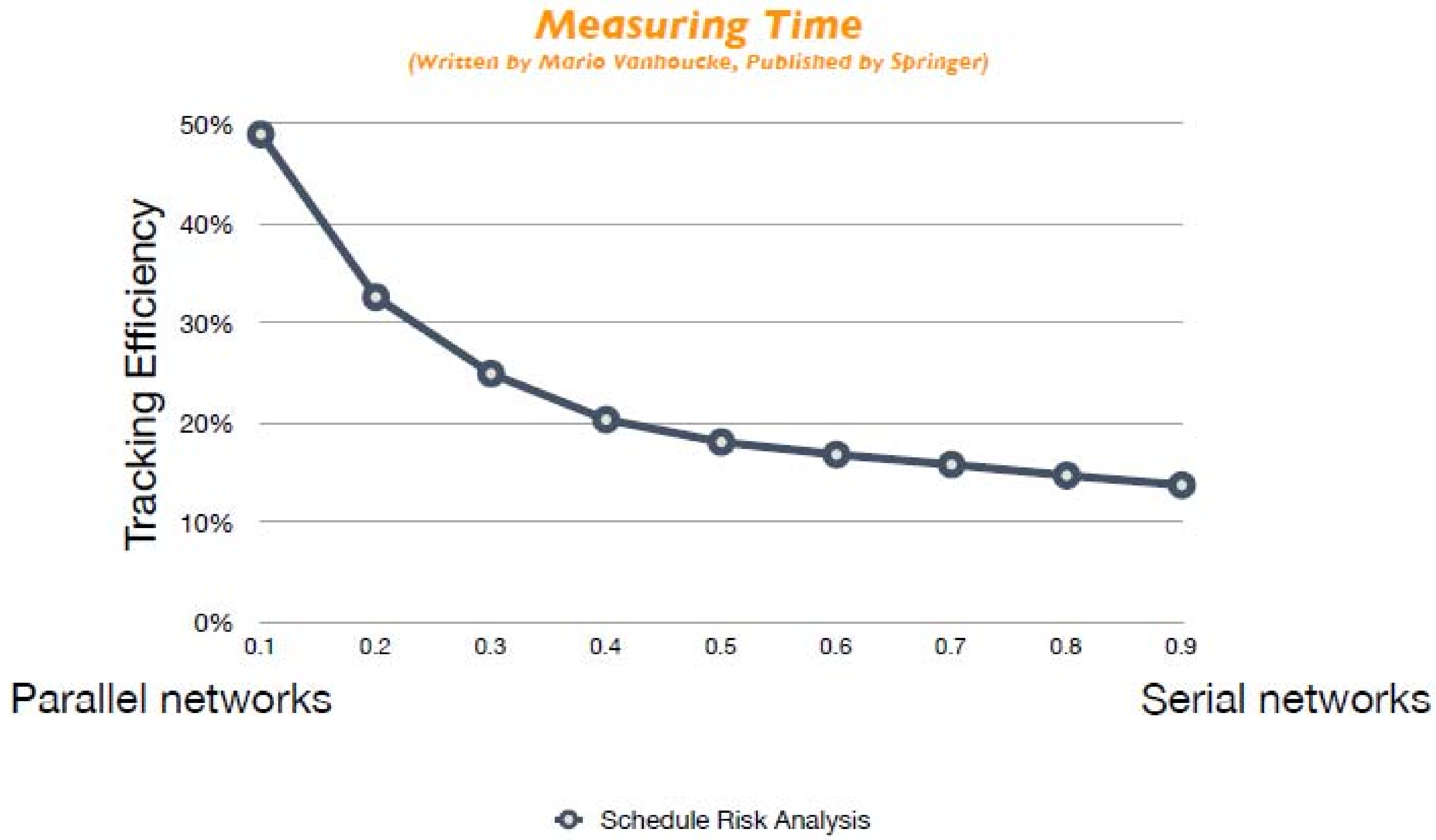
SRA bottom up control



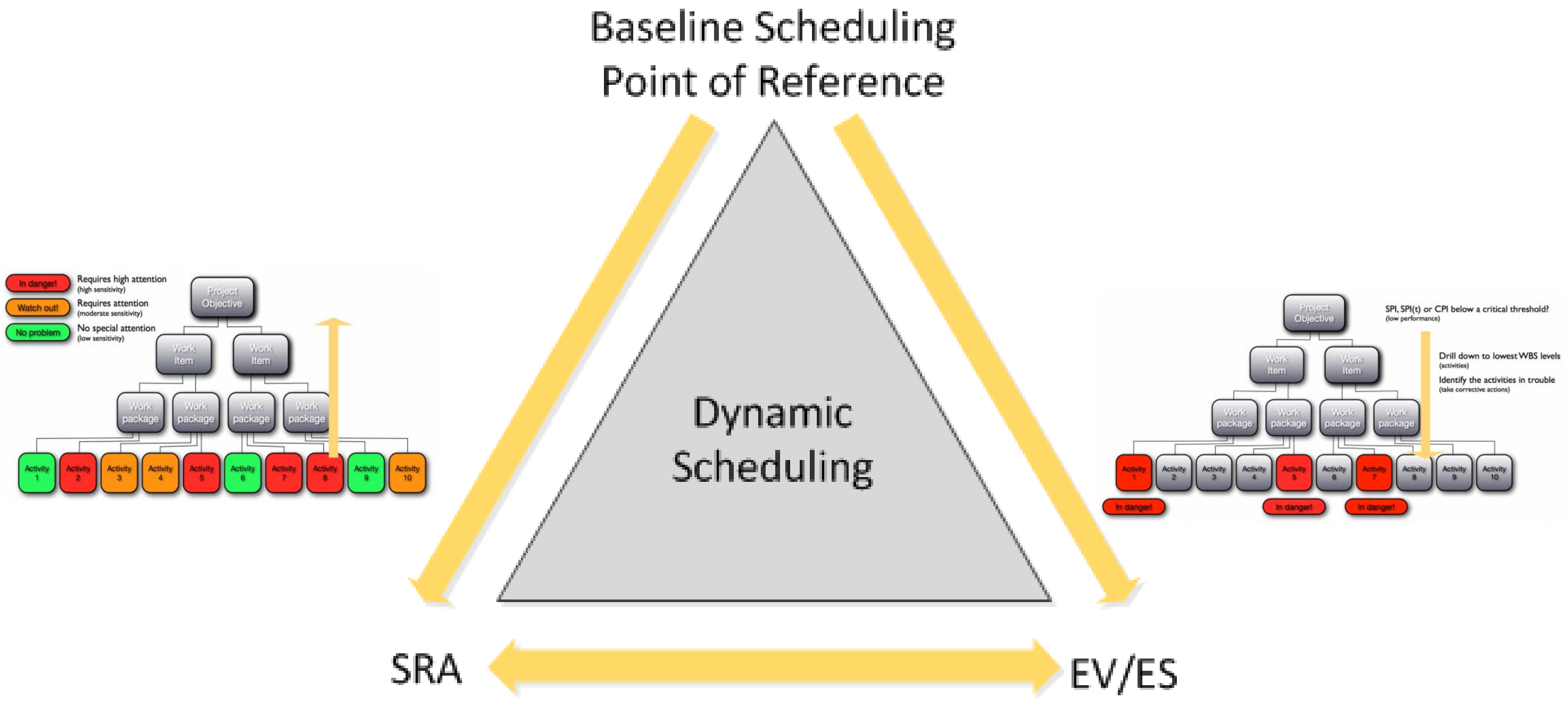
Test methodology: botton-up control



SRA: bottom up control

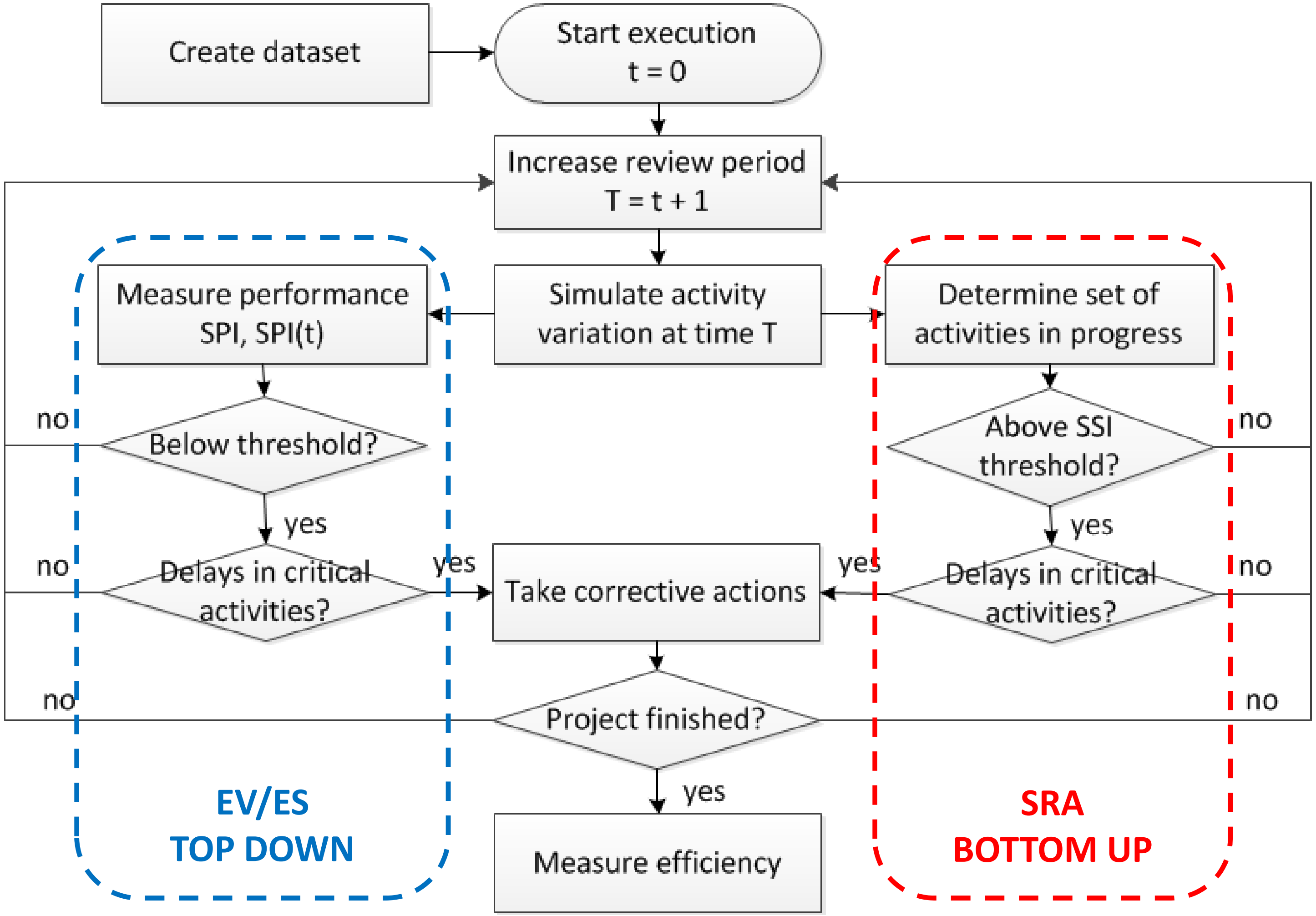


Dynamic scheduling

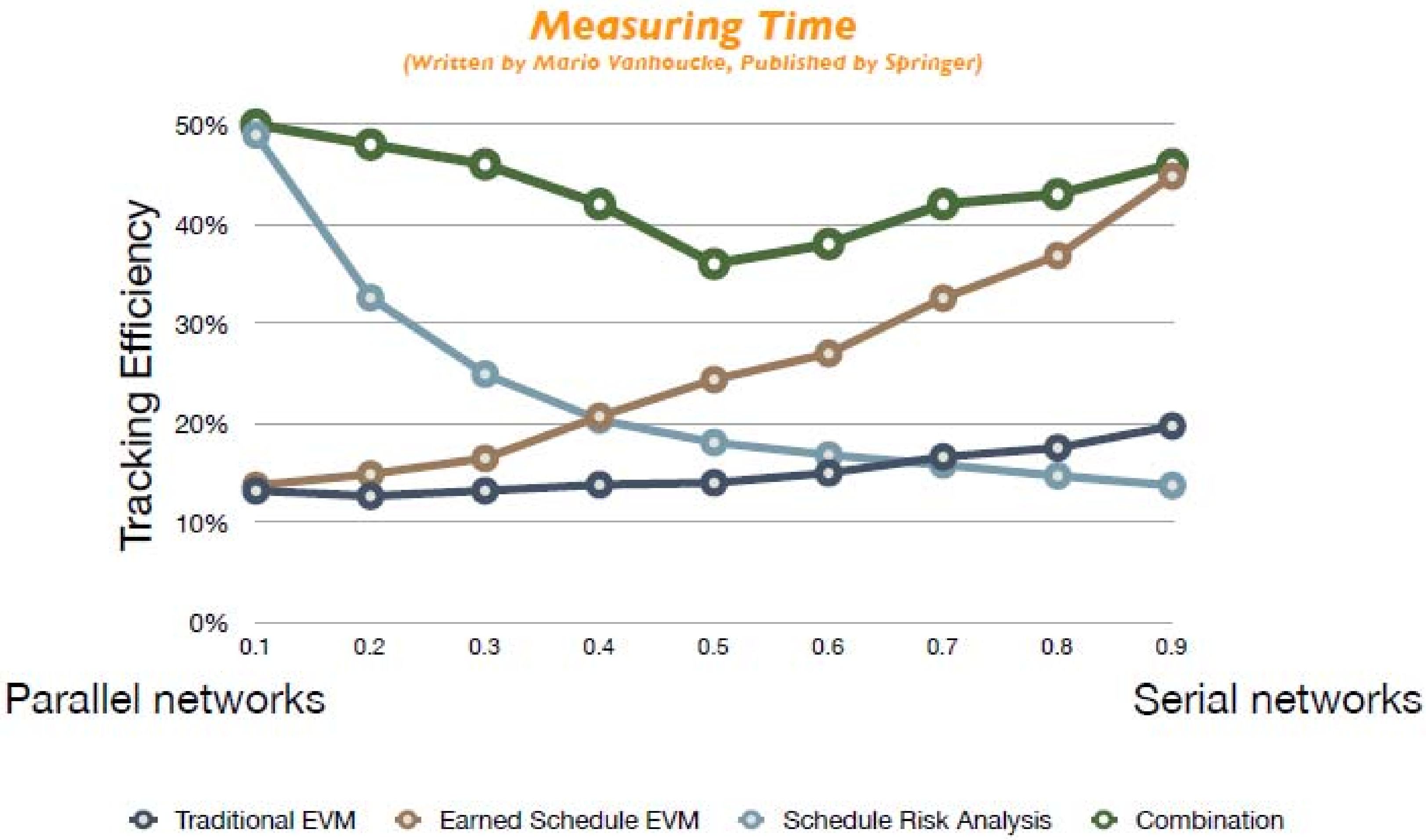


Use both SRA & EV/ES information
to trigger corrective actions.

Test methodology dynamic scheduling

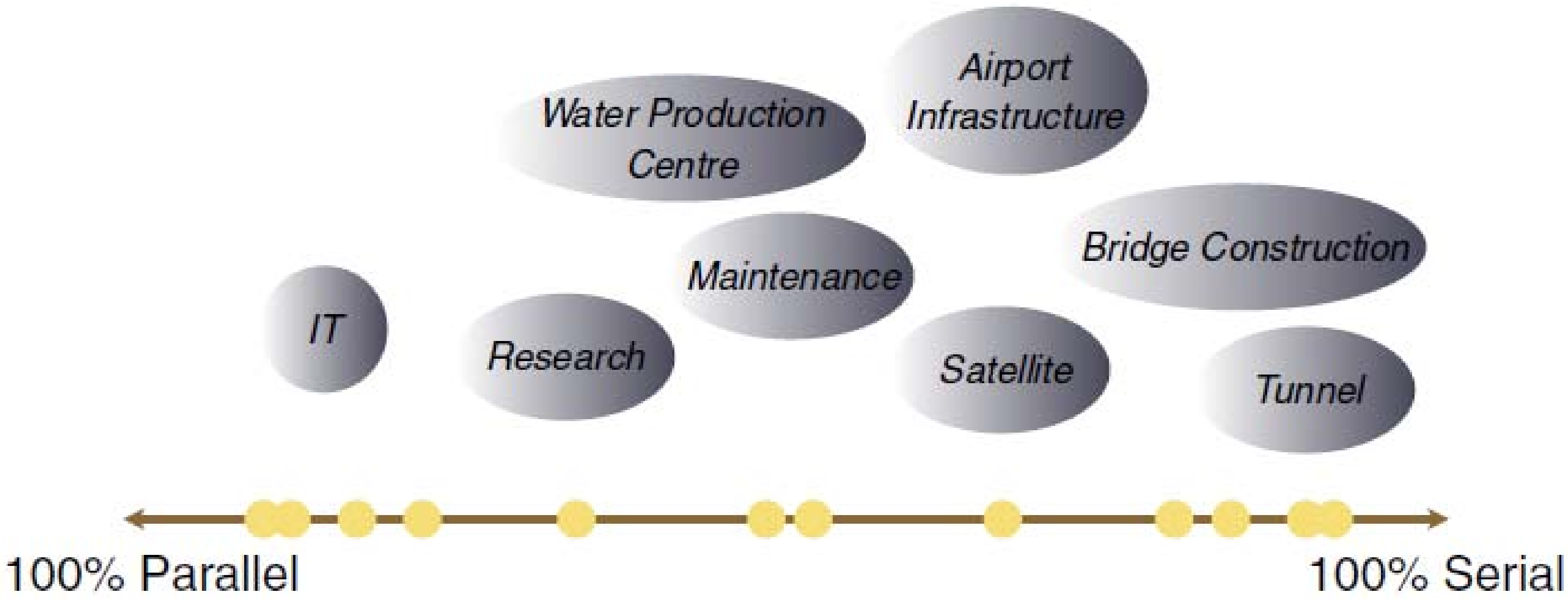


If time is money, accuracy pays dividends!

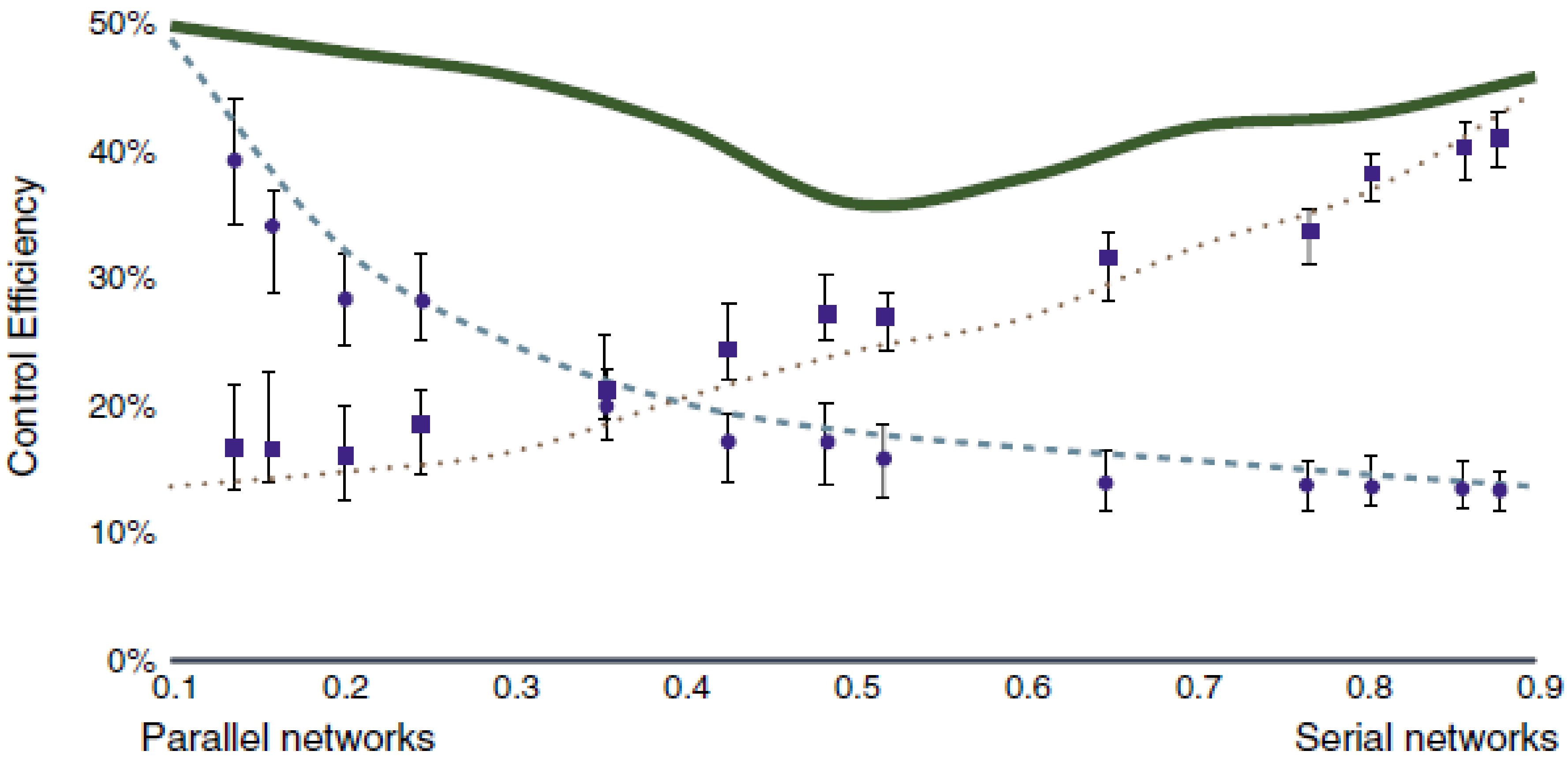


How does this relate to the real world?

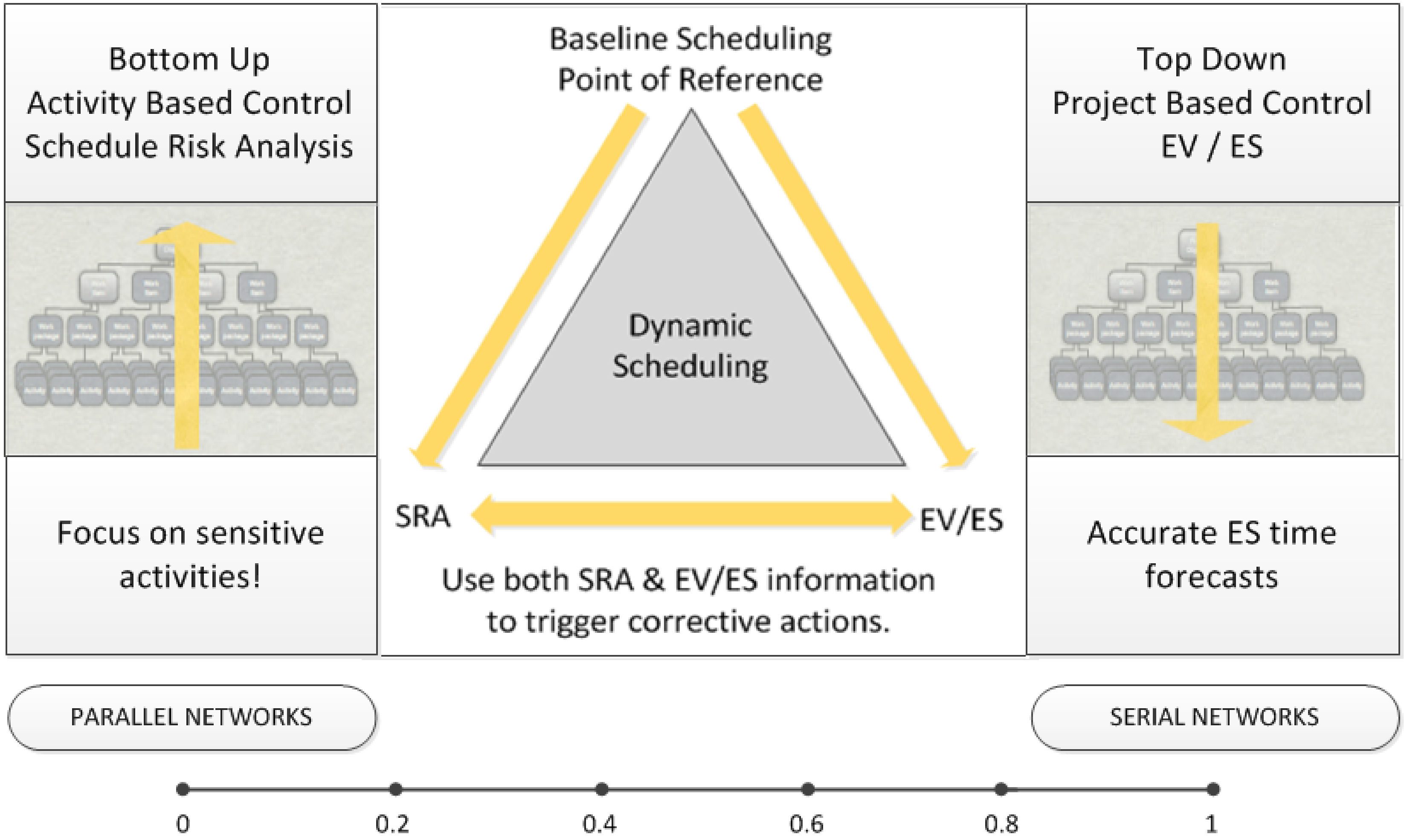
- Period 2007 – 2010:
  - students of Ghent University collected real life data
  - 8 Belgian companies, 48 projects



Research meets practice



Conclusion study 3: best practices



Agenda

1. Intro

2. Past / Recent Work

3. Future Work

- Continue “Measuring Time”
- P-Factor
- CRA program
- Creation commercial project database
- Recognising research

4. Relation with PMI Standards

5. Conclusion

Continuing
"Measuring Time"

Extending / improving methods

- ES LP extension
- Statistical methods
- Probabilistic methods: Bayesian inference, Kalman filter,...
- Regression based models
- Composite forecast methods
    - ex. combining EV & sensitivity information

Extending / improving methods

Elshaer, R., 2013, "Impact of sensitivity information on the prediction of project's duration using earned schedule method", International Journal of Project Management, 31, 579-588.

		CRITICAL ACTIVITIES		
		EARLY	ON TIME	LATE
NON CRITICAL ACTIVITIES	EARLY	1 RD < PD SPI(t) > 1	4 RD = PD SPI(t) > 1	7 RD > PD SPI(t) > 1
	ON TIME	2 RD < PD SPI(t) > 1	5 RD = PD SPI(t) = 1	8 RD > PD SPI(t) < 1
	LATE	3 RD < PD SPI(t) < 1	6 RD = PD SPI(t) < 1	9 RD > PD SPI(t) < 1

Scenario 3

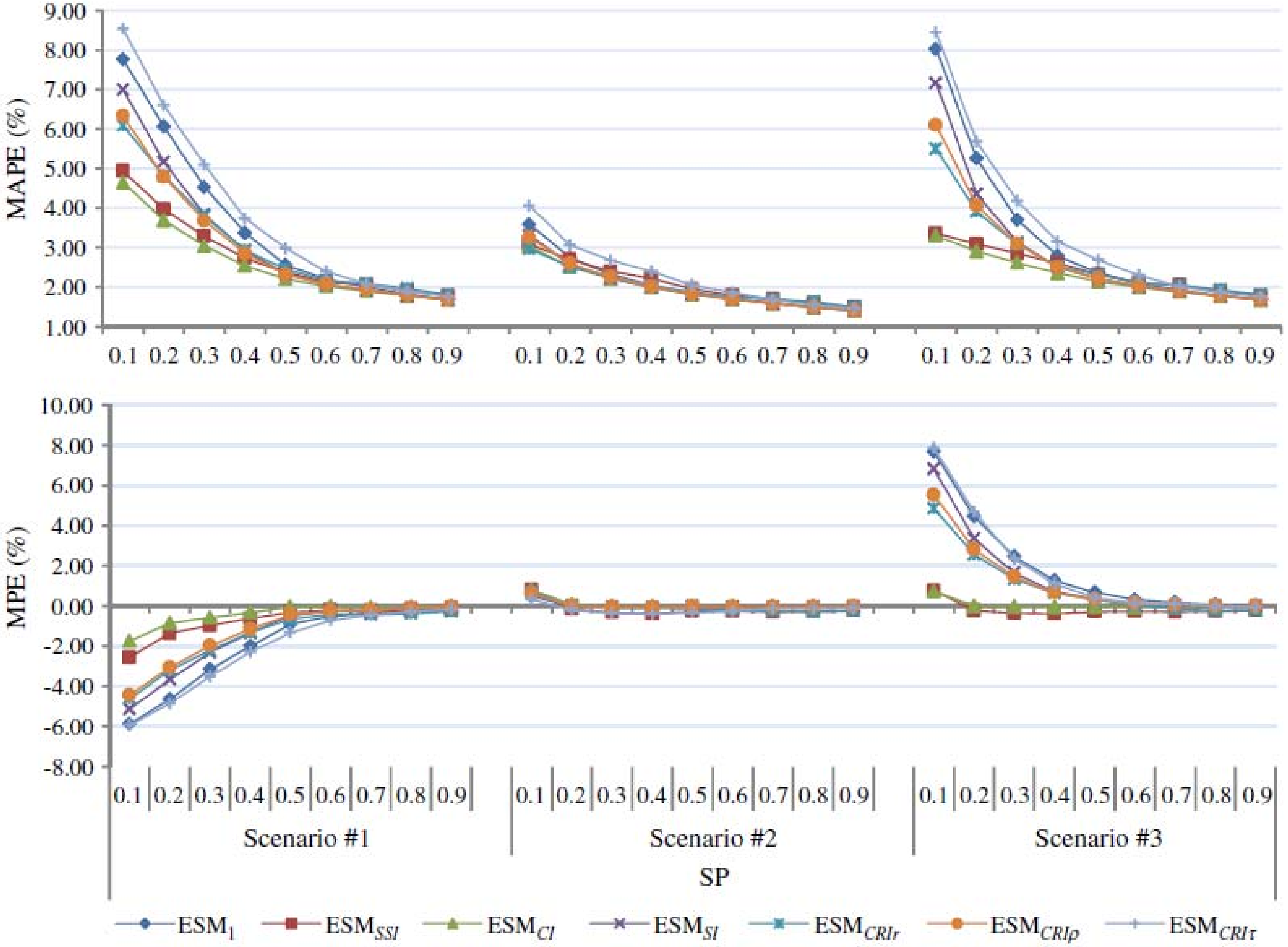
Scenario 1

$$\mathrm{EV}_{\alpha,t} = \sum\nolimits_i \alpha_i \,.\, EVi_{,t}$$

$$\mathrm{PV}_{\alpha,t} = \sum\nolimits_i \alpha_i \,.\, PVi_{,t}$$

$$\alpha \in \{1, CI, SI, SSI, CRI_\rho, CRI_\tau, CRIr\}$$

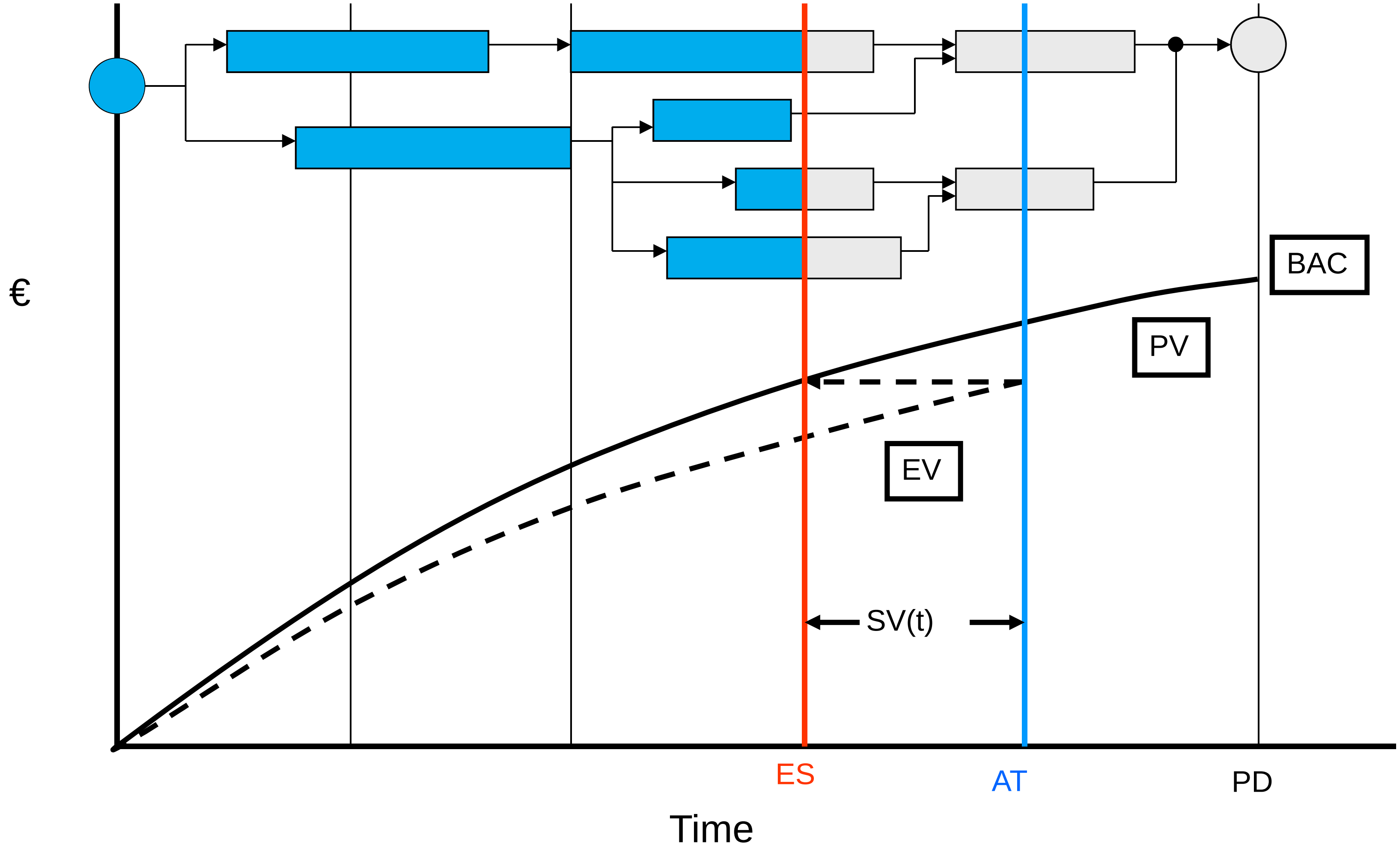
Extending / improving methods



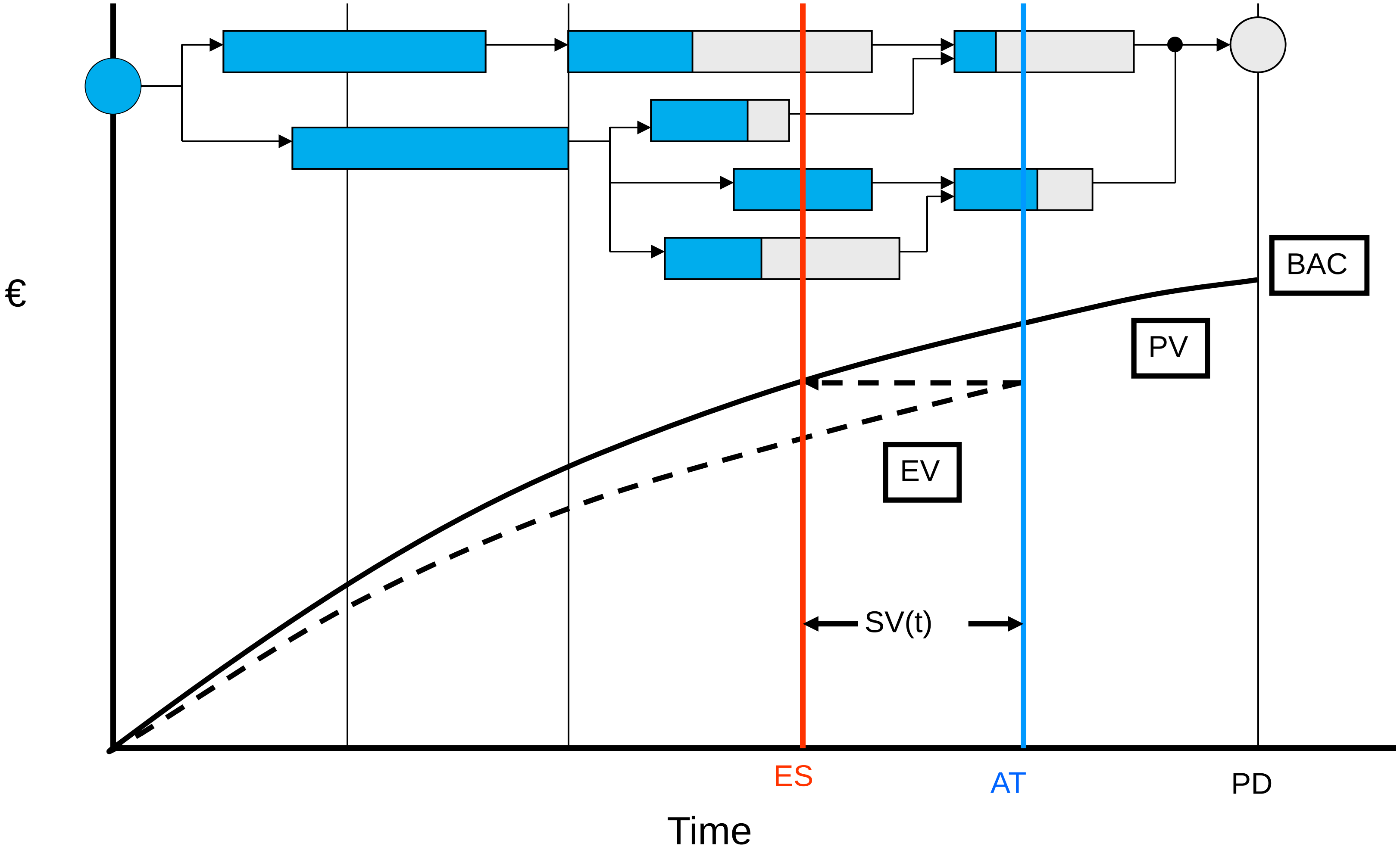
Examining P-Factor

Vanhoucke, M., 2013, “The impact of project schedule adherence and rework on the duration forecast accuracy of earned value metrics”, In E.C. Hoffmann (Ed.), Project Management: practices, challenges and developments, Nova Publishers

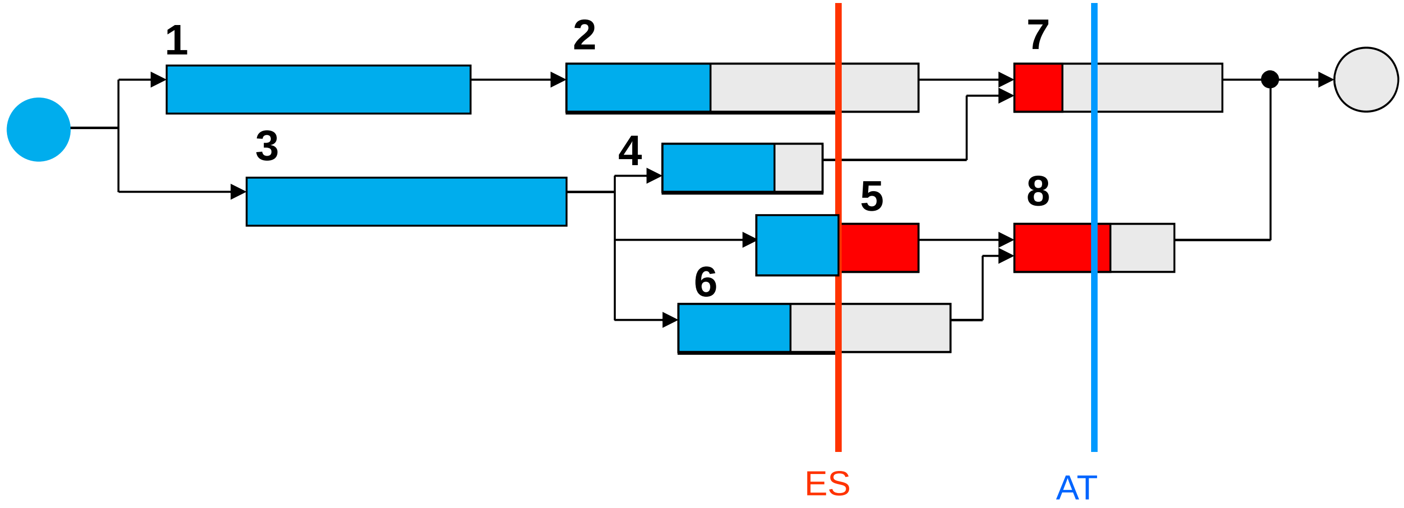
Schedule adherence



Schedule adherence



Schedule adherence

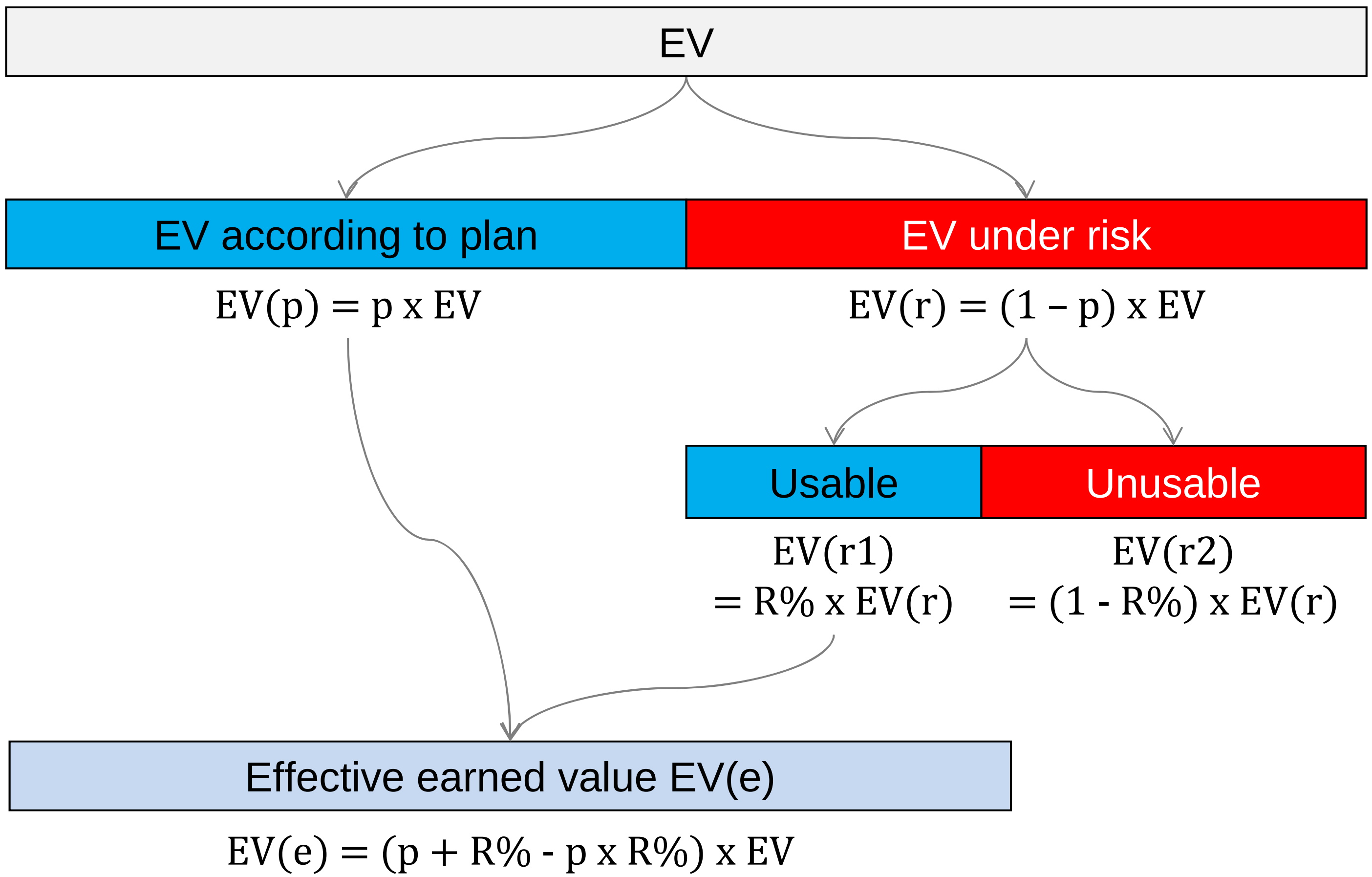


$$p = \frac{\sum_{i \in N} min(\mathrm{PV}_{i,\mathrm{ES}}, \mathrm{EV}_{i,\mathrm{AT}})}{\sum_{i \in N} \mathrm{PV}_{i,\mathrm{ES}}}$$

with

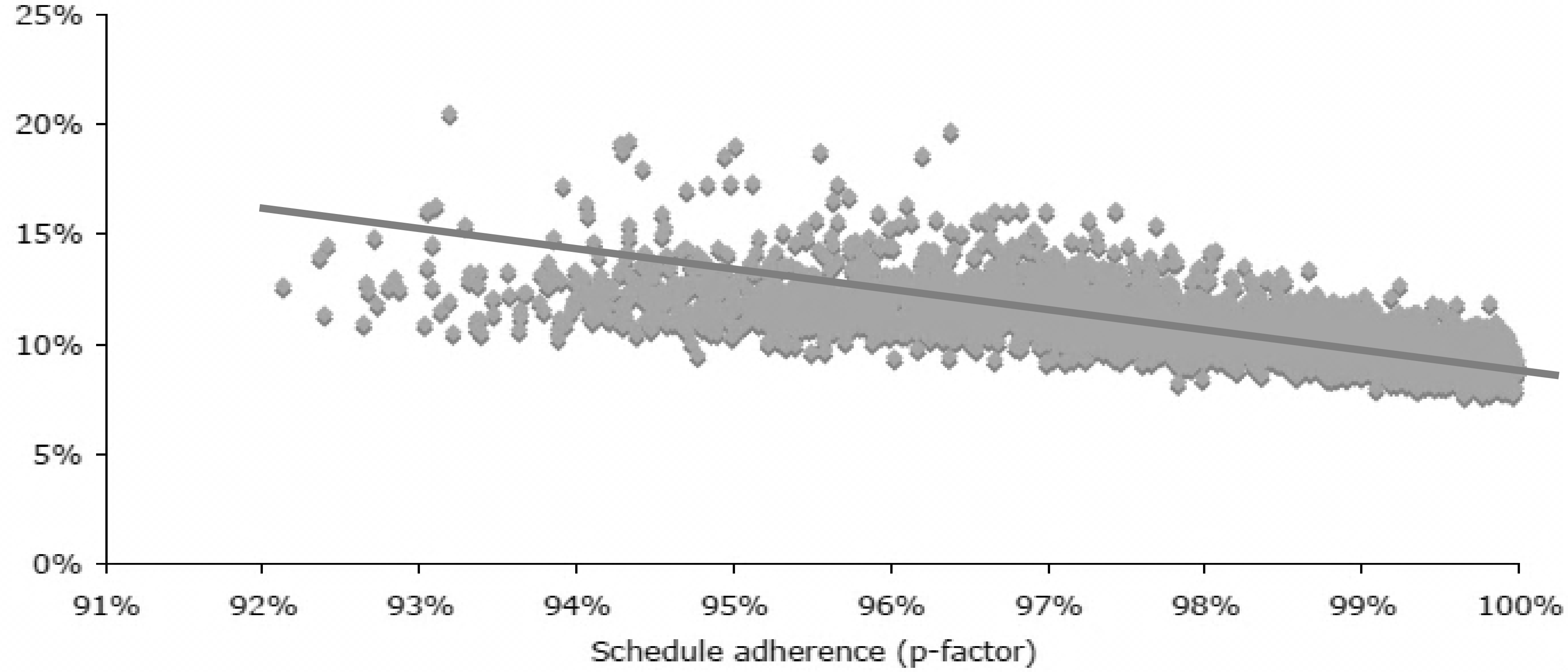
p	Schedule adherence = 1: perfect schedule adherence < 1: lack of perfect schedule adherence
N	Set of activities in the project
$PV_{I,ES}$	Planned value of activity i at time instance ES
$EV_{I,AT}$	Earned value of activity i at the actual time AT

Effective earned value



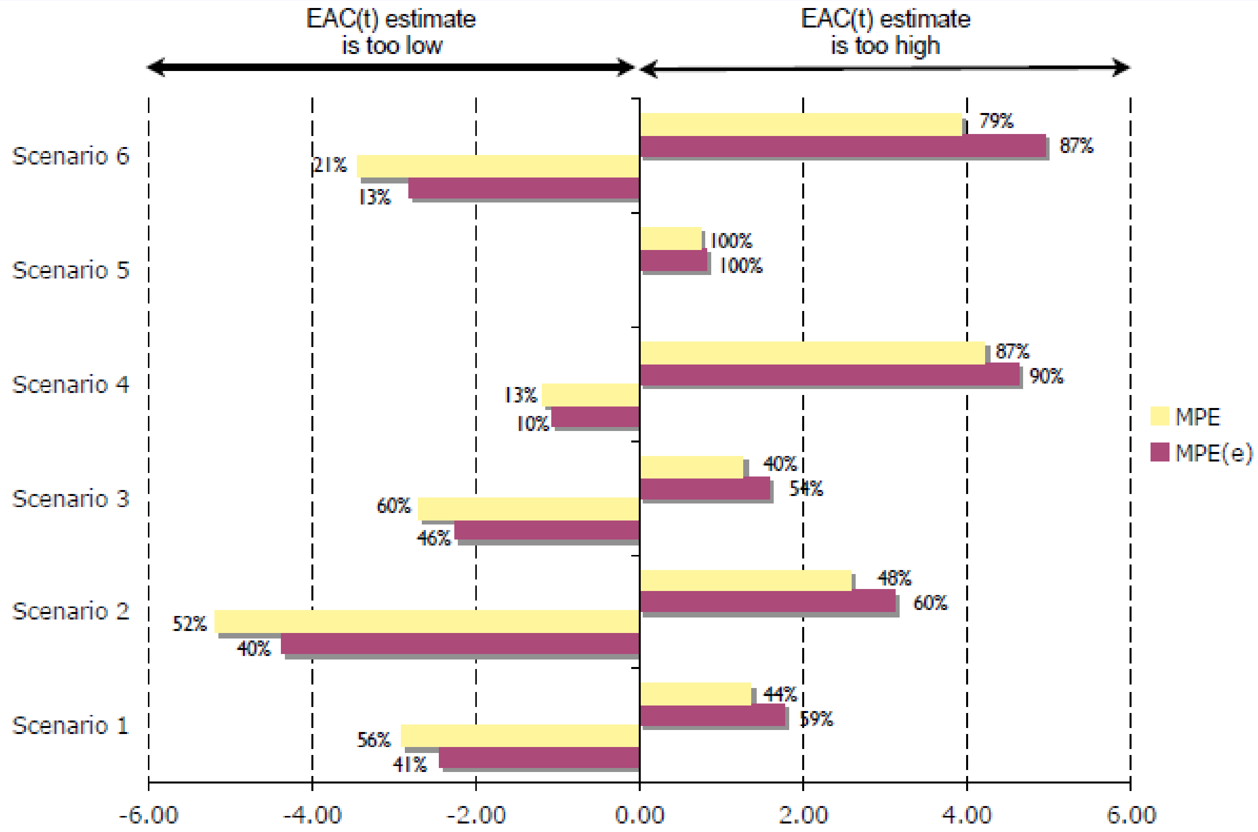
Research finding P-Factor

High P-Factors lead to more accurate forecasts, and thus acts as a warning signal.



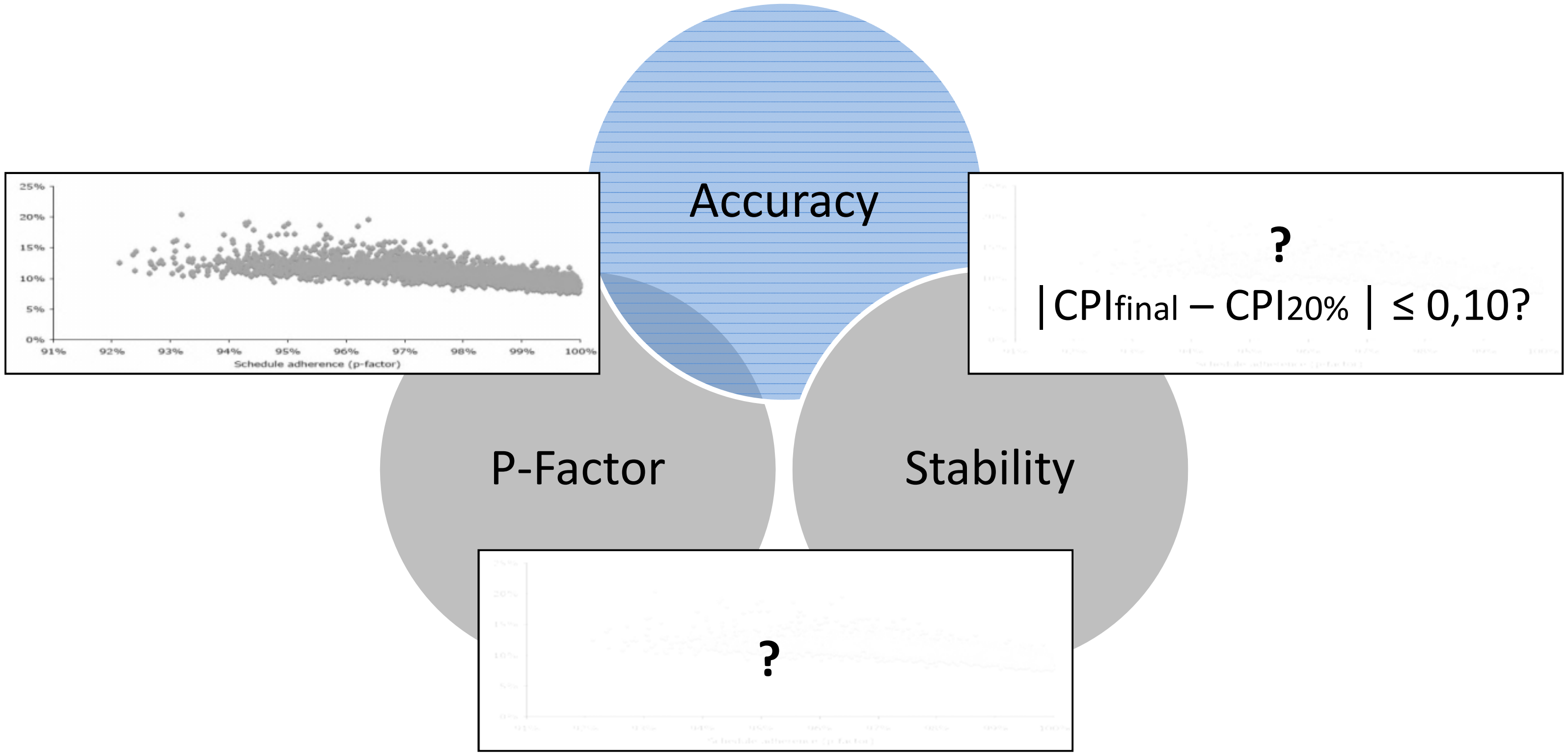
Research finding EV(e)

The use of effective earned value to improve the forecast accuracy of time prediction is limited.



Examining forecast quality

- Conjecture: p-factor may be the link between accuracy & stability



Examining forecast quality

Forecast quality

Accuracy

$$MPE = \frac{1}{T} \sum_{rp=1}^{T} \frac{RD - EAC(t)rp}{RD}$$

$$MAPE = \frac{1}{T} \sum_{rp=1}^{T} \frac{|RD - EAC(t)rp|}{RD}$$

Calculated by project finish

Stability

$$\overline{EAC(t)} = \frac{1}{R} \sum_{r=1}^{R} EAC(t)^r$$

$$\sigma EAC(t) = \sqrt{\sum_{r=1}^{R} (EAC(t)^r - \overline{EAC(t)})^2}$$

P-Factor

$$p = \frac{\sum_{i \in N} min(PV_{i,ES}, EV_{i,AT})}{\sum_{i \in N} PV_{i,ES}}$$

Calculated at each review period

Accuracy = f (P-factor, stability)?

Concerted Research Action Plan

Concerted research action plan

Searching for static and dynamic project drivers to predict and control the impact of management / contingency reserve on a project's success

Research grant awarded by Flemish Government to Prof. Dr. Vanhoucke M., Ghent University

In collaboration with
- George Washington University (U.S.)
- University College London (U.K.)
- CERN (CH)

Budget: > 1.300.000 €

Timespan: 2012 – 2018

CRA: the team

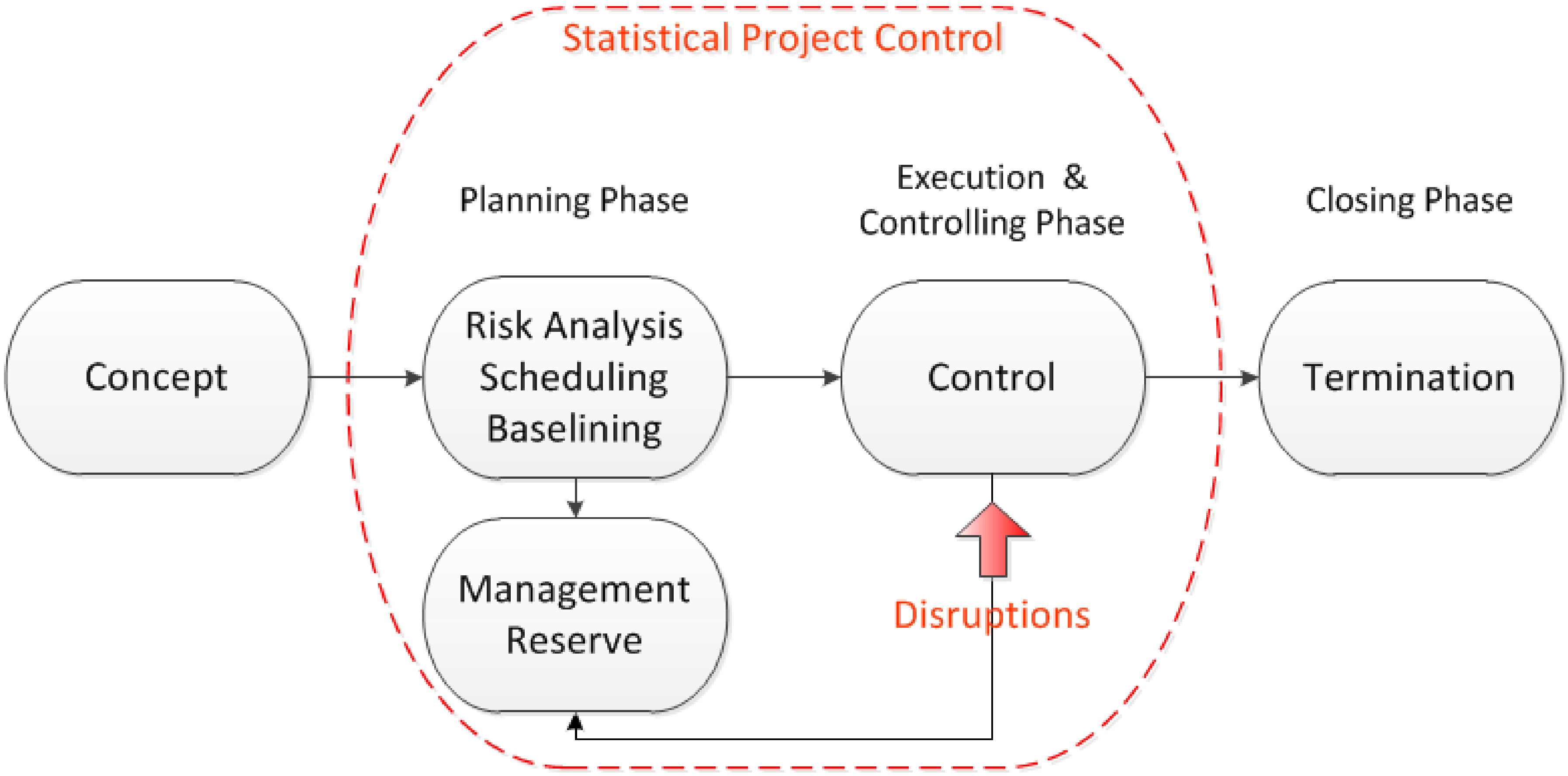
CRA: the toys

High Performance Computing system (HPC)

- VSC (Vlaamse Super Computer)
- Rank 118 (Top500 list of June 2012)

Data size typical similation run: > 1 TB (ca. 1.450 CD’s)

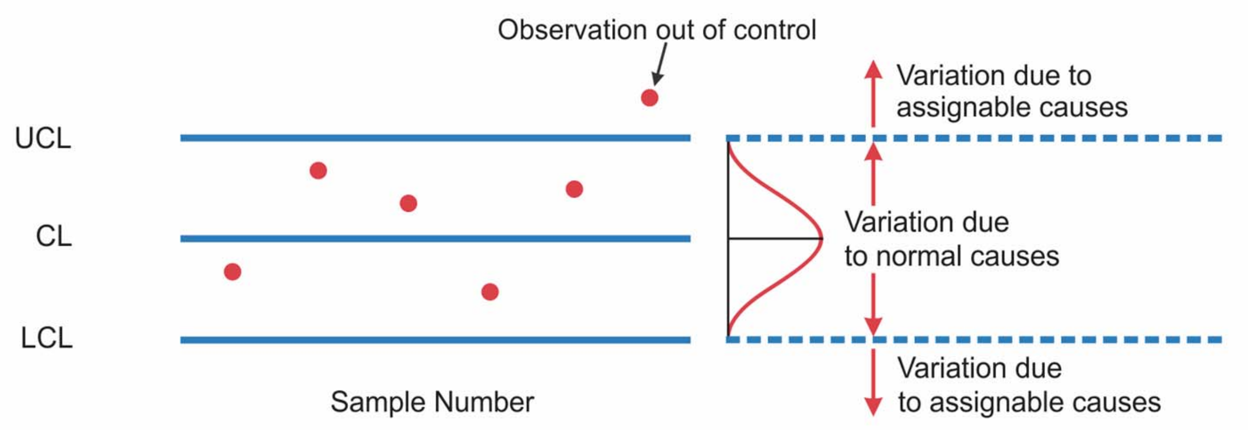
CRA: preparing the next generation



Development of the next generation project control decision tool

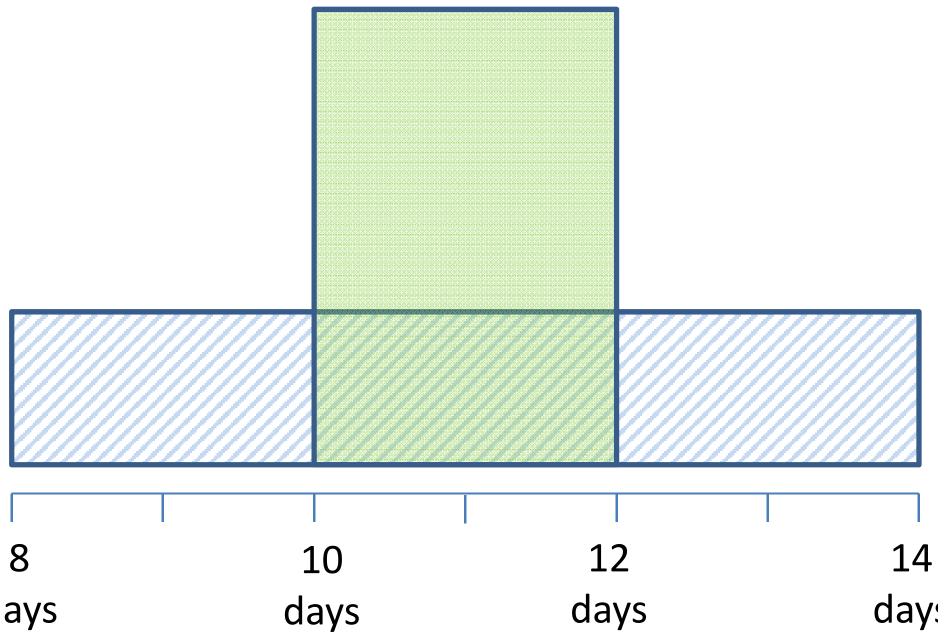
Defining thresholds

- By intuition: rule of the thumb
  - Based on experience of past projects
  - Thresholds may be static, narrowing or widening
- By using statistical process control charts, but:
  - Use of historical performance data (from other projects)
  - Normalised performance data needed (underlying distribution unknown)
  - Based on continuously processes



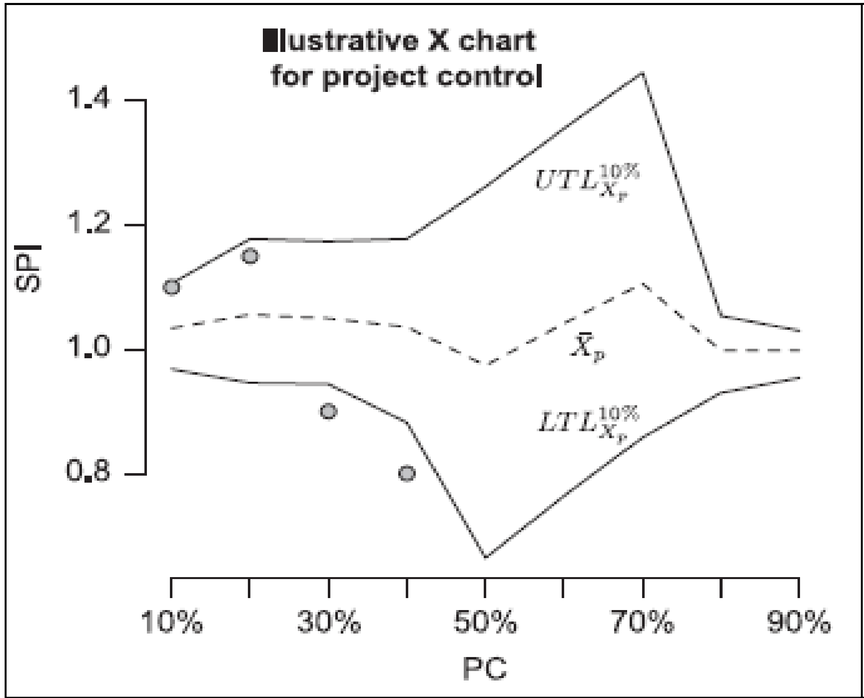
Defining thresholds: tolerance limits

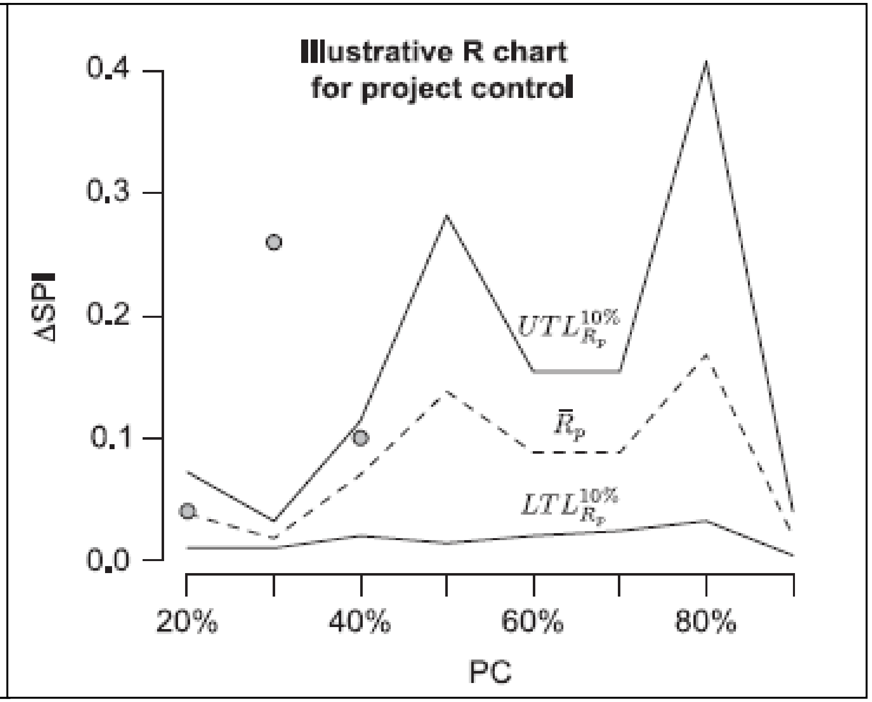
- The "Belgian" way: use of statistical project control & tolerance limits
  - Basic idea: define"as planned variation" during planning phase



Constructing control charts

- Tolerance limits for control charts are defined “ex ante”
  - X-chart: monitors individual observations
  - R-chart: monitors range (difference) between 2 adjacent observations





The way forward: statistical project control

Jeroen Colin, Mario Vanhoucke, 2014, "Setting tolerance limits for statistical project control using earned value management", Omega, 49 (2014) 107–122

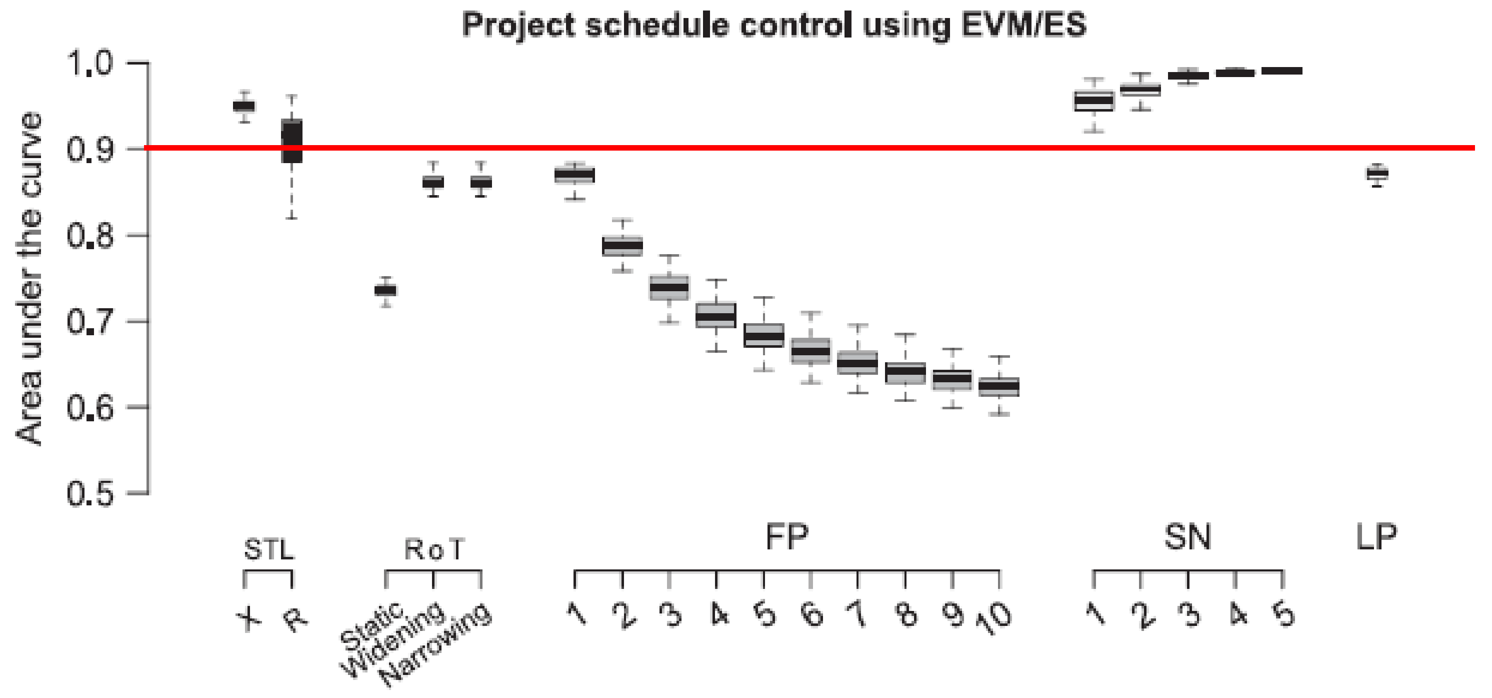


Fig. 15. *Area under the curve* comparison of the X and R charts (**STL**) with other schedule control approaches using EVM/ES.

CRA: publish results

- Publish & present research in academic world
  - Top academic journals ex. JORS, OMEGA, …
  - Specialised conferences
    - 2014: IFORS Conference (Barcelona), EWG PMS (Munchen)

- Translate & present research in professional world
  - Professional journals ex. PMJ, IJPM , JMPM, …
  - Popular journals ex. The Measurable News (CPM), PMWorld, …
  - Professional conferences:
    - 2013: EVM World (Naples, USA), EVM Europe (Ghent)
    - 2014: PGCS Conference (Canberra, AU)

      PMI Chapter Events (Sydney, Barcelona, Belgium)

      IPMA NL (Utrecht)

Spin – off:
Project database

Batselier, J. and Vanhoucke, M., 2014, "Construction and evaluation framework for a real-life project database", International Journal of Project Management, To Appear

Projects database

- Goal: create the largest and most diverse real-life commercial project database
- The 1st in its kind to the best of our knowledge
- Data selected by Ghent University (group works, master dissertations)

Recognising
Project Control Research

Ghent University: master thesis "project control"

May 2014: 10 works

May 2015: 16 works

Recognition by professional institutes

PMI Belgium Thesis Award

2014: Bannelies Martens, “Statistical project control””

2012: Pieter Leyman, "A genetic algorithm for the multi-mode resource-constrained project scheduling problem with discounted cash flows",

2011: Evelyn De Blieck, Ellen De Groote, "An accuracy study on Earned Value Management extensions using Monte-Carlo simulations

Recognition by industry

Arcelor Mittal Thesis Award

2014: Bert Aelter, Jules Branswyck:, “Het introduceren van teamrotatie in een projectomgeving”

2013: Pieter Beeckman, Kenny Vanleeuwen, “An accuracy study and improvement of a time-dependent EV model using Monte Carlo simulation”

2011: Len Vandenheede, “A case study for multi-project planning”

Agenda

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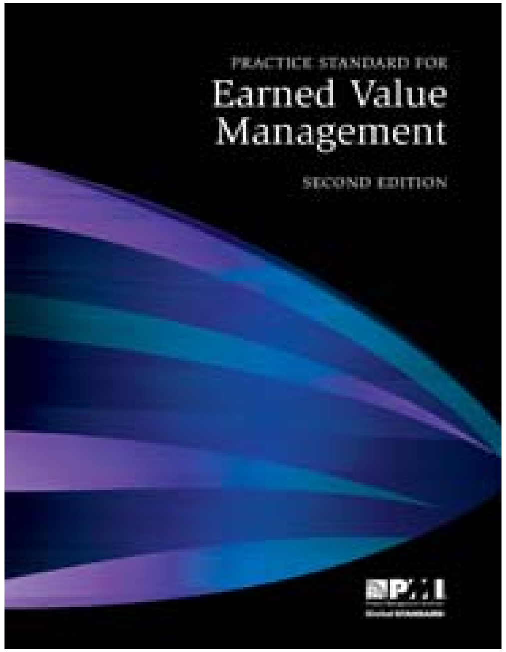
5. Conclusion

PMBOK 5th Edition, 2013
PS EVM 2nd Edition, 2011



PS EVM 2nd Ed., 2011

- Main body text:
  - Section 2.1 Introduction, Page 5
    "EVM can play a crucial role in answering questions such as:
    … When is the project likely to be completed? ..."
  - Section 9 Analyse performance data:
    no information and reference on schedule forecasting
- Appendix D: schedule analysis using EVM & ES data
- Remark: PS EVM 2nd ED. is based on PMBOK 4th Ed., 2008

Process group "schedule control"

PMBOK 4th Ed., 2008 → PMBOK 5th Ed., 2013

Outputs (PMBOK 4th Ed., 2008)

.1 Work performance measurements
.2 Organizational process assets updates
.3 Change requests
.4 Project management plan updates
.5 Project document updates

Outputs (PMBOK 5th Ed., 2013)

.1 Work performance information
.2 Schedule forecasts
.3 Change requests
.4 Project management plan updates
.5 Project documents updates
.6 Organizational process assets updates

PMBOK update suggestion

Inputs

.1 Project management plan
.2 Project schedule
.3 Work performance data
.4 Project calendars
.5 Schedule data
.6 Organizational process assets

.5 Schedule data
Include topological info

.7 SRA data
sensitivities, threshold

Tools & Techniques

.1 Performance reviews
.2 Project management software
.3 Resource optimization techniques
.4 Modeling techniques
.5 Leads and lags
.6 Schedule compression
.7 Scheduling tool

.1 Performance review
Include ES method

.8 Dynamic scheduling

Outputs

.1 Work performance information
.2 Schedule forecasts
.3 Change requests
.4 Project management plan updates
.5 Project documents updates
.6 Organizational process assets updates

.1 Performance info
Include ES indicators

.2 Schedule forecasts
Include forecast range
Include stability info

Agenda

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Conclusion

The ability of EV/ES metrics to augment schedule analysis has been proven both emperically & academically!

As a schedule forecasting tool:

Earned Schedule is the best!

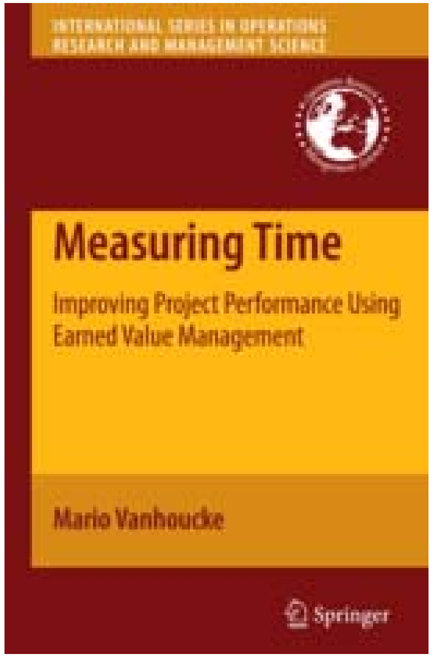
More serial networks → higher accuracy

As a schedule control tool:

Dynamic scheduling (combining ES & SRA) is the most efficient to trigger corrective actions

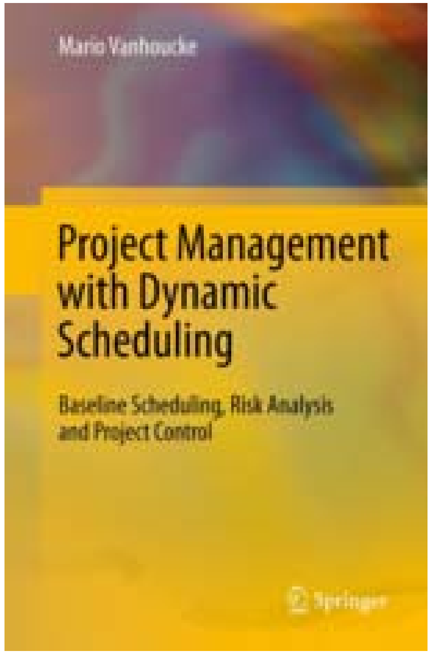
The best is yet to come: statistical project control!

Books



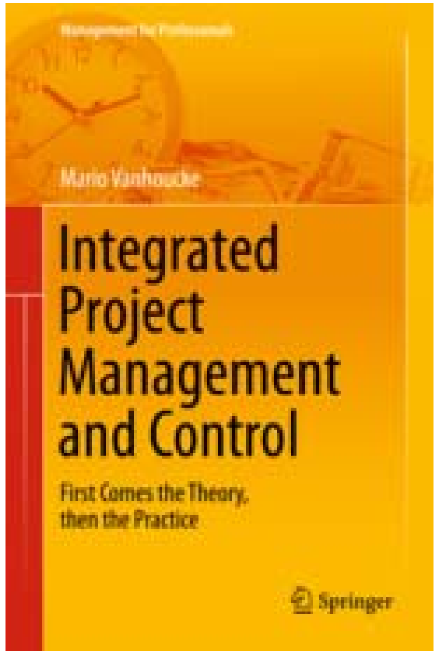
Researchers / Academics
online 09/10/2009

End ‘13:
5,215 downloads



Students
online 10/02/2012

End ‘13:
12,533 downloads



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Operations Research & Scheduling Research Group

www.evm-europe.eu

evm EUROPE ASSOCIATION

Thanks!