הכינוס הלאומי השני להנדסת מערכות
INCOSE_IL 2005

ניהול אפקטיבי של סיכונים מערכתיים

שיטה להערכה ואופטימיזציה של תהליכי בדיקות מערכת

אבנר אנגל - התעשייה אווירית - מו"פ / מטה החברה

I

Introduction

& Justification

Background: EC funded project -

SysTest

SysTest:
Developing
Methodology
For Advanced
Systems Testing

G1RD-CT-2002-00683

SysTest concepts / products

System Lifecycle

Definition

Design

Implementation

Integration

Qualification

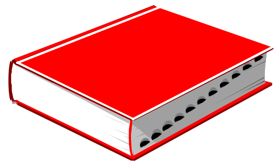
Production

Use/Maintenance

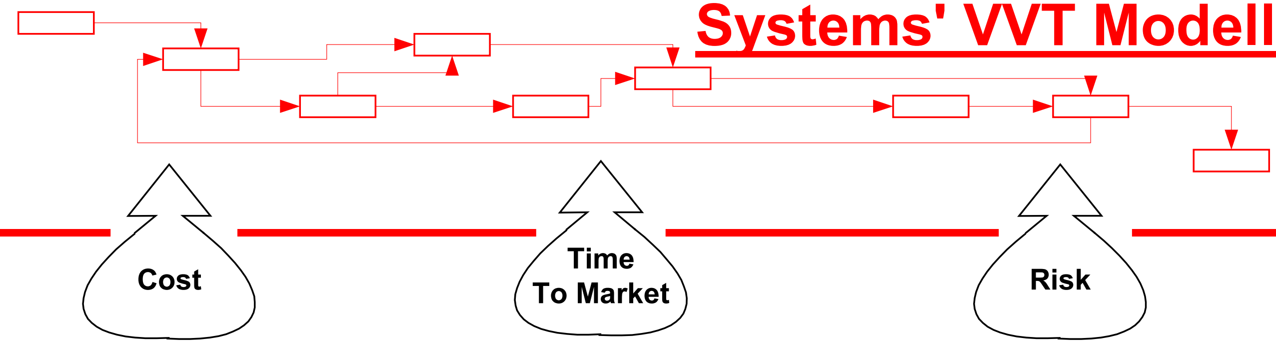
Disposal

VVT=Verification, Validation & Testing

Systems' VVT Methodology



Systems' VVT Modelling

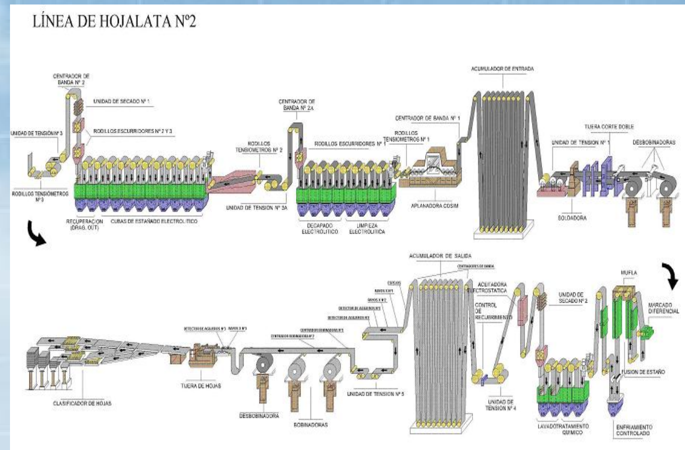


Parameter	Value
Cost	XX
TTM	YY
Risk	ZZ
:	:

Pilot projects

פתוח רצפות יצור (תעשיית מזון) (Tetrapak)

פתוח מערכת בקרה למנוע סילון (HS)



בדיקות ממוחשבות בתהליכי יצור פלדה (Aceralia)

פתוח מערך ממוחשב לרכב יוקרה (DC)

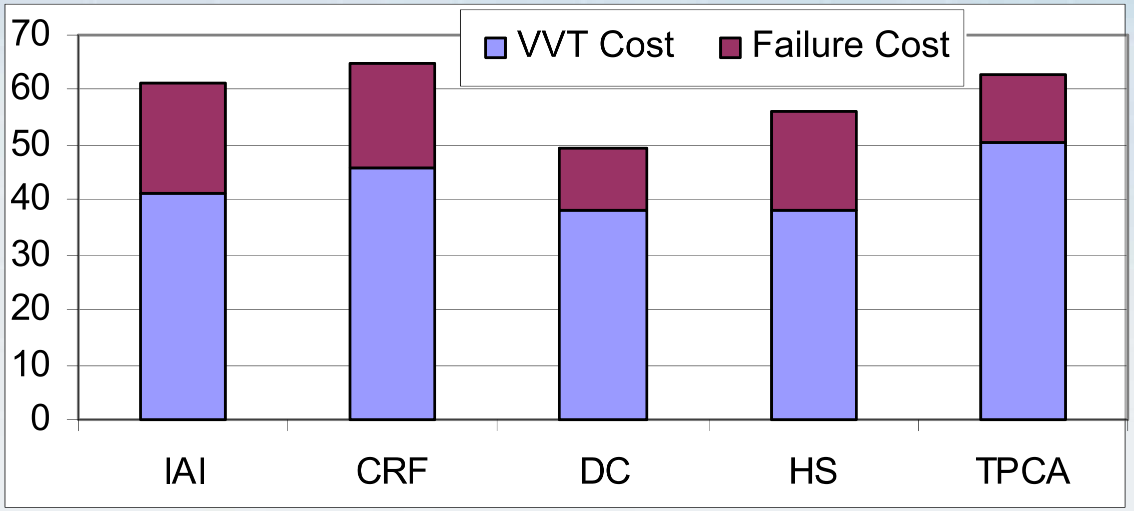
שדרוג אוויוניקה במסוק תובלה (IAI)

פתוח יציקות למנועי משאיות (Fiat)

Cost of quality (systems development)

עלויות האיכות בפרויקט פיתוח = עלויות הבדיקות + עלויות הכשלים =60%

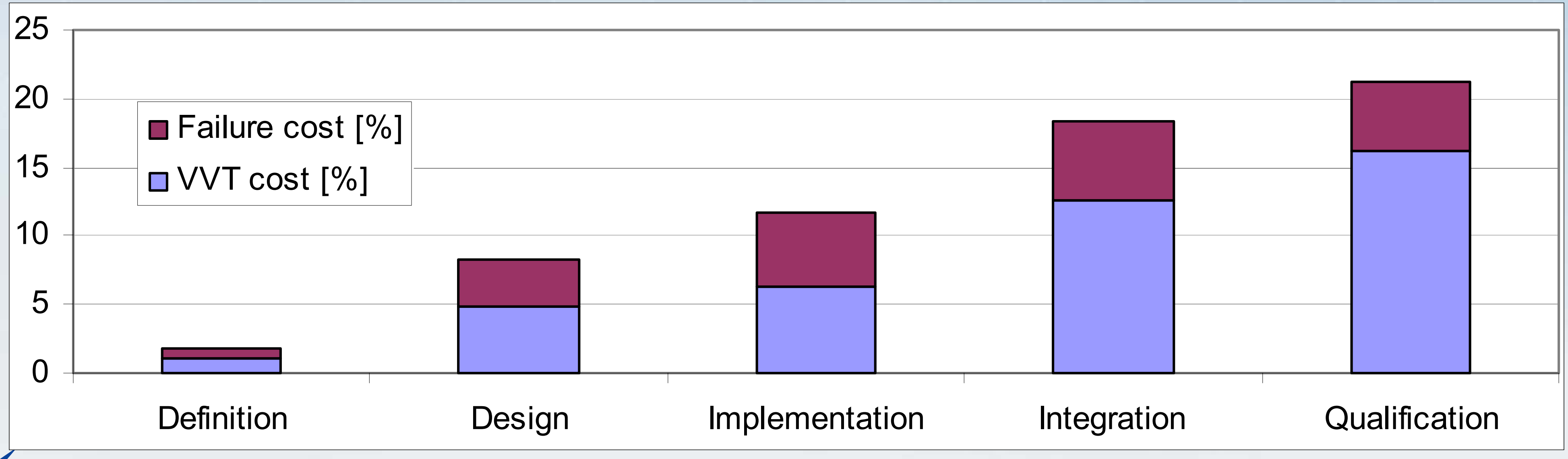
	IAI	CRF	DC	HS	TPCA	Average
VVT Cost	41.0	45.8	38.3	38.0	50.6	42.7
Failure Cost	20.3	19.0	11.3	18.0	12.3	16.2
Quality Cost	61.3	64.8	49.6	56.0	62.9	58.9



Cost of quality distribution

60% עלויות האיכות בתע"א

Item	Definition	Design	Implementation	Integration	Qualification	Total
VVT cost [%]	1.1	4.8	6.3	12.6	16.2	41.0
Failure cost [%]	0.8	3.4	5.3	5.7	5.1	20.3
Quality cost [%]	1.9	8.2	11.6	18.3	21.3	**61.2**



II

VVT Methodology

& Modeloing

Canonical VVT Model (CVM)

Definition — $L_1=1$

VVT - $V_{1,1}$	$Cv_{1,1}$	$Tv_{1,1}$
....		
VVT - $V_{1,n1}$	$Cv_{1,n1}$	$Tv_{1,n1}$

Design — $L_2=2$

VVT - $V_{2,1}$	$Cv_{2,1}$	$Tv_{2,1}$
....		
VVT - $V_{2,n2}$	$Cv_{2,n2}$	$Tv_{2,n2}$

Implementation — $L_3=3$

VVT - $V_{3,1}$	$Cv_{3,1}$	$Tv_{3,1}$
....		
VVT - $V_{3,n3}$	$Cv_{3,n3}$	$Tv_{3,n3}$

Qualification — $L_5=5$

VVT - $V_{5,1}$	$Cv_{5,1}$	$Tv_{5,1}$
....		
VVT - $V_{5,n5}$	$Cv_{5,n5}$	$Tv_{5,n5}$

Production — $L_6=6$

VVT - $V_{6,1}$	$Cv_{6,1}$	$Tv_{6,1}$
....		
VVT - $V_{6,n6}$	$Cv_{6,n6}$	$Tv_{6,n6}$

Use/Maintainance — $L_7=7$

VVT - $V_{7,1}$	$Cv_{7,1}$	$Tv_{7,1}$
....		

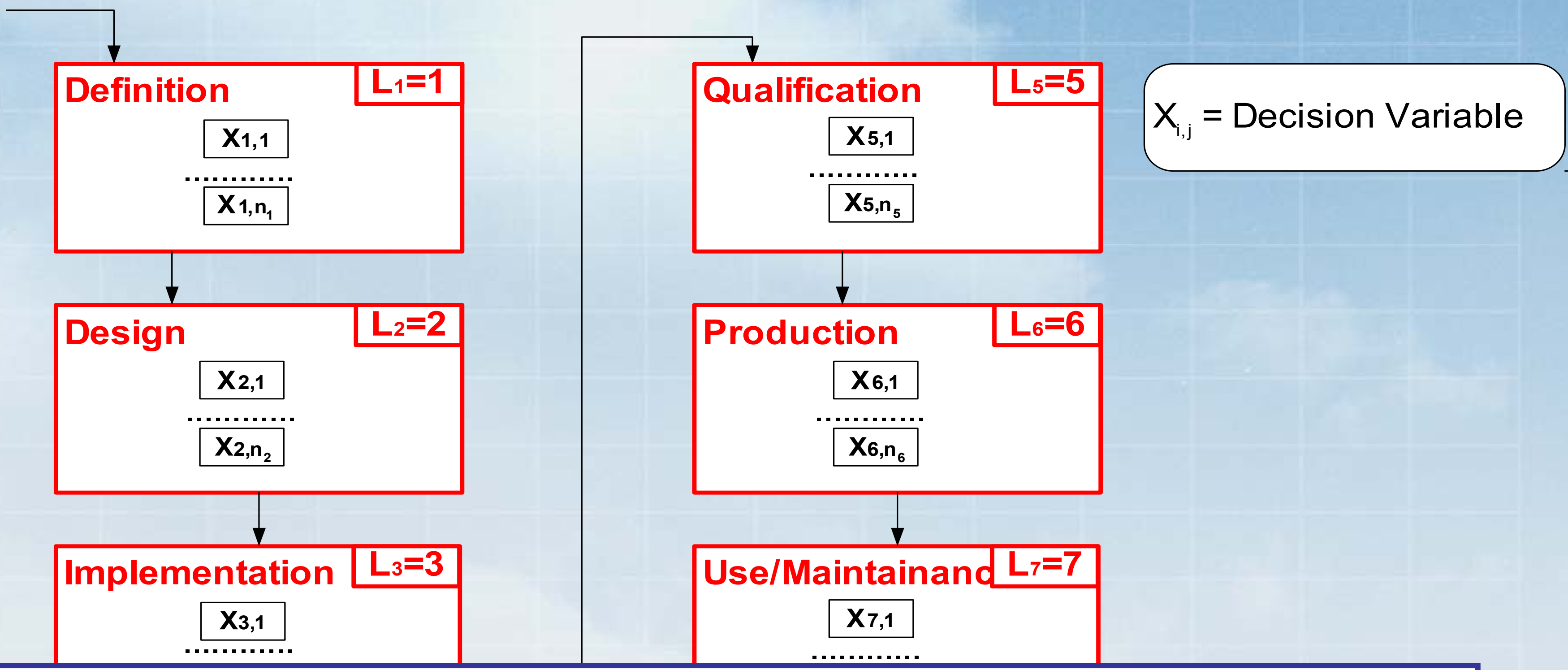
L_i = Lifecycle
$V_{i,j}$ = VVT activity
$Cv_{i,j}$ = CVM Cost
$Tv_{i,j}$ = CVM Time

$$1 \le i \le 8$$
$$1 \le j \le n_i$$

CVM Cost

$$C_{CVM} = \sum_{i=1}^{z} \sum_{j=1}^{n_i} Cv_{i,j}$$

VVT Strategy Model (VSM)



Strategy Cost

$$Cv_{VVT\_Strategy} = \sum_{i=1}^{z} \sum_{j=1}^{n_i} \{ Cv_{i,j} * X_{i,j} \}$$

VVT risks

Primary VVT Risks

Appraisal

Due to inherent imperfect products detected through a VVT activity

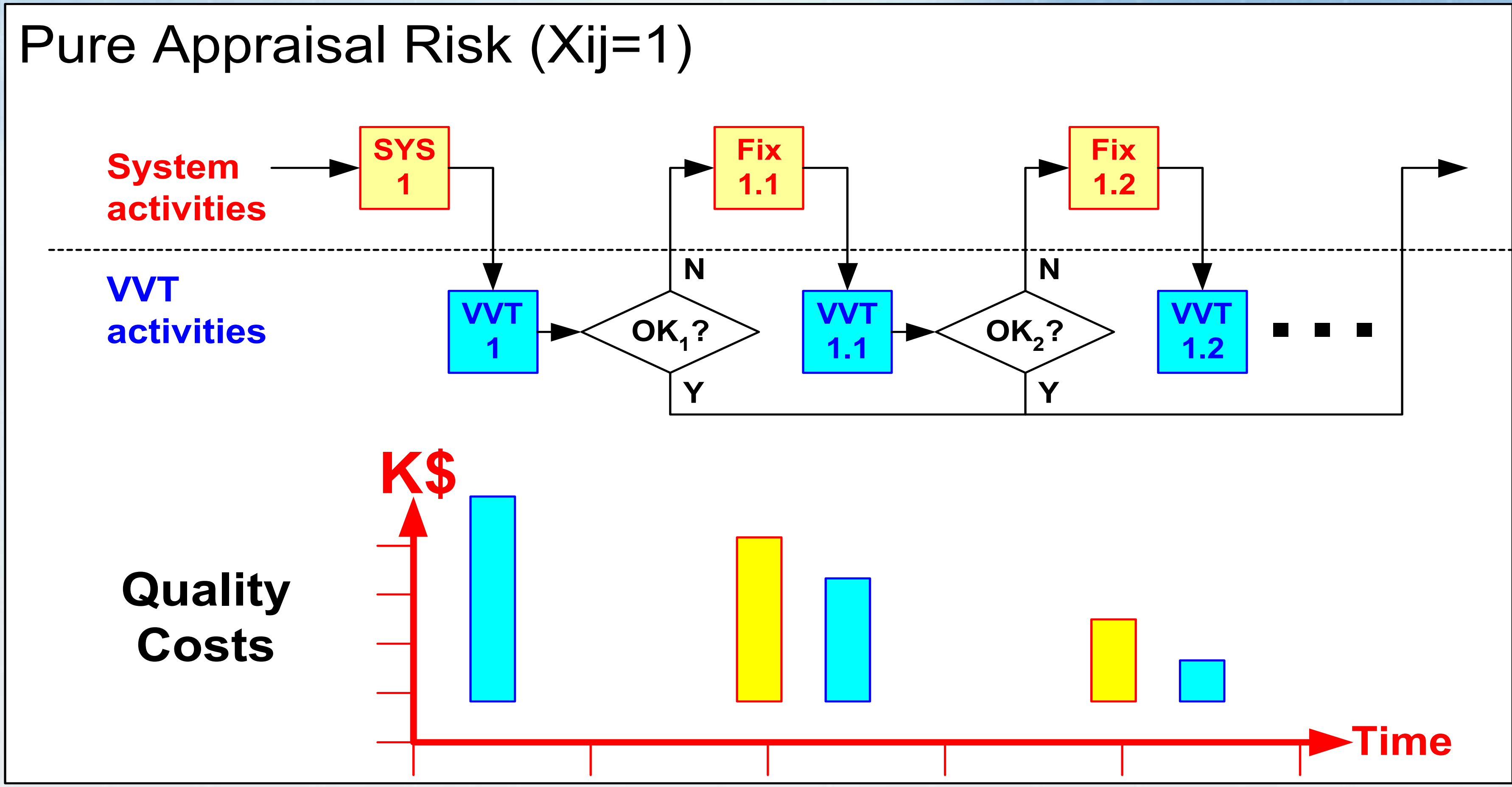
$$X_{i,j} > 0$$

Impact

Due to partial or no performance of a VVT activity

$$X_{i,j} < 1$$

VVT Appraisal Risk Scenario



Appraisal Risk Model (ARM)

Definition — $L_1=1$

$Ca_{1,1}$	$Ta_{1,1}$	$Pa_{1,1}$	$D_{1,1}$
………			
$Ca_{1,n1}$	$Ta_{1,n1}$	$Pa_{1,n1}$	$D_{1,n1}$

Design — $L_2=2$

$Ca_{2,1}$	$Ta_{2,1}$	$Pa_{2,1}$	$D_{2,1}$
………			
$Ca_{2,n2}$	$Ta_{2,n2}$	$Pa_{2,n2}$	$D_{2,n2}$

Implementation — $L_3=3$

$Ca_{3,1}$	$Ta_{3,1}$	$Pa_{3,1}$	$D_{3,1}$
………			
$Ca_{3,n3}$	$Ta_{3,n3}$	$Pa_{3,n3}$	$D_{3,n3}$

Qualification — $L_5=5$

$Ca_{5,1}$	$Ta_{5,1}$	$Pa_{5,1}$	$D_{5,1}$
………			
$Ca_{5,n5}$	$Ta_{5,n5}$	$Pa_{5,n5}$	$D_{5,n5}$

Production — $L_6=6$

$Ca_{6,1}$	$Ta_{6,1}$	$Pa_{6,1}$	$D_{6,1}$
………			
$Ca_{6,n6}$	$Ta_{6,n6}$	$Pa_{6,n6}$	$D_{6,n6}$

Use/Maintainance — $L_7=7$

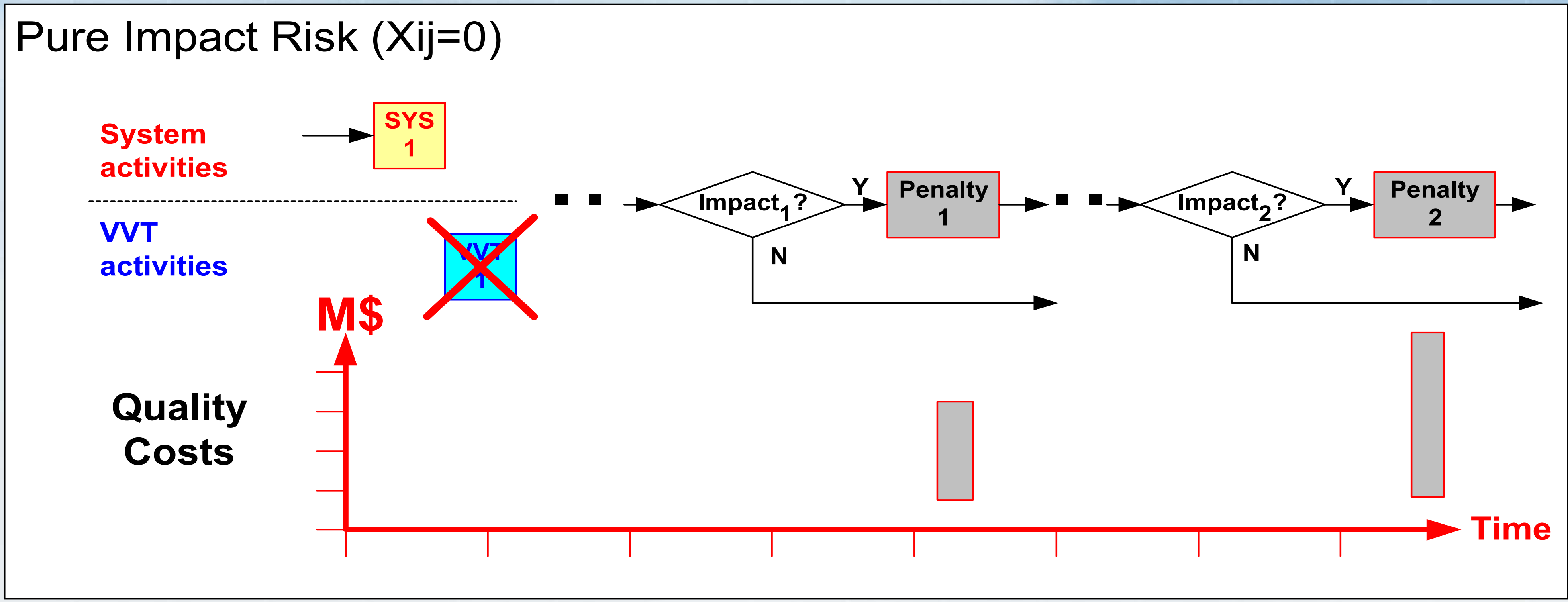
$Ca_{7,1}$	$Ta_{7,1}$	$Pa_{7,1}$	$D_{7,1}$
………			

L_i = Lifecycle
$Ca_{i,j}$ = ARM Cost
$Ta_{i,j}$ = ARM Time
$Pa_{i,j}$ = ARM Prob.
$D_{i,j}$ = ARM Decay

Appraisal Cost

$$Ca_{VVT\_Strategy} = \sum_{i=1}^{z} \sum_{j=1}^{n_i} \{ Ca_{i,j} * (EN_{i,j} - 1) \}$$

VVT Impact Risk Scenario



Impact Risk Model (IRM)

Definition — $L_1=1$

$1 \le i \le L_i; \quad 1 \le j(i) \le n_i; \quad k = 1,2,...$

Risk $R_{i,j}^{(1,k)}$	$Ci_{i,j}^{(1,k)}$	$Ti_{i,j}^{(1,k)}$	$Pi_{i,j}^{(1,k)}$

Design — $L_2=2$

$1 \le i \le L_i; \quad 1 \le j(i) \le n_i; \quad k = 1,2,...$

Risk $R_{i,j}^{(2,k)}$	$Ci_{i,j}^{(2,k)}$	$Ti_{i,j}^{(2,k)}$	$Pi_{i,j}^{(2,k)}$

Qualification — $L_5=5$

$1 \le i \le L_i; \quad 1 \le j(i) \le n_i; \quad k = 1,2,...$

Risk $R_{i,j}^{(5,k)}$	$Ci_{i,j}^{(5,k)}$	$Ti_{i,j}^{(5,k)}$	$Pi_{i,j}^{(5,k)}$

Production — $L_6=6$

$1 \le i \le L_i; \quad 1 \le j(i) \le n_i; \quad k = 1,2,...$

Risk $R_{i,j}^{(6,k)}$	$Ci_{i,j}^{(6,k)}$	$Ti_{i,j}^{(6,k)}$	$Pi_{i,j}^{(6,k)}$

L_i = Lifecycle
$R_{i,j}$ = IRM Risk
$Ci_{i,j}$ = IRM Cost
$Ti_{i,j}$ = IRM Time
$Pi_{i,j}$ = IRM Prob.

Impact Cost

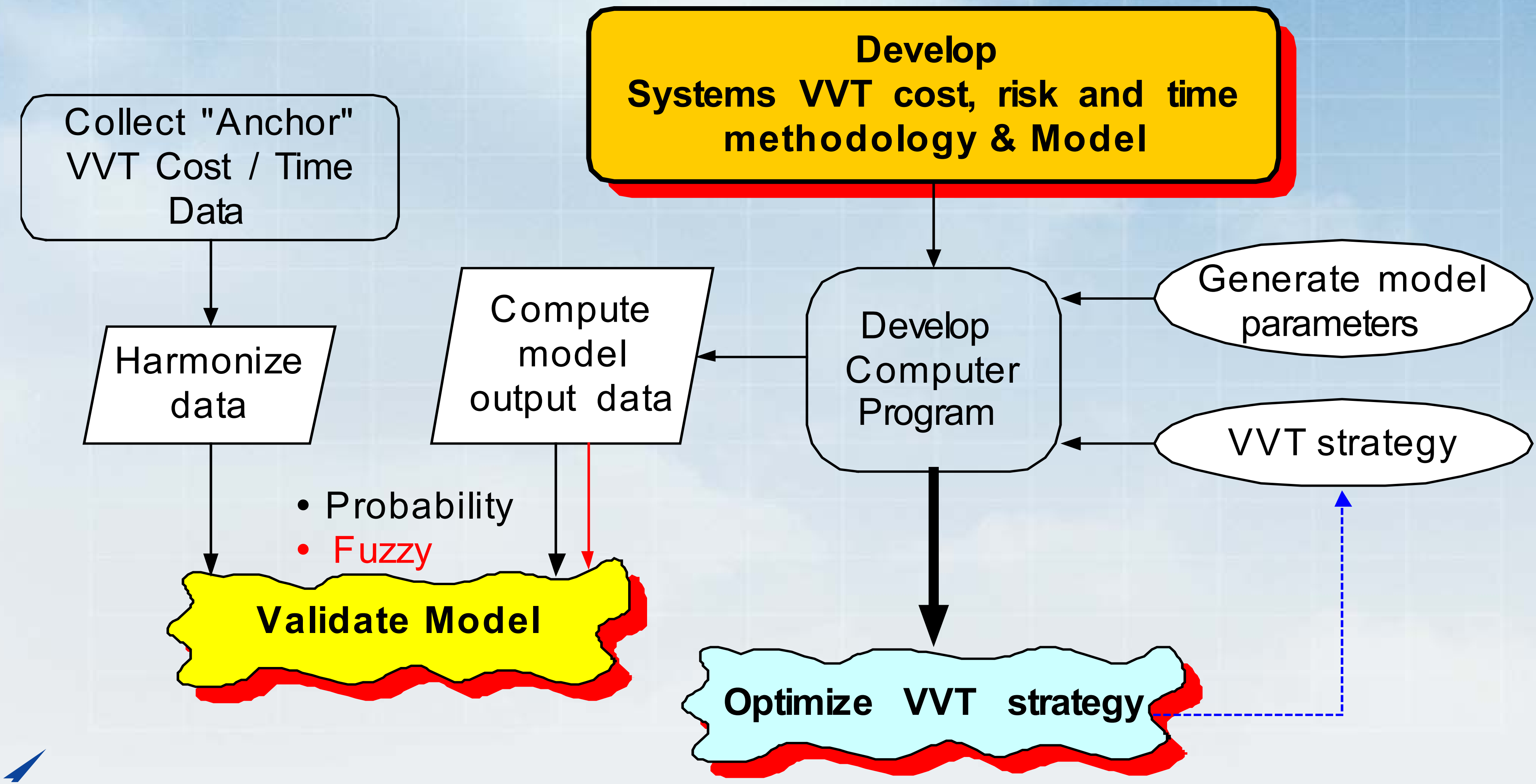
$$Ci_{VVT\_Strategy} = \sum_{i=1}^{z} \sum_{j=1}^{n_i} \sum_{l=i}^{z} \sum_{k=1,2...} \left\{ Ci_{i,j}^{(l,k)} * Pi_{i,j}^{(l,k)} * (1 - X_{i,j}) \right\}$$

Total Cost

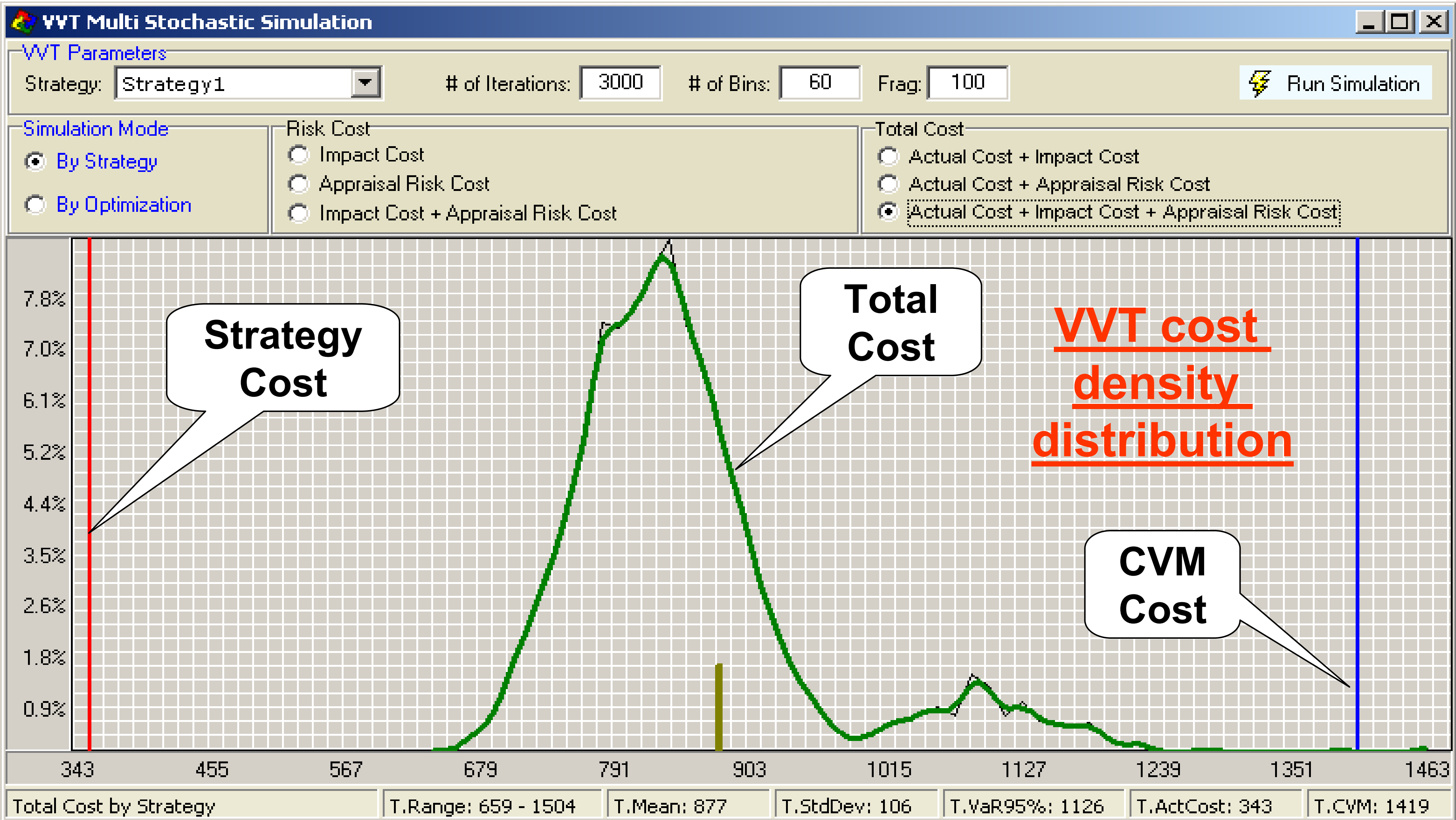
$$C_{VVT\_Overall} = Cv_{VVT\_Strategy} + Ca_{VVT\_Strategy} + Ci_{VVT\_Strategy}$$

III
Cost Validation

VVT Optimization Process Flow

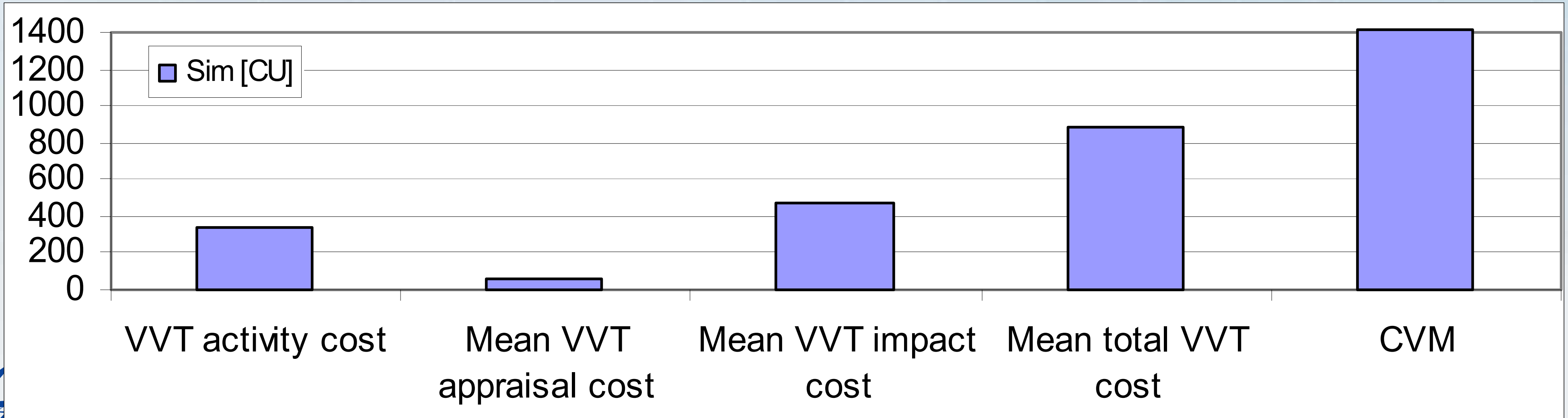


VVT cost modeling - Monte-Carlo simulator



VVT cost components

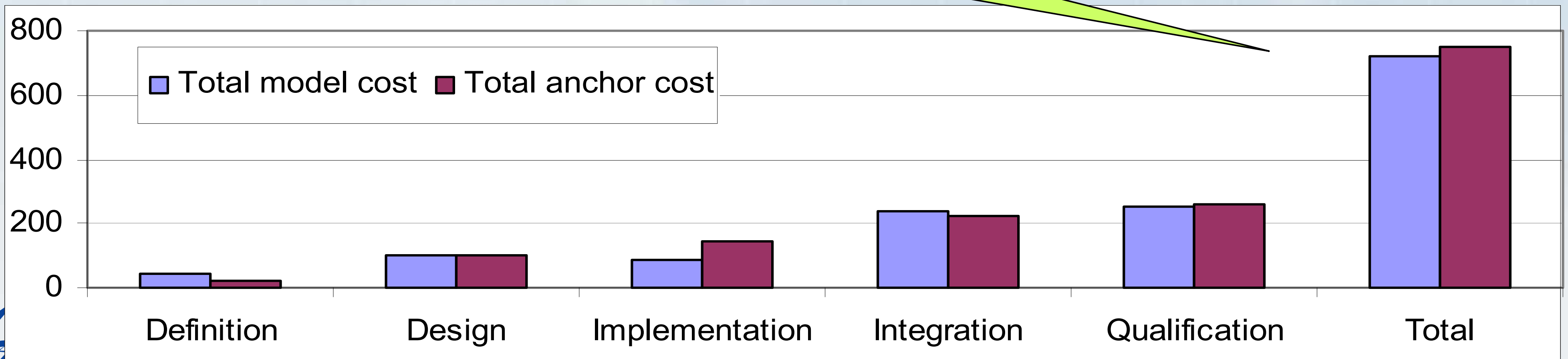
Cost categories	Simulation	
	Sim [CU]	[%]
VVT activity cost	343	39.1%
Mean VVT appraisal cost	62	7.1%
Mean VVT impact cost	472	53.8%
Mean total VVT cost	**877**	**100.0%**
CVM	1419	161.8%
STD-DEV	106	12.1%
VaR95%	1126	128.4%



Probabilistic VVT cost model validation

Cost categories	Definition	Design	Implementation	Integration	Qualification	Total
VVT activity	33	67	49	88	106	343
VVT appraisal	2	12	11	12	25	62
2/3 VVT impact	10	23	27	135	121	315
Total model cost	45	102	87	235	252	720
Total anchor cost	23	101	143	224	261	751
%	97.6%	0.5%	-39.2%	4.7%	-3.6%	-4.2%

Statistical correlation: 0.9944

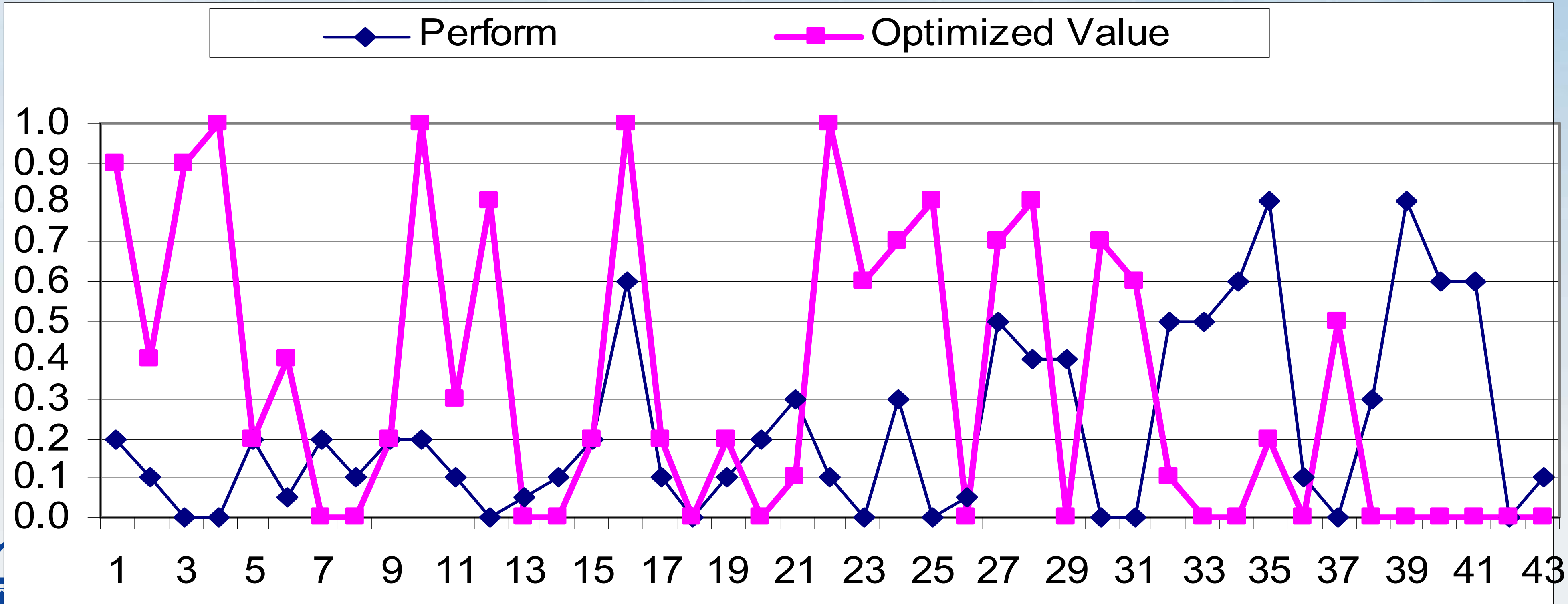


IV
VVT
Optimization

Example-1: VVT cost optimization Minimizing loss function

(Mathematical analysis)

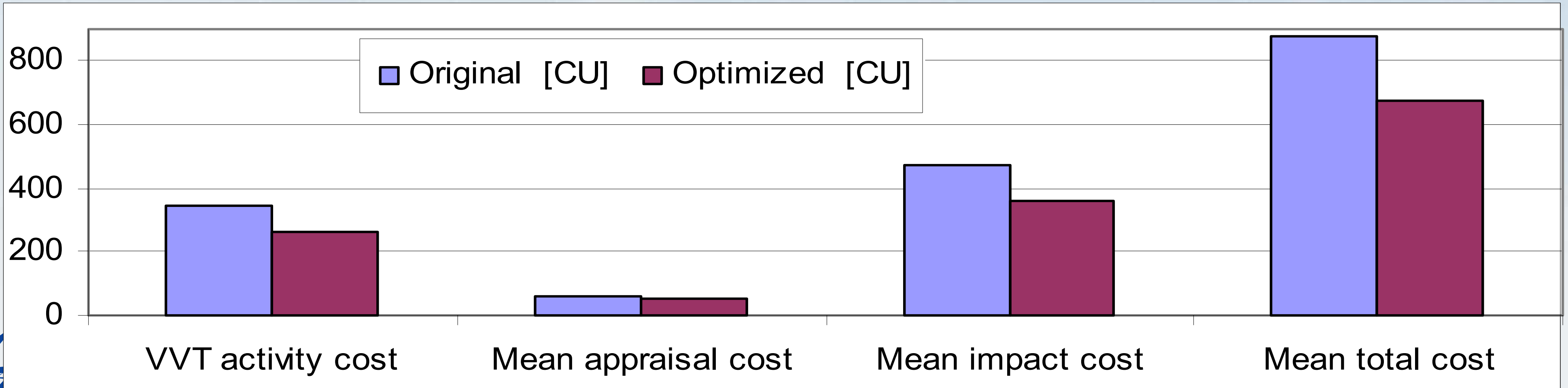
Original & optimized VVT strategies



Example-1: VVT cost optimization (Cont.)

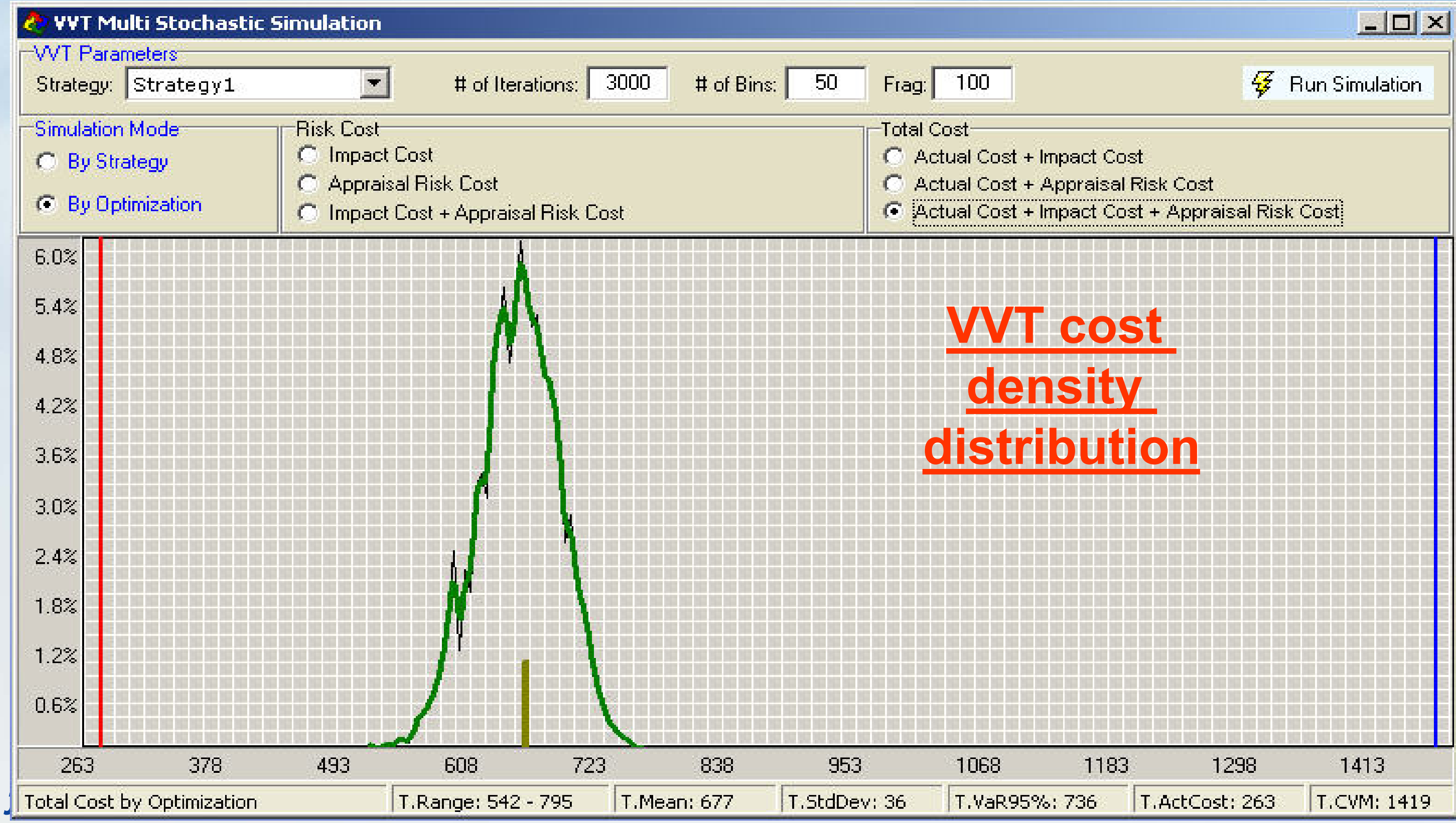
Original & optimized VVT costs

Cost categories [CU]	Original [CU]	Optimized [CU]	Change [CU]	Change [%]
VVT activity cost	343	263	80	23%
Mean appraisal cost	62	52	10	16%
Mean impact cost	472	362	110	23%
Mean total cost	877	677	200	23%
CVM cost	1419	1419	0	0%
STD-DEV	106	36	70	66%
VaR95%	1126	736	390	35%



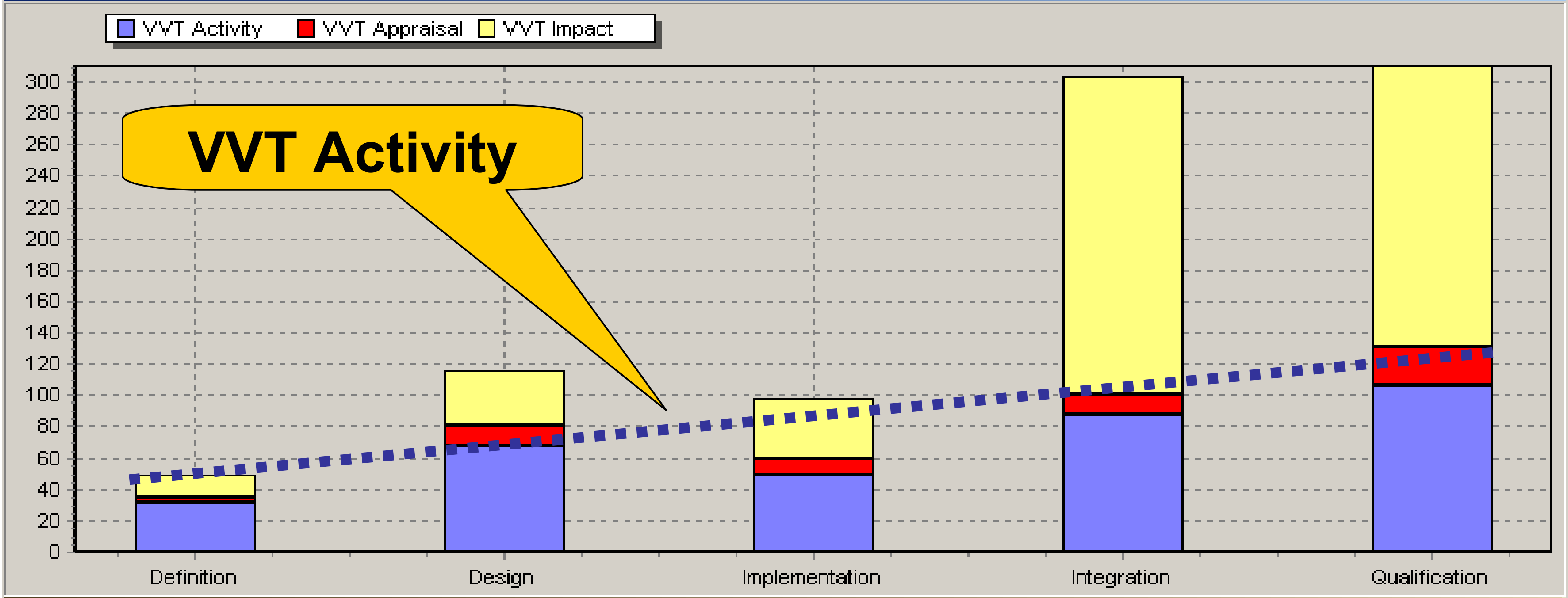
Example-1: VVT cost optimization (Cont.)

Optimized VVT cost histogram



Example-1: Original cost distribution (Total 877 [CU])

Lifecycle Cost Graph



Cost Data

Phases	VVT	VVT Appraisal	VVT Impact	Total	CVM
Definition	32.00	3.03	14.42	49.45	254.00
Design	68.00	12.19	35.21	115.40	455.00
Implementation	49.00	10.02	39.55	98.57	224.00
Integration	88.00	11.87	203.65	303.52	169.00
Qualification	106.00	25.14	179.45	310.59	317.00
Total	**343.00**	**62.25**	**472.28**	**877.53**	**1419.00**

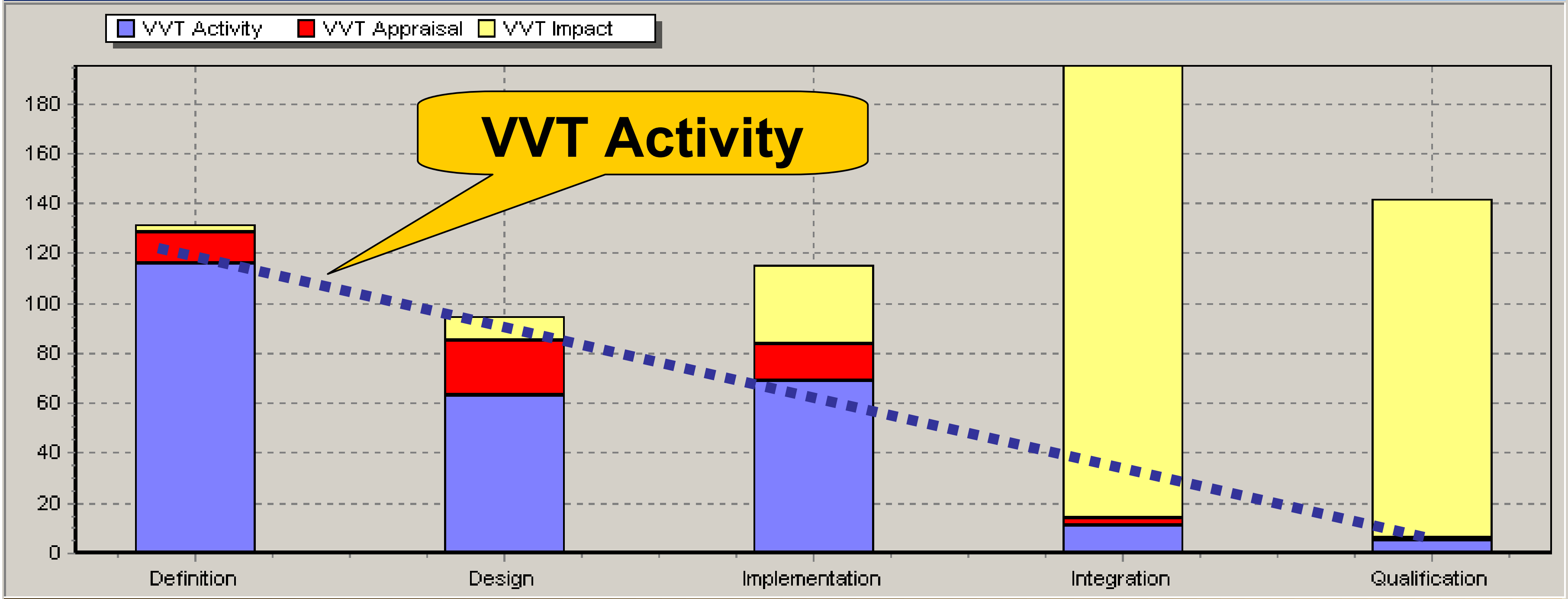
Calculation mode
By Strategy
By Optimization

Strategy: Strategy1

Compute
Report

Example-1: Optimized cost distribution (Total 677 [CU])

Lifecycle Cost Graph



Cost Data

Phases	VVT	VVT Appraisal	VVT Impact	Total	CVM
Definition	116.00	12.01	3.49	131.50	254.00
Design	63.00	22.15	9.65	94.80	455.00
Implementation	69.00	14.73	31.27	115.00	224.00
Integration	11.00	2.74	181.30	195.04	169.00
Qualification	5.00	0.71	135.76	141.47	317.00
Total	**264.00**	**52.34**	**361.47**	**677.81**	**1419.00**

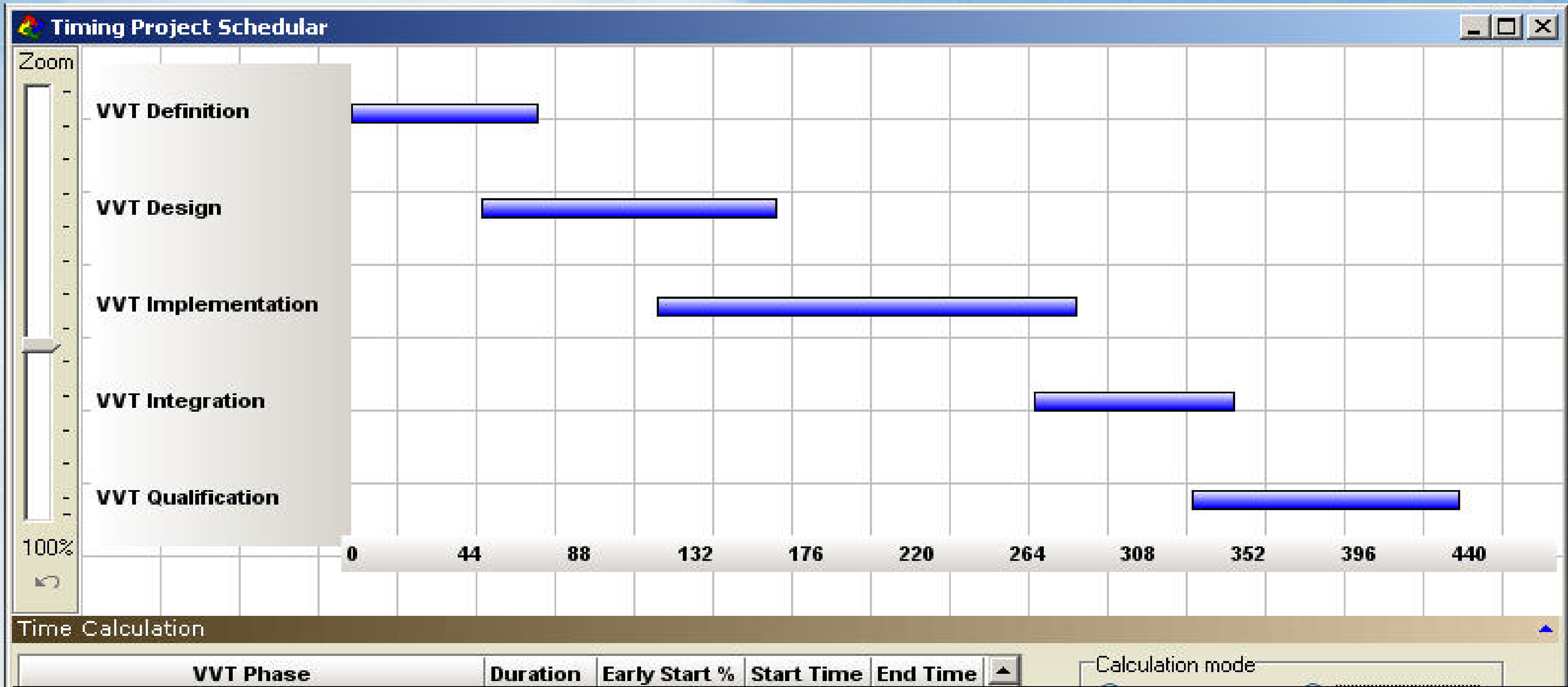
Calculation mode: By Strategy / By Optimization

Strategy: Strategy1

Compute

Report

Example-2: Optimized project duration



	Expected SSGA optimized time & cost			
	Original	Optimize	Change	Change [%]
Cost [CU]	877	798	79	9%
Time [Days]	539	441	98	18%

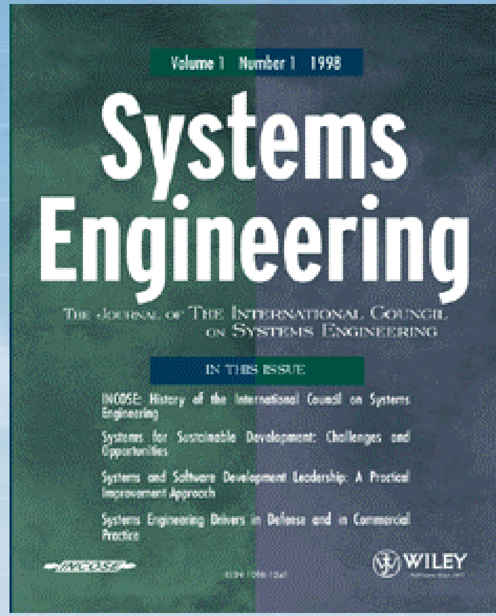
Pointers

VVT model description:

Engel A. and Barad M.,

“A Methodology for Modeling VVT Risks and Costs”,

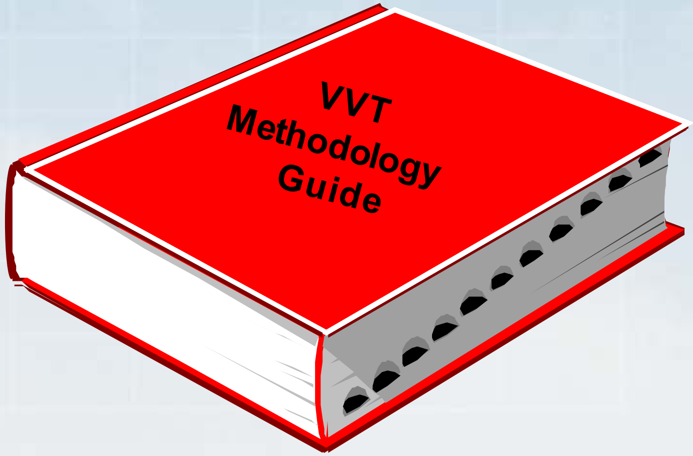
Systems Engineering Journal, Volume 6, issue 3, pp 135 – 151, 2003



SysTest Website:

Systems Engineering Center of Excellence (SECOE)

(http://secoe.org/0105.htm)



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