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Research Center

Valuing System Flexibility via Total Ownership Cost Analysis

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Outline

- **Research Project Context**
- **Flexibility Definitions and Common Cases**
- **Total Ownership Cost (TOC) Results to Date**
  - **Advantages, Challenges, Strategies**
  - **TOC Analysis for Foreseeable Change**
    - **For individual systems**
    - **For families of systems**
  - **Conclusions and Candidate Extensions**
    - **Refined and extended model capabilities**
    - **Integration with alternative valuation models**

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Research Project Context

- **Part of SERC Valuing Flexibility Research Task**
  - **For DDR&E Director of Systems Engineering Steve Welby**
- **Provide business cases for investing in system flexibility**
  - **Vs. buying more copies of less flexible systems**
- **Performed by multi-university team**
  - **Texas A&M, AFIT, NPS, USC, U. Virginia**
- **Using multiple analysis approaches**
  - **Knowledge Value Added, Option Hedging, Portfolio Analysis, Risk Analysis, Total Ownership Cost (TOC) Analysis**

Flexibility Definitions and Common Cases

- Working definition of "flexibility"
  - Ability to adapt cost-effectively to sources of change
- Foreseeable sources of change
  - Within single system: encapsulate sources of change
  - Across family of systems: use commonalities and variabilities
- Unforeseeable sources of change
  - Build in analysis of change traffic, adaptability
  - Build in system margins
- Classes of change effects
  - Capabilities, interfaces, levels of service, project constraints, improvement opportunities

Total Ownership Cost (TOC) Approach

- TOC Advantages, Challenges, Strategies
  - Representative examples
- TOC Analysis for Foreseeable Change
  - Model and tool for individual systems
    - Calibrated to TRW software data (3 systems)
    - Exploring calibration to NPS SHIPMAIN hardware data
  - Model and tool for families of systems
    - Calibrated to COCOMO II software data (161 projects)
    - Exploring calibration to AFIT modular munitions hardware data
- Candidate Extensions
  - Refined and extended model capabilities
    - Particular domains, tradeoff analyses, enterprise analysis
    - Effects of adaptation to unforeseeable change
  - Integration with alternative valuation models

TOC Advantages, Challenges, Strategies

- TOC Advantages
  - Increasingly required (DoDI 5000.02, WSARA 2009)
  - Easy to understand across specialty domains
  - Clear cause-effect relationships, straightforward calibration
- TOC Challenges
  - Defining flexibility investment costs, resulting cost reductions
    - Rework and change-adaptation cost reductions a proxy for benefits
  - Predicting uncertain futures
- TOC Approach Strategies
  - Tailor analysis approaches to common situations
    - DoDI 5000.02 milestone reviews, make-or-buy decisions
  - Explicitly emphasize need to define evolution requirements
    - Not just snapshot capability, interface, KPP, project requirements
  - Start with simple models and tools, refine and extend as needed

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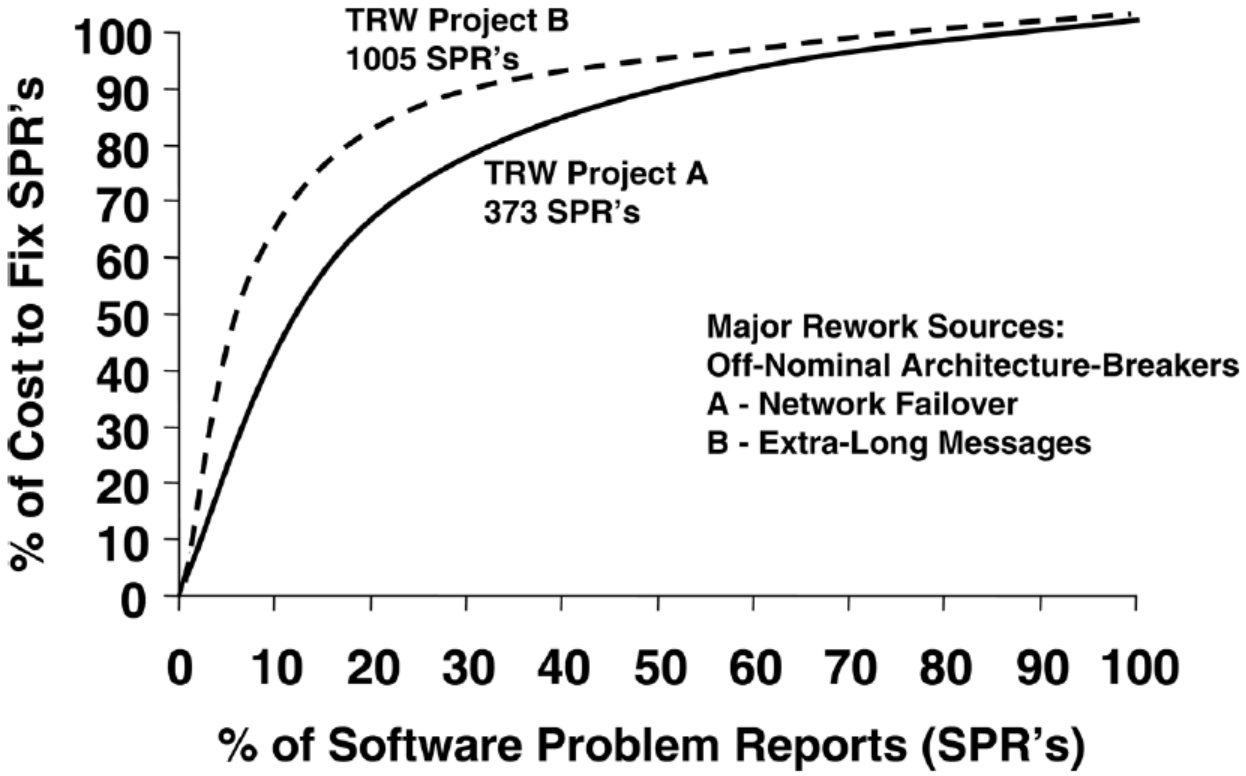
Point-Solution Architectures Cause Major Rework

Contracts: Nominal-case requirements; 90 days to PDR



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Projects A and B Major Rework Sources

- Change processing over 1 person-month = 152 person-hours

Category	Project A	Project B
Extra long messages		3404+626+443+328+244= 5045
Network failover	2050+470+360+160= 3040	
Hardware-software interface	620+200= 820	1629+513+289+232+166= 2832
Encryption algorithms		1247+368= 1615
Subcontractor interface	1100+760+200= 2060	
GUI revision	980+730+420+240+180 =2550	
Data compression algorithm		910
External applications interface	770+330+200+160= 1460	
COTS upgrades	540+380+190= 1110	741+302+221+197= 1461
Database restructure	690+480+310+210+170= 1860	
Routing algorithms		494+198= 692
Diagnostic aids	360	477+318+184= 979
TOTAL:	**13620**	**13531**

Project C: Architecting for Change

USAF/ESC-TRW CCPDS-R Project*

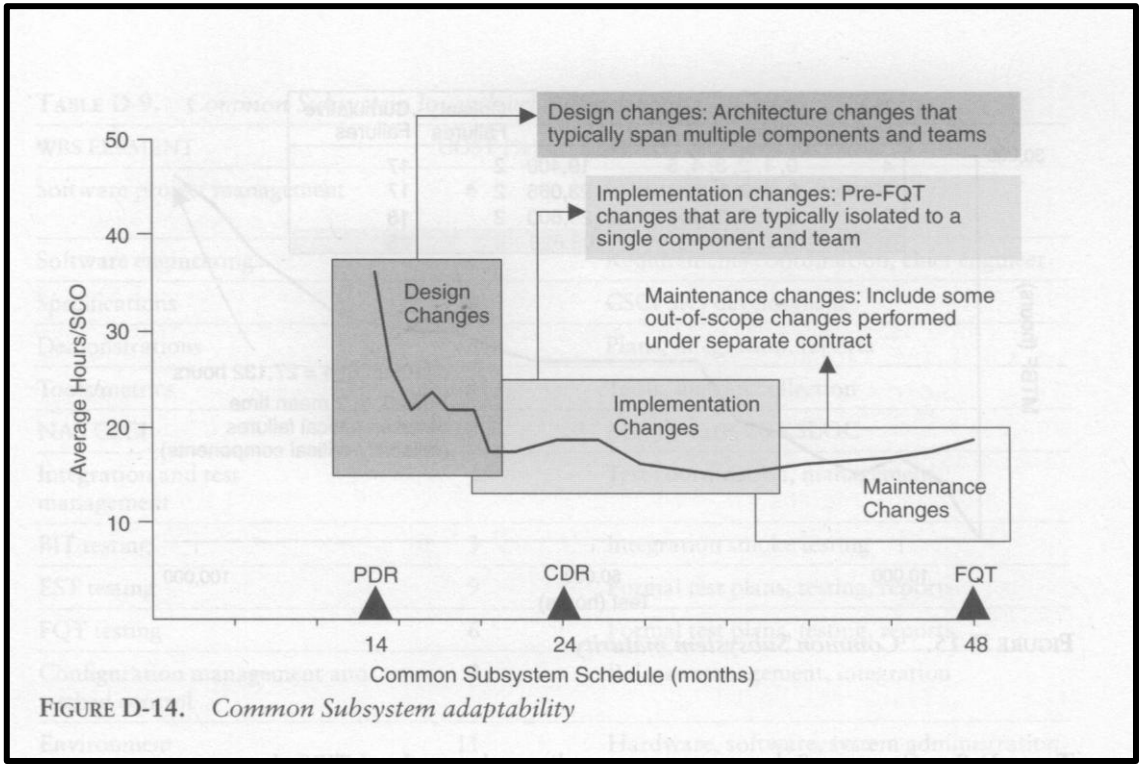


FIGURE D-14. *Common Subsystem adaptability*

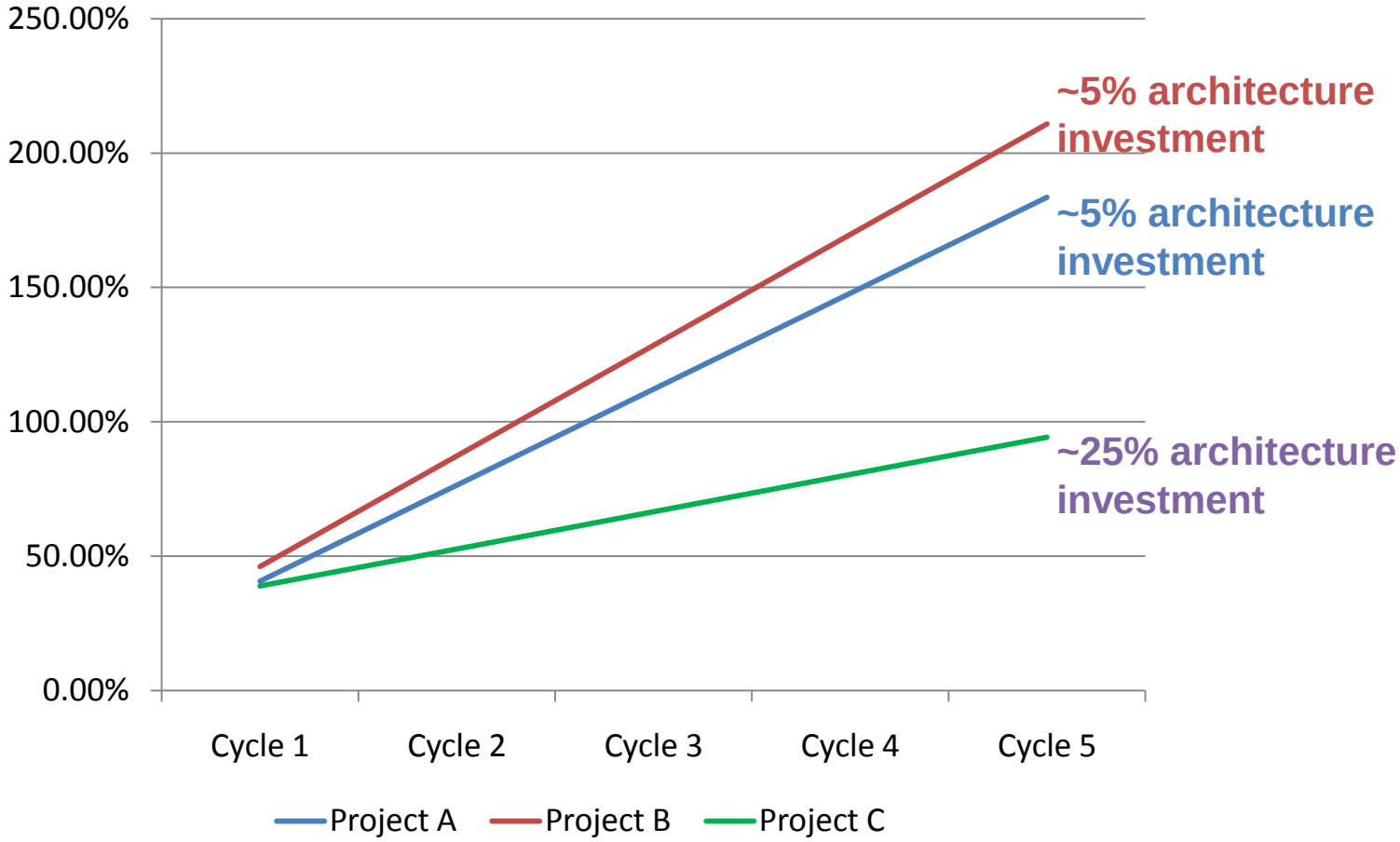
When investments made in architecture, average time for change order becomes relatively stable over time…

* Walker Royce, *Software Project Management: A Unified Framework*. Addison-Wesley, 1998.

Single-System TOC Model Example

	A	B	C	D	E
1	**Input Parameters**		**System**		
2		**A**	**B**	**C**	
3	Software Size (KSLOC)	100	100	355	
4	# Change Requests/Release	373	1005	1600	
5	# Change Requests (I&T only)				
6	# I&T Change Requests/Release/ > 1 PM	27	22		
7	# Total Change Requests/Release/ > 1 PM			16	
8	Change Request Fix Time (See assumption #2)	261	356	263	
9	Total Effort (Person Months)	731	865	1900	
10	% Arch, RESL	5%	5%	25%	
11	% Rework, RVOL	35.70%	41.16%	13.85%	
12					
13	**Cumulative Total Cost of Ownership**	Project A	Project B	Project C	
14	Cycle 1	40.70%	46.16%	38.85%	
15	Cycle 2	76.41%	87.31%	52.70%	
16	Cycle 3	112.11%	128.47%	66.55%	
17	Cycle 4	147.82%	169.62%	80.40%	
18	Cycle 5	183.52%	210.78%	94.25%	

Relative* Total Ownership Cost (TOC)



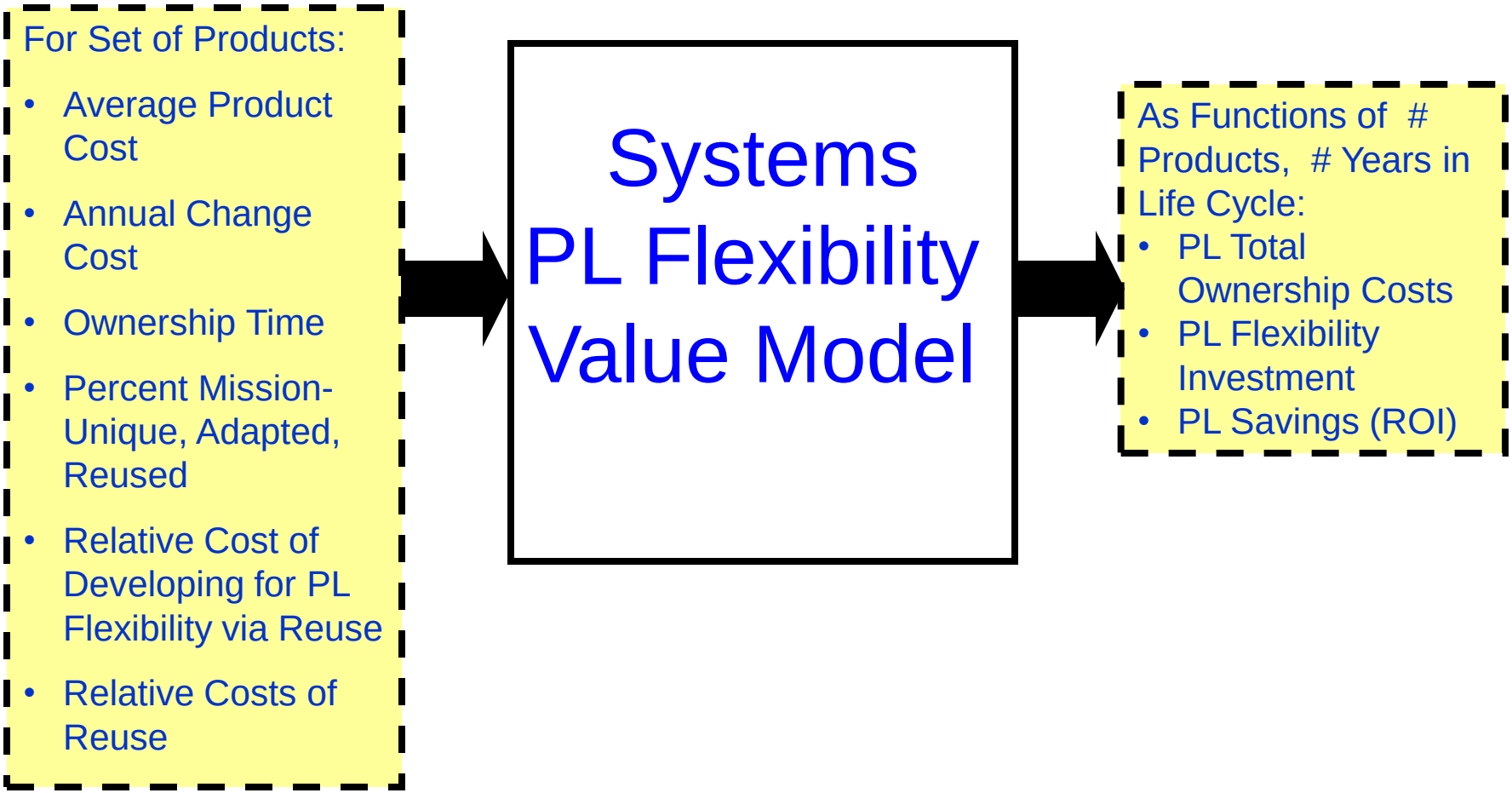
* Cumulative architecting and rework effort relative to initial development effort

Product-Line Flexibility Value Modeling

- USC and NPS collaborating on modeling value of investing in product-line flexibility with Return-On-Investment (ROI) and Total Ownership Cost (TOC) parametric models
  - System-level product line flexibility investment model
  - Software product line flexibility investment model.
  - Net present value (NPV) calculations included
- Models adapted from the Constructive Product Line Investment Model (COPLIMO*)
  - Special versions also developed for Daimler Chrysler and JPL

* Barry Boehm, A. Winsor Brown, Ray Madachy, Ye Yang, "A Software Product Line Life Cycle Cost Estimation Model," Proceedings of the 2004 International Symposium on Empirical Software Engineering, 2004

Systems Product Line Flexibility Value Model



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Systems Product Line Results

Preferences

Systems Product Line Flexibility Value Model

Welcome SERC Collaborator

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System Costs

Average Product Development Cost (Burdened $M)	5	Ownership Time (Years)	3
Annual Change Cost (% of Development Cost)	10	Interest Rate (Annual %)	7

Product Line Percentages

Unique %	40
Adapted %	30
Reused %	30

Relative Costs of Reuse (%)

Relative Cost of Reuse for Adapted	40
Relative Cost of Reuse for Reused	5

Investment Cost

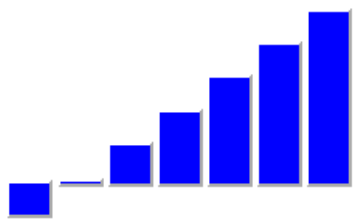
Relative Cost of Developing for PL Flexibility via Reuse: 1.7

Calculate

Results

# of Products	1	2	3	4	5	6	7
Development Cost ($M)	$7.1	$2.7	$2.7	$2.7	$2.7	$2.7	$2.7
Ownership Cost ($M)	$2.1	$0.8	$0.8	$0.8	$0.8	$0.8	$0.8
Cum. PL Cost ($M)	$9.2	$12.7	$16.2	$19.7	$23.1	$26.6	$30.1
PL Flexibility Investment ($M)	$2.1	$0	$0	$0	$0	$0	$0
PL Effort Savings	($2.7)	$0.3	$3.3	$6.3	$9.4	$12.4	$15.4
Return on Investment	-1.30	0.14	1.58	3.02	4.46	5.90	7.34

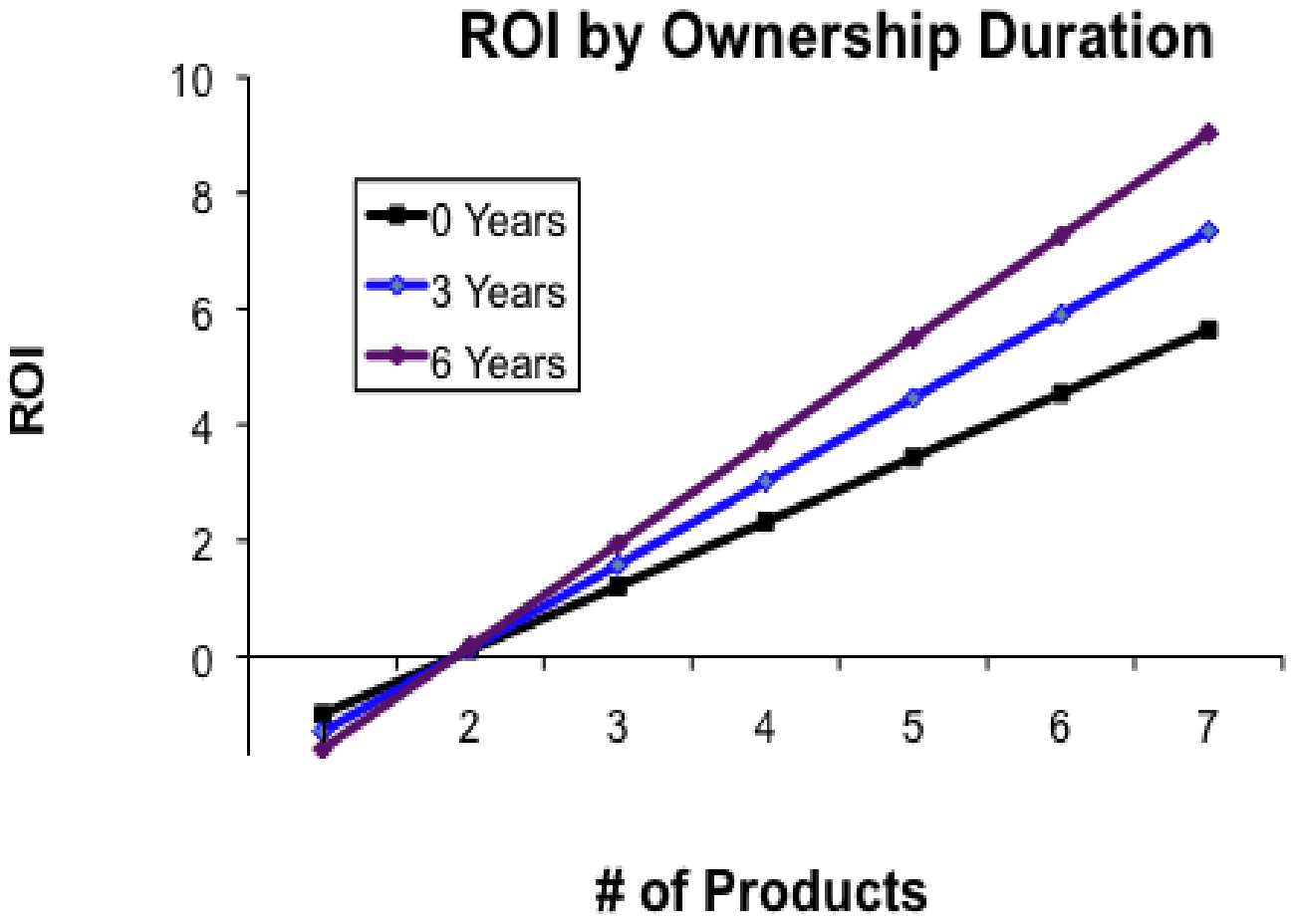
Return on Investment



-1.3	0.1	1.6	3.0	4.5	5.9	7.3
1	2	3	4	5	6	7

Product #

Sensitivity Analysis Example



Conclusions and Candidate Extensions

- TOC approach has several advantages
  - Increasingly required (DoDI 5000.02, WSARA 2009)
  - Easy to understand across specialty domains
  - Clear cause-effect relationships, straightforward calibration
- Important to determine evolution requirements
- Basic models available for foreseeable change
  - Individual systems, families of systems
  - Best to have calibration data
- Candidate Extensions
  - Refined and extended model capabilities
    - Particular domains, tradeoff analyses, enterprise analysis
    - Effects of adaptation to unforeseeable change
  - Integration with alternative valuation models