

Practical Metrics and Models for ROI with Real Options

by David F. Rico

Abstract

Return on investment or ROI is a widely used approach for measuring the value of a new and improved process or product technology. ROI is also used for measuring the economic value of popular approaches to software process improvement or SPI. However, ROI still remains a mystery to some practitioners, along with appropriate techniques for determining the ROI of SPI. This article explains the ROI of SPI, and introduces practical metrics and models for the ROI of SPI. Additionally, this article includes practical examples for estimating the ROI of Inspections, PSPsm, TSPsm, SW-CMM[®], ISO 9001, and CMMI[®]. This article sorts through literature and identifies a small set of practical metrics, models, and examples for the ROI of SPI. And, this article illustrates a simple approach for applying advanced ROI measures such as real options.

Introduction

ROI is a simple arithmetic ratio of benefits to costs, less the costs of course, expressed as a percentage. That is, benefits less costs are the numerator, and costs are the denominator. ROI measures magnitude of benefits to costs, benefits returned above costs, profits achieved after expenses, value of an investment, actual benefits, cost savings, and efficiencies obtained. ROI is a simple and powerful tool for analyzing costs and benefits. Costs and benefits are most often expressed in economic or monetary terms. ROI is a measure of value in dollars and cents. First, benefits are identified and expressed in monetary terms. Then, detailed costs are counted. After the costs and benefits are identified and counted, ROI is calculated by dividing the benefits less costs by the costs, and multiplying the result by 100%. A large ROI indicates money well spent.

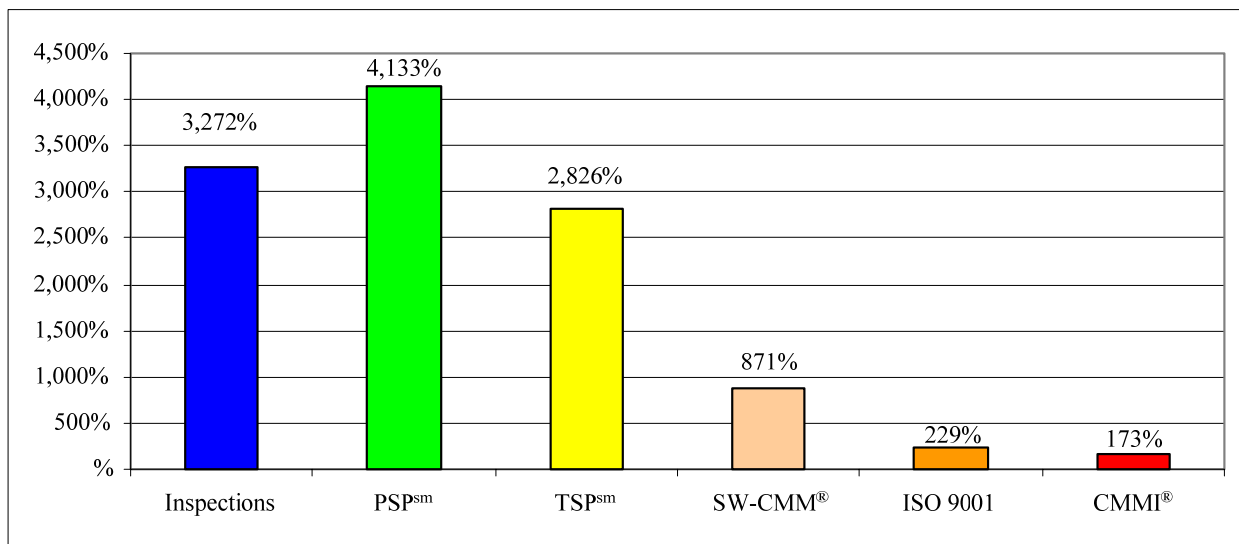


Figure 1. ROI of various SPI methods showing decreasing return on investment from left to right.

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There are a variety of SPI methods for support processes, training programs, management, and supplier selection. Examples include Inspections, PSPsm, TSPsm, SW-CMM[®], ISO 9001, and CMMI[®]. Inspections are meetings held to identify defects in software work products. PSPsm is a curriculum for teaching software engineers basic project and quality management principles. TSPsm is a project, quality, and life cycle management method for large teams of software engineers. SW-CMM[®] and CMMI[®] are guidelines for selecting U.S. DoD suppliers. And, ISO 9001 is a set of quality management system requirements for selecting European suppliers. The next step is to identify metrics and models to determine the ROI of these SPI methods.

ROI Metrics

ROI metrics are used to measure the economic value of a new and improved software process and each ROI metric is an indicator of how much a new and improved software process is worth. There are seven basic ROI metrics, as shown in Table 1. They are costs, benefits, benefit/cost ratio (B/CR), return on investment (ROI), net present value (NPV), break even point (BEP), and real options analysis (ROA).¹⁻² Each ROI metric builds upon its predecessor and refines the accuracy of the economic value of a new software process. ROI metrics are not independent or mutually exclusive and yet each ROI metric must be considered individually. For example, costs may be astronomical or benefits may be negligible, marginalizing the other metrics.

Table 1, ROI metrics showing simplicity of return on investment formulas and their order of application.

Metric	Definition	Formula
Costs	Total amount of money spent on a new and improved software process	$\sum_{i=1}^n Cost_i$
Benefits	Total amount of money gained from a new and improved software process	$\sum_{i=1}^n Benefit_i$
B/CR	Ratio of benefits to costs	$\frac{Benefits}{Costs}$
ROI	Ratio of adjusted benefits to costs	$\frac{Benefits - Costs}{Costs} \times 100\%$
NPV	Discounted cash flows	$\sum_{i=1}^{Years} \frac{Benefit_i}{(1 + Discount\ Rate)^{Years}} - Costs_0$
BEP	Point when benefits meet or exceed cost	$\frac{Costs}{Old\ Costs / New\ Costs - 1}$
ROA	Business value realized from strategic delay due to risk	$N(d_1) \times Benefits - N(d_2) \times Costs \times e^{-Rate \times Years}$

$$d1 = [\ln(Benefits \div Costs) + (Rate + 0.5 \times Risk^2) \times Years] \div Risk \times \sqrt{Years}, \quad d2 = d1 - Risk \times \sqrt{Years}$$

Costs consist of the amount of money an organization has to pay in order to implement a SPI method. Benefits generally consist of the amount of money saved by implementing a SPI method. B/CR is a simple ratio of the amount of money saved implementing a new SPI method to the amount of money consumed.³ ROI is also a ratio of money saved to money consumed by a new SPI method expressed as a percentage. However, the ROI metric demands that the costs of implementing the SPI method must first be subtracted from the benefits.⁴ NPV is a method of adjusting or discounting the estimated cash flows of a SPI method based on projected or future inflation over time. Break even point is a measure of the amount of money that must be spent on a new SPI method before it begins yielding its benefits. Real options analysis is a measure of the amount of money saved by delaying a project until technological risks have been mitigated.

Cost Models

Cost models are simple equations, formulas, or functions that are used to measure, quantify, and estimate the effort, time, and economic consequences of implementing a new SPI method. A single cost model may be all that is necessary to estimate the cost of implementing a simple SPI method such as PSPsm and TSPsm.¹⁻² It may be necessary to combine the results of multiple cost models together in order estimate the costs of implementing SPI methods such as Inspections.^{2,5} The results of multiple cost models must be combined with other empirical data to estimate the complete costs of implementing complex SPI methods such as SW-CMM[®] and CMMI[®].² There are seven basic cost models which are useful for estimating key cost elements of the six major SPI methods as shown in Table 2. There are cost models for Inspections effort and training, PSPsm and TSPsm training, and SW-CMM[®], ISO 9001, and CMMI[®] processes and products.²

Table 2. Cost models with worked examples for a four person team implementing 10,000 lines of code.

Method	Cost Models and Worked Examples	Hours	Costs
Inspections (effort)	$LOC / (Review_Rate \times 2) \times (Team_Size \times 4 + 1)$	708	^a \$70,833
	$10,000 / (120 \times 2) \times (4 \times 4 + 1)$		
Inspections (training)	$Team_Size \times (Fee / Rate + Hours)$	112.4	^b \$11,240
	$4 \times (410 / 100 + 24)$		
PSP sm (training)	$Team_Size \times ((Fee + Expenses) / Rate + Hours)$	1,056	^c \$105,600
	$4 \times ((5,000 + 5,400) / 100 + 160)$		
TSP sm (training)	$Team_Size \times ((Fee + Expenses) / Rate + Hours) + PSP$	1,484	^d \$148,400
	$4 \times ((4,000 + 2,700) / 100 + 40) + 1,056$		
SW-CMM [®] (process)	$561 + 1,176 \times Number_of_Projects$	1,737	^e \$173,700
	$561 + 1,176 \times 1$		
ISO 9001 (process)	$546 + 560 \times Number_of_Projects$	1,106	^f \$110,600
	$546 + 560 \times 1$		
CMMI [®] (process)	$(10,826 + 8,008 \times Number_of_Projects) / 2$	9,417	^g \$941,700
	$(10,826 + 8,008 \times 1) / 2$		

While a discussion of the eight cost models is beyond the scope of this article, the major inputs, terms, and cost drivers will be explained. *LOC* refers to lines of code implemented, *Review_Rate* refers to how fast a product is inspected, and *Team_Size* refers to the number of inspectors and PSPsm and TSPsm trainees. *Fee* refers to the cost per person for Inspections, PSPsm, and TSPsm training and *Rate* refers to the fully burdened cost of an Inspections, PSPsm, and TSPsm trainee. *Hours* refer to the length of time a trainee spends in Inspections, PSPsm, and TSPsm training and *Expenses* refers to cost of airlines, meals, hotels, and other incidentals. *PSP* in the TSPsm training cost model simply indicates that individual TSPsm costs and must be combined with PSPsm costs. *Number_of_Projects* refer to the number of software projects that will be appraised or audited. The constants 561, 546, and 10,826 refer to the effort required to define software processes for SW-CMM[®] and CMMI[®] Levels 3, as well as ISO 9001 Registration. And, the constants 1,176, 560, and 8,008 simply refer to the effort required to meet the documentation requirements for SW-CMM[®] and CMMI[®] Levels 3, as well as ISO 9001 Registration.

Benefit Models

Benefit models are simple equations, formulas, or functions that are used to measure, quantify, and estimate the economic value, profit, savings, or reward of implementing a new SPI method. SPI methods are designed and implemented in order to yield economic or monetary benefits such as increased customer satisfaction, productivity, quality, cost savings, and cycle time reduction. A long used, classical, and authoritative approach to quantifying the benefits of SPI methods is to measure total life cycle costs before and after the introduction of a new SPI method.² There are seven benefit models or total life cycle cost models which are very useful for estimating the economic value of the six major SPI methods as shown in Table 3. There are benefit models for old costs, Inspections, PSPsm, TSPsm, SW-CMM[®], ISO 9001, and CMMI[®].²

Table 3, Benefit models with worked examples for a four person team implementing 10,000 lines of code.

Method	Benefit Models and Worked Examples	Hours	Costs
Old Costs	$LOC \times 10.51 - Test_Hours \times 9$	45,100	^h \$4,509,997
	$10,000 \times 10.51 - 6,666.67 \times 9$		
Inspections	$LOC \times 10.51 - Inspection_Hours \times 99 - Test_Hours \times 9$	17,425	ⁱ \$1,742,533
	$10,000 \times 10.51 - 708.33 \times 99 - 1,950 \times 9$		
PSP sm	$LOC / 25$	400	^j \$40,000
	$10,000 / 25$		
TSP sm	$LOC / 5.9347$	1,685	^k \$168,501
	$10,000 / 5.9347$		
SW-CMM [®]	$LOC \times 10.2544 - Inspection_Hours \times 99 - Test_Hours \times 9$	14,869	^l \$1,486,933
	$10,000 \times 10.2544 - 708.33 \times 99 - 1,950 \times 9$		
ISO 9001	$LOC \times 10.442656 - Test_Hours \times 9 - Rework_Savings$	39,402	^m \$3,940,156
	$10,000 \times 10.442656 - 6,670 \times 9 - 4,995$		
CMMI [®]	$LOC \times 10.2544 - Inspection_Hours \times 99 - Test_Hours \times 9$	14,869	ⁿ \$1,486,933
	$10,000 \times 10.2544 - 708.33 \times 99 - 1,950 \times 9$		

Total life cycle cost is an estimate of complete software development and maintenance costs.² The basic form of the total life cycle cost model is $LOC \times (Defect_Rate \times 100 + Software_Effort / 10,000) - Inspection_Hours \times 99 - Test_Hours \times 9$.² *LOC* refers to lines of code, *Defect_Rate* refers to the defect injection rate, and *Software_Effort* refers to analysis, design, and coding hours. *Inspection_Hours* and *Test_Hours* are self explanatory. With a *Defect_Rate* of 10% or 0.1 and a *Software_Effort* of 5,100, the basic total life cycle cost model simplifies to $LOC \times 10.51 - Inspection_Hours \times 99 - Test_Hours \times 9$. This total life cycle cost model signifies complete software development and maintenance costs, less the benefits of Inspections and testing. If no Inspections or testing are performed, then the total life cycle cost is $LOC \times 10.51$ or 105,100 hours for a 10,000 line of code application. If we perform 708.33 hours of Inspections and 1,950 hours of testing, then the total life cycle cost is $LOC \times 10.51 - 708.33 \times 99 - 1,950 \times 9$ or 17,425 hours, a savings of 87,675 hours. (This is an extensible model which can be calibrated for varying defect rates, software effort, and Inspections and testing efficiencies. Furthermore, it can be augmented to model the economics of automatic static source code analysis and analyzers.²)

The Old Cost benefit model represents a reliance on 6,667 testing hours to remove 667 defects, or 45,100 total life cycle hours for 10,000 lines of code. The Inspections benefit model represents a balance of 708.33 Inspections hours and 1,950 testing hours, or 17,425 total life cycle hours for 10,000 lines of code. The PSPsm and TSPsm benefit models signify a productivity of 25 and 5.9347 lines of code per hour, or 400 and 1,685 total life cycle hours for 10,000 lines of code. (The PSPsm and TSPsm benefit models don't use the total life cycle cost model because they result in zero defects, and therefore exhibit little or no post-delivery economic activity.) The SW-CMM[®] benefit model results in 2,544 development hours at Level 3, 708.33 Inspections hours, and 1,950 testing hours, or 14,869 total life cycle hours for 10,000 lines of code. The ISO 9001 benefit model results in 4,426.56 development hours, 6,670 testing hours, and *Rework_Savings* of 4,995 hours, or 39,402 total life cycle hours for 10,000 lines of code. The CMMI[®] benefit model results in 2,544 development hours at Level 3, 708.33 Inspections hours, and 1,950 testing hours, or 14,869 total life cycle hours for 10,000 lines of code.

Cost and Benefit Summary

The cost and benefit summary helps organize the results of the cost and benefit models. The eight major cost and benefit factors are placed against the six major SPI methods as shown in Table 4. The eight major cost and benefit factors are Inspections, training, process (includes products), preparation (for appraisals), appraisal, audit, old costs, and new costs. The values for the first six cost factors are derived from Table 2, with the exception of preparation, appraisal, and audit costs. Preparation costs consist of indoctrination courses, response conditioning exercises, and mock appraisals. Appraisal costs consist of the costs for the planning, preparation, and appraisal stages, as well as the appraisal fees. The preparation, appraisal, and audit costs were based on bottom up estimates, and no cost models were created to aid in their estimation. The total costs are a simple summation of the values from cost factors one through six. (The letters A through G correspond to the cost model values from Table 2.) The values for old costs and new costs are derived from Table 3. The total benefits are the difference of old costs and new costs. (The letters H through N correspond to the benefit model values from Table 3.)

Table 4. Cost and benefit summary for a four person team implementing 10,000 lines of code.

Factor	Inspections	PSP sm	TSP sm	SW-CMM [®]	ISO 9001	CMMI [®]
1. Inspections	^a \$70,833	n/a	n/a	^a \$70,833	n/a	^a \$70,833
2. Training	^b \$11,240	^c \$105,600	^d \$148,400	n/a	n/a	n/a
3. Process	n/a	n/a	n/a	^e \$173,700	^f \$110,600	^g \$941,700
4. Preparation	n/a	n/a	n/a	* \$36,800	* \$26,400	* \$48,000
5. Appraisal	n/a	n/a	n/a	* \$30,100	n/a	* \$47,700
6. Audit	n/a	n/a	n/a	n/a	* \$36,000	n/a
Costs	\$82,073	\$105,600	\$148,400	\$311,433	\$173,000	\$1,108,233
7. Old Costs	^h \$4,509,997	^h \$4,509,997	^h \$4,509,997	^h \$4,509,997	^h \$4,509,997	^h \$4,509,997
8. (New Costs)	ⁱ (\$1,742,533)	^j (\$40,000)	^k (\$168,501)	^l (\$1,486,933)	^m (\$3,940,156)	ⁿ (\$1,486,933)
Benefits	\$2,767,464	\$4,469,997	\$4,341,496	\$3,023,064	\$569,841	\$3,023,064
<i>(* Preparation, appraisal, and audit costs determined without the aid of a cost model.)</i>						

ROI Summary

The ROI summary shows the estimated costs, benefits, benefit/cost ratio, return on investment, net present value, break even point, and real options analysis for each of the six SPI methods. Table 5 shows the values of B/CR, ROI, NPV, BEP, and ROA using the metrics from Table 1. B/CR is used to determine the magnitude of benefits to costs using the formula $Benefits / Costs$. ROI is used to determine the magnitude of benefits to costs based on adjusted benefits using the formula $(Benefits - Costs) / Costs \times 100\%$. NPV is used to discount the cash flows using the formula, equation, or discounting method from Table 1 (e.g., $SUM (Benefits_i / (1 + Discount Rate)^{Years}) - Costs_0$). BEP is used to determine when the SPI method begins yielding its benefits using the formula $Costs / (Old_Costs / New_Costs - 1)$. ROA is used to determine the added value gained from delaying a high risk project using the simple metric at the bottom of Table 1.

Table 5. Estimated return on investment values for a four person team implementing 10,000 lines of code.

Method	Costs	Benefits	B/CR	ROI%	NPV	BEP	ROA
Inspections	\$82,073	\$2,767,464	34:1	3,272%	\$2,314,261	\$51,677	\$2,703,585
PSP sm	\$105,600	\$4,469,997	42:1	4,133%	\$3,764,950	\$945	\$4,387,781
TSP sm	\$148,400	\$4,341,496	29:1	2,826%	\$3,610,882	\$5,760	\$4,226,031
SW-CMM [®]	\$311,433	\$3,023,064	10:1	871%	\$2,306,224	\$153,182	\$2,784,025
ISO 9001	\$173,000	\$569,841	3:1	229%	\$320,423	\$1,196,206	\$448,055
CMMI [®]	\$1,108,233	\$3,023,064	3:1	173%	\$1,509,424	\$545,099	\$2,267,231

The BEP values represent *total costs* spent on a new SPI method *before* the benefits are realized.⁶ The BEP values should be divided by 400 to account for *Team_Size* and *Rate*. The BEP for Inspections is 129 hours or three weeks, PSPsm is two hours, and TSPsm is 14 hours or two days. The BEP for SW-CMM[®] is 383 hours or 2.2 months, ISO 9001 is 2,991 hours or 1.4 years, and CMMI[®] is 1,363 hours or eight months. Figure 2 is a graphical representation of the costs, benefits, and ROI values from Table 5. Notice that the costs dramatically increase from left to right as illustrated by the red bar in Figure 2. Also notice that the benefits and ROI sharply decrease from left to right as illustrated by the green and blue bars in Figure 2. Furthermore, notice how NPV sharply discounts the benefits, while using ROA restores them in Table 5.

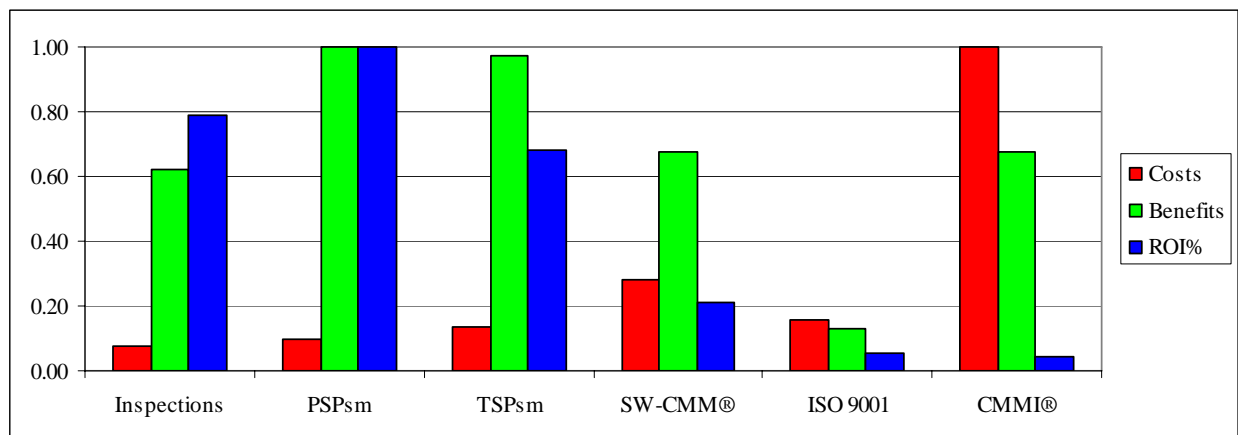


Figure 2. Estimated costs, benefits, and return on investment for software process improvement.

Recommendations

The goal of this article was to introduce practical metrics and models for return on investment. The goals also included introducing basic concepts in ROI, simple metrics for ROI, useful models for costs and benefits, and extensive examples using mainstream methods for SPI. Seven simple ROI metrics were introduced for costs, benefits, net present value, benefit/cost ratio, return on investment, break even point, and real options analysis. And, fourteen cost and benefit models were introduced for Inspections, PSPsm, TSPsm, SW-CMM[®], ISO 9001, and CMMI[®]. More importantly, each of the ROI metrics and models were thoroughly exercised to demonstrate how return on investment is estimated for software process improvement. *(Total life cycle costs were introduced to estimate the benefits of SPI, which is one of the most elusive concepts. And, an important contribution was introducing simple parametrics for applying real options to SPI.)*

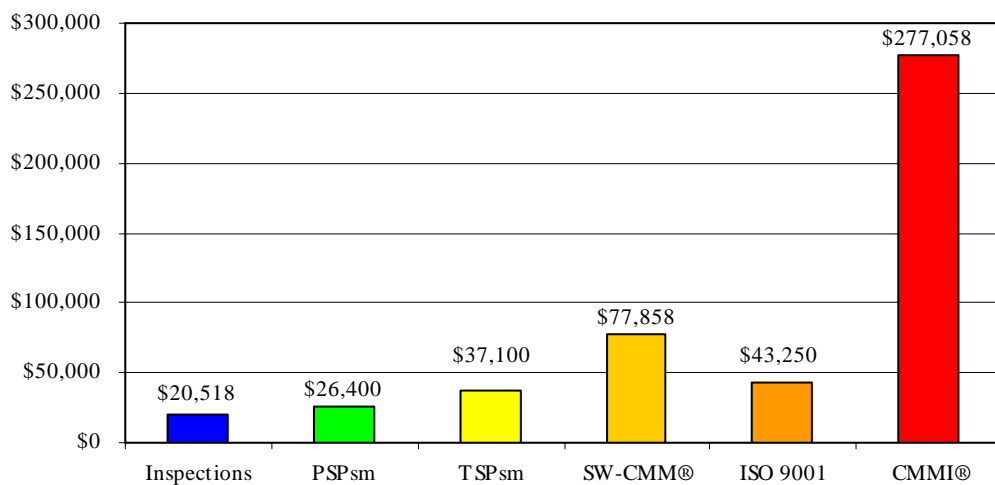


Figure 3. Cost per person showing increasing costs for various SPI methods from left to right.

As mentioned near the beginning of this article, ROI metrics are not mutually exclusive. The result or value of one ROI metric should not overshadow the value of another. For instance, Figure 1 illustrates impressive ROI values of 3,272%, 4,133%, 2,826%, 871%, 229%, and 173% for Inspections, PSPsm, TSPsm, SW-CMM[®], ISO 9001, and CMMI[®]. Before you run out and immediately implement one of these methods, you must consider the costs. The cost per person for these SPI methods is \$20,518, \$26,400, \$37,100, \$77,858, \$43,250, and \$277,058 as shown in Figure 3. These figures may not seem daunting for monolithic well endowed non-profit organizations. However, you can rest assured knowing that the average commercial firm could not afford the least expensive of these SPI methods. The probability of sustained commitment and execution of expensive and manually-intensive software processes is nearly zero.

- **Choose a simple set of metrics and models for ROI:** Use the ROI metrics recommended in this article. They're simple, classical, authoritative, and well established. You can't go wrong using these metrics. There are hundreds of confusing metrics littered throughout literature.
- **Don't spend a lot of money to achieve a high ROI:** Don't implement SPI methods with a high ROI and high costs. It's not necessary to spend a lot of money to achieve a good ROI. There are methods with even higher ROI and lower costs than those mentioned here.

- **Don't go bankrupt using expensive SPI methods with a low ROI:** Don't implement expensive SPI methods with a low ROI. The goal of SPI is to improve the economic performance of your organization. The goal of SPI is not to confound your economic posture.
- **Seek low cost automated SPI methods with a high ROI:** There are many SPI methods from which to choose. Don't feel obligated to implement one of the SPI methods mentioned here. The best SPI methods are automated solutions, such as automatic static analyzers.
- **Don't wait until you're SW-CMM®/ CMMI® Level 5 to use ROI:** The field of ROI is all about metrics and models. Some people still believe software measurement is only for Level 4 and 5 organizations. Balancing your budget is for everyone, not just mathematicians.
- **Don't spend too much money measuring ROI:** Estimating the ROI of SPI can be quickly performed by everyone. Some ROI methodologies recommend hiring scientists to estimate ROI over a period of months and years. Don't consume your benefits looking for ROI.
- **Proactively plan for ROI, don't wish for ROI after-the-fact:** Identify SPI methods with proven ROI values, implement them, and then measure the results yourself. Don't implement expensive SPI initiatives with little ROI, and then hire teams of consultants to hunt for ROI.
- **Use ROI to right size a SPI program for your organization and overhead budget:** Study the ROI concepts in this article, identify SPI methods with known ROI characteristics, and then design a SPI program that's right for your organization's economic posture.
- **Apply metrics and models for ROI before it's too late:** Use ROI to give yourself a strategic advantage. The technological revolution is all about ROI, or being better, faster, and cheaper. Ride the technology wave driven by ROI, instead of getting swept away by change.

Everyone should manage a SPI program like they are personally paying for the costs. Use ROI metrics and models to manage your SPI program like this is coming out of your personal paycheck. The ROI metrics and models exhibited in this article are simple, but are not perfect.¹⁻² However, the process for estimating ROI is extensible, improvable, and highly useful.³⁻⁵ Use the ROI framework in this article with great care, especially when you are committing the priceless economic resources which form the foundation of your organization's future success.⁶

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