Framework to Evaluate Software Process Improvement in Small Organizations

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Abstract. Organizations of all sizes understand the benefits to consider Software Process Improvements (SPI) investments, still many of them and in particular the smaller ones are reluctant to embrace this kind of initiatives. A systemic model is presented in this article as a tool aiming aiming to provide an initial understanding over the behavior of the different organizational variables involved and their complex interactions within a SPI effort, their contribution to the improvement effort, the resulting value sensitivity to model parameters, the systemic relations at large and the limits derived from the holistic interaction of all in order to be used as a scenario analysis tool to identify the SPI strategies which best suit a given organization business context thru the maximization of the value obtained from the investment.

Keywords: Software Process Improvement, SPI, CMMI, Simulation, Dynamic Models. Small Organizations, Software Engineering Economics. Net Present Value.

1 Introduction

For software development organizations, specially small and medium sized, the management dilemma is how to justify the investments required to improve the software processes (Software Process Improvement, SPI) [07] on a business context where bigger competitors, quite of a global scale, undertake similar actions leveraging much larger structures and therefore able to absorb better the costs impacts produced by the SPI initiative [40] . At the same time the consideration of competitors of similar scale which not introducing significant improvements on their core processes enjoy a short term competitive advantage and less margin erosion is needed.

Organizations of all sizes understand the benefits to consider SPI initiatives, still many of them and in particular the smaller ones are reluctant to embrace this approach. Scenarios and results captured by the bibliography [08,28,39] reflects the experiences of large scale organizations leaving smaller ones wondering whether an SPI approach is realistic for them. A perception of larger companies being able to tap

Q. Wang, D. Pfahl, and D.M. Raffo (Eds.): ICSP 2008, LNCS 5007, pp. 36 – 50, 2008.

on deeper pockets or leverage corporate financial muscles to fund SPI investments leads to the *a-priori* estimation on smaller companies that formal endeavors to perform structural changes in their software development process through an structured SPI effort are simply outside their realm of possibilities.

This aspect turns out to become of particular relevance since on the national or regional context of emerging economies small and medium software companies offering off-shore services to a globalized landscape are far smaller than the organizational sizes typically referred to at the bibliography.

Even though SPI efforts attempted at small and medium companies has been documented previously [10,13,25,31,32,49] the focus is often placed at qualitative or methodological factors rather than quantitative ones; it seems the implicit assumption is for SPI efforts to be unconditionally a good initiative no matter what the business context where the company operates really is.

This notion has been challenged by several authors [16,23] where the actual affordability and suitability of formal CMMI oriented SPI initiatives for *Small and Medium Enterprises* (SME) is questioned from different perspectives.

The paper proposes a contribution in three areas at the evaluation of SPI initiatives. First a systemic framework aimed to model the main parameters driving an SPI effort and their interrelations in a single model for the overall value gained by the organization on doing the SPI investment is proposed. Although many of the relations can be found dispersed in the referred sources, the consolidation into a single model and the validation of their systemic consistency is a contribution of the research activity performed by the authors.

Second the *Net Present Value* (NPV) is proposed as a suitable instrument to measure that value as part of a decision process as a difference with the economic indicators most often used by the bibliography.

Finally, the third contribution is to run the model under a combination of ranges found in the literature and assumptions made by the authors in order to preliminary explore the usefulness of such instrument for a small or medium sized organization to validate decisions and explore trade-offs using a rational base.

Since actual data aren't fluidly available the analysis is performed through a dynamic stochastic simulation model where the behavior of different factors, their contribution to the improvement effort, the sensitivity of the final result to the model parameters and the practical limits can be explored.

The model is built by identifying the main factors involved at the organization level, the external context and the intrinsic components of the SPI effort as reflected in the available bibliography (see *Investment Modeling*), because of space constraints identified relationships between factors and transfer functions considered in the model has been consolidated in the appendix of the paper (see *Appendix II*).

In order to handle the dispersion of the parameters as reported by the bibliography a Monte Carlo simulation technique is used where the system variables, the uncertainty of the results, the Sensitivity to different investment strategies and the limits for a reasonable return can be explored (see Model *Execution*).

Finally some limits of the approach and conclusions are explored (see *Conclusions*).

1.1 Process Improvement Framework

The SEI CMMI v1.2 reference model guides the deployment of SPI efforts through the formulation of a framework to help develop a comprehensive process that unveils the organization's technologic potential at delivering software products; positive correlation between the maturity level and better performance is backed up by many industry and academic references [03,12,19,28,34,35,47]. The SEI-CMMI model specifies what goals must be achieved at *Process Areas* through the satisfaction of both generic and specific *goals* on each one through the usage of generic and specific *practices* [12,43], actual details of the implemented process is left to each organization to decide.

Although other reference models can equally be eligible for this purpose, the SEI-CMMI receives significant industry acceptance at a global scale, a long standing record of application and some metrics for the results obtained by different organizations as referred by different authors [02,07,19,34,35,38]. The framework is not going without significant criticism. Conradi [16] among others had presented evidences against formal CMMI based SPI approaches to obtain sustainable improvement at many organizations, but at the same time seems to conclude that organizations faces substantial competitive pressure to achieve market required levels of maturity under a globally recognized framework as an essential requirement from international customers trying to reduce the "*buyer risk*" of undertaking off-shore projects.

It's certainly not a surprise that the SEI records shows [43] a significantly higher number of organizations undertaking formal SEI-CMMI evaluations at off-shore markets than typical target markets for off-shore activities like the US and Europe.

2 Investment Modeling

In order to address a SEI-CMMI based SPI initiative the organization will require undertaking a significant effort into developing and implementing policies, plans, processes, instruments and metrics associated with the satisfaction of each one of the *Process Areas* of each *Maturity Level.* The transfer functions has been established starting with the variables and systemic relations relevant to a software process as identified originally by the work on dynamic models formulated by Abdel-Hamid [01] and later proposed by Carrillo [09] and Ruiz [41] as to be used in the analysis of software process improvements efforts; the internal factors of the process improvement modeling has been used as identified by Hayes [27] .

This paper integrates also functional relations dispersed in the bibliography into a consolidated model enabling the study of their systemic behavior as one of the contributions. The model relations are going to be discussed in detail at the next section.

2.1 Implementation Costs

Different authors [19,21,28,42,50] supports the need to invest a significant fraction of the organizational resources through the implementation of a mature process as a *Software Process Improvement Effort* (E_{spi}) which would require a proportion of the *Total Organization Staff* (N) to be allocated to the SPI activities (K_{spi}), the Software Process Improvement Effort is then given by [[Ec 2].

The implementation has to be followed by an institutionalization effort aiming to ensure the implemented processes are effectively understood and used by the organization at large through a sustained *Training Effort* (E_t). Walden [50] among others provide some data on the magnitude of this effort.

The training effort is composed by the *Training Preparation Effort* assumed to be related to the number of *Process Areas* (N_{PA}) to be evaluated on the target maturity level and the effort to deliver the training which is made by the *Training Effort per Person and Process Area* (E_{PA}), the total Training Effort will then be as in [[Ec3]:

The Training Effort would be distributed, assumed evenly in this model, through the entire SPI implementation.

At the same time the formal assessment of the maturity level means to transit a number of informal evaluations as defined by the *Standard CMMI Appraisal Method for Process Improvement* (SCAMPI) Class "C" and "B" or equivalent, followed by a maturity level assessment given by a formal Class "A" appraisal (SCAMPI-A); the SEI and other authors [28,43,48,50] provides a framework to estimate the *Appraisal Preparation Effort* (E_{ap}) and the *Appraisal Delivery Effort* (E_{ad}) the organization has to incur to get ready and perform the appraisal. Also the organization will need to fund during the appraisal the *Appraisal Costs* (C_a) for consultancy fees and other event related expenses; this cost is normalized into effort units for model consistency through the *Cost per Engineer* (C_{PE}) the organization has as in [[Ec 4]. The total *Appraisal Effort* (E_a) is considered to be incurred mostly toward the end of the implementation period and it is given by [[Ec5]

2.2 On-going Returns

Assuming the organization achieves the aimed maturity level after the assessment a fraction of the resources would still be required to maintain, adapt and evolve the implemented process framework deployed in order to ensure a consistent usage as well as an on-going alignment with the organizational goals, the effort to perform this activity is the *Software Engineering Groups Effort* (E_{sepg}) which will be a proportion (K_{sepg}) of the Total Organization Staff (N) as shown by [[Ec 6]

Although it would be reasonable to expect organizations to realize benefits as they move through the implementation of the different practices a conservative approach taken in this model is to assume all benefits will realize only after the organization is formally evaluated on the target maturity level.

At the same time, it is likely that even if the organization fails to achieve a given target maturity level all major software process areas would be in a better performance than at the beginning of the project. This model assumes that no benefit will be collected out of the investment performed unless the maturity level is formally obtained. The benefits of a given maturity level would came in the form of an improved quality as measured by an reduction in the *Cost of Poor Quality* (CoPQ) [17,18,30] , an enhanced capability to meet schedule commitments as well as significant improvements in cycle time and in overall productivity among others [04,07,19,35].

Clark [11], provides the perspective that all benefits could be summarized as a reduction of the non-value added effort expended by the organization to achieve a result in a way that less effort can be required to achieve the same result or more results achieved with the same effort. This can also be seen as an improvement of the overall productivity. The modeling approach used the *Productivity Income* (I_{prod}) as the return of the SPI effort to represent the savings achieved compared with operating in a lower level of maturity; this is considered the source of return of the SPI effort and the main financial reason to justify it. The magnitude of this factor is assumed to be an equivalent fraction (K_{prod}) of the *Total Organization Size* (N) as reflected by [[Ec 7]:

The net *flow of benefit* (V_i) the organization are going to receive as shown by [[Ec8] will occur since the appraisal is completed at *Implementation Time* (t_i) and as long as the *Investment Horizon* (t_p) allowed by the organization to collect resources last. This timeframe is often called the *Recovery Time* (t_r).

Although the nature of the SEI-CMMI improvement process, with several non-rating instances of appraisal, allows for a comprehensive evaluation of the organization progress at implementing the different Process Areas the factual data [44] still suggest the final appraisal success is not guaranteed.

A surprisingly high number of appraisal failures for organizations trying to achieve maturity level 2 and a reduced number for higher maturity levels suggest the need to factor this element in the model.

The *Appraisal Success Rate* (ξ), even with a risk of being too optimistic, corresponding to each maturity level (see *Appendix I*) are considered and reduces the expected flows as seen in [[Ec8] by this rate as shown in [[Ec9].

2.3 Investment Analysis

The *Return on Investment* (ROI) has been extensively used in the bibliography [05,07,19,23,46] as the main indicator to evaluate investments in SPI; it measures the investment as the relation between *expenditures* required and *incomes* obtained within a given timeframe selected by the organization as the *Investment Horizon* (t_p).

Ideally all investments verifying the condition ROI ≥ 1 are desirable to be made. Given different simultaneous investment opportunities the one with the higher ROI should capture in preference the organization resources as it would create the higher wealth in return. This approach has been criticized [35,48] as not providing uniformity among different initiatives making difficult to compare results between different organizations.

At the same time, the ROI has very limited capability [06] to factor a proper compensation for the time and risk value of money. Given the fact that SPI efforts require quite significant investment horizons and are performed by organizations operating at moderate to high risk levels it is relevant to introduce both factors in the decision analysis.

Investment analysis based in the *Net Present Value* (NPV) captures both the time and risk through the discount of the flows over time at a rate called the *cost of the capital* or the *opportunity cost* (r) and therefore it is often referred to as having a better performance at evaluating an investment than other pure economical based methodologies [04,06,22,29]; for this reason it is adopted in this paper as the way to compute the value created.

The NPV discounts the cash flows using the best return the organization could get out of an investment of equivalent risk. Cash flows are typically a sequence of discrete individual flows $\{F_1,..,F_n\}$ whose NPV is given by [Ec 10]. In some cases the flows are better modeled by a continuous function rather than discrete events and therefore it is also possible to represent them as a *continuous flow* F(t) where the expression turns into [Ec11] where the instantaneous *opportunity cost* (δ) is a continuous equivalent capitalization cost. By combining the values of [Ec 2] through [Ec9] normalized to their present value the Net Present Value can be expressed by [

Replacing terms in the [Ec1] a final expression for the NPV used in the model is obtained [Ec1B]

[Ec1B]

[Ec1] $$NPV_i = PV(V_i) - PV(E_a) - PV(E_{spi}) - PV(E_t)$$

Replacing terms in the [Ec1] a final expression for the NPV used in the model is obtained [Ec1B]

[Ec1B] $$NPV_i = \xi \int_{t_i}^{t_p} V_i \times e^{-\delta t} dt - \left[\frac{E_a}{(1+r)^{t_i}} + \int_0^{t_i} (E_{SPI} + E_t) \times e^{-\delta t} dt \right]$$

Although the NPV is intended to reflect cash flows this model uses a normalized cost based on the effort in order to concentrate in the relations between factors rather than the absolute magnitude in any given currency. In this scenario the organization decides at which *Total Organization Size* (N) the operation is desired, which *Maturity Level* (CMMI) as defined by the SEI CMMI v1.2 model wishes their processes to be executed and what is the competitive *Investment Horizon* (t_p) allowed to obtain tangible results from the investment which is required to yield a reasonable return for the time and risk as measured by the opportunity cost (r).

The nature of the improvement effort defines which is the likely *Implementation Time* (t_i) a given maturity level requires and that defines the remaining time to obtain the benefits which make the investment viable.

At the same time each maturity level will drive which percentage of the organization has to be allocated to the SPI Effort (K_{spi}) as well as the maintenance effort proportion (K_{sepg}) afterwards and the effort improvement (K_{prod}) which is realistic to expect as a result. The selected maturity level selected (CMMI) would define the number of *Process Areas* (N_{pa}) which are going to be implemented as well as the likely training effort (E_{pa}) associated to each one.

The model assumes the organization progress from one maturity level to the next available level in a discrete and monotonic increasing way.

2.4 Other Investment Critical Factors

Some authors [20,33,38,44] highlights other intangible factors obtained from the SPI investment such as improvements in organizational image, staff motivation, customer satisfaction as well as organizational cultural climate as strong motivations for the effort to be performed. Small and medium sized organizations in particular will depend critically for their survival on several other factors [16,23,25,45] such as the quality of the human resources, the establishment of agile organizational relations, the business model flexibility, the legal context, the organizational model adopted and the decision speed as well as interrelation fabric between areas, the debt taking capability, the critical adaptability speed and the very low capacity to survive on a restricted cash flows environment among others.

Although very important the previously enumerated factors are difficult to incorporate in a model like the one presented by this paper; however all of them can conceptually be considered increasing or decreasing the strengths of the organization and therefore changing the certainty of their results.

As the certainty of the results ultimately drives the risk under which the organization operates these factors should largely be represented by the risk premium component of the opportunity cost the organization uses to evaluate their investment decisions. Then by incorporating the opportunity cost on the model some of the critical factors, even partially, can be captured.

This represents a clear improvement in the analysis of an SPI investment as compared with the more classic usage of ROI and other economic formulations where neither the time nor the risk cost of the money is factored in the investment decision.

2.5 Opportunity Cost

As the organization progressively improves the maturity level as measured by the SEI-CMMI model the bibliography reflects a consistent improvement in the cost and schedule performance. Therefore a reduction in the business risk should drive a reduction of the opportunity cost as well.

In order to compute the variation because of this factor the average variation and the standard deviation of the Net Present Value in a maturity level (μ_i,σ_i) is compared with the same factors when a maturity increase has been made (μ_o,σ_o); the *risk variation factor* (λ)[26] is then defined by [Ec12].

The return provided by a secure financial asset provided by the market, often the yield of the 30 yr US Treasury bonds is used with this purpose, is considered the time compensation for the money ant it is called the *risk free discount rate* (r_f) the *modified cost of opportunity* (r') reflecting the reduction in uncertainty would given by [[Ec13] and all other factors being equal a reduction in the opportunity cost would improve the NPV which can be considered a legitimate additional value created by the increased level of maturity achieved through the SPI effort. Previous effort by the authors provided some insights in the possible range of values this factor could take [14,15].

3 Model Execution

In order to compute the model it is implemented using a GoldSim® platform [29] where the variables, relations and typical value distributions are defined as per the Equations shown in *Appendix II.*

When computed in this way the typical NPV evolution of a simulation instance can be seen at Figure 1; the expenditures in the deployment of the SPI actions drives the NPV to become more and more negative; towards the end of the implementation time (t_i) the rate of change accelerates as the expenditures reaches a maximum when appraisal related costs are incurred.

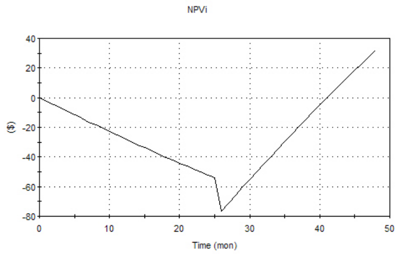

Fig. 1. NPV evolution with time on a typical SPI simulation run

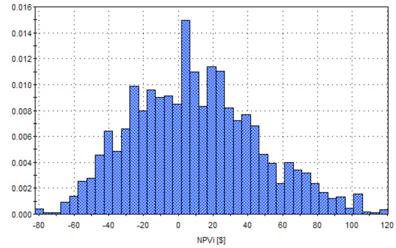

Fig. 2. NPV Probability distribution for a typical SPI simulation run

Once the new maturity level is obtained at time t_i after a successful appraisal the organization starts to collect productivity gains net of the process maintenance costs which drives an improvement of the NPV until it eventually, if allowed enough time, become positive, the moment in time the NPV becomes positive is where the investment has been fully paid back in financial terms.

The fact most variables can not be assigned with unique values but for ranges or probabilistic distributions of possible values makes the model to be far from being deterministic; the bibliography reports ranges of values for each parameters and in some cases suggest some possible distributions; this information is used to run the model with an stochastic methodology in order to evaluate the range of possible results; a sample outcome for a given run would be, as seen in Figure 2, where a typical probability distribution of the NPV is shown summarizing the results of the stochastic evaluation of the model.

By computing the area below the curve for values where a positive NPV is obtained the probability of a project success can be assessed; each organization could then match their own risk acceptance profile with the investment parameters that yield an acceptable outcome.

The results of a run with variations in all major parameters is shown in Figure 3; the model highlights increases in the NPV as to be sensible to Organizational Size (N), the CMMI level at which the organization is willing to achieve and the Investment Horizon (t_p); increases in these factors also increases the NPV outcome.

As either the Appraisal Cost (C_a) and the Opportunity Cost (r) increase the NPV is reduced. The Cost per Engineer (C_{PE}) improves the NPV as it gets higher likely because the fixed SPI costs gets diluted by the higher returns provided by the improved productivity from the operation in a higher maturity level by a more expensive group.

Several scenarios are explored by means of varying the external parameters of the model. Just to perform a quick overview of the main trends it's assumed a typical organization are assumed to have a staff of 100 persons, trying to achieve a maturity level given by CMMI Level 3, they will allow a total investment horizon of 48 months, will operate in the offshore environment with a typical cost per engineer of

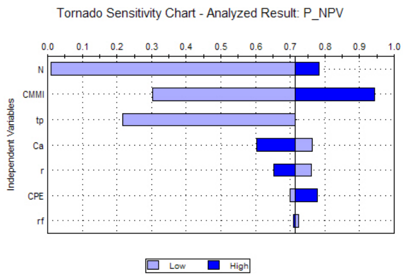

Fig. 3. NPV Sensitivity to Organizational Factors

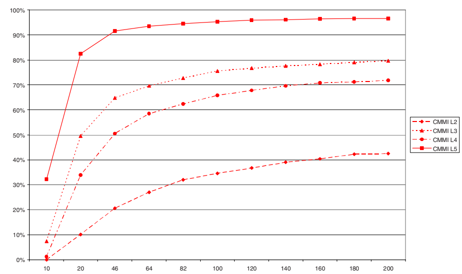

Fig. 4. Dependency of Organization Size

USD 30K per year and will financially take as the opportunity cost an effective annual rate of 15%. All scenarios are ran varying one of the parameters through the range of interest while keeping the rest set at the previous values in order to be able to evaluate the variation dynamics.

3.1 Organization Size Sensitivity

Running the model for different maturity levels and organizational sizes the probability to obtain a viable project increases with the size of the organization as seen in Figure 4; this can be interpreted as the effect of the critical mass required for the productivity gains to offset the investment required. In this implementation of the model the apparent difficulty of organizations to achieve CMMI Level 2 is derived from the relatively high failure rate this level has as reported by the SEI-CMMI and other sources [43], although this result strikes as odd at first glance it results reasonable on deeper analysis, specially counting on the fact that the number of failed attempts at maturity level increases are likely to be much higher but not captured by any formal framework.

On a higher level of analysis there are no significant differences in the ranges of parameters observed during the SPI effort with the organization size other than the obvious capability to sustain a larger investment horizon, to perceive the investment as less risky for the entire operation and having fewer dependencies on cash flow issues associated with the appraisal effort. While the options larger organizations might have at their disposal in terms of the key strategies to adopt for their SPI might be larger than in smaller organizations the behavior of their outcomes and parameters does not necessarily are different.

3.2 Investment Horizon Sensitivity

As the Investment Horizon increases the likelihood of a successful project increases as well. Considering the time to implement and the time to recover the model suggest 48 months to realistically be the horizon required to obtain returns at reasonable risk as shown in Figure 5.

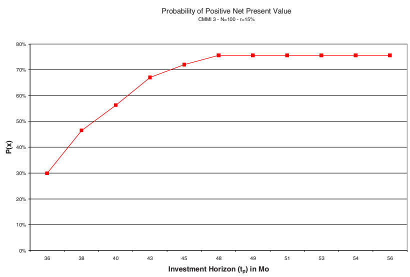

Fig. 5. Dependency from Investment Horizon

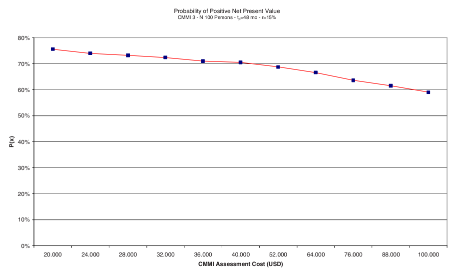

Fig. 6. Dependency from Maturity Appraisal Costs

3.3 Appraisal Cost Sensitivity

Many small organizations might perceive a formal CMMI appraisal is too upscale for them. Then the model is used to validate that perception by a simulation. The result shows in Figure 6 the probability of achieving a positive NPV is influenced very little by the Appraisal Costs suggesting this shouldn't be a strong consideration when undergoing an SPI investment.

3.4 Cost per Engineer Sensitivity

Through the model formulation a typical off-shore cost per engineer (C_{PE}) has been considered, especially to seize the relative impact of the fixed appraisal costs in the overall cost of the project. The impact of varying this parameter can be seen in Figure**.** 7. As expected the higher the Cost per Engineer is the better the results of the SPI effort are projected to be.

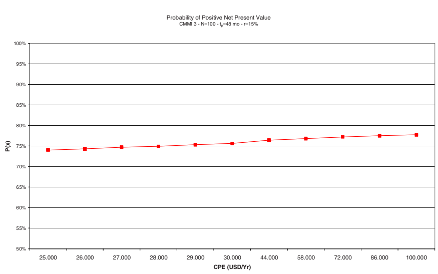

Fig. 7. Dependency from Cost per Engineer

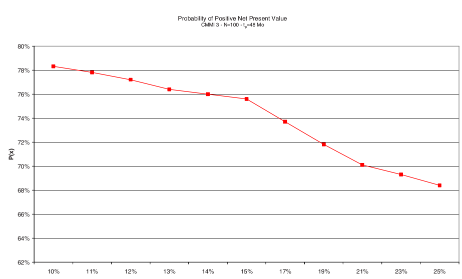

Fig. 8. Dependency from Opportunity Cost

It is remarkable that although this should suggest a bigger drive to undertake SPI efforts in business contexts where the C_{PE} is higher (typically target for off-shore offerings) evidence shows [43] exactly the contrary which requires as a conclusion that other factors needs to be considered. Among the factors to make candidate to capture this behavior is the value of reducing the "*buyer risk*" for the customer enabling new customers or additional work from existing customers. Off-shore companies willing to mitigate the perceived risk on the customer for a workload transfer to a remote location might present a higher maturity in their processes as the strategy to address the issue.

3.5 Opportunity Cost Sensitivity

Through the evaluation a typical opportunity cost of 15% was used as assumed to be a reasonable value for technology companies. It is natural to evaluate the impact for organizations discounting their investment projects at different levels representative of the operational risks at different industries and business contexts.

The results shown in Figure. 8 shows that NPV results deteriorates as the organization operates in more volatile segments of the market where the risk is higher and therefore the opportunity cost should reflect that.

This back ups the findings by Conradi [16] who suggested that many small organizations could not afford to step into an investment with a large horizon because of the demanding nature and volatility of the markets they choose to operate.

3.6 Limitations and Further Work

Many simplifications has been adopted in the formulation of the model, therefore the results has opportunity for improvement and should be taken as preliminary; the ranges used for the parameters requires further research and confirmation.

The model is evolving from a research and theoretical construct and further validation with practical observations needs to be done.

Additional factors are needed to identify additional benefits explaining organizations with lower Cost per Engineer to embrace SPI efforts often than these with higher costs as it should make sense based on the current set of benefits.

Data ranges for typical parameters has been integrated from different sources and even if the author's validation shows no obvious conflicts further steps to validate the model as a whole needs to be done.

Finally, the model also requires incorporating additional factors such as the intangible organization impacts obtained from the SPI effort; a better calibration based on maturity improvement experiences from organizations at the National or Regional level would be an important improvement to perform in order to verify the ranges of results obtained in the bibliography holds.

4 Conclusions

The model formulation and validation process can be regarded as complex but the actual execution to evaluate a given organizational environment and decision options can be quite straightforward; the end results is given in standard financial analysis terms and therefore should be easily integrated into a conventional investment analysis case.

The work suggest the usefulness to enable small organizations facing a SPI investment decision with the ability to use the model as a tool during the decision process; the match between the outcome of the model and results reflected by the bibliography are encouraging.

For this organizational target to have the possibility to evaluate the trade-offs between different investment scenarios is one of the benefits of the approach, even considering further work is required to refine the parameters used and the need to capture some additional elements to better explain the empirical evidence.

The usage of the NPV as the main evaluation of the investment seems to add flexibility and to better capture the realities of the financial pressure small organizations have when facing this type of investment.

The preliminary execution of the model suggest that maturity improvements to up to CMMI L3, which is typically considered the gate to participate in larger international projects, can be achieved by relatively small organizations with reasonable risk and organizational sacrifice.

The results to achieve higher maturity levels are aligned also with what the authors estimate is the reasonable growth of a successful organization in the technology markets in the implementation time of the higher maturity levels and still are within the realm of relatively small companies.

A realistic investment horizon seems to be 48 months, the probability of a successful investment with smaller horizon although not zero is considerably smaller.

Organization, especially SMEs, will require help to hedge the difference between the payback required by their financial resources and the investment horizon required by SPI initiatives. Therefore the model might also bring some aid to formulate industry or government policy to create financial and economic instruments to sponsor SPI initiatives.

The sensitivity of the final result is very much depending on the implementation schedule as this factor is having a two fold impact on the NPV because if the time gets larger the implementation costs would typically be greater and the returns will be farther into the future therefore reducing their financial attractiveness.

The need of placing emphasis in methodologies, best practices and tools to reduce this time as a gate factor for smaller companies to become enabled to operate as high maturity organizations is strongly suggested by the results.

The appraisal cost has a lower impact in the overall investment performance than often assumed; although in need of being optimized the results suggest this is not necessarily a priority direction to be taken by the industry.

The organizations operating in highly volatile market segments, and therefore discounting their capital investment at higher opportunity costs would have objective issues on implementing formal projects unless there is income or underlying assets outside the software development projects that gets impacted in their valuation because of the higher certainty yield by the operation at higher maturity levels.

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Appendix I-Model Parameters

Parm	Name	UM	Min	Med	Max	Reference
Ksepg	% Organization to SEPG	%Org	0,8%	0,8%	0,8%	[15,20,30,35]
Kprod	Productivity Gain after SPI	%Org	8,0%	22,0%	48,0%	[07]
Kspi	% Organization to SPI	%Org	0,8%	0,8%	2,3%	[15,20,35]
Ca	Assessment Costs	Person/Mo	8,0	12,0	16,0	Based on $20K-$30K-$40K range
Eae	Appraisal Execution Effort	Person/Mo	2,7	2,7	6,5	[09,20],10Persx2Wks+3Persx2W
Eap	Appraisal Preparation Effort	Person/Mo	0,6	0,9	1,3	[09,10,20]
ti	Time to Implement	Months	18,0	20,0	32,0	[10,15,18,20,35,37]
Etp	Training Preparation Effort	Person/Hr	12,0	18,0	24,0	[Authors estimation]
Epa	Training Effort per PA-Person	Person/Hr	4,0	6,0	8,0	[20,41]

CMMI Level	λ(**)	Npa	ξ (*)
Level 3	0,633	21	94%

(*) McGibbon [44] and SEI Assessment Data Base [50] / (**) Colla & Montagna [11,12,13]

Appendix II-Modeled Relations and Equations

[Ec 2] $E_{spi} = K_{spi} \times N$	[Ec3] $E_t = \lfloor (E_{PA} \times N) + E_{tp} \rfloor \times N_{PA}$	[Ec 4] $E_{ca} = \left(C_a / C_{PE} \right)$
[Ec5] $E_a = E_{ap} + E_{ad} + E_{ca}$	[Ec 6] $E_{sepg} = K_{sepg} \times N$	[Ec 7] $I_{prod} = K_{prod} \times N$
[Ec8] $V_i = (K_{prod} - K_{sepg}) \times N$	[Ec9] $V_i = \xi \times (K_{prod} - K_{sepg}) \times N$	[Ec 10] $NPV = \sum_{t=0}^{n} \frac{F_t}{(1+r)^t}$
[Ec11] $NPV = \int_0^{\infty} F(t) \times e^{-\delta t} dt$ $\delta = Ln(1+r)$	[Ec 12] $\lambda = \frac{\mu_i}{\sigma_i} \frac{\sigma_o}{\mu_o}$	[Ec13] $r' = r_f + \lambda \times (r - r_f)$