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Paper ID #: SER3167
Title: A Software COst Estimation MOdel for Product Line
Engineeering: SOCOEMO-PLE
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A Software Cost Estimation Model for Product Line Engineering: SoCoEMo-PLE

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Abstract - Economic models for reuse can help managers to forecast the benefits of a reuse investment before committing any resources. In this paper, we propose a Software Cost Estimation Model for Product Line Engineering (SoCoEMo-PLE). In fact, PLE approaches to software development seem to be very attractive in matter of product quality and time-to-market. Thus, we need an economic model to quantify the predicted benefits of using such approach. In this paper, we present an introduction in section one. In section two, we present the economic models that were the basis of the development of SoCoEMo-PLE. Then, in section three, we detail the model SoCoEMo-PLE and recapitulate its contribution in a synthesis. We end with a conclusion in section four.

Keywords: Software Reuse, PLE, Cost Estimation Model.

1. Introduction

Many economic models are achieved to quantify software development costs in reuse [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, and 23]. However, a few models deal with PLE cost estimations. Since PLE seems to be very attractive in matter of quality and time to market, we seek to have an economic model that helps to estimate the pretended benefits achieved by the adoption of a software development approach using product lines. Thus, we investigated models that can help to obtain a PLE specific cost model. The integrated cost estimation model for reuse, presented in [24, 25], is proved to be a generic model. Poulin’s economic model for PLE, presented in [26], proposes a global formula that estimates the ROI of a project using PLE.

To obtain our software cost estimation model for PLE, we investigated strong points over the pre-cited models and achieved a new cost model for PLE, SoCoEMo-PLE, detailed in [27].

2. Software cost estimation in reuse

In this section we emphasize two models studied and used as basis to achieve the SoCoEMo-PLE.

2.1. Integrated cost estimation model for reuse

The integrated cost estimation model for software reuse is characterized by:

a. Variety of investment cycles. The model defines four distinct investment cycles and identifies how they feed into each other: The corporate, the domain, the component and the application engineering cycles.

b. Variety of cost factors. The cost factors used to define the various economic functions are quantified for each investment cycle and they include:

- Investment cycle (Y), in years.
- Start Date of the investment (SD).
- Discount rate (d) is an abstract quantity that reflects the time value of money.
- Investment Costs (IC), in person months (PM).
- Periodic Benefits (B(y)), at year y, for SD+1≤y≤SD+Y, in PM.
- Periodic Costs (C(y)), at year y, for SD+1≤y≤SD+Y, in PM.

c. Variety of economic functions. The economic
functions used to assess the worthiness of the investment are:
- Net Present Value (NPV),
- Return on Investment (ROI),
- Profitability Index (PI),
- Average Rate of Return (ARR),
- Average Return on Book Value (ARBV),
- Internal Rate of Return (IRR),
- Payback Value (PB).

d. Variety of viewpoints. The integrated model analyzes the cost factors for each stakeholder (corporate managers, domain engineering teams, application engineering teams, and producers of reusable assets). Only IC, B(y) and C(y) factors are discussed, since factors Y, SD, and d are uniform within a corporation.

2.2. Poulin’s model for PLE

Poulin defines the ROI by the formula:
\[ ROI = \sum_{i=1}^{n} RCA_{i} - ADC \]

where:
- RCA is Reuse Cost Avoidance by the reuse of components i in the project: \( RCA = DCA + SCA \),
- DCA is Development Cost Avoidance by the reuse of a component:
  \[ DCA = RSI \times (1 - RCR) \times (NewCodeCost) \]
- RCR: Relative Cost of Reuse. It represents the ratio of the effort that it takes to reuse software without modification to the cost normally incurred to develop it to use once.
- SCA is Service Cost Avoidance by the reuse of a component:
  \[ SCA = RSI \times (errorRate) \times (errorCost) \]
- ADC is Additional Development Cost assumed by the reuse:
  \[ ADC = (RCWR - 1) \times (CodeWrittenForReuseByOthers) \]
  \[ * (NewCodeCost) \]
- RCWR: Relative Cost of Writing for Reuse. It represents the ratio of the effort that it takes to develop reusable software to the cost of writing it to use once.

Poulin defines too the payoff threshold \( n_0 \). It tells us how many times we have to reuse a component before recovering the investment made to develop it:
\[ n_0 = RCWR / (1 - RCR) \]

3. A Software cost estimation model for PLE: SoCoEMo-PLE

A few models deal with cost estimation for PLE. The integrated cost estimation model for reuse (cf. section 2.) is proved to be a generic model. It seems to be applicable to PLE after some adaptations. Poulin’s economic model for PLE (cf. section 2.) is a rapid and simple model. It doesn’t consider many cost drivers like the discount rate. It proposes a global formula that estimates the ROI of a project using PLE, without detailing costs and benefits for each co-operant in the reuse program.

In this section, we propose a Software Cost Estimation Model for PLE (SoCoEMo-PLE) detailed in [27] and based on the pre-cited models.

3.1. Presentation of SoCoEMo-PLE

To obtain SoCoEMo-PLE we:

a. Adapt the integrated cost estimation model for reuse to the particularities of the development life cycle with PLE by:
- Detailing the integrated model’s equations terms to emphasize cost components that are inherent to PLE.
- Adding (when it is necessary) new terms to the integrated model’s equations.

b. Transplant particularities of Poulin’s model on the equations obtained in a., particularly:
- Calculus of payoff threshold in the component investment cycle.
- Introduction of the RCA, DCA and SCA functions.

c. Specify, for each term of the equations, if it is determined by expert judgment or by a function that is given.

SoCoEMo-PLE takes the following considerations:
- Notational conventions used are: \( \gamma, \delta, \alpha, \rho \) which denote respectively component, domain, application and corporate engineering factors.
- Cost factors used are: Y, d, SD, IC, C(y), B(y) (cf. section 2.).
- Economic functions used to quantify investment decisions after the estimation of cost factors are:
Net Present Value (NPV)

\[ NPV = \sum_{y=0}^{Y} \frac{B(SD + y) - C(SD + y)}{(1 + d)^y} \]

Return on Investment (ROI)

\[ ROI = \frac{NPV}{IC} \]

Profitability Index (PI)

\[ PI = \frac{NPV_h}{NPV_c} = \sum_{y=0}^{Y} \frac{B(SD + y)}{(1 + d)^y} / \sum_{y=0}^{Y} \frac{C(SD + y)}{(1 + d)^y} \]

Average Return on Book Value (ARBV)

\[ ARBV = \frac{NPV}{Y} \left( 1 - \frac{1}{IC} \right) \]

Payback Value (PB): it is the smallest value of Y for which NPV is positive.

3.2. SoCoEMo-PLE cycles

SoCoEMo-PLE estimates cost factors for four engineering cycles. For each cycle estimations are done for three cost factors IC, C(y), and B(y), since Y, d, and SD are uniform in a corporation.

3.2.1. Component engineering cycle.

Estimations are:

a. Investment cost of component engineering cycle is estimated by:

\[ IC_{\gamma} = C_{\gamma}(SD) = ER + LI \]

where:

- LI: Certification and Library Insertion cost. Determined by expert judgment.
- ER: Estimation of development cost for Reuse) formulated by:

\[ ER = E(RCWR)Pay \]

where:

- E: Estimation of development cost without reuse and to use once. Estimated by COCOMO in organic mode:

\[ E = 3S^{1.12} \]

Pay: Average monthly salary of the developer.

- RCWR: Relative Cost of Writing for Reuse.

Here, we propose that the component engineer calculates the payoff threshold n_0 before developing the component. He can use the values of RCWR and RCR that are proper to the organization or use default values of Poulin, respectively (1.5 and 0.2).

b. Episodic cost of a reusable component γ of the product line is estimated in year y by:

\[ C_{\gamma}(y) = OC(y)Payl + MN(y)Paydın \]

where:

- OC(y): Operating Cost of the library, given by:

\[ OC(y) = \frac{Total\,Operationnel\,Cost\,of\,Library}{Components\,Number} \]

- Payl, Payd: Average monthly salary respectively of the librarian and the developer.
- MN(y): Maintenance Cost, estimated by COCOMO: \[ MN(y) = E(\text{ACT}) \]

where ACT is Annual Change Traffic (the ratio of the yearly maintenance cost to the development cost).

c. Episodic benefits of a reusable component γ of the product line are estimated in year y by:

\[ B_{\gamma}(y) = freq_{BB}(y)BP_{\gamma}(y) + freq_{WB}(y)WP_{\gamma}(y) \]

where:

- freq_{BB}(y) and freq_{WB}(y): Respectively component black box and white box use frequencies in year y. Determined by existing data or by expert judgment.
- BP_{\gamma}(y) and WP_{\gamma}(y): Respectively Black box and White box Prices of the component, given respectively by:

\[ BP_{\gamma}(y) = RBP \times E RBP \]

\[ WP_{\gamma}(y) = RWP \times E RWP \]

where RBP and RWP are respectively Relative Black Box and Relative White Box Prices, determined by expert judgment.

3.2.2. Domain engineering cycle. Estimations are:

a. Investment cost of the domain engineering cycle is estimated by:

\[ IC_{\delta} = PLADC + \sum_{\gamma \in \delta} C_{\gamma}(SD) \]

where:

- C_{\gamma}(SD): Investment cost of component γ.
- PLADC: Product Line Architecture Development Cost which comprises costs relative to the different steps to build the PLA described by [28]: BCAC (Business Case Analysis Cost), SC (Scoping Cost), PFPC (Product and Feature Planning Cost), DPLA (Design of Product Line Architecture Cost), CRSC (Component Requirement Specification Cost), VC (Validation Cost). Thus:

\[ PLADC = BCAC + SC + PFPC + DPLA + CRSC + VC \]

Costs in PLADC equation are determined by expert judgment.

b. Episodic costs for domain engineering cycle are:

\[ C_{\delta}(y) = AEC(y) + \sum_{\gamma \in \delta} C_{\gamma}(y) \]

where:
AEC (y): Architecture Evolution Cost. In [28], evolution includes changes to components of the product line, to the relations between them, etc. Determined by expert judgment.

Cγ(y): If y is the year where γ is developed, then Cγ(y) is the development cost of γ. (Cγ(γ=SD)=ICγ), else, Cγ(y) is the episodic cost of γ in year y.

e. Episodic benefits of domain engineering cycle are estimated in year y by:

\[ B_\gamma(y) = \sum_{\gamma \in \delta} \gamma(y) \]

where \( B_\gamma(y) \) is episodic benefit of component γ in year y.

3.2.3. Application engineering cycle. Estimations are:

a. Investment cost in the application engineering cycle is estimated by:

\[ IC_\alpha = \sum_{i=1}^{NC} PR_i = C_\alpha (SD) \]

where:

- PRi: price of component i used in application α. It is estimated by BPI or WPI, respectively Black box and White box Prices of the component. Determined by expert judgment.
- NC: total number of components used in application α.

b. Episodic costs of an application are nulls because it is achieved in a year, thus:

\[ C_\alpha(y) = 0 \]

c. Episodic benefits for year SD are estimated using RCA to quantify cost economies for an application α in year SD. Thus:

\[ B_\alpha(SD) = \sum_{\gamma \in \alpha} RCA_\gamma \]

where \( RCA_\gamma \) is reuse cost avoided by component γ.

For years y after SD, we consider that benefits of an application α in the product line come from cost economies achieved by the use of high quality reuse components, pretended to need less maintenance:

\[ B_\alpha(y) = \sum_{\gamma \in \alpha} SCA_\gamma \]

where \( SCA_\gamma \) is service cost avoided by component γ.

3.2.4. Corporate engineering cycle. Estimations are:

a. Investment cost of the corporate engineering cycle is estimated by:

\[ IC_\mathcal{P} = INF + C_\delta (SD) \]

where:

- INF: Infrastructure cost. Determined by expert judgment.
- \( C_\delta (SD) \): Investment cost of domain δ of the product line.

b. Episodic costs in the corporate engineering cycle are estimated by:

\[ C_\mathcal{P}(y) = C_\delta (y) \]

where \( C_\delta(y) \) is episodic cost of domain engineering cycle in year y.

c. Episodic benefits of the corporation are given by:

\[ B_\mathcal{P}(y) = \sum_{\alpha \in \mathcal{P}} B_\alpha(y) \]

where \( B_\alpha(y) \) is episodic benefit of application α in year y.

3.3. Synthesis

SoCoEMo-PLE estimates costs and benefits of software development with PLE for four investment cycles: component, domain, application and corporate engineering cycles. All of them cooperate to ensure their own interest and also the collective one of the organization that adopts a PLE approach to develop software. SoCoEMo-PLE is based on the equations of the integrated cost estimation model for software reuse. Some costs are the same in both models. This happens when an activity in the PLE development cycle doesn’t have particularities comparing with reuse in general. Otherwise, some other costs are detailed, modified or added in SoCoEMo-PLE to take into consideration the PLE development particularities. In addition to that, SoCoEMo-PLE integrates some functions announced by Poulin in his economic model for PLE. Table 1 summarizes both the integrated model and SoCoEMo-PLE equations.

The component engineering cycle equations are the same either in SoCoEMo-PLE or in the integrated model. Calculus of Poulin’s payoff threshold \( n_0 \), which is proposed in this cycle in SoCoEMo-PLE, helps the components engineer to take the good decision concerning developing or not a reusable component.

In SoCoEMo-PLE, the initial investment equation in the domain engineering cycle emphasizes the domain architecture cost. The different components of PLADC are detailed. Concerning episodic costs of the domain engineering cycle, architecture evolution cost AEC is added to the episodic costs inherited from
the components engineering cycle.

Poulin’s RCA, DCA and SCA functions are introduced in the episodic benefits equations of the application engineering cycle.

In the corporate engineering cycle, the initial investment cost includes the PLE domain’s initial investment cost during year SD. Episodic costs of the corporate engineering cycle come from the PLE’s unique domain.

Table 1. SoCoEMo-PLE recapitulation

<table>
<thead>
<tr>
<th>Investment cycle</th>
<th>Model</th>
<th>Integrated model</th>
<th>SoCoEMo-PLE</th>
<th>Remarks on SoCoEMo-PLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component engineering cycle</td>
<td>$IC_\gamma = C_\gamma (SD) = ER + LI$</td>
<td>$IC_\gamma = C_\gamma (SD) = ER + LI$</td>
<td></td>
<td>- LI is determined by expert judgment (EJ). - Calculus of the payoff threshold $n_0$.</td>
</tr>
<tr>
<td>Domain Engineering cycle</td>
<td>$IC_\delta = DA + \sum_{\gamma \in \delta} C_\gamma (SD)$</td>
<td>$IC_\delta = PLADC + \sum_{\gamma \in \delta} C_\gamma (SD)$</td>
<td></td>
<td>- Emphasis and detail of the PLADC’s costs (determined by EJ).</td>
</tr>
<tr>
<td>Application engineering cycle</td>
<td>$IC_\alpha = \sum_{i=1}^{NC} PR_i = C_\alpha (SD)$</td>
<td>$IC_\alpha = \sum_{i=1}^{NC} PR_i = C_\alpha (SD)$</td>
<td></td>
<td>- PR$_i$ is determined by EJ.</td>
</tr>
<tr>
<td>Corporate engineering cycle</td>
<td>$IC_\rho = INF = C_\rho (SD)$</td>
<td>$IC_\rho = INF + C_\rho (SD) = C_\rho (SD)$</td>
<td></td>
<td>- IC$_\rho$ includes the domain cost in year SD.</td>
</tr>
</tbody>
</table>

- An application developed with PLE needs less than one year.
- Introduction of RCA and SCA.
- For PLE, C$_\rho$ is determined from the unique domain of the product line.
- Similar to the integrated model.
4. Conclusion

In this paper we presented a software cost estimation model for product line engineering: SoCoEMo-PLE. This model is based on the calculus of costs and benefits for four investment cycles in an organization. It considers typically two cost models for software development with reuse: the integrated cost estimation model for software reuse and Poulin’s model for PLE. We have developed an environment supporting this cost estimation model and experimented it for a case study which presents promising results. Our current work is concerned by testing much more case studies while the near future work consists in investigating the estimation for projects dealing with COTS (Commercial Off The Shelf) components both in a PLE approach and in a COTS based development approach.

5. References

[19] W., Frakes, and C., Terry, "Reuse Level Metrics", *Proceedings of Third International


Las Vegas (June 27-30, 2005).

Kind regards,
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*****************************************************************************
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