Systematic Review of Solutions Proposed for Product Line Economics

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Abstract

This paper presents a systematic review of all the solutions addressing different economic aspect of software product lines (SPL), e.g. SPL adoption cost-benefits, PL architecture decisions, SPL test strategies project cost overrun and so on, presented for the years 2000 to 2007. The goal of the review is to analyze the level of empirical application and/or validation of the proposed solutions with the purpose of mapping maturity as well as to what extent proposed solutions might be proven in terms of usability and usefulness. The important finding of this review is that although many economic solutions for SPL have been proposed over the years, the absence of qualitative and quantitative results from empirical application and/or validation makes it difficult to evaluate the potential of proposed solutions with respect to their usability and/or usefulness in relation to industry adoption. Suggestions have been presented to improve the existing situation.

1. Introduction

Software product families have received significant attention from the software engineering community since the 1990s [1, 2] . The concept of product lines aims towards having a set of systems that share a common, managed set of features, which satisfy the particular needs of a market segment, developed from a common set of core assets in a certain given way [1]. The product line approach is recognized as a successful approach for reuse in software development [3] with the major benefits of product lines adoption reported as reduced time to market [4, 5], reduced cost [6] and improved quality [4, 6, 7]. For these reasons many companies developing software intensive products have either adopted or are considering the adoption of a SPL approach [5, 8].

For making rational decisions about product line processes and products, it is important to answer the question "Does it pay?" [9]. In order to make sound software engineering decisions it is required to understand the business impact of those decisions and vice versa [9]. Without economic evaluation of adopting product line processes or products, a company might end up in spending more and getting fewer benefits. Therefore, evaluating the economic viability of product line adoption is critical.

Several economic measurement and evaluation models/methods aimed at SPL have been presented in academia and as industry experience reports. However, in order to gauge the usability and usefulness of the proposed models/methods, it is important to see the empirical evidence of their application and/or validation, e.g. in industry or through a simulation [10].

This paper presents a systematic review (based on the systematic review technique proposed by Kitchenham in [11]) conducted on the papers, which either proposed or reported on experience with economic/cost/cost-benefit/ROI models/methods (called *solutions* from now on) for SPL. The motivation was to gauge the level of actual industry adoption, i.e. to what extent the presented solutions are applied and/or validated in industry. In addition to industry validation all other types of empirical results are collected and taken into consideration to offer a detailed summary of the empirical evidence available. To achieve this, the selected papers are categorized and analyzed from several perspectives, such as research basis, method, level of validation and type of empirical results in relation to usability and usefulness of the proposed solutions. For industry practitioners, looking to perform economic evaluations using a certain solution, the results of the study can be used as an indication of maturity as well as to estimate potential risk of a certain solution. From an academic point of view researchers planning studies and evaluation of a solution can use this study as inspiration for study design as the evaluation criteria of the review presented in this paper could be seen as a checklist to test a solution's usability and usefulness.

2. Related Work

Four previous studies ([12]; [13]; [14] and [15]) have reviewed the state of empirical research in different areas e.g. computer science, software engineering, web engineering and so on. However, to the best of our knowledge no other study has been conducted with the same focus as the review presented in this paper. This review does not aim to systematically classify proposed economic solutions as methods, models, tools, framework or classify the papers according to the classification and evaluation scheme suggested by W. Roel et al. [16]. The goal of this review is to analyze practical application and validation of proposed solutions in industry to gauge their practical usability and usefulness. In addition to this other empirical evidence is also considered e.g. proof of usability and/or usefulness demonstrated through simulation or experimentation.

3. Design

3.1. Research Questions and Definitions

The four research questions driving the systematic review can be viewed in Table 1.

Table 1 – Research questions and motivation.

Research Questions and Motivation
RQ1. Are proposed solutions based on needs identified in industry?   **Motivation:** Is the solution presented based on any need/issue/problem (called a need from here onwards) identified in industry though empirical investigation? Examples can be process assessments, case studies, participation knowledge, surveys, observations, and so on. Both direct and indirect sources will be considered, giving the presented studies the benefit of the doubt.
RQ2. Are proposed solutions applied and/or validated in laboratory setting or industry?   **Motivation:** Is the solution presented applied/validated through simulation or in industry as a part of the presentation in the paper?   Any validation in industry from static validation to dynamic validation will be considered [17].
RQ3. Are the proposed solutions usable?   **Motivation:** If the authors of a proposed have applied/validated it in industry or demonstrated its application/validation through simulation, identify any indications/proof/reports on its usability in the venue of the application/validation (usability is defined below).
RQ4. Are the proposed solutions useful?   **Motivation:** If the authors of a proposed have applied/validated it in industry or demonstrated its application/validation through a controlled experiment, identify any indications/proof/reports on its usefulness in the venue of the application/validation (usefulness is defined below).

The two main terms used in the research questions, namely *usability* and *usefulness*, are defined and exemplified below.

Usability is defined in terms of;

- Scalability of Introduction. How scalable the proposed solution is in terms of its introduction and application cost including e.g. which metrics have to be collected, who collects the metrics?

- Scalability of Use. How scalable is the proposed solution in terms of metrics collection and recording? For example, if a cost-benefit estimation model is proposed and certain data is required for making estimations, do the defined metrics provide the data required even when the size of a product grows and multiple products come in to play, or does it make simplified estimations with simple data collected or is there any indication that product line grade scalability is possible (or even considered by the creators of the solution)?

Scalability of Introduction and Scalability of Use point to a micro quality of a solution and that is its efficiency. If a proposed solution is demonstrated to have any of these aspects of efficiency, the corresponding paper is counted as having some proof of usability.

Usefulness is defined in terms of;

- Better Alternative Investment. For example, a proposed solution (X) is better than an alternative (maybe previously used) solution (Y), and/or,

- Effectiveness. The effectiveness of a proposed solution in relation to achieving goals or solving the problems it was designed for. For example, solution X makes estimations 15% more realistic than before.

Again, a solution demonstrating either of the two aspects of usefulness is counted as having some proof of usefulness.

3.2. Review Design

In this section, the systematic review design is presented describing paper identification method, inclusion/exclusion criteria, and the classification scheme.

3.2.1. Search Strategy. The search string used to identify literature for the mapping study is given below:

((("software product line" AND economic) WN KY) AND (2000-2007 WN YR)) or ((("software product line" AND (ROI OR {return on investment})) WN KY) AND (2000-2007 WN YR)) or (((software NEAR/0 product NEAR/0 lin* AND cost NEAR/0 model*) WN KY) AND (2000-2007 WN YR)) or ((("software product line" AND economic* NEAR/0 model*) WN KY) AND (2000-2007 WN YR)) or ((("software product line" AND {value based software engineering}) WN KY) AND (2000-2007 WN YR))*

When applying the search string, the aim was to identify highly relevant sample of product line literature by focusing on the Software Product Line Conferences (SPLC) and the Workshops on Product Family Engineering (PFE). SPLC is the premier forum for practitioners, researchers, and educators presenting and discussing experiences, ideas, innovations, as well as challenges in the area of SPL. SPLC also has a relatively large industry presence. In order to identify the articles related to SPL economics' aspects, the search string was applied on all papers in all the previous SPLC and PFE proceedings (2000-2007). To further extend the study papers from international, peer-reviewed journals have also been included. The databases that searched are Inspec, Compendex, ACM Digital Library and IEEE. In total, 79 papers were identified through the searches.

3.2.2. Identification and Selection of Papers. The procedure used for the identification of relevant papers (out of the 79 generated from the search string) can be described as follows. The Title, Abstract and Conclusions were read for all the 79 papers. Only if none of the parts contained any potentially relevant information within the scope of the review was a paper dismissed. This means that if there was any new proposed economic solution for SPL or any experience report indicating use of any SPL economic solution, it was included otherwise discarded.

The inclusion and exclusion criteria were pilot-tested by the authors on a random sample of 10 papers. An agreement on inclusion and exclusion was achieved. After the pilot, the primary author screened the remaining papers and marked them as included/excluded based on the approach described.

3.2.3. Data Extraction Procedure. Based on the research questions identified (see Section 3.1.), a set of data extraction categories was identified. The categories were identified through using the Goal Question Metric (GQM) approach [18] during several brain storming sessions to ensure that categories identified addressed the aspects required to answer the research questions. Due to reasons of brevity, the data extraction categories are not included but can be made available upon request to the authors.

The categorization of quality attributes (usability and usefulness) into quantitative and qualitative is not intended to indicate a preference or valuation of one over the other. Any empirical data is judged on its own merits. For example, quantitative results obtained through a simulation might not be as valuable as the expert opinion obtained in a case study with industry practitioners who actually applied a particular solution

in industry. Moreover, context, background description and design also weigh in as the purpose is to categorize the reported empirical data to analyze the levels of usability and usefulness of a proposed solution. For example, a claim about the usability and/or usefulness of the presented solution without any description of context or how the claim can be substantiated is still considered as empirical evidence from the perspective of the study, but further analysis lets the reader weigh the value of the evidence.

Similar to the inclusion/exclusion process, the data extraction process was tested by the authors using a sample of 7 included papers. This was done to ensure that there was a common understanding of the categories defined and the classification was agreed upon by two researchers avoiding the potential bias and error source of having only one researcher performing the categorization.

4. Results and Analysis

Out of 79 papers found through the search string (see Section 3.2.1), 19 papers [9, 19-36] were selected. The selected papers are analyzed with respect to the research questions posed in Table 1.

4.1. RQ1 (Are proposed solutions based on needs identified from Industry?)

All the selected papers are based on the need identified from industry except [20, 21, 23, 27, 35]. However, a deeper analysis of the empirical basis reported can be seen in Table 2 which shows that a majority of the papers have mentioned identified needs as "Statements only" ([9, 19, 20, 24-26, 28, 29, 31, 33, 36], 78.57%), or as "Participation knowledge" ([21, 22, 32, 34], 28.57%). None of the papers have mentioned e.g. interviewing experts to identify needs, or using some form of process assessment in industry to identify the need for the proposed product line economics' solutions. The technical reports referenced in some papers were also read but empirical process used to identify the need was not found. These results make it hard to judge the credibility of the empirical basis of the solutions proposed due to the absence of presentation of e.g. process assessment and/or any other empirical study. In addition, due to the almost total lack of how the practitioners knew about the needs that constitute the basis for the solutions proposed, it is impossible to draw any conclusions.

Moreover, it is found that although a majority of the papers claims empirical basis, only 4 [28, 31, 32, 35] papers out of 19 are based on future work described by previously published papers, or extend previously

published solutions. This may indicate that in the absence of a proper empirical investigation investigating the needs in industry, the needs quoted may not be representative or valid for other companies in similar situations.

The answer to RQ1 is that a majority of the proposed solutions are based on needs identified in industry, however, the actual method used and the validity of the results is impossible to ascertain as very little information is given.

4.2. RQ2 (Are proposed solutions applied and/or validated in laboratory setting or industry?)

In order to answer this question, let us do an analysis of the application/validation methods used and the explanation of results obtained. An application/validation could range from controlled experiments/simulations to full-fledged industry pilots.

In total, 14 papers [21-32, 34, 35] out of 19 have performed some application/validation of the proposed solutions. This seems to be a positive thing but a deeper analysis of the papers, claiming application/validation, reveals that only 6 ([21, 22, 28, 29, 32, 34], 42.85%) out of these 14 have used case study as an application/validation method whereas the remaining papers (57.14%) have demonstrated application/validation through simplified examples using simplified or fictitious data. This makes it harder to judge the scalability of introduction and scalability of use of the proposed solutions.

Empirical studies are the building blocks essential for collecting evidence and to determine what situations are best for using a particular solution [37]. The current situation means there is a lack of quantitative or qualitative data that a new solution is better than an already existing one, or what the impact of implementing the new solution might be. This makes it impossible to gauge efficiency or effectiveness of proposed solutions either alone or in relation to better alternative investment (BAI).

Table 2 - Selected papers, "Basis" categorization.

Basis Reported as	Total
Statements only	11
Participation knowledge	4
Interviews	0
Process assessment	0
Total	15

Moving on from the analysis of application/validation methods used to the analysis of

the application/validation design details, Table 3 shows the categorization of the application/validation design explanation given in the selected papers. It can be seen that some form of application/validation was performed. By examining the last column it is possible to see that 11 out of 14 papers (78.57%) either provide a short summary ([21, 22, 24, 25, 34, 35]) or explain application/validation in detail ([28-32]). This seems to be a positive outcome, i.e. most of the papers have explained the application/validation in detail. However, after analyzing the level of application/validation results (see Table 4), it can be seen that a majority of the papers ([21, 23, 25, 26, 30-32, 34, 35]) have only statements about the application/validation results. Only 2 papers ([28, 29]) provide qualitative results and only 2 papers ([22, 24]) provide quantitative results.

Table 3 - "Application/Validation Design Explained" categorized.

Application/Validation Design Explained	Total
Statements only	3
Application/Validation summary	6
Application/Validation in detail	5
Total	14

Figure 1 presents another aspect in relation to RQ2, i.e. how many solutions from each year are based on solutions presented previous years. Figure 1 shows that many new solutions have been presented over the years, but very few actually have been used as a basis for further development or adopted in industry. For example, by the year 2005 a total of 10 new product line economics' solutions had been proposed but none of the papers reported use of any of the previously proposed solutions (in industry or as a basis for refinement of a solution). By 2007 the number of new solution papers had reached 19, but only 4 papers ([28, 31, 32, 35]) were based on previously proposed solutions. The technical reports referenced in some papers were also read but qualitative and quantitative results were not found.

Table 4 - "Application /Validation Results" categorized.

Application/Validation Results Explained	Total
Nothing	1
Statements only	9
Results as experts opinion	2
Quantitative data	2
Qual +Quant	0
Total	14

This can indicate that the proposed solutions are not applicable in industry or that due to missing application/validation results the solutions are not applied by practitioners and not used by researchers. This problem has been indicated by others as well e.g. in [38]. This can imply that a focus on validation and proper reporting should be premiered over the continuous presentation of new solutions. Another possibility is that the proposed solutions do not solve the challenges in industry, which in turn implies that there is a need to understand the challenges. Another possible conclusion could be that industry practitioners are not up to date with the new solutions proposed, thus the solutions go unused. None of the papers reported replicated studies.
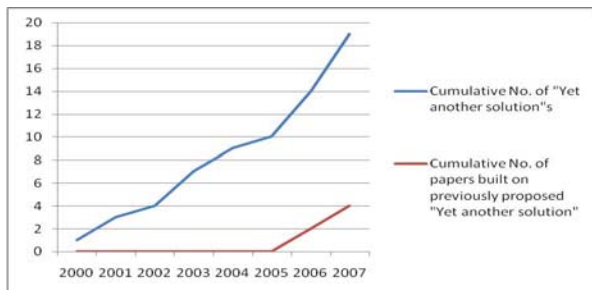

Figure 1 - Cumm No. of "New Solution" VS Cumm No. of papers built on previously proposed solutions.

Summarizing all the aspects analyzed above, the answer to RQ2 is that although 73.68% of the proposed solutions from 2000 to 2007 have reported some form of application/validation, the absence of detailed results other than statements and the lack of replicated studies make it difficult to evaluate the potential of the proposed solutions.

4.3. Answering RQ3 (Are the proposed solutions usable?) and RQ4 (Are the proposed solutions useful?)

By looking at Table 5 it is possible to see that 15 out of 19 selected papers have not stated anything about usability in terms of scalability of introduction or scalability of use. 4 papers out of 19 ([24, 27, 28, 30], 21.05%) have only statements claiming usability. For example, *"It was hard to collect, for example, the cost of a typical product released using the traditional style. In such cases, apply well-known prediction models and validate with managers."*[28]. None of the papers have given qualitative and quantitative evidence of usability.

Clearly with the usability statements as exemplified above, it is difficult to judge the usability of a proposed solution. A majority of the papers do not include either qualitative or quantitative data in relation to solution

scalability of introduction or scalability of use, making it harder for practitioners to evaluate usability. It is important to understand that the intention in this review is not to criticize papers but to highlight the absence of qualitative and quantitative evidence in relation to usability, which might be a barrier for the industrial adoption of the proposed solutions.

Table 5 - "Usability" reported

Usability	Total
Statements only	2
Results as experts opinion	0
Quantitative results	0
Qual +Quant	0
Total	2

Looking at the "Total" column in Table 6, 2 ([20, 34], 10.52%) out of 19 papers have not mentioned anything about usefulness. The remaining 17 papers have reported positive results which seem to be very good, but a deeper analysis shows that these 17 papers out of 19 have claims of usefulness as statements only. For example *"We feel that the uncertainty analysis can reveal more insights about the ROI in a product line, and can give statistical evidence to the managers about investing into a product line"* [28] or *"we regard the economic model we are about to develop as a key step towards sound engineering for product line development"* [23]. There is not a single paper that provides qualitative and/or quantitative data about usefulness. The technical reports referenced in some papers were also read but qualitative and quantitative evidence of usability and/or usefulness were not obvious.

Table 6 - "Usefulness" reported

Usefulness	Total
Statements only	17
Results as experts opinion	0
Quantitative results	0
Qual +Quant	0
Total	17

The answer to RQ3 and RQ4 is that although there are statements about usability and usefulness in the papers published between the years 2000 to 2007, a lack of qualitative and quantitative evidence makes it difficult to evaluate how usable and useful the proposed solutions and collected experiences are. In industry, time and resources are scarce. If a practitioner cannot in any manner determine the time and resources required to implement a solution, and at least approximate the possible usefulness of the solution in comparison to available better alternative investments,

it is very unlikely that the solution will be adopted. Similarly, if authors do not show any evidence regarding scalability of use of a particular solution for industry grade problems, practitioners would probably not take the risk of implementing a solution falling short on reporting even rudimentary evidence of efficiency and effectiveness.

5. Suggestions

There are several lessons from Software Engineering research and practice which Software Product Line community can learn from.

5.1. Conduct Process Assessment

Instead of stating that that solution is based on participation knowledge a light-weight software process assessment methods (e.g. [39]) can be employed to ensure that the need identified is triangulated and has empirical basis. This can help research community to investigate the real needs which can consequently result in further research papers based on the needs identified. Industry would benefit from the proposed solution for the need identified as it would be applicable for the real problems faced in industry.

5.2. Conduct Empirical Studies

Once a solution is proposed (based on the empirical need identified through process assessment) small controlled and well planned experiments/simulations and replications with real data, even if conducted offline can be valuable. The potential benefits of such studies include: getting initial evidence to confirm or refute hypotheses, controlling factors that can affect the study, proving the relevance of the research to the research community and industry, fine-tuning the proposed method before full-fledged industry pilot. After the initial evaluation showing positive results the validation can be taken one step further by conducting a case study in industry. This could be used to fine-tune the proposed solution before a pilot could actually be implemented. Inspirations can be taken from example papers like [14, 28, 29] and [22, 24] as how to design studies and collect and present the real qualitative and quantitative empirical results. A model for technology transfer [17] can be used to design the validation steps. Due to complexity involved in designing empirical studies for SPL area in general and SPL economic solutions in particular, it is necessary to identify the limitations and customize the existing empirical methods for proposed economic solutions

rather than having only statements about empirical evidence.

5.3. Identify Metrics

It is understandable that in case of SPL, the complexity of conducting empirical studies increases but to deal with this, an important aspect is that proper metrics are identified to measure different aspects of proposed economic solutions. The definitions of usability and usefulness stated in this paper can be used as a starting point to identify what metrics to collect and report when claiming usability and usefulness of the proposed SPL economic solutions. Some of the example papers that employed such metrics in their empirical studies are [40], [41]. Collecting data for the identified metrics during the empirical evaluation would greatly enhance the quality of reported usability and usefulness evidence both for research community for further research and for industry considering adoption of a particular solution.

6. Conclusion

This paper presents the systematic review of all the papers, proposing solutions for SPL economical aspects, from the year 2000 until 2007. After screening 79 papers published, 19 papers were selected, that discuss different aspects of product line economics, to *analyze the practical application and validation of proposed solutions in industry to gauge their practical usability and usefulness,* four research questions were specified (see Section 3.1.). Based on the goal and corresponding research questions to achieve that goal, a data extraction procedure was defined. Against the defined procedure, data was extracted from the included papers about the basis, practicality, usability and usefulness, future work and authors.

The major findings of the review can be summarized as follows:

1. *Issue:* Many solutions discussing economics aspects of product lines have been presented over the years and majority of the papers address needs identified in industry, but they fall short on the strength of the approach used to identify the need for a solution. Most papers only claim that they based the solution on a need identified in industry or state that through participation knowledge they found the need for the proposed solution. *Consequences:* Such claims and statements may be valid, but they raise validity questions both from a research perspective and an industrial adoption perspective. Without interviewing experts in industry or performing some form of process assessment, it is hard to triangulate the need identified

thus raising the issue that the need may not be representative of the current situation. As a result, this poses questions about the internal and external validity of the needs identified and corresponding solutions proposed. *Suggestions:* conduct process assessment (see Section 5.1.)

2. *Issue:* Many papers claim that they have applied/validated the proposed solutions in some form; however, a deeper analysis reveals that a majority of the claims are merely statements (see Table 4) and qualitative and quantitative evidence supporting these claims is generally missing. *Consequence:* Claims and statements may be valid, but in the absence of clear qualitative evidence as experts' opinions and/or quantitative data (by using real data in simulations) about the benefits of the proposed solution, it is hard to evaluate the potential of these solutions for industry adoption. *Suggestions:* Conduct empirical studies (see Section 5.2.).

3. *Issue:* Papers claim usability and usefulness of the proposed solutions in some form, however a deeper analysis reveals that majority of the claims are also merely statements about usability and usefulness (see Table 5 and Table 6). *Consequence:* As mentioned previously such claims may be valid, but they raise validity questions from both a research and industrial adoption perspective. Without experts' opinions and/or quantitative data supporting the usability and usefulness claims, it is difficult to evaluate the validity of the claims, and similarly it is difficult for the practitioners to evaluate the usability and usefulness of a proposed solution for application in industry. *Suggestions:* identify metrics (see Section 5.3.).

The overall goal of this review was not to expect or demand perfect evidence of usability and usefulness following perfect and extensive data collection in industry. However, many studies over the years have shown that it is possible to validate solution suggestions in any number of ways. Simulation could be used in academia with real data. Static (preliminary) validation can be performed in industry through workshop, interviews, or surveys. Dynamic validation (e.g. pilots) can be performed collecting metrics and

qualitative data though interviews with practitioners [42]. The data collected is not complete, but vastly better than no data at all.

In addition to doing validation (e.g. in industry), the way in which the validation is planned and reported is also crucial. The papers reviewed are full of statements, claiming usability and usefulness. The good thing is that this indicates that our interest in these two concepts in this systematic review is relevant, i.e. usability and usefulness of solutions are important. However, even if statements are common, no evidence is presented. Both in terms of absence of data, but also absence of design for the studies presented. The only seemingly complete validation is when there is no real validation, e.g. in case of presenting simplified examples. The use of simplified examples is not without merit, e.g. it can be used to explain and exemplify the use of a method, but the use of a simplified example is not the same as validation, but at least it could be made better with real data to demonstrate the usefulness of the solution.

This review does not attempt to say that the proposed solutions have no empirical application/validation results and empirical usability and usefulness data instead it highlights that this evidence needs to be made explicit to encourage industry adoption. The presence of empirical evidence of any sort with at least some intent to explain the overall design and execution of a validation (e.g. a pilot test in industry) could be very beneficial for both researchers and industry practitioners. From an academic point of view the possibility to learn and extend on presented research is crucial for progress. In addition, one of the foundations of research is the possibility to replicate studies. None of the papers included was a replicated study.

From a practitioner point of view, a design and illustration of how conclusions about usability and usefulness are made can vastly improve the relevance of any paper. The absence of data or evidence is problematic from two perspectives. First, can the results be trusted? Second, even if the authors are given the benefit of the doubt, is the proposed solution relevant for all cases?

6. References

[1] P. Clements and L. Northrop, *Software product lines : practices and patterns*. Boston MA: Addison-Wesley, 2002. 0-201-70332-7.
[2] S. Deelstra, S. Marco, and B. Jan, "Experiences in Software Product Families: Problems and Issues During Product Derivation," in *Proceedings of Third International Conference, SPLC2004* Boston, MA, USA: Springer, 2004.
[3] M. Kim, S. Park, V. Sugumaran, and H. Yang, "Managing requirements conflicts in software product lines: A goal and scenario based approach," *Data Knowl. Eng.,* vol. 61, pp. 417-432, 2007.

[4] W. A. Hetrick, C. W. Krueger, and J. G. Moore, "Incremental return on incremental investment: Engenio's transition to software product line practice," in *Companion to the 21st ACM SIGPLAN conference on Object-oriented programming systems, languages, and applications* Portland, Oregon, USA: ACM, 2006.
[5] J. C. Dager, "Cummins's experience in developing a software product line architecture for real-time embedded diesel engine controls," in *Proceedings of the first conference on Software product lines : experience and research directions: experience and research*

directions Denver, Colorado, United States: Kluwer Academic Publishers, 2000.

[6] K. Pohl, G. Boeckle, and F. van der Linden, *Software Product Line Engineering*: Springer, 2005. 10 3-540-24372-0 Springer Berlin Heidelberg New York.

[7] M. Staples and D. Hill, "Experiences adopting software product line development without a product line architecture," in *Software Engineering Conference, 2004. 11th Asia-Pacific*, 2004, pp. 176-183.

[8] G. Bockle, "Model-based requirements engineering for product lines," in *Proceedings of the first conference on Software product lines : experience and research directions: experience and research directions* Denver, Colorado, United States: Kluwer Academic Publishers, 2000.

[9] R. S. Faulk, R. Harmon R., and D. Raffo M., "Value-Based Software Engineering," in *Proceedings of the first conference on Software product lines : experience and research directions: experience and research directions* Denver, Colorado, United States: Kluwer Academic Publishers, 2000.

[10] D. I. K. Sjoeberg, J. E. Hannay, O. Hansen, V. B. Kampenes, A. Karahasanovic, N. K. Liborg, and A. C. Rekdal, "A survey of controlled experiments in software engineering," *Software Engineering, IEEE Transactions on,* vol. 31, pp. 733-753, 2005.

[11] B. A. Kitchenham, "Guidelines for performing Systematic Literature Reviews in Software Engineering," in *Technical Report EBSE-2007-01*, 2007.

[12] V. Ramesh, L. Glass Robert, and I. Vessey, "Research in computer science: an empirical study," *The Journal of Systems and Software,* vol. 70, pp. 165-176, 2004.

[13] R. L. Glass, I. Vessey, and V. Ramesh, "Research in software engineering: An analysis of the literature," *Information and Software Technology,* vol. 44, pp. 491-506, 2002.

[14] E. P. Dewayne, A. P. Adam, and G. V. Lawrence, "Empirical studies of software engineering: a roadmap," in *Proceedings of the Conference on The Future of Software Engineering* Limerick, Ireland: ACM, 2000.

[15] E. Mendes, "A systematic review of Web engineering research," in *Empirical Software Engineering, 2005. 2005 International Symposium on*, 2005, p. 10 pp.

[16] R. Wieringa, N. Maiden, N. Mead, and C. Rolland, "Requirements engineering paper classification and evaluation criteria: a proposal and a discussion," *Requir. Eng.,* vol. 11, pp. 102-107, 2005.

[17] T. Gorschek, C. Wohlin, P. Garre, and S. Larsson, "A model for technology transfer in practice," *IEEE Software,* vol. 23, pp. 88-95, Nov-Dec 2006.

[18] V. Basili, G. Caldiera, and H. D. Rombach, *The Goal Question Metric Approach*: John Wiley & Sons, 1994.

[19] S. Klaus, "An Initial Model of Product Line Economics," in *Revised Papers from the 4th International Workshop on Software Product-Family Engineering*: Springer-Verlag, 2002.

[20] P. Knauber, J. Bermejo, G. Bockle, J. C. S. d. P. Leite, F. v. d. Linden, L. M. Northrop, M. Stark, and D. M. Weiss, "Quantifying Product Line Benefits," in *Revised Papers from the 4th International Workshop on Software Product-Family Engineering*: Springer-Verlag, 2002.

[21] K. Schmid and M. Verlage, "The Economic Impact of Product Line Adoption and Evolution," *IEEE Softw.,* vol. 19, pp. 50-57, 2002.

[22] K. Schmid, "A Quantitative Model of the Value of Architecture in Product Line Adoption," in *SPLC*, 2003.

[23] G. Böckle, P. Clements, J. D. McGregor, D. Muthig, and K. Schmid, "A Cost Model for Software Product Lines," in *Software Product - Family Engineering. 5th International Workshop* Siena, Italy: Springer Berlin / Heidelberg, 2003, pp. 310-316.

[24] D. R. Peterson, "Economics of Software Product Lines," in *Software Product - Family Engineering. 5th International Workshop* Siena, Italy: Springer Berlin / Heidelberg, 2003, pp. 381-402.

[25] B. Boehm, A. W. Brown, R. Madachy, and Y. Yang, "A Software Product Line Life Cycle Cost Estimation Model," in *Proceedings of the 2004 International Symposium on Empirical Software Engineering*: IEEE Computer Society, 2004.

[26] G. Bockle, P. Clements, J. D. McGregor, D. Muthig, and K. Schmid, "Calculating ROI for software product lines," *Software, IEEE,* vol. 21, pp. 23-31, 2004.

[27] S. B. A. B. Lamine, L. L. Jilani, and H. H. B. Ghezala, *Cost Estimation for Product Line Engineering Using COTS Components*, 2005.

[28] D. Ganesan, D. Muthig, and K. Yoshimura, "Predicting Return-on-Investment for Product Line Generations," in *Proceedings of the 10th International on Software Product Line Conference*: IEEE Computer Society, 2006.

[29] K. Yoshimura, D. Ganesan, and D. Muthig, "Defining a strategy to introduce a software product line using existing embedded systems," in *Proceedings of the 6th ACM; IEEE International conference on Embedded software* Seoul, Korea: ACM, 2006.

[30] M. Nonaka, L. Zhu, and M. Ali Babar, *Project Cost Overrun Simulation in Software Product Line Development*, 2007.

[31] M. Nonaka and L. Zhu, "Impact of Architecture and Quality Investment in Software Product Line Development," in *Proceedings of the 11th International Software Product Line Conference*: IEEE Computer Society, 2007.

[32] D. Ganesan, J. Knodel, R. Kolb, U. Haury, and G. Meier, "Comparing Costs and Benefits of Different Test Strategies for a Software Product Line: A Study from Testo AG," in *Proceedings of the 11th International Software Product Line Conference*: IEEE Computer Society, 2007.

[33] P. C. Clements, "An Economic Model for Software Architecture Decisions," in *Proceedings of the First International Workshop on The Economics of Software and Computation*: IEEE Computer Society, 2007.

[34] Y. Matsumoto, "A Guide for Management and Financial Controls of Product Lines," in *Proceedings of the 11th International Software Product Line Conference*: IEEE Computer Society, 2007.

[35] H. P. In, J. Baik, S. Kim, Y. Yang, and B. Boehm, "A quality-based cost estimation model for the product line life cycle," *Commun. ACM,* vol. 49, pp. 85-88, 2006.

[36] H. Schackmann and H. Lichter, "A Cost-Based Approach to Software Product Line Management," in *International Workshop on Software Product Management, 2006. IWSPM '06.*, 2006, pp. 13-18.

[37] S. L. Pfleeger, "Albert Einstein and empirical software engineering," *Computer,* vol. 32, pp. 32-38, 1999.

[38] M. Kircher, C. Schwanninger, and I. Groher, "Transitioning to a Software Product Family Approach - Challenges and Best Practices," in *Proceedings of the 10th International on Software Product Line Conference*: IEEE Computer Society, 2006.

[39] T. Gorschek, "Software Process Assessment & Improvement in Industrial Requirements Engineering," in *School of Engineering - Department of Systems and Software Engineering* Ronneby: Blekinge Institute of Technology, 2004, p. 154.

[40] E. Magnus, B. Jürgen, and B. Kjell, "The PLUSS Approach - Domain Modeling with Features, Use Cases and Use Case Realizations," in *Ninth International Conference on Software Product Lines* Rennes, France, 2005.

[41] T. Gorschek, M. Svahnberg, A. Borg, A. Loconsole, J. Borstler, K. Sandahl, and M. Eriksson, "A controlled empirical evaluation of a requirements abstraction model," *Information and Software Technology,* vol. 49, pp. 790-805, 2007.

[42] T. Gorschek, P. Garre, S. Larsson, and C. Wohlin, "Industry evaluation of the Requirements Abstraction Model," *in print Requirements Engineering.*