Improving Traceability by Focusing on Value during Development

Stefan Cedergren

Mälardalen University
School of Innovation, Design, and Engineering
P.O. Box 883, Västerås, Sweden
+46 21 107017

stefan.cedergren@mdh.se

Stig Larsson

Mälardalen University
School of Innovation, Design, and Engineering
P.O. Box 883, Västerås, Sweden
+46 21 124290

stig.larsson@mdh.se

ABSTRACT

Product delivering companies invest resources in software development activities in order to create value. Still, when performance in software development is to be measured, focus easily turns to time, cost, and quality in the later stages of the development process. Time, cost, and quality are important dimensions of performance but they are not revealing the complete picture. Missing is the value perspective.

This paper outlines a method for how customer value can be used to evaluate performance and improve traceability during the development of a new product. The first step in the method is to value each requirement in the development project according to their perceived customer value. Hence, the value propagation can be monitored as the activities related the requirements are completed during the development. This information can then be used in order to improve traceability by visualizing the value propagation and performance during the development. The paper is concluded with outlining four key needs for future research.

General Terms

Management, Measurement, and Performance

Keywords

Software development, Product development, Traceability, Requirements and Value

1. INTRODUCTION

All organizations exist to create value for their stakeholders. Value can be created in many different ways of which developing new products is one way. Successful product development contributes to a corporation's value creation by generating revenues and profits that otherwise would not have been generated [2]. In this paper the focus is on evolutionary product development of software-intensive systems that typically is performed in large organizations.

Looking at the literature there is a broad spectrum of research focusing on value creation. We propose to view value creation in a product development context as an iterative flow of capturing value, developing value, and finally realizing value, see Figure 1. Traceability is of great importance in this value flow because it is the key to understand what creates value and what is not.

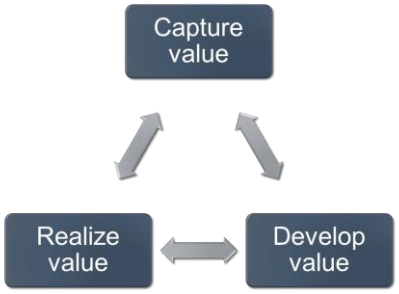

Figure 1. Iterative value flow in Product Development.

The Capture value is typically the starting point in this iterative product development value flow and it relates to answering the key questions why, what, how, and when to develop a new product. Understanding what the customer wants and why, and matching this with the capabilities of the organization in order to decide what opportunities to pursue is a key ingredient in successful product development. The interface between capturing and realizing value is typically a go or no-go decision concerning the initiation of the development of a new or improved product. This decision is often primarily based on a business case, developed as part of the capture value flow.

The development value flow is initiated when a development project is started aiming at developing a product based on what has been decided during the capturing value flow. The develop value flow ends as the development project is finalized and the overall product development value flow is continued through the realization of the captured and developed value.

Realizing value is the third step in the product development value flow and it relates to the marketing and sales activities. Value is realized when the developed product has been delivered to the customer and revenues are generated.

In the following sections our proposed product development value flow is used to categorize the existing literature focusing on value and product development.

1.1 Capture Value Flow

In a review of the Fortune 1000 companies Ryan and Ryan [14] conclude that the two methods mostly used for evaluating an investment are the net present value (NPV) and the internal rate of return (IRR). The NPV of an investment opportunity is the sum of the present values of the expected future income stream. Each future income amount in the stream is discounted, meaning that it is divided by the opportunity cost of holding capital from now until the year when the income is received. The opportunity cost can either be how much you would have earned investing the

capital someplace else, or how much interest you would have had to pay if you borrowed the capital. The IRR for an investment represents the discount rate that makes the NPV equal 0.

One limitation of the discounted cash flow measurements is that they do not recognize the value of a wide range of competitive commitments [3]. They do not value commitments to innovate in advance of the competition. When a firm invests in a new product that decreases the value of existing products, it is said to be cannibalizing its business. Capital budgeting systems are explicitly designed to prevent cannibalization [3]. However, if ultimate success depends on deterring the competition, cannibalization may be the key to survival and success in the long run.

An alternative the discounted cash flow measurements are real options. Real options valuation is analogous to financial options valuation, except that the underlying asset is a system or product to be deployed in the future, rather than a financial instrument [5]. In staged funding systems, such as the Stage-Gate model [8], the decision to fund a particular stage of a product development can be treated as a purchase of a call option, where exercise of that option involves funding a later stage or stages [6]. The real options method has been viewed as the valuation method of the twenty first century, but Block [4] concludes that it is still only used by a small percentage of the Fortune 1000 companies.

1.2 Develop Value Flow

In contrast to the capture value there are no generally agreed methods to assess value during the develop value flow. Within the project management literature the earned value methodology is commonly used to evaluate the performance of a project as it moves from project initiation to project closure [13]. Earned value analysis is a project monitoring method that combines the Schedule Performance Index with the Cost Performance Index, to address questions such as "how much value did we get from the effort we spent?" [10]. The Earned value methodology is used to measure work accomplished and quantify the impact of known issues and uses this data to forecast estimates at completion. However, despite its name the value in earned value is not based on customer value; it is based on the organization's development cost, since the activities are valued according to the planned cost of producing the result.

1.3 Realize Value Flow

There are several methods used to evaluate the value created in the realization value flow. The new sales ratio [17], defined as the percentage of revenues related to products developed in the latest X years is a way of evaluating the realization value. The "X" years depend on the market and type of product but 2-5 years are commonly used. Other measurements of the realize value flow include productivity. Cooper and Edgett [9] define productivity in product development as output, measured as new product sales or profits, divided by input, measured as development costs and time.

One limitation with productivity measurements and the new sales ratio is that they are lagging measurements by X years and thus is of little use when the value of the current activities during the development of new products is to be evaluated. The challenge lies in evaluating the value of the output created during its development in order to avoid a lagging perspective.

1.4 General conclusion

The different methods used to evaluate the created value in the three value flows are in essence not connected, and give little support for tracing the value through the development life-cycle. Better connections between the three steps are needed. Also when looking at efficiency and effectiveness, better methods are needed to ensure that we are focusing on what can be best for the organization long term in each of the steps.

From a productivity point of view, performance can be improved both by increasing the expected benefit and/or by decreasing the expenditures of creating the output. However, as concluded by Kelm et al. [12], the literature on valuation of product development efforts has primarily focused on decreasing expenditures. Steele [16] argues that most measurements of activities within product development finally become measurements that can be expressed in terms of human resources and money. Traditional methods are generally not appropriate because of the nature of the output of product development which is long term and often intangible [15]. We argue that there is a need for methods that make it possible to evaluate how value is created during the development of a new product, i.e. to make the develop value flow more explicit and possible to trace throughout the project and product life cycles.

2. THE VALUE METHOD

In a previous paper by the same authors [7] a method called Products in Development (PiD) was introduced aiming at bridging the gap between the Capture value and the Realize value flow. PiD is a method for integrating perceived customer value as a measure of performance during the development of new products. In this way a bridge between the business case and the sales of new products can be made. Developing a product usually involves numerous steps and activities. Looking at the activities involved in software-development it is evident that the different activities play different roles in the creation of value. Hence it is difficult to compare e.g. test and implementation activities. However, common for all the development activities is that they are initiated in order to satisfy specific requirements that can be valued according to their perceived customer value.

The proposed framework for analysing the value flow in product development, shown in Figure 1, enables the analysis and evaluation of performance on a high level. In this paper we focus on the Development value flow activities carried out in a software-development project that typically can be categorized as requirements and design, implementation, integration, and verification and validation. In particular the objective being to determine how value is being created in these categories of activities during the development. In order to perform this detailed level of analysis, requirements are proposed as the unit of analysis in order to evaluate the value created during the development. An overview of the proposed framework is shown in Figure 2. The set of requirements is an interface that product managers, line managers, engineers, customers and other stakeholders can discuss and agree upon. Also, it is the requirements that generate different activities that in their turn contribute to the Development value flow.

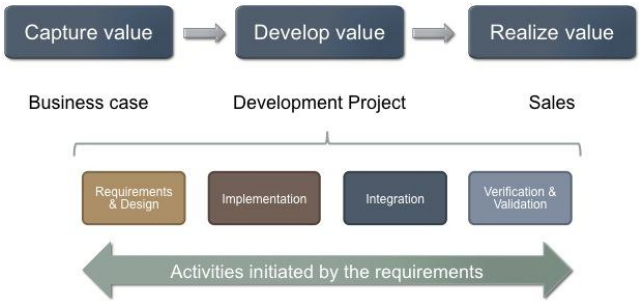

Figure 2. Overview of the proposed framework.

2.1 Generic Outline of Products in Development

The different steps and prerequisites included in a general version of the proposed method for evaluating value during the development are presented in this section. The PiD method requires a set of inputs that are assumed given, and they are:

• A set of n requirements

• An initial assessment of the perceived customer value for each of the n requirements

• A set of m phases or activity categories in the development value flow

The terminology for describing value in the PiD method is defined according to:

• The Captured value is the sum of the perceived customer value of the n requirements.

• The Developed value is the current value of the activities related to the n requirements for each of the m phases or activity categories in the development value flow.

• The Developed value completed is the minimum value of the m phases or activity categories of the developed value.

Given these assumptions and definitions the PiD method can be described by the following steps:

Step 1: The Captured value is equaled to the value set in the business case. The Developed value and the Developed value completed are both set to 0. Step 1 is to be conducted as the development project is initiated.

Step N: The captured value is reassessed according to the changes in requirements from Step N-1. Requirements can be added and/or subtracted during the development. This is followed by an updating of the perceived customer value of the updated set of requirements. As the activities in the development project are continued to completion, the Developed value and the Developed value completed are updated accordingly.

The number (N) of steps of the PiD method depends on the complexity of the development project. They can be performed in conjunction with a gate review, when the next iteration is planned, or on some other occasion depending on the contextual needs. The responsibility of assessing the value of the requirements should be allocated to the product manager or other representative of the organization financing the development project.

2.1.1 An example of Products in Development

In one of our pilots where we have applied the method in practice it was decided to divide the development value flow into four different activity categories (m=4): Specification and design, Implementation, Integration, and Verification and Validation. These stages were chosen with the objective of visualizing where value were created or lost during the development of a new release of a product.

The first stage, Specification and design, includes all the activities involved in the writing and approval of the requirement specification and the development of a design for the incorporation of these requirements in the product. Once this is performed for a requirement, the value related to that requirement is earned for that stage. This procedure is then repeated for each of the other three stages.

The activities can be either completed or not completed, and once the activities related to a requirement are completed the inherent value is earned. Figure 3 presents a possible snap-shot of the Developed value when using an iterative development process. In this snap-shot the value has been normalized to 100 percent in order to visualize the developed value.

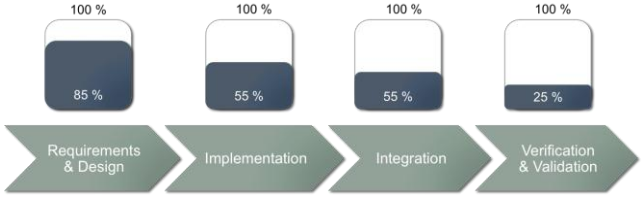

Figure 3. A possible snap shot of the value in progress during the development.

In one of the pilot case studies in which we tested the method, the product manager and the project manager jointly valued the requirements according to their perceived customer value. In this case the customer was not explicitly involved in the valuation but could have been; it is the perception of customer value of the product manager and the project manager that is used in the valuation of the requirements.

2.1.2 Two Value Dimensions

When evaluating and analyzing the value created during the development value flow it is important to acknowledge that there are two dimensions of value to focus on:

1) The internal value - Where are we gaining/losing value during the development of a product?

2) The external value – Are there any market or scope changes affecting the valuation in the requirements during the development?

These two dimensions of value are to be viewed as internal and external from the perspective of the development project. In order to be able to be successful in the realization of the value both the internal and external value dimensions needs to be managed during the development. The internal value that is the developed value in the PiD method is dependent on the capabilities of the project to be able to complete the necessary activities derived from the requirements. Also, it is common to add or remove requirements from the initial list during the development and this is important to include in the internal value dimension. From the external value perspective a requirement could be valued highly in

the beginning of the development but during the development the market change and this could have implications for the valuation.

From an organizational point of view, it is important that both the internal and the external value dimensions are taken in to consideration since the overall value will depend on the result of both the internal and external dimensions. The responsibilities for these dimensions are typically separated. The project manager and the project team are ultimately responsible for the internal value dimension i.e. for the activities developing the value according to the captured value. The product manager is responsible for the external value dimension i.e. for monitoring market changes or other similar changes in the captured value that will affect the overall created value.

3. RESEARCH PROPOSALS

The use of requirements and the value of requirements in the evaluation of a project and the performance in the project during development will encounter different obstacles. These should be further explored and investigated. In the development of the PiD method, several areas have thus emerged for future research, and these are summarized in this section. We also think that as the method is further tested, new research areas will evolve.

Research need 1: Understanding the value of a specific requirement

A fundamental prerequisite when using PiD is to assign a value to each of the requirements based on perceived customer value. The possibility to do this and the ability to get reliable data will differ for different types of software-intensive products. For products where functions are easily distinguishable and would be possible to market and sell separately, this task may be minor. For system products where functions are combined into solutions, this may be harder.

A solution that has been used during the initial use of the method has been to start from the overall business case for the project (or new release) and divide this value between the different requirements that are included in the development. This means that the assignment of value to a specific requirement will be in relation to other requirements included. A first step is most likely to use some method to rank the requirements, and as a second step assign a relative value. In one of our pilots, this resulted in one requirement having 50 % of the market value, while the more than 20 remaining requirements share the remaining 50 % value. Other considerations may include the division of the business case into different markets (e.g. geographically, new or add-on business) as the different requirements may attract these different markets.

For many of the requirements, there are uncertainties that can be of importance. One tool that can be used to illustrate this, and to rank the requirements, is tornado diagrams [11]. This will assist in performing sensitivity analysis of the ranking of requirements.

More detailed and descriptive methods for different types of products and markets should be developed and tested.

Research need 2: Balancing different types of requirements

Product and system requirements can be divided into different types. When deciding on the content of a new release, there is a need to balance these different types of requirements to achieve a high value. It is however difficult to determine how much of the expected value of a release that can be attributed to a specific type.

A common way of dividing the requirements is into functional requirements and requirements related to quality attributes (non-functional). Architectural investments are often a response to non-functional requirements. In addition to defined requirements, there is also a market value in reducing the known problems. An example can be an error that prevents the user of a system to use a specific function even if it is implemented and described as a feature. Also the effort to refactor systems is often classified in this category.

A straightforward solution to the need to balance the effort is to do it strategically: the effort and resources needed to develop a specific release of a new product is divided into different parts for the different types of requirements. If possible, the size of these parts should be based on an estimated business value for the specific project. As an alternative, this can be decided based on the overall experience about the market regarding the value the products have on the market, how the market is affected by errors, and what value can be attributed to architectural improvements.

Once the division of perceived customer value, and how to use resources for the different types of requirements is decided, the prioritization and value can be determined for each type independently of the other types. A prerequisite is that the organization can assign a business case to each of the parts so that this can be divided as to evaluate each requirement or error.

Research is needed to understand how the size of the effort spent on the different types of requirements should be determined, as well as determining the overall value of different types of quality attributes.

Research need 3: Valuing knowledge buildup and reducing risk

Similar to the balancing of different types of requirements is the balance between development of tangible artifacts and the evolvement of knowledge in an organization. The increased knowledge in the organization will decrease risk for failure and thus contribute to the increased value. By taking risks into account, the possible events that can lead to significant decrease of value can be either avoided or mitigated. In extreme cases, the knowledge about a risk that would have vast impact on the value if it occurred can make the organization avoid that particular development direction.

One way of handling knowledge buildup and risk can be to add a risk component for each of the requirements and reduce the value based on the remaining risk that the requirement may not be met. For quality related requirements this can be a continuous scale (e.g. the ability to meet requirements on fuel consumption; reaching a lower level will increase market value, but the value will not be zero if the initial target is not met).

An additional possible direction for controlling the knowledge buildup is to investigate the use of Function-Means Trees [1] where the requirements (functions) can be linked to different proposed solutions (means). As a result, the breakdown of functions may be possible to trace to the detailed solutions.

The addition of a risk and knowledge buildup component to the method described in section 2 has not been piloted, and is thus a first step in the continued research along this track.

Research need 4: Tracing value to development artifacts

Although the described method is designed to cover the full development cycle, it is not always easy to determine the value of

a specific artifact such as specifications, code files, test cases or test results. The initial approach to this is that the requirement is the primary carrier of value; a specific requirement must have been fully achieved and confirmed in a step before the value of that requirement can be considered achieved. Some requirements will be difficult to verify during the development, as it may not be possible to fully verify without integration. However, a possible solution is to use linking between the artifacts implementing the requirement. These links would then also carry an assigned portion of the value for a specific requirement, and the value of an artifact would be the sum of the contributions from the different requirements. This possibility need further investigation, and may be contradicting the original idea that the value is not achieved until the full requirement is passing a phase in the development.

The research needed here is to see how the verification of requirements can be achieved throughout the development effort and implemented in different types of development projects.

4. CONCLUSIONS

In this paper an iterative value flow of capture, develop and realize value has been presented. This assumption is built on a holistic view of how products are created in an organization. Based on the gap in the literature a model, Products in Development, is suggested to evaluate value creation during the development of a new product. Products in Development uses requirements as unit of analysis and the activities related to these requirements carried out during the development. In this way traceability is improved in what creates value and what is not contributing to value in the development process.

As described in section 3, many aspects need to be further explored. However, the most important continuation is probably to test the method in additional projects with development of different types of products and systems for different types of markets. This will give further direction for future research.

5. ACKNOWLEDGMENTS

Our thanks go to companies that have participated in pilots and discussion in the development of this method. This research was partly funded by the Swedish Knowledge Foundation.

6. REFERENCES

[1] Andreasen, M.M. Syntesemetoder på Systemgrundlag, Lund Technical University, Lund, Sweden, 1980.

[2] Annacchino, M.A. *The Pursuit of New Product Development - The Business Development Process*. Butterworth-Heinemann, 2007.

[3] Baldwin, C.Y. How Capital Budgeting Deters Innovation - And What to Do About It. *Research Technology Management*, *34* (6). 39-46.

[4] Block, S. Are Real Options Actually Used in the Real World? *The Engineering Economist*, *52* (3). 255.

[5] Bodner, D.A. and Rouse, W.B. Understanding R&D value creation with organizational simulation. *Systems Engineering*, *10* (1). 64-82.

[6] Boer, F.P. Valuation of technology using "real options". *Research Technology Management*, *43* (4). 26-30.

[7] Cedergren, S., Larsson, S., Wall, A. and Norstrom, C. Towards integrating perceived customer value in the evaluation of performance in product development *PICMET 2010 Technology Management for Global Economic Growth*, 2010, 1-11.

[8] Cooper, R.G. Perspective: The Stage-Gate® Idea-to-Launch Process - Update, What's New, and NexGen Systems. *The Journal of Product Innovation Management*, *25* (3). 213.

[9] Cooper, R.G. and Edgett, S.J. Maximizing productivity in product innovation. *Research Technology Management*, *51* (2). 47-58.

[10] Ebert, C. and Dumke, R. *Software Measurement - Establish - Extract - Evaluate - Execute*. Springer-Verlag, Berlin, 2007.

[11] Howard, R.A. Decision Analysis: Practice and Promise. *Management Science*, *34* (6). 679-695.

[12] Kelm, K.M., Narayanan, V.K. and Pinches, G.E. Shareholder value creation during R&D innovation and commercialization stages. *Academy of Management Journal*, *38* (3). 770-787.

[13] PMI *PMBOK - A guide to the project management body of knowledge*. Project Management Institute Newton Square, Pennsylvania, USA., 2004.

[14] Ryan, P. and Ryan, G. Capital budgeting practices of the Fortune 1000: How have things changed. *Journal of Business and Management*, *8* (4). 355.

[15] Stainer, A. and Nixon, B. Productivity and performance measurement in R&D. *International Journal of Technology Management*, *13* (5-6). 486.

[16] Steele, L.W. Evaluating The Technical Operation. *Research Technology Management*, *31* (5). 11-19.

[17] Whitley, R., Parish, T., Dressler, R. and Nicholson, G. Evaluating R&D performance using the new sales ratio. *Research Technology Management*, *41* (5). 20-22.