A Survey of Quality Measurements in Product Development

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Abstract—**There is a lack of definitions of clear quality measurements within existing product development literature. Several literature sources that mention measurements in product development base their attitude on the triple constraints division into time, costs and functionality/quality. This article summarizes proposed literature definitions of what to include within quality measurements in product development. The article also proposes a statement of different existing viewpoints of quality measurements within some organization's development process.**

Index Terms—**Customer satisfaction, process, product development, project model, quality measurement**

I. INTRODUCTION

It is natural that organizations have to be competitive to maintain a position in the market. In a competitive market the only way for organizations to be successful is to keep the customers satisfied with their products [1]. That can be achieved by conducting successful development projects. Such a development project does not only deliver the product the customer requested, but also a product the customer is satisfied with. Of course, it is not obvious how to identify and measure whether a customer is satisfied or not. Particularly not during development projects when it is common that the customers' desires are not clear [2].

After a purchase of some kind, customers evaluate if the product was of sufficiently high quality. If so, the customer is probably willing to come back to the company in the future, but if not, it is likely that the customer turns to a competitor on the market. Taking this customer evaluation into the product development process where the product is first created, it becomes even more complicated. The challenge for organizations is to identify what makes a high qualitative product according to the customer. [3] argues that the customers' validation of high quality seems to imply satisfied customer but also that customers who are satisfied with their products tend to be loyal to the company.

Many organizations use financial measurements as their primary development project follow up evaluation metrics. It is however unclear whether this factor really affects the success of a product and in the long run the organization or not. Furthermore it is hard to measure what is a high qualitative product and what makes the customer satisfied. Also to find out whether a customer is satisfied or not could be difficult. Finally, there exist several readings within and between organizations of which measurements are useful and what constructs to use in every situation.

The measurement of development project and what it brings about is not either well-established in literature. This article discuss to what extent different measurements presented in literature and used in organizations are relevant for successful development project in the sense of satisfied customer. The aspects of following up development projects considered in this article are measuring quality during the development process and evaluating quality of the (fulfilled) development project discussed in relation to characteristics of a successful development project. The article only disputes development projects dealing with development of new products in the sense of physical product, processes or services. Other kinds of development projects such as business development etc. are not considered.

The purpose with this article is to clarify which aspects traditional measurements of development project elucidate and propose additional useful metrics and measurements to evaluate development investments in terms of customer satisfaction. Also, the usage of different constructs with different readings of process versus project will be discussed.

The remaining of this paper is structured as follows. Theory about the different aspects of a development project, a development process, a development project model and how they deal with measurements is presented in chapter 2. Chapter 3 presents the applied method. The quality managers' views of product development measurements, generated from interviews, are presented in chapter 4. In chapter 5 a discussion about the different viewpoints of measurements and quality in development projects from literature and interview respondents are held. Finally, the paper ends with a conclusion in chapter 6.

II. THEORY

A development investment is the initiative to find new technical and commercial accepted solutions based on converted expected customer needs (unspoken), defined customer needs and unexpected customer needs (unspoken) [4], [5]. Each initiative of a new development investment is unique but some of them also share features that can be reused within several situations. To understand and find the common features there needs to be a structure and a distinction between constructs and activities conducted during development investments.

The following section presents literature definitions of the different occurring constructs of development initiatives divided within the notions: development project, development process and development project model. These

definitions or headline structure are not univocal and the intention with this section is to compile existing author positioning.

A. Development Project

A development project is a specialization of the project phenomena [6]. Just like any kind of project the development project is a unique investment with a well-defined beginning and a definite end that has defined goals, a fixed budget and a temporary organization [6], [7]. The specific property of a development project is the creation of a unique product (which also could be a service or a process) [6]. To realize such an investment, support in terms of a development process and/or a development project model normally exists.

B. Development Process

A development process is defined differently in different literature sources. In this article a development process is defined as a repetitive set of activities carrying a result that simplifies performance of the development project in accordance to statements by [7] – [9]. The development process includes tollgates and specific activities to realize within the different process phases. According to [10] the development process should be one of an organization's few non-repetitive processes since the purpose with this process is to generate new information. In a development process it must be possible to generate new information by doing wrong and thus find opportunities for improvement to avoid future mistakes. Therefore, the process must be changeable [10], [11]. Such working methods are for instance conducted at NASA where the astronauts are allowed to fail, since failure is the best way to learn and failsafe before an actual mission in space. It is however only accepted to do the same fault once [12].

Within the development process, there are normally process gates where the progress is evaluated before continuing to the next process step. After fulfillment of a development process the result sometimes is required to be evaluated relative the initial defined functional requirement specifications. If that is not the case it is up to the individual organization and/or project group to follow up the result of the process since no other generic measurements for development processes exist.

C. Development Project Model

According to [13] product development is more than just a process. Solely a process does not contain an organizational structure and it also misses tools for capacity management and project economics. The process is a necessary part of a sufficient development framework, but it is not a complete project model.

The requirement of organizational structure, tools for capacity management and project economics as complement to the development process requested by [13] is just the contribution of the development project model. A project model is a schematic description of management aspects of project work. It normally includes a process model with process steps, working activities and definitions of milestones but also a conceptual framework and a project organization [7]. The purpose with a project model is to create a standardized work flow to secure that several

projects could be conducted in a similar way. The project model perspective offers a systematic, structure, consensus and joint terminology [14].

The process within a project model could be compared to the-one mentioned as a development process in the previous subchapter. The process could be seen as the project's lifecycle and illustrates its included phases but also gives information about activities to conduct within the different phases [7]. A project model's process could also provide information about the technical work activities that should be conducted within the project phases and which personnel that should be involved in a specific phase and activity [6]. To pass from a previous process phase into the next one in the project model some concrete working deliverables have to be finished [6]. Also, there are milestones included in the process that have to be approved before passing into the next project phase [7].

The project model also provides additional information to detail the content of the process phase. This part of the project model thus brings in mechanisms to achieve the defined result within the process [15]. Within the mechanisms of a project model normally information about appropriate project organization and roles (both resources and expertise), usable tools and techniques, suggestion of useful phase location for these and available technology resources are included [7], [15].

Within the investment of a project model it is important to have a normative assessment base using consistent constructs with the same reading. Different departments of an organization use different frameworks to perform their activities which in turn have applied different constructs for the same reading as shown in [16]. A conceptual framework is a compilation of organizational internal information and definitions that creates a consistent notion base for an organization. The guidelines that a conceptual framework provides also make people using the same construct with the same interpretation and to understand the usage and purpose of tools and activities within a project. Thus, several project models provide a conceptual framework that contains internal readings of project constructs, purpose and descriptions of frequently occurring tools and techniques [7]. The conceptual framework can also consist of factors limiting the project scope like ethical, environmental, logical, legal or indirect effects [15]. The main construct within a project model though is the focus on measurements in terms of time, cost and quality [15].

In contrast to the development process the development project model normally has structured follow up routines. The success of a project conducted within the project model is evaluated based on the corners in the triple constraint. Consequently the final products functionalities, cost of the development project, used resources and spend project time are measured [15]. In addition to these measurements the project model includes follow-ups during the process in terms of process gates and work deliverables [6], [7].

III. METHOD

A literature review has been conducted to find different measurements of quality and successful development

investment. The same aspect has been inquired in organizations by interviews and finally the results from these two approaches are compared in the discussion.

The empirical material was collected from participants at a quality manager course including representatives from both service and manufacturing sectors. Their common attribute is that all of them have experienced a twenty day quality manager course, which brings them a consistent notion base within the quality field. This basic quality education provides the respondents with a common quality subject domain that according to [17] contributes to minimizing the bias in expert elicitation. The conducted interviews dealt with information regarding measurements and follow up of development projects within the respondents' organizations.

Data has been collected from 13 quality managers in different kind of organizations. The data was collected through semi-structured interviews and guided by Yins' theories [18] to ensure high validity and reliability. The three interview questions presented below were sent out in advance to the respondents.

1. What characterizes a successful development project in your organization?

2. How do you measure quality within your development projects?

3. What kinds of measurements do you follow-up within your development projects (besides quality)?

These three questions also composed the base for the interview discussions where the respondents were forced to explain their organization's approach to following up in and after development projects preferably based on real project examples. After the interviews, the respondents got the possibility to correct misunderstandings by proofread written summaries of their responses.

A summary of the interview responds is presented in table I below. In this breakdown each interview response is presented together with information about whether a respondent represents a service or a manufacturing organization. Based on three interview questions that were submitted to the respondents in advance the responses are divided into three columns within table I. The separation of responses to the different columns of the table is based on the respondents' categorization of their answers to question number one, two or three. Thus, some information could have been inappropriate positioned according to the subject distribution of the columns since the respondents positioning of their answers gets higher priority relative the theoretical subject content.

IV. INTERVIEW RESULTS

Below the interview result is presented, in table I. The mentioning of time or cost as a response to a question is indicated by a grey shadowed cell in the table. The kind of represented organization for each respondent is specified as manufacturing or service and indicated in the respondent column. Also, the respondents' answers are referred in the following text using Roman numbers.

Considering the interview results compiled in table I it can be seen that several respondents appear to mix the different constructs that are used in the questions. Different

interpretations have been used to answer the first two questions about distinctions of a successful development project and quality measurements of development project. Some respondents claim that cost [I, IV, VI, VII, VIII] and time [I, II, III, VI, VII, IX, XII] are distinct characteristics of successful development projects whilst others argue that these two factors rather are measurements of quality in development projects [I, VI, X, XI, XIII]. It also appears a lot of soft properties describing successful development projects such as knowledge grown in organization [II], deliver of a usable product [VIII] and deliver something good for the customer [XI]. Hands on measurements as delivery precision [VI], customer complaints [V] and required functionality [XIII] are also mentioned as quality metrics of development projects.

The difference between column two and three in table I is the time aspect, where column three consider follow up measurements during ongoing development projects whilst column two present the respondents follow up activities after finished projects. Within these two columns it does not appear any distinct measurements that are commonly occurring in several organizations. Looking into the responds in column three it turns out to be different readings of that question. The usefulness of yearly evaluation of process and lessons learned after project as measurements to follow up quality during development projects are not obvious. The first of these measurements would rather be used to evaluate and improve development projects whilst the second measurement is useful to evaluate quality of development projects.

From the different interpretations of the interview questions and their impact in the compiled table, the difficulty of the different wordings crystallizes. When it comes to the constructs development process and development project it seems to be hard for the respondents to separate the meaning of these words. However, one of the respondents [XIII] tried to clarify the different reading of the constructs by summarizing three theses:

1. Distinction between project and process. A project is measured on time and budget, thus it requires invariable requirements. The process is measured on customer benefit and efficiency so it requires flexibility and ability to manage improvements.

2. Process vs. project model. The process provides support of how to practice and realize the work whilst the project model supports the execution of the work.

3. Process vs. project. The process describes the way ahead during work performance and is a specific case of a project.

Even though these definitions do not fit perfect with the literature review in this article, it is still complete and consistent. Moreover, this distinction of definitions was only presented from one of the 13 respondents. Several of the other respondents are not that clear-sighted. Some of them frequently mix the usage of different constructs with the same meaning. Other respondents claim that the discussed aspects do not occur at all in the organizations. E.g. that one organization does not follow up projects [III] and that another organization does not measure project results [II]. Another interesting aspect related to the presented thesis is

the organizations stating that all personnel are familiar with the definition of different constructs even though they sometimes might mix usage of the words [IV, VI].

TABLE I: COMPLETE COMPILATION OF INTERVIEW RESPONDS

Respondent	Characteristics of successful development projects	Quality measurements of development project	Following up during development projects
Respondent I manufacturing	Fulfilled customer requirements: ability to good publishing by using our products Time Cost	Evaluation based on Plan including: process model, project resources, project goal Cost	-
Respondent II service	Satisfied customer Time Knowledge grown in organization	Purpose and goals	-
Respondent III service	Satisfied customer Time Understanding of customer needs	Purpose and goals	Regular follow-ups
Respondent IV manufacturing	Supply coordination Cost	Stage gates Project reviews	-
Respondent V manufacturing	Fulfillment of business case (profit)	Customer complaints	Cost
Respondent VI manufacturing	Deliver usable product Fulfillment of external and internal requirements Time Cost	Cost Delivery precision Requirement fulfillment Earned value	Project reviews Project Maturity Review (PRM)
Respondent VII manufacturing	Fulfillment of project goal Functionality Time Cost	Evaluation based on project plan Speed	Time Security during project Control of supplier during project
Respondent VIII service	Deliver usable product Cost	Satisfaction survey to former customer	Personal contact with customer during process Yearly evaluation of process
Respondent IX manufacturing	Good final product In time	Cpk Gage RandR Cost of poor quality	Tollgates Lessons learns after project
Respondent X manufacturing	-	Producible products within competitive price Time Competitive products	Reviews and gates within Product Management Planning model
Respondent XI service	Deliver a result (new product, knowledge etc.) Fast development cycle Customer satisfaction with new product Deliver something good for the customer	Time Cost Experiments and field test Comparison with competitors	Weekly pulse meeting Monthly status report Steering committee meeting
Respondent XII manufacturing	A selling product Intended use of resources In time		Checkpoints of project phases
Respondent XIII manufacturing	Meet customer requirement Profitable product	Required functionality In time	Cost Profitability

V. DISCUSSION

At organizations conducting product development sometimes the completeness of a development project model is missing and a development process is the only structuring resource that exists within the development work. Characteristic for this kind of organizations though are kind

of a chaotic feeling with a lot of ad-hoc activities but also an uncertainty among the personnel since no-one knows in which project to be included when. Also a lot of time delays appear in these organization's projects since it is more of a rule than an exception that competence roles or technical resources are unavailable when they are required in a project.

Independent of whether there exists a project model or not it seems to be a concept-confusion at many organizations today. Further, the same phenomena can be found in the literature, where the same author can use different notions in different books. One example of this phenomenon is Reinertsen advocating for the development process as being a required but not sufficient resource in development projects [13]. He also discusses the product development process as a complete process model for a development investment including activities, tasks and working distribution in [10] thus as a permanent process in continuous change.

The separation of these wordings (development process, development project and development process model) is not distinguished so it is understandable that it is hard for organizations to define and use a consistent notion. Also, it turns out that most organizations separate between a process, a project, and a project model in rather clear sense even though it not appears in their use of consistent constructs. It is still alarming that not even quality managers can separate neither between measurements done within and after a fulfilled development project nor between what a measurements of the development project is and what the characteristics of a successful project are. In this case of course some confusion might be related to unclear asked interview questions but on the other hand, such confusion should have appeared in the subsequent validity check.

On the other hand characteristics of successful development projects and quality measurements of development projects would preferably be related to each other, since it should be natural to measure and evaluate projects based on measurements that affect the success factors. In an entrepreneurial climate where no soft success measurements are considered these parameters could be seen as equal. Thus, the mixture of interview answers between the two questions in this survey is not a problem for the conducted analysis.

A. How to Measure Quality of Development Investments?

According to the previous chapters the measurements of development projects can be divided into three groups; the ones advocated within development project models, the ones occurring in development process descriptions and realized measurements in organizations. So, are there any differences between these? And if there are, what separates these measurements from each other? A summary of the three discussed aspects of measurements is compiled in Table II and related to the different studied time perspectives, during- and after development projects. The aspects are cursively marked in the following text.

The measurement items summarized from the interviews are of course not all the responds but rather a reading of the frequently occurring answers according to the multiple sources of evidence line [18]. For a complete compilation of the interview responses see Table I.

The main difference between the development process and the development project model is that the evaluation part in a development project model is based on each project's change requirement. The development project model evaluates for instance work deliverables during the project process based on initiatives from earlier process gates and realized activities. Also, the final time, cost and functionalities of a project conducted according to a development project model are reviewed relatively to the final defined project circumstances. The corresponding measurements within the development process are based on fixed initial project descriptions containing requirements for accepted process gates and fulfillment of initial product requirements. Relatively these measurements, the presented solutions during interviews are well adjusted. The regular requirement follow up during development project can be seen as synonym to process gates and time and cost as final evaluation criteria after finished development project fit in to the development project model approach described above. Though, fulfillment of required functionality is an unclear mixed equivalent to both the development project model's functionality measurement and initial product requirement measured after fulfilled development process. The content of fulfillment of required functionality indicates that some organizations are measuring development project the "development process-way" and others the "project model-way".

B. What is a Qualitative Development Project?

Quality, or functionality that frequently are equalized [15], is the fussiest of the trade-off measurements in development project models. Synonymous with both of these words are a successful project. If you often succeed with fulfilling development projects within time, receiving a good trade-off from the project and making the required properties then you have a high qualitative development process according to existing measurements of the triple constraint [15].

TABLE II: SUMMARY OF ASPECTS OF MEASUREMENTS IN DEVELOPMENT PROJECTS

	Measurements	
	During development projects	**After finished development project**
Development project model	Process gates	Time
	Work deliverables	Cost
		Functionality
Development process	Process gates	Initial product requirements
Interview responds	Regular requirement follow up	Time
		Cost
		Fulfillment of required functionality

But still, to become successful, you need to develop products that the customer finally wants and thus there is a need of the fourth perspective within the definition of quality in development projects, dealing with customer satisfaction [3]. Looking to the empirics, only three [II, III, XI] of the interview respondents mention customer satisfaction as a characteristic for successful development projects. Enlarging the scope to include also the respondents discussing customer satisfaction as a quality measurement of development

projects the amount increases to four [II, III, VIII, XI] responses out of 13. Related to the fact that a company can have complete development working routines, performing all their development projects within time, budget and functional requirement and still make losses since the customers are not satisfied with their final products it is surprisingly few companies that consider this aspect. But to get the customer satisfaction dimension into organization's evaluation criteria, it has to become a natural measurable as time or cost.

Common to the organizations dealing with customer satisfaction is the fact that all of them are representing service organizations. Several of these respondents initiated their interview responds with answers like "my organization is bad on following up projects" [III] or "we don't measure development project result at all" [II]. These specific comments are not distinguished in the interview breakdown but can be found in the interview summaries validated with the respondents. Maybe these organizations are a bit worse on following up initial requirements compared to manufacturing organizations. On the other hand they seem to have other approaches of what is important to measure. Of course, time and budget are useful evaluation indicators of successful development projects but rather a qualitative development project measurement. Indicators of successful development projects preferable are emotional factors that result in marketable and appreciated products, just like customer satisfaction. One reason for service organization being more successful when it comes to customer satisfaction evaluations might be the fact that service organizations have a closer contact with their final customer than manufacturing companies. In that manner these organizations have to represent their product (service) in a definite way whereas most manufacturing organizations have a sales liaison handling the final customer relations.

Of course there also exist producing companies that evaluates and measure customer satisfaction. An example is [19], which uses advanced methods and analysis models to identify customer behaviors, changed customer needs during development projects and follow up activities after fulfillment of a development project. All these initiatives aim to be able to market the organization's products and thus to remain competitive in the market.

Another aspect is the fact that development projects are relatively short and the project organizations resolve when the project is completed. For manufacturing organizations the product still has to be produced before the product reaches the customer and the customer satisfaction aspect can be evaluated. To get continuity in development project models, experiences about previous customer satisfaction requirements also have to be reused by interchange between projects regarding project's requirement specification and changed requisites. Still the customer satisfaction has to be a remaining evaluation within the development process that is realized after the end of the development project when the customer receives the product.

However, the nine interviewed manufacturing organizations do, according to the interview responds, not deal with customer satisfaction. Do they not care about the result of their development projects? Of course they do! All

of them still follow up time and/or cost during or after the projects. The fact is that softer measurements like customer satisfaction are difficult to follow up and analyze since there does not exist any measurements to use for this characteristic. So, how do organizations that succeed do? [19] is one example of an organization which has applied a concept that endeavors towards development of new products and an increasing customer satisfaction [20] – [22], namely Design for Six Sigma. This concept is used at [19] as an extension of their coherent quality investments.

A majority of the respondents works in organizations that already have applied some of the quality concepts, Six Sigma or Lean. Design for Six Sigma (DFSS) or Lean Product Development (LPD) should for these organizations be a natural extension of their business development investment within the development projects. By applying any of these concepts the possibility of internal benchmarking appears since many core senses are the same in the development concepts DFSS or LPD and the improvement programs Six Sigma or Lean. Even though it can be hard to expound an improvement solution to a development project it still can be easier than the alternatives of studding general solutions or external benchmarking since the development- and improvement projects deal with the same business.

VI. CONCLUSION

Apparently it is hard to measure development project success. Many organizations evaluate their development projects based on used amount of time and financial resources just because these are clear measurements that matter for the board of directors. The customer perspective partly exists in theory and practice. Some of the studied organizations [II, III, VIII, XI] work with the customer perspective but too many do not. Also, some literature sources proclaim the importance of customer satisfaction [1], [3]. Things that get measured get done but applicable measurements of successfulness in terms of customer satisfaction that is disputed within this article do not exist. Attempts to measure become even harder since there are ongoing construct confusions within organizations. These factors cause that people within the same organization sometimes use different words discussing the same thing and other times talk about different viewpoints using the same construct with diverse readings.

To be able to conduct organized development investments a basic condition thus is the ability to distinguish between process, project and project model. According to both the presented literature [6], [7] and one of the interview respondents [XIII] a development project is the realization of a development investment. A development project preferably is conducted according to a project model. The development process is one part of the development project model's content but can sometimes be the only documented development structure.

Given the fact that it is important for organizations whether the customer is satisfied with a newly developed product or not, organizations also need to follow up if the customers become satisfied. Service organizations turn out to be more successful in taking the customer satisfaction

perspective in consideration than manufacturing organizations. This might be a natural result of the fact that service organizations have a closer and more personal relation to their final customer without any sales liaison in between. Also, manufacturing organizations have the lead-time of production between the end of a development project and the final customer launch. Consequently participants in the development team already are resolved and into new projects when it is possible to evaluate customer satisfaction. Therefore, it is even more important to consider customer satisfaction requirements and interchange of earlier experiences to secure a successful result in the end.

To realize this purpose manufacturing organizations need help to create measurements and evaluation characteristics that elucidate the customer satisfaction perspective within their development investments. Though, there exists several development concepts specialized on customer orientation today that push the question of customer satisfaction. Two such concepts are Design for Six Sigma and Lean Product Development, both with the purpose to streamline the development process while maintaining the customer satisfaction as pervading the process. These concepts could be useful to get inspiration from, particular for the manufacturing organizations, to get the customer satisfaction perspective included in their development investments.

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