Customer Value in Architecture Decision Making

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Abstract. This paper focuses on the business aspects of architecture decision making – in particular how to quantify the customer value of quality improvements to support architecture investment decisions. We developed concepts for quantifying the impact of quality improvements on customer value, customer value-in-use, and customer segments. In two real-life case studies we present (1) how the concept for quantifying customer value was used, (2) how the customer value relates to the existing value indicators in the organization, and (3) how the importance of customer value for architecture decision making was assessed by practitioners in the organization.

Keywords: architecture investment, decision making, customer value.

1 Introduction

The aim of any architecture improvement is fulfilling quality attribute requirements aligned with the business goals [1]. Since implementing such an improvement typically requires a large investment of time and effort, an organization that makes an architecture decision wants to be confident that the value created justifies the investment. The existing approaches for supporting architecture investment decisions focus on proposing business cases [2] based on cost savings, e.g., in product lines [3-5], or quantified benefits of quality attributes [6] to justify the architecture investments.

According to Kotler and Keller [7] the task of any business is to deliver customer value at profit. This becomes also apparent in an increasing number of organizations that follow a market-differentiation strategy to satisfy customers' needs and create the value derived from the customer benefits. In such circumstances the old economy model organized by product units, focused on profitability and transactions, looking primarily at financial scorecards is shifting to the new economy model organized by customer segments, focused on customer life-time value, and looking at marketing scorecards [7].

Therefore, any approach for supporting architecture investment decisions will need to incorporate the customer value to adapt to the new economy model. The most used concept of customer value refers to the to the price customer is willing to pay for a product offering in terms of the set of perceived benefits that the product offering provides to the customer. In the context of this paper, we broaden this definition to the value that drives decisions about product development and modification, pricing, and

M. Ali Babar and I. Gorton (Eds.): ECSA 2010, LNCS 6285, pp. 263–278, 2010.

marketing communication. The literature refers to market scoping [8] or coarse benefit functions for assessing the market benefits [4] as examples of using customer value in architecture decision making. These models are primarily used in making business cases and do not include structured guidelines on how to determine and quantify the customer value of the quality improvements.

To accommodate the existing approaches and at the same time satisfy the urgent need for making the customer value explicit in decision making, we address the question: *How to quantify the customer value of quality improvements to support architecture decision making in practice*?

To answer this question, we propose to use the well-known marketing concepts customer value-in-use and customer segments [7] in the architecture context. Depending on the business goal of the architecture improvements, these concepts can be used alone or together to estimate the customer value. In two real-life case studies, we applied these concepts for quantifying the customer value derived from architecture improvements in the imaging systems organization in Philips Healthcare [9]. The customer value concepts were compared to the existing value indicators in the organization and evaluated by decision makers.

The rest of this paper is organized as follows. Section 2 describes the study design that we have used for conducting research. Section 3 describes the first study for quantifying the customer value–in-use. Section 4 describes the second study for quantifying customer segments. Finally, Section 5 elaborates on applicability of the customer value in architecture decision making in practice and concludes with recommendations for improvements.

2 Methodology

We have been conducting a large-scale study[1] in cooperation with Philips Healthcare [9] to support architecture decision making aligned with a customer-centric and market-driven strategy. During the last four years we have conducted several real-life case studies realizing that the economics of architecture is necessary but not sufficient for architecture decision making [10] and further improvements should propose linking quality improvements to customer value indicators explicitly [11].

Because so far in the literature little attention has been paid to quantifying the customer value of architecture and our aim was a practice-oriented approach, the descriptive practice-oriented case study [12] was chosen as the appropriate research strategy for this investigation. We used a step-by-step process for conducting our case studies as shown in Figure 1.

The first step proposes a concept to quantify the customer value by adopting established marketing techniques to the architecture context. We elaborate on this step in each study in more detail.

The second step focuses on selecting the case. We selected the cases in which the quality improvements were directly observable by the customers and were the main

[1] This work has been carried out as a part of the Darwin project at Philips Healthcare under the responsibility of the Embedded Systems Institute. This project is partially supported by the Dutch Ministry of Economic Affairs under the BSIK program.

drivers of customer value creation (rather than the introduction of new functionality). With the fact that the quality/price ratio rather than price is the main determinant of the purchase decision in the professional (business-to-business) market, we deliberately selected the architecture decision making cases from the professional market.

The third step focuses on collecting the data to identify the existing value indicators used in the organization and to quantify the customer value using the proposed concept. In this step we also collected the time spent on quantifying the customer value, which is relevant for the evaluation session.

The fourth step is about analyzing data by comparing the elicited customer value with the existing value indicators. According to Rogers [13] any change in the organization can only be accepted if it is based on small incremental changes. Thus, understanding the relation between the customer value and the existing value indicators in the organization can help us to better understand the acceptance of the customer value concept for decision making in the organization.

Finally, the concept of quantifying customer value was evaluated with respect to the cost involved in collecting the data and the importance of the quantified customer value in architecture decision making in practice. The evaluation was done by initiating and observing a discussion between business decisions makers about the study findings at an hour review meeting. The two authors of the paper shadowed the discussion and cross-checked their observations immediately after the meeting.

We envision that improvements of each concept require repeating the study. Since this study focuses on how and whether customer value can be used, we decided to conduct a single case study for each customer value concept.

The two case studies following this study design were conducted in Philips Healthcare using internal and external documentation, interviews, meetings, and observations as the main source of evidence.

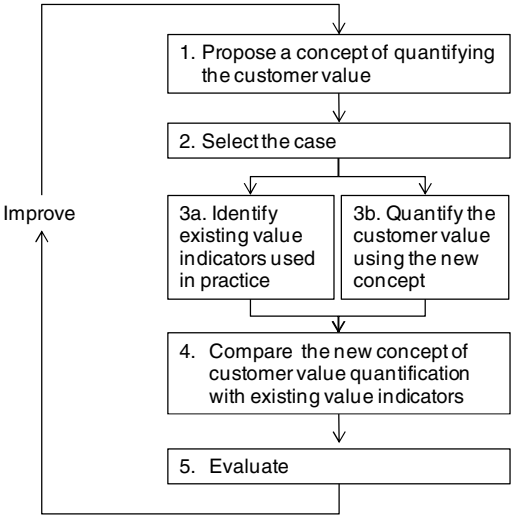

Fig. 1. Study design

3 Study 1: Customer Value-in-Use

A state-of-practice study about customer value assessment in business markets highlights that business decisions about product modification and redesign apply different techniques such as internal engineering assessment, field value-in-use assessment, focus group value assessment, or importance rating [14]. Among those techniques, the value-in-use assessment was the most frequently used technique for supporting new investments. Therefore, we selected value-in-use as a suitable technique for architecture decision making. Adapted to the scope of our study we define the value-in-use as differential cash flow generated in using the product with improved quality in the customer business.

Knowing the customer-value-in-use would offer a twofold benefit to the organization. First, the value-in-use can be used to demonstrate the added value of the new product with quality improvements to the customer and as a value indicator for the architecture. Second, the value-in-use can be used to estimate the customer's willingness to pay for such improvements, and therefore to define the potential cash flow of quality improvements that can be compared to the architecture investment.

In this study we investigate *how the customer value-in-use of quality improvements can be quantified and used in architecture decision making*.

3.1 Step 1: Concept of Quantifying Customer Value-in-Use

To quantify the customer value-in-use we need to understand the customer business, in particular how the quality improvements impact the business indicators in the customer business. We propose the concept for quantifying the value-in-use of quality improvements in Figure 2.

In the first step, we identify the customer business goals in the context of using a particular product. In the second step, we identify the business indicators in the customer business and model the customer business to better understand how the product in use affects the business indicators. Finally, we analyze conceptually the impact of quality improvements on the business indicators.

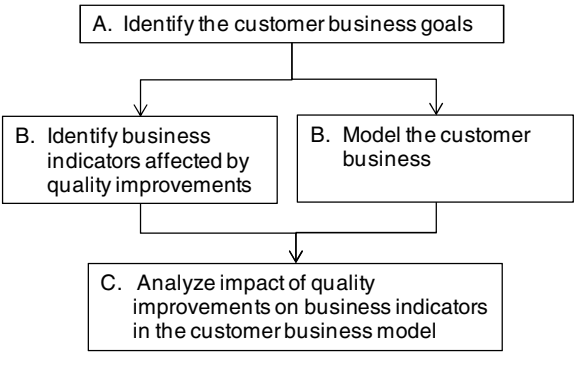

Fig. 2. Concept: Customer value-in-use

3.2 Step 2: Explorer Case[2]

Explorer is a workstation consisting of dedicated hardware and clinical applications used for viewing medical images acquired by a scanner and post-processing of these images to support radiologists and cardiologists in making a diagnosis.

Using Explorer in a hospital can take up an hour per patient. One of the reasons is that the user needs to delineate manually up to 3,500 myocardial contours to make a diagnosis. Therefore, although Explorer was proven to be clinically beneficial, it has been used mainly for research purposes by academic hospitals and rarely for routine use in community hospitals where the throughput has the highest priority.

Philips Healthcare, in cooperation with clinical partners, decided to do an architecture redesign to improve the usability and simplify the use of Explorer [15]. No new clinical application areas were added. The usability redesign involved (1) minimizing the amount of interaction needed for post-processing, through judicious use of automation and (2) introducing new viewing protocols that better reflect the users' way of working. The validation study of the redesign in a laboratory setting has shown significant efficiency improvements described in more detail in the following section. Despite strong evidence that the quality improvements were significant, the main question in the business was whether such improvements make a difference once the product is in use in hospital.

We were asked to assess the value-in-use of usability improvements in the BEST hospital. BEST was selected as a preferred customer of Philips Healthcare because of the strong cooperation and the most efficient use of Explorer in a clinical workflow among all customers. Thus, if the customer value-in-use would show sufficient contribution to the BEST business, all other hospitals would have higher benefits of using Explorer with improved usability.

The study question was *how usability improvements impact the customer business when Explorer is being used in hospitals.* This study was conducted using several sources of evidence, such as scientific publications, internal documentation, expert interviews, and observing users while working with Explorer in the BEST hospital.

3.3 Step 3: Data Collection

This step involves two activities: (1) to identify existing value indicators used in the organization in the given case and (2) to quantify the customer value-in-use applying the concept proposed in Section 3.1.

3.3.1 Existing Value Indicators

As we have seen, automation in image post-processing and the new viewing protocol were the two main improvements in Explorer. The value of these improvements was assessed using technology assessment techniques and expert opinion.

Technology assessment. The validation study in a lab setting had shown that users need significantly less time to verify and correct fully automatically detected contours

[2] The major identifying details for this case, such as product name and hospital name have been replaced with pseudonyms for confidentiality reasons.

than they need for drawing these contours manually in the four main procedures as shown in Table 1 [15].

Table 1. Time required delineating an exam manually and with automation

	Images	Contours	Manual (minutes)	Auto (minutes)
Procedure 1	500	1500	90	5
Procedure 2	420	6	6	3
Procedure 3	20	40	10	1
Procedure 4	600	1800	120	10

Expert opinion. Furthermore, the senior doctor from the BEST hospital estimated that new viewing protocols will result in time gains in the clinical workflow:

- 10-15% for experienced cardiologists
- 50-60% for novice cardiologists

Thus, the efficiency improvement in the procedure completion from the technology assessment and the experts' first order estimates about productivity improvements were the two value indicators used for demonstrating the value of usability improvements of Explorer in the organization.

3.3.2 Customer Value-in-Use

In the Explorer case the main quality improvements were in usability. To identify usability measures we used the established concept of measuring usability in context obtained by measuring the user's satisfaction, effectiveness, and efficiency [16]. In the Explorer case most benefits were expected in the efficiency improvements, therefore we simplify our investigation to understand the impact of Explorer efficiency improvements in the BEST hospital business. Further, we will follow the concept of quantifying the customer-value-in-use presented in Figure 2.

A. Identify customer business goals. To identify the BEST business goals we interviewed the head of the cardiology department. The global trend of improving quality of care and reducing cost was also apparent in BEST. The quality of care improvements are seen in reducing the patient waiting list with increased productivity to gain enough time for making an additional exam per day. Such an improvement would also affect the BEST business as each exam would be reimbursed for about € 800.

To achieve the business goal of increasing the number of exams, the most urgent issue in the department was to shorten the time needed from the scan start to the final report without compromising the quality of image analysis. To get an overview of the current business in BEST at the moment of the study: Yearly 2000 imaging exams were performed per scanner with an average time from scan start to report ready of 15-25 minutes.

B. Identify business indicators and model the customer business. From the interview with the department head we learned that examination volume per modality was the main business indicator monitored regularly in BEST. That agrees with the literature about the most frequently used productivity indicators [17].

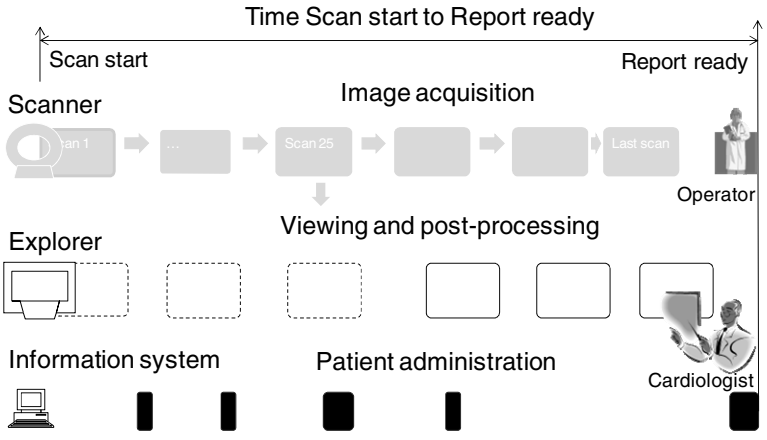

Fig. 3. Explorer in the clinical workflow in BEST hospital

To understand how Explorer is used we shadowed an experienced cardiologist in the clinical workflow. We identified three parallel activities in the clinical workflow: Image acquisition from the scanner, image viewing and post-processing using Explorer, and patient administration done on the cardiology information system, see Figure 3.

We model the clinical workflow as time spent on parallel activities (rectangles) in the hospital to address the potential contribution of usability improvements of Explorer towards minimizing the time from the scan start to report ready, therefore towards achieving the customer business goal. The clinical workflow can be described as follows. The image acquisition begins with "scan start" initiated from the console by the operator, who is sitting next to the cardiologist. It takes some time until the acquired images are available for viewing and post-processing on Explorer. That gap time the cardiologist usually uses for checking old exams (dashed rectangles) or administrating patient data on the information system such as writing a report (black rectangles). Once the scan is available at Explorer the cardiologist starts viewing and post-processing images. If he notices some irregularity in the images, he might request from the operator to repeat the image acquisition or look at the console to help the operator to define the right acquisition parameters. We observed that the ends of all three activities, image acquisition, image viewing and post-procession, and reporting almost coincide. When the patient leaves the scan room the report is ready. Typically, this clinical workflow will be followed for all routine exams. In such a highly-efficient workflow, improvements in efficiency of image viewing and post-processing during scanning were critical to shorten the scan start to report ready time, in order to fit in another exam.

C. Analyze the impact of quality improvements. We analyzed the different exams in the clinical workflow to identify when and how usability improvements of Explorer would achieve the most time gain. We realized that different exams in the exam portfolio benefit differently from usability improvements. Regarding viewing improvements, all exams would benefit from a time saving of 1.5 minutes in average. On the other side, automation improvements would make a significant contribution only to

one exam, which was performed every second day and the gain would be approximately 7 minutes per exam considering the technology assessment of task efficiency improvements in Section 3.3.1. In other exams delineation was performed rarely or never because of the tedious manual work. Thus, automation would not make significant improvements in the BEST hospital except for the one exam type.

We presented the results of interviews and shadowing to the participants in the study in BEST and they confirmed our findings about the clinical workflow model and productivity improvements due to usability changes of Explorer. Since the 1.5 minutes improvements were too short to schedule the new exam, only the automation improvements were considered for potential scheduling of an additional exam every second day. This resulted in 2 additional exams for 50 weeks amounting to the value of 80K€ per year.

This study required 1 person-month for a researcher to quantify the customer value-in-use.

3.4 Step 4: Comparison

We realized that the expert opinion about productivity improvements (10-15%) for the new viewing protocol closely relates to the estimated time savings in the clinical workflow (1.5 minutes in the 15-25 minutes exam). On the other side, estimates about task efficiency of automation (see Table 1) in the lab setting did not relate directly to the improvements in clinical practice. This difference can be explained with the fact that procedures which required manual delineation of many contours were used only a few times, therefore automation improvements would not be observed directly in the existing clinical workflow. Nevertheless, once the automation becomes available the cardiologist may start using these procedures more frequently.

Furthermore, we can conclude that the task efficiency and expert opinion indicators have to be correlated to the real-life clinical workflow to understand the potential customer value created in a real-life setting. The concept of quantifying the customer value-in-use provides this information. However, it became apparent that only by understanding the hospital workflow the relationship between usability improvement and customer value-in-use can be established.

3.5 Step 5: Evaluation

An evaluation of the Explorer case findings was conducted with the product marketer and a clinical scientist responsible for estimating the efficiency improvements in the organization. We presented our findings and asked the review team to discuss how the proposed framework for quantifying the customer value-in-use can possibly support the decision making process in the organization. Two themes emerged from the discussion: the cost of applying the concept of quantifying the customer value and the importance of such a concept for the organization.

Regarding the time spent on quantifying the customer value-in-use the organization has to account for an additional effort of 1 person-month if the efficiency indicators are already available. This time spent could be shorter for an expert knowing the domain or having already modeled the workflow of the hospital.

In the Explorer case the practitioners found the customer value-in-use promising and at the same time incomplete for decision making. Making the value of quality improvements

in the hospital business explicit was perceived positively. However, analyzing a high diversity of hospitals and their workflows would be very labor-intensive.

Nevertheless, if improving the business of existing customer is the main strategic goal of the organization, this analysis can be used for selected representative hospitals to support the right architecture changes. Another use is envisioned in the case when quality improvements are so large that details of the hospital workflow do not impact the customer value-in-use. Then the customer value-in-use can be used generically for all hospitals and therefore become a relevant value indicator.

4 Study 2: Customer Segments

According to Kotler and Keller, the new economy is organized by customer segments grouping customers by their needs and their value to the organization [7]. In this section we develop the concept to link the quality improvements to the customer segments, exemplified by a real-life case and evaluated by the decision makers.

4.1 Step 1: Concept of Quantifying Customer Segments

The first step of analyzing any architecture investment is to identify the business goals of architecture changes, as shown in Figure 4. If the business goals involve addressing new customer segments or addressing existing segments in a new way, then it makes sense to identify the customer segments affected by the architecture changes, which is done in the second step. In the same step, several possible architecture scenarios to meet the business goals are proposed. Finally, the third step, analyses the impact of proposed quality improvements on the identified customer segments for different scenarios.

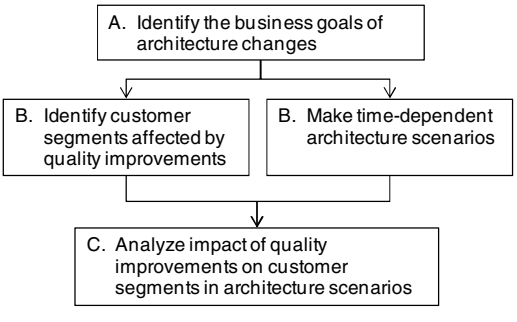

Fig. 4. Concept of quantifying customer segments

4.2 Step 2: Tricorder Case[3]

Tricorder is a product line consisting of dedicated hardware and clinical applications to make a diagnosis and prepare treatment. Over the last years, with an increasing market pressure to release new applications quickly, the Tricorder architecture has

[3] The major identifying details for this case, such as product names and data have been replaced with pseudonyms for confidentiality reasons.

been eroding, resulting in increased development effort and difficulties to predict time-to-market of new application releases. Furthermore, the newest market research about customer insights has shown opportunities for improvement in:

- *Usability:* The system should be *easier to use*; i.e. the user interfaces of the various applications should be harmonized
- *Accessibility:* The applications should be *accessible from any workplace*
- *Multi-modality:* The system should offer *viewing of images from other product lines*

To meet these challenges, it has been decided to migrate all Tricorder applications to the architecture of a successful existing product line. This decision of merging product lines was made also to strengthen the competitive advantage of Tricorder by offering applications from another product line.

The architects selected two potential architectures from existing product lines, *LabTricorder* and *ViewAll*. Regardless of the architecture choice, the marketers requested phased development to offer a few market releases of the new Tricorder to incrementally meet the customer needs during the migration. It was estimated that in both scenarios the migration process would last for two years.

At the moment of this study the business had already made the first multi-attribute ratings of scenarios and favored the LabTricorder scenario. To support this informal decision to invest in the LabTricorder scenario, the product marketer was asked to make a business case for the LabTricorder investment.

At the same time, we were asked to estimate how the customer segments will be affected by the LabTricorder and ViewAll scenarios during the migration as an input for evaluating the ongoing architecture investment decision making process. Thus, the study question was: *How will Tricorder's quality improvements impact customer segments during the migration process in the LabTricorder and ViewAll scenarios?*

This study was conducted using several sources of evidence such as internal and external documentation, observing decision making meetings, and interviewing practitioners.

4.3 Step 3: Data Collection

Following our study design in Section 2, in this section we identified value indicators used for modeling the business case and quantified the customer segments using the customer value concept proposed in Section 4.1.

4.3.1 Existing Value Indicators

As we already mentioned the business case was made only for the LabTricorder scenario conforming to the informal decision that has already been made. The total sales of the LabTricorder and Tricorder product was used for estimating the present value (PV) of the difference in the cash flow facilitated with migrating to the LabTricorder or keeping the existing Tricorder architecture over four years as shown in Figure 5. The positive business case confirmed the LabTricorder informal decision.

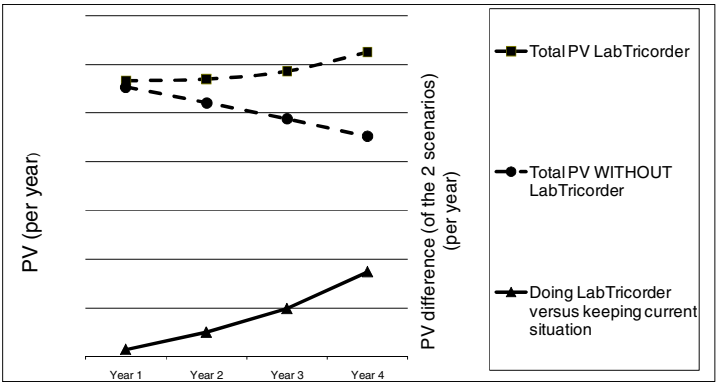

Fig. 5. Present value difference upon introduction of Tricorder

4.3.2 Customer Segments

Although the decision to invest in the LabTricorder scenario was already made, it was not clear to decision makers how the quality improvements made a difference in generating the customer value in the LabTricorder and ViewAll scenarios.

A. Identify the business goals of the architecture changes. In multiple one-to-one interviews with the program manager of Tricorder, the system architect, and product marketer we spent a significant time to identify the business goal. We realized that the Tricorder project had a large impact across several business units resulting in diverse business incentives of the project such as quicker time-to-market, improved maintenance by reducing the number of lines of codes, meeting customer needs, and improving customer satisfaction. Finally, a consensus was reached on the business goal to *increase the number of customers with met imaging needs,* including not only Tricorder customers but also customers using LabTricorder or ViewAll.

B. Identify customer segments and architecture scenarios. Based on the business goals we identified two customer segments that would be affected by the architecture changes (shown in Figure 6).

As expected, the Tricorder customers would benefit from access to the applications from anywhere and from the harmonized user interface. At the same time LabTricorder or ViewAll customers would benefit from being able to use Tricorder applications on their respective products. Thus, we needed to understand the impact of the quality improvements on the number of Tricorder and LabTricorder/ViewAll customers in meeting their imaging needs in different scenarios.

Since the marketer requested phased development to maximize the customer value before all applications are migrated to the new architecture, we needed to make two time-dependent scenarios to understand how customer segments would be affected by the products offered in different phases. We interviewed 20 stakeholders involved in this project and read product documentation to reconstruct the time-dependent LabTricorder and ViewAll scenarios shown in Figure 7.

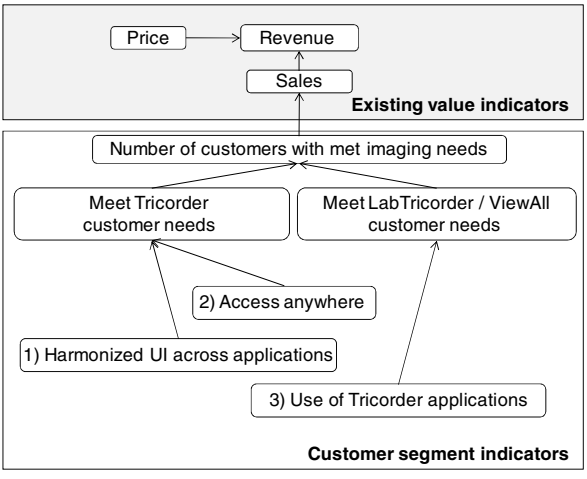

Fig. 6. Existing value indicators (top) and customer segments (bottom)

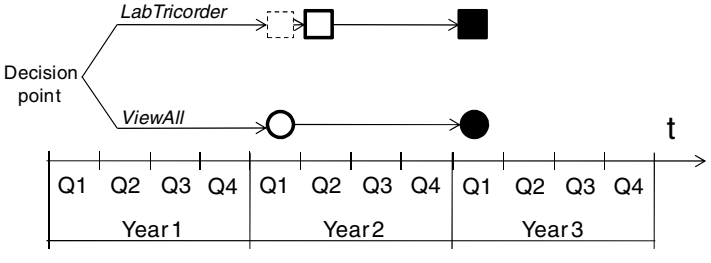

Fig. 7. Scenarios used for quantification of customer segments

The LabTricorder scenario was envisioned in three phases. Phase 0 (dashed square) enables viewing but not post-processing of all Tricorder images on the LabTricorder platform in a year. Phase 1 (square) offers a few Tricorder applications with harmonized user interface while the remaining applications would be still available on the existing Tricorder in the next quarter. Finally, in Phase 2 (filled square) the remaining Tricorder applications would be available on the LabTricorder architecture in the two years from the moment of this study. All applications would be accessible from any PC in the hospital (thin client).

The ViewAll scenario was envisioned in two phases. Phase 1 (circle) enables migration of all Tricorder applications to the ViewAll architecture in a year. Tricorder would not be available on the market anymore. In Phase 2 (filled circle), the Tricorder applications can be used on multiple dedicated hardware terminals (thick client) in two years. The Tricorder applications become available for ViewAll customers.

C. Analyze the impact of quality improvements on customer segments in architecture scenarios. As we have seen, in both scenarios the customer needs are met but with different solutions (thin vs. thick client) and different timing of releases (phases),

which satisfy different customer segments. To quantify the customers whose imaging needs are met we used sales of Tricorder and LabTricorder/ViewAll products from the previous year as proxies for number of customers, see Table 2.

Table 2. Number of customers with met imaging needs over time in LabTricorder and ViewAll scenarios

LabTricroder scenario									
		Phase 0	Phase 1			Phase 2			
	Y0	↓	↓ Year 1			↓	Year 2		
Segmented customers	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Tricorder	66	68	75	75	77	79	80	80	80
LabTricorder	30	34	34	34	34	34	34	34	34
Total	96	102	109	109	111	113	114	114	114
View All scenario									
Tricorder	66	66	69	71	71	71	72	73	73
ViewAll	38	38	38	38	38	40	40	40	40
Total	104	104	107	109	109	111	112	113	113

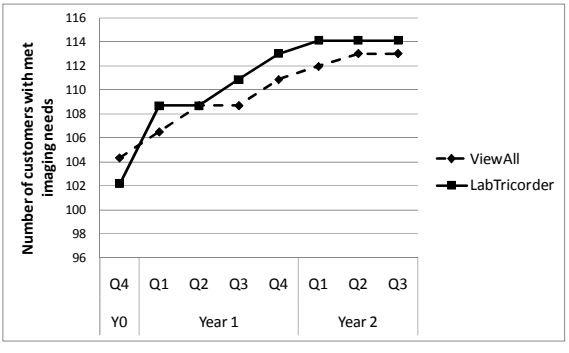

Fig. 8. Total number of customers whose imaging needs are met over time

The estimates were made by the architect, who corrected the individual quarterly sales using information from Figure 6 and Figure 7, resulting in the total number of customers whose imaging needs are met in both scenarios (see Figure 8).

The total effort to quantify the customer segments affected by the architecture changes was 3 person-month for a researcher.

4.4 Step 4: Comparison

According to Figure 8, the LabTricorder scenario offers a higher number of customers whose imaging needs are met, averaged over the in migration period. That can be used as a value indicator for the LabTricorder investment, which was consistent with the business case analysis. With the fact that the organization estimated only the present value for the business case in the LabTricorder scenario, we compared the customer segment analysis and the present value in the LabTricorder scenario resulting in the following observations:

- The customer segments analysis did not consider the negative effect on meeting the customers' needs if the investment were not made
- The customers with met imaging needs estimates were estimated only during the migration process without considering the long-term effect that was the part of our assignment
- The increase of the number of customers with met imaging needs (Figure 8) is related to the increase in the present value generated in the LabTricorder scenario in the first two years (Figure 5).
- The maximum number of customers with met imaging needs was a predictor of making a decision in favor of the LabTricorder scenario (Figure 8) that was aligned with the business case findings

As we have seen large similarities between the concept of customer segments and present value used for making the business cases, we expect that customer segments can be used in architecture decision making.

4.5 Evaluation

We presented our findings to the program manager, the system architect, and the marketers in a one-hour review meeting asking them to discuss whether and how the customer segments could support decision making process in the organization.

The consensus was reached that an explicit link between quality improvements and the customer segments supports common understanding between decision makers on how quality improvements create customer value in different scenarios. Furthermore, such structured analysis would prevent individual business incentives from dominating the decision making process. Therefore it would facilitate more objective decisions. The marketer especially emphasized that the customer segments analysis could be used to fine-tune estimates in the business case modeling to improve accuracy of the existing data. Regarding the time spent for collecting the data, the practitioners were not concerned as they envision that quantifying customer segments would be part of the existing business case modeling process, so this time would pay off and even potentially shorten the whole decision process.

Although the importance of customer segments was recognized the practitioners still wished to translate quality improvements directly to the financial (sales) data to have a direct comparison of the monetary value to the architecture investments to support architecture decision making.

5 Discussion and Conclusion

In this paper we proposed the two concepts of quantifying customer value for particular customer-centric business strategies and we applied these concepts in real-life architecture decision making projects.

We made two main observations about the proposed concepts. First, the proposed customer value concepts increased understanding on how quality improvements contribute to the customer value creation. Second, the proposed customer value concepts

established more suitable input for architecture decision making than the existing value indicators in the organization.

Regarding the first observation, it became apparent that a systematic approach of quantifying customer value helped the practitioners to discuss the architecture changes in the context of customer value. We also realized that understanding and acceptance of the customer segment concept (Tricorder case) was higher than the customer value-in-use concept (Explorer case). This can be explained with the fact that the customer segment concept was closer to the business case concept already used in the organization, which is consistent with the diffusion of innovation theory stating that people are only able to accept small incremental changes [13].

In the second observation, it became apparent that the proposed customer value concept was better tailored to the architecture decision making than the existing indicators in the organization. In the Explorer case, the technology assessment of efficiency did not provide the sufficient knowledge of the hospital's actual usage of Explorer; therefore the architecture redesign could be overlooking the main customer needs reflected in the value-in-use. This observation is consistent with findings about low percentage of judged success using technology assessments in business decisions [14]. On the other side, the customer segments provided more accurate data, which can be used as fine-grained input for making the business case (Tricorder case).

With respect to the time involved in data collection, we observed that additional labor would be spent in quantifying the particular customer value only if this became important to the business strategy of the organization. For example, if the organization has the business goal to retain customers by demonstrating the value of product improvements in the customer business, value-in-use would be used.

Drawing upon the findings of our study, some ways to advance the concept of quantifying customer value can be suggested. Our results indicate that practitioners most easily accept concepts similar to their existing concepts. A challenge for researchers is to identify the practitioners' way of working and propose a customer value concept with small incremental changes compared to practice to increase acceptability of the concept. One useful approach would be to make an inventory of customer value concepts used in practice for assessing the architecture changes as a starting point in developing this research domain further.

By themselves, the studies described in this paper do not prove absolutely that quantifying customer value via these concepts really supports architecture decision making. However, confidence in our findings is increased [18] by several other case studies indicating that cost data are necessary but not sufficient for decision making [10] and that there is a need for customer-related information linked to quality attributes [11]. Furthermore, those findings suggest that customer value concepts need to be broadened to include the other concepts as well.

We conclude this paper with the proposition that quantification of customer value linked to quality improvements should be used for architecture decision making when the customer value is closely aligned with the business strategy of the organization and the time spent on data collection is acceptable.

Acknowledgments. We would like to thank the people at Philips Healthcare and our colleague Rob van Ommering for their comments on earlier versions of this paper.

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