Understanding Failure Severity in New Product Development Processes of Consumer Electronics Products

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***Abstract*-Reliability feedback information from the field is essential for product improvement. Traditionally, consumer electronics service centers have provided the product designers with reliability information about product generations on the market at that time. However, within the field of high volume consumer electronics, movement of the business processes to emerging markets, increasing time-to-market pressure, increasing product complexity and increasing customer requirements have led to an increasing number of non-technical failures. Moreover, these business trends have resulted in higher requirements on the information that is needed in the development process. Particularly, information about the root causes of non-technical failures is required to determine the impact of these failures on the overall product reliability. This study investigates the suitability of current service processes for the collection of information about non-technical failures and their root causes in order to prioritize them within the development process of consumer electronics. Three case studies, performed at service centers for consumer electronics products, indicate that the recent trends in the field of consumer electronics have resulted in an information gap between developers and users of these products. In order to close this gap, the authors suggest the development of a new failure prioritization model for consumer electronics products.**

I. INTRODUCTION

Reliability feedback information from the field is essential tool product improvement [1]. Traditionally, consumer electronics service centers provided the product designers with reliability information about product generations on the market at that time. This information mainly consisted of number of repaired parts within the different consumer electronics products [2]. This information was used by the product designers to identify and prioritize major reliability issues in current product generations or to prevent this problem from appearing in future product generations. This failure prioritization aims at assuring that these product failures are dealt with in accordance to their negative impact on overall product reliability.

However, within the field of consumer electronics, manufacturers are currently working under strong pressure, because they have to deal with four different and often conflicting, business trends, namely globalization and segmentation of the business processes, increasing time-to-market pressure, increasing product complexity and increasing customer requirements [2]. These business trends directly have led to a situation where products are rejected even when they still perform according to the technical specification. To reach customer satisfaction, it is necessary to extend the definition of reliability to include these non-technical failures as well. Moreover, these business trends also impose new requirements for reliability feedback processes in services centers: collect reliability feedback information that can be used to prioritize these failures in the development process. The main purpose of this study is to investigate the suitability of current service processes for the collection of sufficient and relevant information to perform failure prioritization within the development process of consumer electronics.

The first step in this investigation is presented in section 2. In this section, a more extensive description of the business trends within consumer electronics industry is given together with the implications of these trends for the requirements of reliability feedback processes in service centers. Subsequently, in section 3, the results of three case studies are presented. These case studies were performed at three service centers for consumer electronics products. Based on the results of these three case studies, some conclusions can be drawn about the suitability of current service processes for the collection of information to perform failure severity prioritization within the development process of consumer electronics. These conclusions are summarized in section 4.

II. BUSINESS TRENDS & IMPLICATIONS

The first market trend is the globalization and outsourcing of the business processes. In their paper "foundation and funding opportunities for globalization", Gerstenfeld and Njoroge define globalization as "the construction of a global economy largely through the activities of private firms that move their economic activities around the world" [3]. As alternative approach for managing product creation activities globally, companies can focus on their core-business and outsource the other activities globally. Another advantage for the outsourcer is the reduction in overhead costs. Nevertheless, there are some serious risks attached to the outsourcing process that should be considered. Outsourcing can cause unwanted dependencies of suppliers [2]. Moreover, effectively managing outsourced relationships becomes a core competence itself. Insufficient communication and unclear interfaces between the products of outsourcing and supplying companies may result in serious product failures. Some of these failures may only be discovered after market introduction, generally resulting in serious financial and technical consequences.

The second trend, time-to-market, has become a central point in many industries recently [4]. Development time determines how responsive a company can react to competitive forces and to technological developments, as well as how quickly a company will receive returns form their development effort [5]. In order to keep up with competitors, it has become essential for companies to introduce more products to the market faster.

The third market trend is the increasing complexity of products and the accompanying product creation processes. Probably the best illustration of the ongoing increase in product complexity is the growing software content of consumer electronics products. Around 1995, an average consumer electronics product contained around 100 000 lines of code. In 2000 this number had already increased to an average of 1 000 000 lines of code. This implies a tenfold increase in software content within 5 years. It is expected that this rapid growth in software complexity for consumer electronics will continue [6]. The increase in software content of consumer electronics products has resulted in an corresponding increase in state space of these products. The interaction between the different software and hardware components makes it almost impossible to determine all possible failure mechanisms of these products [2]. Not only is the complexity of the technical content of products increasing, but the diversity and the variety of products as well. Together with that, the "openness" of consumer electronics products is continuously increasing. This means that these products become involved in networked environments that affect them in ways that were not foreseen during their creation. It is not difficult to see that in the situation of open systems, product interactions are more difficult to predict. Eventually this may also result in unexpected field failures and higher levels of warranty costs.

Companies have to deal with this increasing complexity in their product creation processes by delivering products that satisfy customer requirements [4]. However, at the same time, meeting customer requirements has become more difficult as a result of the increasing customer expectations. Besides that, customers often do not realize the complexity behind the systems they use, and therefore they do not see the difficulties that come with complex systems and just expect them to work [7]. The trend of increasing customer requirements is also expressed in the warranty period and warranty coverage. Nowadays, a warranty period of one year is normal and two years quite common. In the past warranties only covered the products that did not comply with the product specifications, like replacement of defective components. These days, most manufacturers tend to follow a "no questions asked policy". This means that a product is considered to have failed if customers are simply dissatisfied with its performance.

Implications of the business trends

The above described business trends directly affect the quality and reliability research area and also the requirements for reliability feedback information. One important development in this research area, resulting from these business trends, is the extension of the reliability definition. In 1996 Lewis defined reliability as "the probability that a system will perform its intended function for specified period of time under a given set of conditions" [8]. In this definition a product is said to fail when it does not perform its intended function. However, these business trends have led to the situation in the field where products can be rejected despite the fact that they do comply with their technical specifications [9]. These products are rejected because they do not perform according to the expectations of the user. This is especially true in high volume consumer electronics industry. Therefore, in order to deal with reliability in consumer electronics the classical definition needs to be extended. In this paper, the extended reliability definition is adopted in which a product is said to fail when it does not comply with the expectations of the user. The extended reliability definition has led to the denomination of another category of failures namely, non-technical failures [10].

Complains about the (lack of) functionality are caused by a mismatch between customer expectations of the product and the actual experience of the customer with the product. As a result of an increasing reliability of components together with an increasing product complexity and customer requirements, component related reliability problems have become a minority of current field complaints [11]. On the other hand, the increase in customer requirements has resulted in more non-technical reliability problems entering the product service process. It is very questionable whether current service processes are designed in such a way that these reliability problems can be identified and prioritized. It is very questionable whether current service processes are designed in such a way that these reliability problems can be identified and prioritized.

Literature review indicates that earlier described business trends have resulted in higher information needs [1]. Information about the root causes of failures is necessary to distinguish between technical failures and non-technical failures and to determine possible solutions for the failure in current or future product generations. This root cause information is also required for the determination of the impact of the failure on the overall product reliability.

Therefore, the service processes that are suitable for failure severity prioritization in consumer electronics industry should (at least) be able to:

- identify and prioritize non-technical reliability problems in the product.
- perform root-cause analyses for the determination of the impact of the failures on the overall product reliability.

III. CASE STUDIES [1]

As mentioned earlier, the main goals of this section is the investigation of the suitability of current service processes for the collection of sufficient and relevant information to perform failure prioritization within the development process of consumer electronics. Based on the identified business trends, this investigation will concentrate on service centers ability to perform root cause analyses and to identify and prioritize non-technical reliability problems.

Introduction to Case Studies

The case studies described in this section are all performed in the field of high volume consumer electronics. In order to get a complete overview of current service processes, three third party European service centers of a large consumer electronics company (Company X) were visited. These service centers are located in the Netherlands, Germany and France and are responsible for most of company X's repairs in these countries. However, these three service centers work independent of each other. The service process is one of the many business/consumer processes that connects the consumer with the product. After market introduction, consumers buy company X's products and start to use them. When the products do not meet their requirements, products are send to the service centers via a number of different channels. After repair, products are returned to the customers and reliability information with various levels of detail on the repair-action performed is send back to company X.

Case study approach

The case studies consisted of the following activities:

- The case study preparation
    - Selection of a carrier product. This carrier product was followed during the service process in the different service centers. The selection of one carrier product makes it easier to trace the different service activities and to compare service centers.
    - Definition of key persons, operational and managerial, who represent the different activities within the service process.
    - Acquisition of full commitment of the involved service centers. This commitment was acquired with the help of Company X.
- Interviews and cross check
    - Operational process mapping by interviewing people involved in the service process.
    - Operational process verifying by cross checking with on site observations in the service process.

[1] The name of the company, presented in these case studies, cannot be disclosed due to reasons of confidentiality. This information, however, is available to the authors.

Case study results: the service process

Although the three service centers worked independent of each other, the service processes of these service centers appeared to be quite similar. An overview of the general service process is given in Fig. 1. The service process consists of five phases, namely:

- Reception, unpacking and identification
- Diagnosis, repair and correction
- Quality check
- Packaging
- Dispatching

The German service center in some cases applied, in addition, the so-called "swap" procedure. Subsequently, an explanation of the different process phases will be given.

Reception, unpacking and identification

As part of the service agreement between Company X and the service centers, the three service centers collect field returns of Company X's products from various dealers and distributors. The service centers can also receive direct returns from the end users. After reception, all returned products are unpacked and visually inspected. The identification is based on product type and serial number. At the request of Company X, for all products the basic customer information (e.g. name, address, date of purchase) is logged in a computer program. Subsequently, the different product types are sorted out and forwarded to the involved repair station.

Diagnosis, repair and correction

In Germany and the Netherlands, the people repair only a restricted number of product types. As a result of that, the people can be considered true experts regarding these product types. For several product failures, the repair engineers have executed complete root cause analyses and designed repair processes or work-around solutions. In the case of a product entering the service process for the second time within three months without a clear problem, the repair engineer will contact the customer to ask for extra information about the failure behavior of the device. Some failures are then solved by giving some extra use-information to the customer. Sometimes they write down instructions themselves and in other cases they copy pieces of the user manual. For other failures, the repair engineer will start a root cause analysis based on the customer information of the failure, in order to solve it.

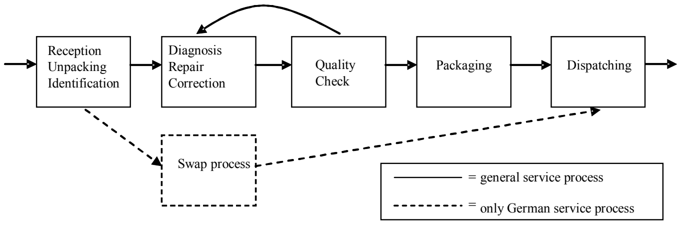

Fig. 1. Overview of the service process

In France, two levels of repair processes are defined by the service center. The first level of repair is concerned with common failures in the products. These repairs can be executed by non technical repair personnel according to a standard repair protocol. The second level of repair is similar to the standard diagnosis, repair and correction process of the Dutch and German service centers. In this second level of repairs, all less common failures are dealt with by technically educated repair personnel. Again, these repair people can be considered as true experts with regard to the involved product types. However, this French service center does not contact the customers in case of repeating repairs.

Quality Check, Packaging and Dispatching

In the Quality Check phase, a number of tests are performed. The test process is defined by the service centers with the requirements from Company X. About 50 percent of the products that have passed the repair process will be tested at the Quality Check. Products that do not pass the tests at the Quality Check are sent back to the repair process. Products that initially did not pass the quality check are always tested a second time after the second repair process.

Subsequently, all repaired products are packed properly. All necessary documents will be attached and than the product will be sent to the customers directly or via distributors and dealers.

Swap Procedure

In Germany, some product types are immediately replaced by new products. For these products no repair takes place. The customers of these products always receive an alternative product in stead of their own product. This swapping process is called: a swap. This swap process is also used for some immature products for which no root cause analysis has been performed to identify the main causes of failure. Important information about failure mechanisms in these products is discarded together with the products. In future product generations, these failures will not be prevented due to this loss of information about the root causes of these failures.

Root cause analysis

As was indicated in the previous section, service processes suitable for failure severity prioritization in consumer electronics industry should (at least) be able to perform root cause analyses on failed products. In these three service processes failure analysis is performed as follows:

For every new product introduction, Company X defines that a number of first returned sets are analyzed in detail and repaired at an Customized Repair Center (CRC). All three repair centers are indicated as CRC repair centers for new product introduction. The CRC implies that the technical department at the service centers will repair the products with the support from Company X. Subsequently, detailed root cause information is send back to Company X. For some of these CRC products, Company X requires that a certain number of these products are to be exchanged and directly sent back to the factory for further analysis.

This process is called the Initial Repair Factory (IRF). Company X decides for every product type whether the sets are to be changed or repaired. The CRC and IRF approach are part of a new procedure within Company X to improve production quality.

For other repairs (not new product introduction), the repair centers send repair job sheets back to Company X via the central service organization. From these job sheets, Company X can learn what failure symptoms the returned products have and what repair actions were taken. Based on this information, Company X calculates the amount of service costs that should be paid to the service center. The content of this information source is logistically oriented. As a result of this logistical orientation of this information, this repair information is hardly suitable for reliability analysis and reporting.

Moreover, Company X requires from the service centers that they use so-called IRIS code to describe the failures. IRIS code is a standard failure description code for consumer electronics. However, the IRIS failure descriptions are very general. All service centers indicated that this IRIS code does not specify the failures symptoms specific enough. As a result, the service centers internally use their own failure description to classify the failure symptoms more specifically. But this information is not sent back to Company X because it is not requested for.

Another important observation was that the service centers often classify the failure symptoms on the basis of the repair actions that were taken. This is quite understandable considering the logistical orientation of this feedback information. However, the repair actions aim to remove the failure symptoms in stead of solving the failures from their root cause level. That means that the failure classification does not provide any information about the root causes of the different failures.

In general can be concluded that feedback information based on CRC data is very detailed and does contain root cause information. However, the number of sets used in CRC is very limited. It is very uncertain whether all failure root causes are identified in the CRC process. Feedback information based on the normal repairs is of limited quality since it describes failure symptoms using IRIS code. The service centers collect more root cause information than Company X requires. Within the current logistical organization of the service process failure severity prioritization using root cause information is impossible.

Non-technical Failures

The other requirement for the service process, in order to be suitable for failure severity prioritization in consumer electronics industry, is that the process should (at least) be able to identify and prioritize technical **and** non-technical reliability problems in the product.

In these three service processes all non-technical failures follow the so-called No Fault Found (NFF) process. The NFF process is a special case of the repair process. This describes the situation in which no clear failure can be identified during the repair process in the service center.

When a product enters the service center for the first time and the repair engineers can not find a problem, the device software will be updated. By updating the software, the service center hopes to solve the intermittent failure or the interaction failure that was possibly present in the product. However, the non-technical reliability problems can not be solved by this software update. After this software update, the product is packaged and dispatched to the customer. All these product failures are reported as being software failures to Company X.

The service centers receive a fixed amount of money per repair for every product type. When a product enters the service process for the second time within three months, Company X will only pay material costs for this second repair. The procedures for the second NFF-service for the same product within the first three months differs between the three service centers. In France the procedure is exactly the same as for the first NFF service. After a new software update the product is dispatched to the customer. Only at the third request for service for the same product, this service center will ask Company X to offer this customer a so-called "commercial solution". This means that Company X will offer this customer another product or (part of) their money back.

In the Netherlands and Germany, the procedure for the second NFF service is different. Both service centers will do another software update but also provide extra use-information to the customer. As mentioned before, they will type their own instructions or copy parts of the user manual. By providing this information to the customers, the service centers try to solve non-technical failures that are caused by incomplete customer understanding of the product.

However, another group of non-technical failures, caused by customer's dissatisfaction with the functionality of the product, is not given any attention not to mention solved by the service processes.

The complete service process is designed for managing technical reliability problems. The only non-technical reliability problems that are (sometimes) dealt with are the issues of so-called ignorant customers. These actions are initiated by the service centers and not by Company X. Company X does not pay these service centers for these activities. As a result, the customers depend on the goodwill of the service center whether they will provide this extra information. No formal procedures are formulated for the management of customer requirement problems. No information about non-technical reliability problems is provided to Company X. Consequently, Company X does not use any non-technical reliability information in their failure prioritization process.

IV. CONCLUSIONS AND RECOMMENDATIONS

The main goal of this research was to investigate the suitability of current service processes for the collection of sufficient and relevant information to perform failure severity prioritization. The results of the case studies indicate that the recent trends in the field of consumer electronics have resulted in an information gap between the developers and users of consumer electronic products. The current logistical structure of the service organization is not suitable for the collection of information about root causes of failures and about non-technical reliability problems. As a result of that, product developers are thrown back on their own intuition with respect to failure prioritization. Moreover, the failure severities of technical reliability problems are being over-emphasized as a result of neglecting non-technical reliability problems.

In order to close this information gap, the authors propose the development of a new failure prioritization model for consumer electronics products. This model should support product developers to collect and organize the appropriate failure and customer information in order to make founded decisions on product failure severities. Furthermore, this model should recognize the new information needs of the development process as a result of earlier described business trends. This model will contribute to a reliability improvement process in which product failures are dealt with in accordance to their negative impact on overall product reliability. Eventually, this should add to the improvement of current and future generations of consumer electronics products.

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