FIELD-FEEDBACK IN INNOVATIVE PRODUCT DEVELOPMENT: A COMPARISON OF TWO INDUSTRIAL APPROACHES

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ABSTRACT

Consumer electronics is a highly dynamic and competitive industry. Continuous influx of new technology, whilst creating huge opportunities for new product-market combinations, leads to high levels of uncertainty about if/how/when users will adopt the outcome. Accordingly, the increased benefits of utilizing real field data to ensure *user-perceived* quality and reliability of products are recognized. Our investigations in a multinational consumer electronics company revealed room for improvement in their systems for more *efficient and effective* collection of field data, to better handle the repercussions of current market trends. Specifically aimed at understanding causes of unexpected user-product interactions through analysis of field data, we propose an improved scheme of failure classes to capture such information via data collection systems. This scheme is intended as a meaningful, modular, unambiguous, generic, and practicable way of categorizing reported field issues.

INTRODUCTION

High-volume consumer electronics (CE) is a fast-paced and competitive industry. Products with growing degrees of innovation are developed and put out on the global market in decreasing time periods to meet the more demanding expectations (e.g. re extended warranty periods) of a variety of customers (e.g. with different cultural backgrounds etc.). Due to these circumstances, leading multinational companies are well aware of the increased benefits of exploiting real field-feedback data to ensure the quality and reliability of the products they manufacture. Therefore, they seek to incorporate new information and insights obtained from the field into the development of (same or next generation) products. However, since the market is continuously evolving at the same time, it is a challenge to render their improvement activities (both at the front- and back-end of a product development process) fruitful and sufficient along the lines of changing needs.

The uncertainty involved in the development of innovative electronics products is big. Typically, manufacturers of such products cannot know in advance how a new technology will really perform in the field (e.g. usage-scenarios that products will be subjected to in different physical settings or countries) or to what extent the product will meet the requirements and wishes of the customers. By analyzing data from the field, it is possible to detect this information in reality, per country over time. The relay of this information then back to the product development process (PDP) enables relevant improvement actions to be taken to better meet customer expectations. In order to render this feedback loop mechanism as *efficient and effective* as possible in short-cycle PDPs, the information collected from the field should be *well-structured and meaningful*, respectively. This in turn necessitates conforming to a *syntactically and semantically* correct and complete (failure) classification scheme. The focus of this study is to see how the currently used field-feedback collection systems in the delineated industrial context can be enhanced to optimally comply with such a scheme. In view of that, we suggest ways of improving these systems to be competent specifically in identifying classes of dissatisfying interactions experienced by users with products that actually function according to specifications; hence *soft reliability* issues.

The paper is organized as follows: The following section provides background on soft reliability, and positions it with respect to related work. Current industrial approach to dealing with (soft) failures is presented in the third section. Here, the information flows in practice from users back to the manufacturing company is also discussed. Then, the fourth section gives the details of our study of analyzing field data and our findings. Finally, the last section concludes the paper and indicates future research activities.

BACKGROUND ON SOFT RELIABILITY

Formerly, failures encountered in products were typically technical component failures, which displayed violations of product specifications (Pecht and Ramappan, 1992). However, within the current, rapidly evolving market circumstances, additional classes of failures are increasingly being observed. At present, these new classes of failures (sometimes attributed to specifications omissions, usability/learnability problems, customer misunderstandings, or local conditions) are not identifiable and manageable through existing quality and reliability measures taken by the industry (Brombacher *et al.*, 2005; Ouden *et al.*, 2006). The result is a lot of "product assistance" calls at call centers, "no fault found" labeled products at service/repair centers, returned products at dealers that seemingly function well, and to top it all, damaged brand image of companies. The realization of this trend was the starting point for making a distinction between *hard* versus *soft reliability* concerns (Brombacher *et al.*, 2005; Geudens *et al.*, 2005).

The traditional quality and reliability approaches are to a large extent capable of identifying and handling hard reliability problems of repairable systems with constant hazard rates. Exceptions include some intermittent or irreproducible hard failures that prevent the device from performing part or all of its functions as listed in its specifications (Pecht and Dasgupta, 1995). Additional techniques are nonetheless necessary to be able to manage soft reliability problems and to ensure the superseding *user-perceived quality* of products.

In the same way new product development (NPD) is a multi-disciplinary domain, so is soft reliability, which is involved therein. Among the customary NPD fields, soft reliability specifically concerns (i) product "quality and reliability", which is largely determined by (ii) "customers in the market".

(i) "Quality and reliability" on the one hand, is concerned both with the hard "engineering" of the product, and the soft "design" of it (including the organizational design decisions to include/exclude certain functionalities or use of materials). Conversely, the "design" of the product is concerned with the "user" in terms of his/her socio-cultural context and hence related expectations. From the user's perspective, hard "engineering" is about making the product right, whereas soft "design" is about making the right product (with the required functionalities, ease of use, appeal, etc.).

(ii) Getting to know the "customers in the market" on the other hand, concerns getting to know "customer segments" in an "evolving market", both of which relate to the marketing domain. Knowledge of these aspects contributes to better identifying customer needs and requirements, and to better positioning of a new product within the market. In addition to these presales concerns, marketing also involves handling post-sales services. Minimizing customer dissatisfaction requires a deep understanding of "consumer complaint behavior" and the key points of what is referred to as "customer relationship management (CRM)".

A good understanding of all these domains is necessary in order to be able to manage soft reliability, which currently presents a growing, uncontrollable problem in NPD.

Related Work

Given the multi-disciplinary nature of soft reliability, it is most relevant to see how the related disciplines may be utilized to clearly identify soft failures and hence devise ways to solve them.

A considerable part of the NPD community has long perceived marketing as the main culprit of failing NPD projects. In the earlier literature, researchers often stressed the overlooked importance of front-end activities in NPD (Cooper and Kleinschmidt, 1987; Page and Stoval, 1994). However, with the shift towards new market trends in high-volume CE industry that fueled the awareness of soft reliability problems, the charges against marketing expanded significantly. For instance, (Christensen *et al.*, 2005) criticize the strict compliance to some elemental paradigms of marketing, such as methods/models for market segmentation. Instead of focusing too much on narrow demographic segments, they promote *satisfying needs* through "designing products that do the job", which requires *the job* and not *the customer* to be the fundamental unit of analysis. On another marketing concern, (Dahl and Hoeffler, 2004) examine ways to better position and communicate a product to consumers depending whether the product is *incremental* or *really new* with respect to its innovativeness. This is important in moderating the degree of disparity that results from a customer's disconfirmation of expectations about perceived product performance (Anderson, 1973; Spreng *et al.*, 1996). Related to the post-sales activities of marketing, research on CRM has long since been of interest as a distinguishing factor in achieving success in the increasingly competitive market. CRM is a crucial intermediary in maximizing/minimizing customer satisfaction/dissatisfaction, and a strong tool for increasing product/service quality through a closed feedback loop (Cho *et al.*, 2002). While CRM is a potential resource to understand soft failures in the field and to allow the company to take *corrective* actions, some market research techniques on the front-end (e.g. prototype testing, customer visit programs, empathic design, Beta version testing) seem like promising candidates for taking *preventive* measures (Mohr *et al.*, 2005) against the occurrence of soft failures.

Evidently, marketing activities share their role as a contributor to the root causes of soft failures with product-design activities. This has been recognized as being more so ever since the introduction of digital and wireless technologies to our everyday lives (Bly *et al.*, 2006; Bouwmeester and Bosma, 2006; Ketola, 2005; Palen and Salzman, 2002). Such technologies, embedded in personalizable/adaptable/context-aware products, have brought the effect of (social and physical) environment more to the forefront. Whereas the interest used to be specifically concentrated on the user-product interface, it has now expanded to cover the *evolving context of the user, or multiple-users for shared products,* as a whole. This is because users often have to alter their behaviors in order to obtain the benefits that really new products offer (Bouwmeester and Bosma, 2006; Ketola, 2005), and this has various consequences depending on different work/home environments the product is used within or cultural/geographical differences, all affecting the acceptance of the product (Venkatesh *et al.*, 2003). Acceptance and then adoption (to daily life) of a product comes in last, namely after the successful completion of (i) commercial product exposure and communication, (ii) creating user awareness for the (many) features and functions the product has, (iii) making these functions appealing for the user in order to motivate use, and (iv) making the product intuitive to use (Bouwmeester and Bosma, 2006). (Mukherjee and Hoyer, 2001) demonstrated that the inclusion of novel attributes on high-complexity products prompted negative inferences about learning costs. Therefore, it is a real challenge to balance all of the mentioned aspects to work out fine in a product, but such is the goal, through managing soft failures.

THE CASE: CURRENT INDUSTRIAL APROACH TO (SOFT) FAILURES

There are various sources of feedback data in a business to consumer (B2C) setting: Call center logs, service center reports, Internet posts (e.g. public forums, product reviews), trade information (e.g. sales figures, dealers' feedback to manufacturing company upon contact with customers), and test information (e.g. consumer experience tests, Beta tests). From among these, trade information is usually not readily retrievable or reliable in high-volume CE industry, due to the high involvement of third party retailers. While test information remains most indicative owing to direct observation in a simulated or real field environment, the amount is bound to be restrictive due to the infeasibility of testing every aspect of a product with many types of users. Therefore, field-feedback is identified as a very valuable source of information, since it may potentially reveal *real* usage-scenarios and is available in *large* quantities.

In the multinational high-volume CE manufacturing company we studied as our case, field-failures are managed through outsourced call or service center organizations. These organizations collect field failure data in a way that conforms to a certain structure that is prescribed by the manufacturing company. This structure is embedded within the (sophisticated and highly networked) information systems used at these organizations. Upon encountering a field failure, the call center agent or the service center engineer logs the related data in their respective information system, conforming to the prescribed structure. The failure types in this structure, which are used by the employees to label (and hence classify) the failures, have been observed to be semantically ambiguous, and also inadequate in capturing the essence of many soft reliability related issues. Details on these structures, as we observed them onsite, are discussed in the following subsections.

Upon shared realization of increasing numbers of soft failures in the general industrial context, and the insufficiency of the currently used models to capture them, some attempts have been made as initial steps to understand the nature of these problems. This has led to preliminary proposals for failure classifications (Geudens *et al.*, 2005; Hartmann, 2005), which were later shown as incomplete or unsound reflections of reality (Koca *et al.*, 2006). Moreover, the classes in these schemes also do not fully cover or help to easily identify the different soft reliability problems.

The need for a semantically-improved classification approach is also inevitable when considering the feedback information flows from the customer through to the development team in the manufacturing company. The data captured from the field go through many translations and abstractions in the course of closing the feedback loop. By the time it reaches the people who can improve the developed products, it is already quite aggregated and degraded in terms of useful (feedback) content.

In the case that we investigated for this specific work, the link between the customer and the development team is traced as follows: The customer initiates the feedback process by reporting to a call/service center. The issue is captured by an agent as it gets logged to the information system. Field data from different information systems then get automatically merged in one central system on a daily basis, intended for the monitoring of the manufacturing company. This central system is housed in the manufacturing company. Within the company there are different business units responsible for different families of products. Each unit has its own development team. The *knowledge engineer*s from respective units monitor relevant data from the central system, and share their observations and findings as to the limitations of their products with the *quality engineer*s. This information is then examined, interpreted, and prioritized by the quality engineers before it is conveyed to the product manager and the rest of the development team. We believe that an initial contribution to improving such a flow is through enhancing the content quality that is captured to begin with. This motivation has been identified, and detailed in (Sander and Brombacher, 2000; Molenaar *et al.*, 2002).

Call Center scheme

We visited three (of the many) call centers in northern Europe that are all subcontractors of the same multinational high-volume CE manufacturing company. Two of them belong to the same call center organization (called CC_1 hereafter), and one belongs to another call center organization (called CC_2 hereafter). Both CC_1 and CC_2 are CRM specialists, and operate on a worldwide scale as subcontractors of many globally recognized companies. In order to ensure quality of service of the subcontractors, all call center agents initially receive a thorough hands-on training about the products they support, in addition to the training they get about the respective information system they will use.

The information systems used by these call centers are not the same, although they both log field data in a similar structure: Beyond the customary statistics for customer profile, agent details, time and product code related data, both structures have call classes for the agents to select from (one of each). These call classes, namely call_type, call_reason, and call_resolution, are either set or approved by the manufacturing company. Furthermore, both call centers also log a free-text field so that the agent can fill in the summary of the call, and any additional information.

In terms of feedback content, the call classes as well as the free-text information are (potentially) the most valuable log data per product gathered in call centers. Nonetheless, in practice, the used list of call classes does not serve its purpose of correctly capturing field issues to feed back to the product development team. In addition, the free-text data logged by the agents typically do not have the standard syntax necessary for automatic processing. The main differences between the two call centers' general operations, collection of free-text and their call classification mechanisms are elaborated in what follows.

CC_1

CC_1 uses an in-house owned and maintained information system. The products they provide service for are generally PC-based home entertainment devices and PC-related electronics products such as peripherals. Although CC_1 provides service for many European countries, all data that eventually get logged in their system is in English. This is an advantage from the data processing point of view. Another advantage is the way they structure the free-text data, such that agents are encouraged to fill in the free-text by explicitly addressing three aspects: (i) purpose of the call, (ii) 'troubleshooting' that has been undergone, and (ii) the result of the call or next steps if there are any. The major drawback of their information system is the call classes: There are too many categories for call_reason to choose from per product family, some of which seem indistinguishable, and there is no registered definition/description guide of these categories for the agents to refer to in case of doubt. Therefore, the selections made are based on no standard scheme and are hence prone to subjectivity. Moreover, it was observed that most of the calls get classified as *Usage_Assistance required*. Figure 1 depicts the percentages of the numerous call_reason categories from the CC_1 data set we analyzed for our experiment.

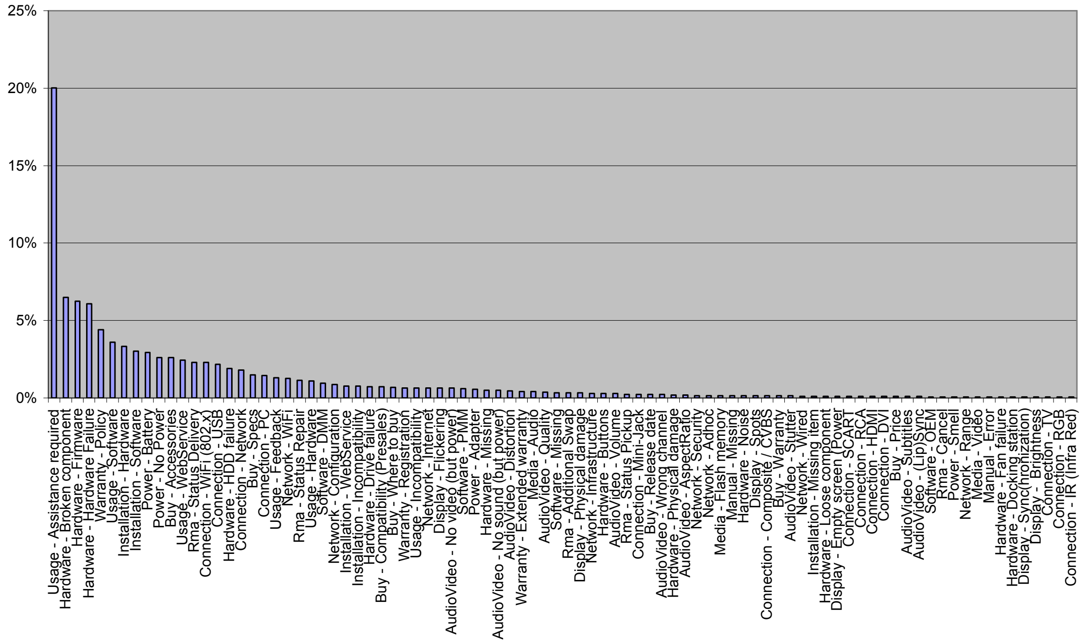


Figure 1 Percentages of Call_Reason Categories of CC_1 *(Note that there are too many categories)*

The information flows within CC_1 in dealing with various types of field issues is self-contained, covering management of repair operations as well. In addition to the reporting of the log data from the in-house owned information system to the manufacturing company's central system on regular intervals, there is also a spoken means of communication. The spoken means is through weekly telephone conferences between the related business units of the manufacturing company and the *mentor* at CC_1 (i.e. the most experienced agent responsible for resolving issues that bounce from other agents), during which he shares his observations about field issues of (respective) products. Based on the incoming feedback information from CC_1 via these two channels, the development team is informed and hence can plan improvement actions accordingly.

<u>CC_2</u>

CC_2 uses an information system that is owned by the manufacturing company. They process field issues generated in northern Europe, about mainstream CE products such as audio visual equipment (e.g. TVs, DVD players-recorders). Agents log free-text data in the respective language of the customer, which makes it difficult to process for the knowledge engineers at the manufacturing company. Furthermore, logging free-text data does not require the agents to follow any specific structure and hence agents can subjectively fill in this field for different purposes. A relatively positive aspect of CC_2 operations, in comparison with CC_1, is about their call classification scheme: The list of categories for call_reason to choose from is the same for all products and not as populated, and there is a standard document of call class descriptions that the agents can consult in case of doubt. However, similar ambiguities among CC_2 category definitions render agent classifications subjective in practice.

Moreover, it was observed that the majority of the calls get classified as *Product_Assistance*, which leaves few calls for the remaining categories. Figure 2 depicts the percentages of the call_reason categories from the CC_2 data set we analyzed for our experiment.

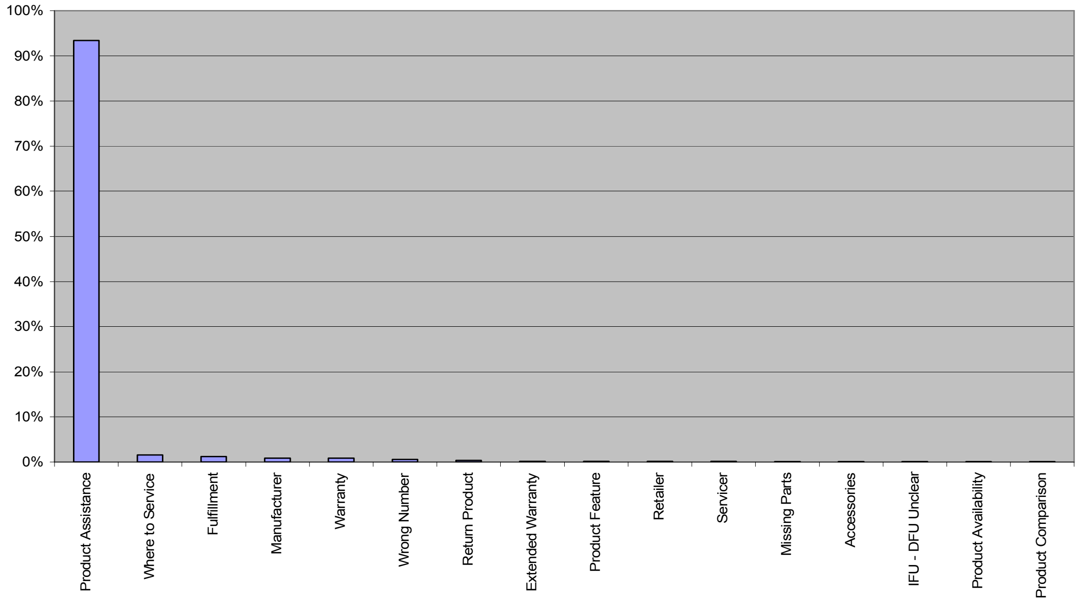


Figure 2 Percentages of Call_Reason Categories of CC_2

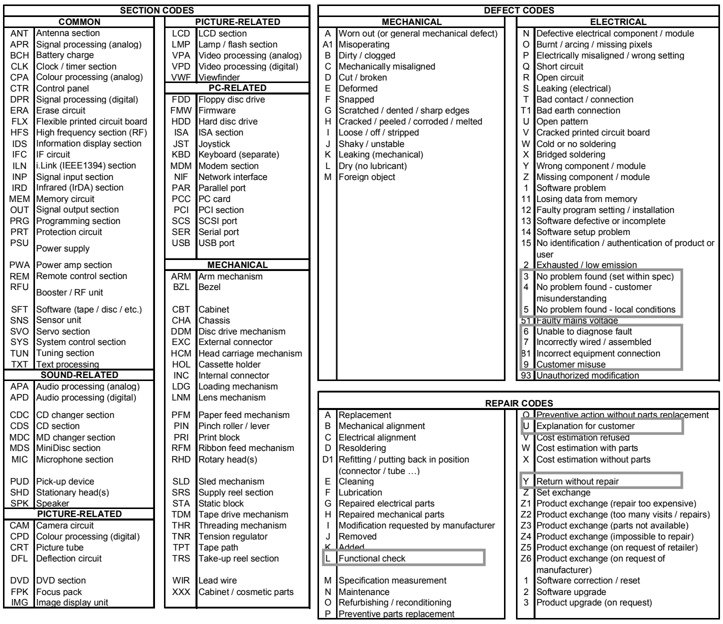
The information flows within CC_2 in dealing with various types of field issues is self-contained, but is not executed under the same roof. Unusual technical repair cases they (i.e. agents and the mentor) cannot resolve in their satellite *frontline* office, get reassigned to their central *backline* office, which currently happens to be in another European country. In those cases where also the backline office cannot resolve a problem through repair/advice, the relevant business unit in the manufacturing company is informed via *escalat*ion of the issue.

Service Center scheme

Service centers are typically subcontracted by the manufacturing company to perform repair actions. Products that need to be repaired are referred to the nearest by service center by the call center or the dealer. In some cases (depending on state policies re consumer rights, etc.) the customer can also directly take the product to the service center. At the service center, engineers examine the product, and after they perform the necessary actions, each such case is logged into a system to be monitored by the manufacturing company for purposes of claiming repair costs (i.e. if the product is covered by warranty), or just for purposes of reporting field-feedback.

The structure of the data logged is different than the one used by call centers: Besides the customary statistics of the service center, time (e.g. case receipt date, repair completion date) and product code related data, this structure uses code lists for capturing the condition, symptom (as perceived by the user), area, nature, and repair type of the examined cases (cf. Figure 3). These code lists -namely for condition, symptom, section, defect, and repair codes-, which are part of the European format of IRIS (a.k.a. International Repair Information System) coding standard as promoted by the European Association for Consumer Electronics Manufacturers (EACEM), are imposed by the manufacturing company. The data logging structure also has a failure_description field and a (free-text) comments field, so that the (technical) summary of the failure, and any additional information can be recorded, respectively.

In rare situations, such structures may include free-text fields for customer complaint, observation of technician, and repair solution.



SECTION CODES

COMMON	
ANT	Antenna section
APR	Signal processing (analog)
BCH	Battery charge
CLK	Clock / timer section
CPA	Colour processing (analog)
CTR	Control panel
DPR	Signal processing (digital)
ERA	Erase circuit
FLX	Flexible printed circuit board
HFS	High frequency section (RF)
IDS	Information display section
IFC	IF circuit
ILN	i.Link (IEEE1394) section
INP	Signal input section
IRD	Infrared (IrDA) section
MEM	Memory circuit
OUT	Signal output section
PRG	Programming section
PRT	Protection circuit
PSU	Power supply
PWA	Power amp section
REM	Remote control section
RFU	Booster / RF unit
SFT	Software (tape / disc / etc.)
SNS	Sensor unit
SVO	Servo section
SYS	System control section
TUN	Tuning section
TXT	Text processing

SOUND-RELATED	
APA	Audio processing (analog)
APD	Audio processing (digital)
CDC	CD changer section
CDS	CD section
MDC	MD changer section
MDS	MiniDisc section
MIC	Microphone section
PUD	Pick-up device
SHD	Stationary head(s)
SPK	Speaker

PICTURE-RELATED	
CAM	Camera circuit
CPD	Colour processing (digital)
CRT	Picture tube
DFL	Deflection circuit
DVD	DVD section
FPK	Focus pack
IMG	Image display unit

PICTURE-RELATED	
LCD	LCD section
LMP	Lamp / flash section
VPA	Video processing (analog)
VPD	Video processing (digital)
VWF	Viewfinder

PC-RELATED	
FDD	Floppy disc drive
FMW	Firmware
HDD	Hard disc drive
ISA	ISA section
JST	Joystick
KBD	Keyboard (separate)
MDM	Modem section
NIF	Network interface
PAR	Parallel port
PCC	PC card
PCI	PCI section
SCS	SCSI port
SER	Serial port
USB	USB port

MECHANICAL	
ARM	Arm mechanism
BZL	Bezel
CBT	Cabinet
CHA	Chassis
DDM	Disc drive mechanism
EXC	External connector
HCM	Head carriage mechanism
HOL	Cassette holder
INC	Internal connector
LDG	Loading mechanism
LNM	Lens mechanism
PFM	Paper feed mechanism
PIN	Pinch roller / lever
PRI	Print block
RFM	Ribbon feed mechanism
RHD	Rotary head(s)
SLD	Sled mechanism
SRS	Supply reel section
STA	Static block
TDM	Tape drive mechanism
THR	Threading mechanism
TNR	Tension regulator
TPT	Tape path
TRS	Take-up reel section
WIR	Lead wire
XXX	Cabinet / cosmetic parts

DEFECT CODES

MECHANICAL	
A	Worn out (or general mechanical defect)
A1	Misoperating
B	Dirty / clogged
C	Mechanically misaligned
D	Cut / broken
E	Deformed
F	Snapped
G	Scratched / dented / sharp edges
H	Cracked / peeled / corroded / melted
I	Loose / off / stripped
J	Shaky / unstable
K	Leaking (mechanical)
L	Dry (no lubricant)
M	Foreign object

ELECTRICAL	
N	Defective electrical component / module
O	Burnt / arcing / missing pixels
P	Electrically misaligned / wrong setting
Q	Short circuit
R	Open circuit
S	Leaking (electrical)
T	Bad contact / connection
T1	Bad earth connection
U	Open pattern
V	Cracked printed circuit board
W	Cold or no soldering
X	Bridged soldering
Y	Wrong component / module
Z	Missing component / module
1	Software problem
11	Losing data from memory
12	Faulty program setting / installation
13	Software defective or incomplete
14	Software setup problem
15	No identification / authentication of product or user
2	Exhausted / low emission
3	No problem found (set within spec)
4	No problem found - customer misunderstanding
5	No problem found - local conditions
51	Faulty mains voltage
6	Unable to diagnose fault
7	Incorrectly wired / assembled
81	Incorrect equipment connection
9	Customer misuse
93	Unauthorized modification

REPAIR CODES

A	Replacement	Q	Preventive action without parts replacement
B	Mechanical alignment	U	Explanation for customer
C	Electrical alignment	V	Cost estimation refused
D	Resoldering	W	Cost estimation with parts
D1	Refitting / putting back in position (connector / tube …)	X	Cost estimation without parts
E	Cleaning	Y	Return without repair
F	Lubrication	Z	Set exchange
G	Repaired electrical parts	Z1	Product exchange (repair too expensive)
H	Repaired mechanical parts	Z2	Product exchange (too many visits / repairs)
I	Modification requested by manufacturer	Z3	Product exchange (parts not available)
J	Removed	Z4	Product exchange (impossible to repair)
K	Added	Z5	Product exchange (on request of retailer)
L	Functional check	Z6	Product exchange (on request of manufacturer)
M	Specification measurement	1	Software correction / reset
N	Maintenance	2	Software upgrade
O	Refurbishing / reconditioning	3	Product upgrade (on request)
P	Preventive parts replacement		

Figure 3 Section, Defect, and Repair Codes from IRIS

Commonly, the code lists, as seen in Figure 3, are hard reliability oriented, and are not detailed to capture soft reliability issues. Also the technician not always registers the symptom code in the intended way. Therefore service center logs are typically poor in content for analysis of soft failures. The increasing numbers of cases that get labeled by one of the highlighted codes (Brombacher *et al.*, 2005), however, confirm the need for a deeper approach to work on them.

THE EXPERIMENT: FAILURES REPORTED TO CALL CENTERS

Based on our findings from the case described in the previous section, we conducted an exploratory failure analysis and classification experiment on data gathered by CC_1 and by CC_2. With the initial objective of identifying particularly soft reliability issues in these data sets, we also compared our analysis results with the call_reason categories as labeled by the call centers (i.e. Figure 1 and Figure 2). The comparison aims to demonstrate the degree of useful content information that can actually be retrieved from the same data as currently collected by both call centers, and to indicate the potential to improve this content.

Data sets

Two data sets, one from each call center, were analyzed. Both sets comprised of calls from the Netherlands and were collected over the same three-month period. The data set from CC_1 consists of 2321 calls about five product families, and the data set from CC_2 consists of 1368 calls about two product families. The products were selected for analysis based on their observed tendency to generate soft failures in the field. Specifically, these are (wired/wirelessly networked and/or multifunctional) products that are strongly innovative and hence really new for both the manufacturing company and the market.

Analysis results and discussion

The analysis comprised firstly of delving into the free-text summaries of calls made to CC_1 and CC_2, while also making use of extra information such as date of purchase where necessary (e.g. in identifying whether or not the product has been newly bought). With the approach we take towards soft reliability, as discussed in the background section of this paper, we distinguished six categories relating to soft failures: (i) *Usage_within (product) capabilities_product*, (ii) *Usage_within (product) capabilities_user*, (iii) *Usage_within (product) capabilities_environment*, (iv) *Usage_beyond (product) capabilities_disliked structural attributes*, (v) *Usage_beyond (product) capabilities_disliked functional features*, (vi) *Usage_beyond (product) capabilities_nonexistent features*. We used these categories, descriptions of which are in what follows, the typical hard failure category (i.e. *Product repair necessary*), and other marketing-sales-services related categories, as alternates to the existing call_reason categories of CC_1 and CC_2. Their performance on CC_1 data and CC_2 data is depicted in Figure 4 and Figure 5, respectively.

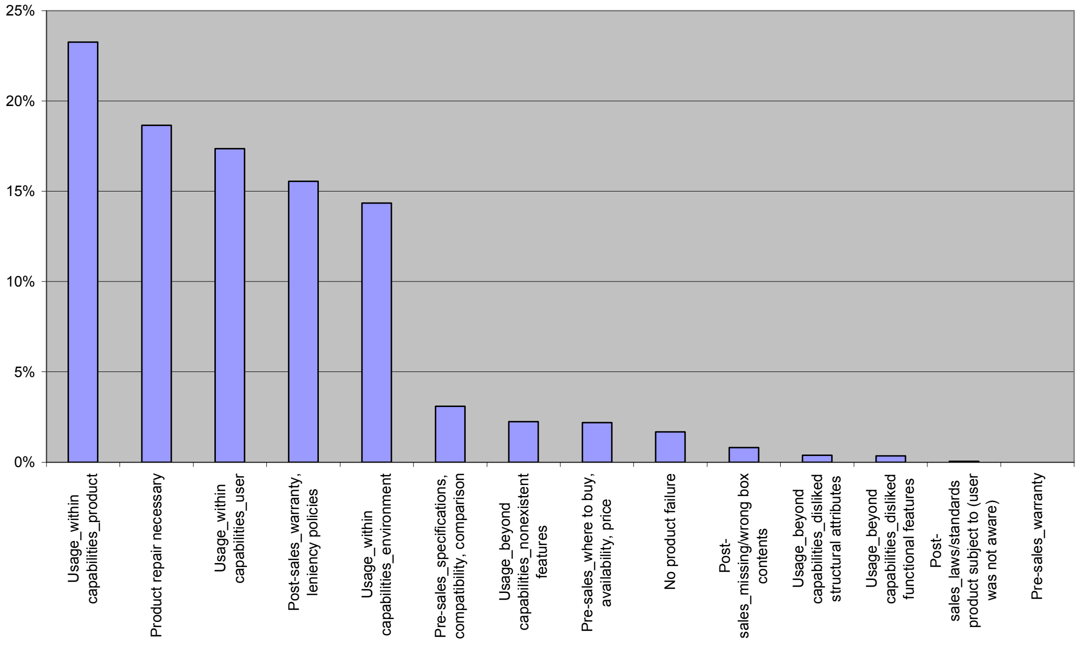


Figure 4 Percentages of Call_Reason Categories Observed in CC_1 Data

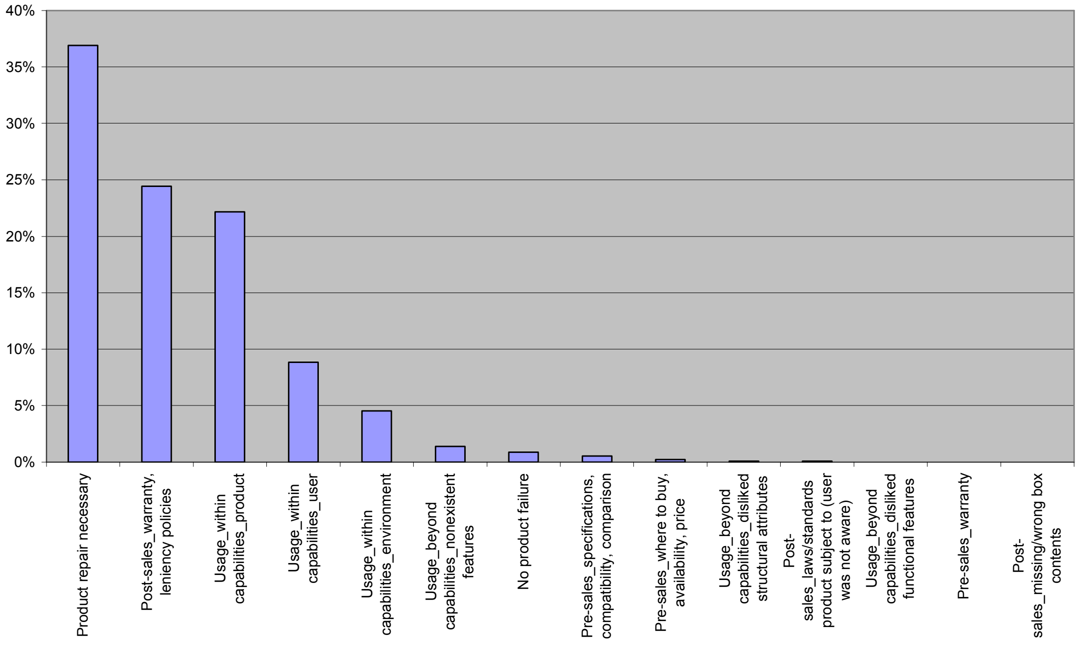


Figure 5 Percentages of Call_Reason Categories Observed in CC_2 Data

The six soft failure categories we propose make a distinction between two main types of soft reliability problems: The problems with usage that can be resolved *within* the capabilities of the product by means of following instructions; versus the problems with usage due to users' expectations that are *beyond* what the product can offer and can only be addressed by providing (the missing) information to the user to compensate for the discrepancy. This distinction corresponds to errors of omission and commission (Krippendorff, 1989), in that order.

The former kind of failures, i.e. within product capabilities, is further grouped into those that -for recovery- require a change in: the *product* itself (e.g. software upgrade, reset/restart), the *environment* (e.g. adjusting the physical place of the product or the devices it connects to) or the *user* (e.g. remedying learnability or usability overhead).

The latter kind of failures, i.e. beyond product capabilities, is further grouped into three categories, based on if the product is failing to meet with the quality degree of the user-desired *structural attributes* (e.g. fan noise level, speed, luminosity level, ergonomics design), *functional features* (e.g. having to do a tedious procedure every time to get a certain 'goal' done), or if a functionality expected by the user is completely missing in the product (e.g. specifications omissions: no way to get a certain 'goal' done).

The percentage distributions of CC_1 and CC_2 data on our categories reveal some deviations between the PC-related electronics products and the mainstream CE products. While 54% of calls in CC_1 data are about usage problems experienced *within* the capabilities of the product, this is the case for 36% of CC_2 data. An interpretation is due to the *technology-push* trend in the PC industry versus the *market-pull* trend in the CE industry. That is, users of PC-based or related products are typically not fully aware of how to interact with the product that they end up buying, and thus they often experience difficulties with it. Users of mainstream CE products are more informed about the product itself, and mostly generate field calls when they experience hard reliability problems (37%) or marketing-sales-services related issues (25%). This implies that, based on detailed field feedback, PC-related products should be designed to be more intuitive (e.g. more automated instead of manual software updates) and the product capabilities should be better communicated to the users (e.g. simpler and more descriptive user manuals). These inferences are based on expert interviews we conducted in our case, but more research would be necessary to validate and generalize such correlations.

The specific improvement our proposed categories bear for the current CC_1 scheme is the reduced number of categories that are equally applicable for many (strongly innovative) product families. The specific improvement brought about for the CC_2 scheme is the more meaningful and transparent breakdown of calls. Moreover, the general advantage to both schemes is the attainment of improved insights on soft reliability issues, and realizing a step forward to an all-encompassing, unambiguous, and practicable classification of field-feedback for the development team.

An important aspect of our analysis that needs highlighting is that we observed our categories based on the already collected field data. This implies the promising potential for content improvement, in terms of collecting more relevant and structured data first hand. The approach of CC_1 to structuring the logging of free-text information is helpful in this respect. However such structuring could be improved to explicitly collect other relevant information also, such as, if the user referred to the user manual at all, and if that was useful. This information would not only clarify the ways of improving documentation in order to prevent or remedy soft and marketing-sales-services failures, but would also give insights about usage-scenarios. Likewise, richer information on whether or not the problem was there during earlier use would reveal if the failure happened during *first use* (of the functionality/feature) or during *extended use*. This in turn, would reveal to the development team whether, for instance, it is the product (e.g. frequently requires software upgrades during extended use) or the user (e.g. experiencing difficulties with the unintuitive interface during first use) that needs further attention.

CONCLUSIONS

In this study we first set the current global context for high-volume CE industry. This involved mentioning influx of new technology, and the market trends that induce various uncertainties in NPD projects. The uncertainties form root causes of what has recently been recognized as soft reliability problems. Contrary to the available techniques for managing hard reliability problems, there is not yet a methodological approach in dealing with soft reliability problems. Therefore, manufacturing companies increasingly realize the importance of field-feedback, and hence try to optimally exploit it to improve the soft problems of their products and services.

Our observations and findings from the case we investigated regarding field-feedback management of a multinational high-volume CE manufacturing company revealed that various data resources are used to collect field-feedback. The investigation of these resources, and the information flows involved, enabled us to identify the most suitable setting and data to analyze for our purposes. Due to their management of content-wise richest data, and to their closer ties with the manufacturing company, we specifically focused on call centers. We demonstrated how their structures of collecting data to feed back to the development team can be improved.

Aimed at enhancing the understanding of soft reliability issues through the analysis of real field data, and as a valid means of capturing such information via the feedback data collection systems of call centers, we proposed a new scheme of call classes. This scheme is intended as a meaningful, modular, unambiguous, generic, and practicable way of categorizing reported field issues.

Our ongoing work consists of ensuing experiments for validation and verification of an all-encompassing failure classification model to be used on *various data resources* (i.e. not just call center data), for *single- and multi-user systems*, and *across industries* for strongly innovative PDPs. Such a flexible and adaptable model is expected to enable companies to quickly spot deviations in product failures and hence infer usage patterns per country over time. As Charles Darwin pointed out: “It is not the strongest species that survive, nor the most intelligent, but the ones most responsive to change.”

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