Towards a Classification of Reliability Problems Concerning Strongly Innovative Products

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***Abstract*- This paper proposes a conceptual framework to distinguish between different classes of reliability problems encountered in strongly innovative products.**

Next to the conventional (hardware and software) problems, new classes of failures have emerged with a wide range of often strongly related definitions, such as: soft failures, "No Fault Found" failures, "Fault Not Found" failures, "Cause Not Found" failures, nuisance failures. The fact that these new classes of failures do not have precise and orthogonal definitions, leads to difficulties in failure identification and classification.

A list of dimensions is proposed to identify and classify failures in an unambiguous manner. Contribution of this research is two-fold: From the academic point of view, it encourages precise reasoning about the emerging failure classes in the general context of reliability problems, as well as forming grounds for consistent use of terminology within the community. From the industrial point of view, it potentially provides more accurate and easier detection of failures, hence facilitating more effective and efficient ways to handle them.

I. Introduction

Traditional reliability approaches consider product reliability as a predominantly technical issue, which often is raised when product specifications are violated [1]. With the emergence of new market trends (namely, increasing complexity of technology upon the pacing up of the innovation rate of products, strong pressure on time to market due to large competition among manufacturers, increasing outsourcing activities and globalization, and increasing customer demands) however, other classes of failures have materialized in addition to such technical failures [2]. Some of these failures cannot be traced back to their root causes and/or cannot be reproduced. They are often named as No Fault Found or Fault Not Found failures. Furthermore, the terms hard failures and soft failures are used to differentiate between technical failures and non-technical failures [2][3].

Whereas literature reveals that many attempts have been made to capture these new failures with an often intuitive nomenclature, the vagueness in their descriptions has lead to inconsistencies and even confusions with respect to their usage among the studies conducted recently. It is evident that pinning down all failure classes via well-founded definitions is necessary for further and precise reasoning about the new classes of failures. Only then, the failures can effectively and efficiently be addressed.

The paper is organized as follows: Section 2 presents the background in which the existing terminology for various reliability problems, together with their commonly used definitions, is presented. Here the available models (both from the service and research perspectives) aimed to capture all failures are discussed, pointing out their deficiencies in application. Then Section 3 proposes a list of criteria that should be taken into account in an improved framework to effectively capture all reliability problems encountered in the field. Finally Section 4 concludes the paper by listing our findings, and indicates directions for future research.

II. Background

Literature on the quality and reliability of particularly innovative electronic products has recently recognized the existence of new classes of failures. This owes to the rapid increase in and diversification of consumer[1] complaints as well as inexplicable product returns (i.e. causes of returns cannot be traced back in the product), observed by large consumer electronics companies since the 90s (See Fig. 1). Initially these unknown/unclassifiable field calls have been gathered under the name "No Fault Found", or NFF, by service centers of the manufacturing companies. Such failures fall outside the scope of the current prevention and recovery techniques. This fact lead to the recognition of a new class of reliability problems: soft failures.

Recent definitions for classes of reliability problems make a distinction between failures of a *hard* versus a *soft* nature [2]: *Hard failures* are the ones where the product is not able to meet the explicit technical product specifications and hence the consumer requirements. Typical examples would be physical failures of hardware components, software failures due to the activation of latent design faults, etc. *Soft failures*, on the other hand, are those where the consumer complains on the (lack of) functionality of the product, despite the product meeting with its specifications. These are often due to mismatches between the actual product operability/functionality and consumer expectations.

[1] This paper uses *consumer* and *customer* interchangeably.

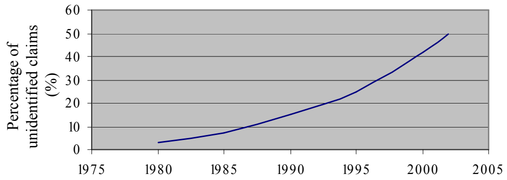

Fig. 1. Percentage of claims in modern high-volume consumer electronics where cause of claim is not known [2]

An important distinction, however subtle may it be, that should not be overlooked is that between the usage of the label NFF (in the industry, so far) and soft failures. Since none of these failures can be recovered by service centers, there is a tendency to view them as being equivalent. This misconception often yields to these two names being used interchangeably. The reason underlying this fallacy is not merely due to the somewhat vague definitions of the concepts involved, but also to the fact that these problems were initially confronted by the industry where categorization of failures is done only from a service point of view, as depicted in Fig. 2. The "No Fault Found" here is often mistaken for soft failures and "Fault Found" for hard failures. Although "Fault Found" in the figure appears to correlate much with the existing definition of *hard failures*, "No Fault Found" here is definitely not the same as *soft failures*: It just denotes any kind of field calls whose root cause cannot be traced and/or any failure of a product which cannot be repaired. Therefore field calls tagged as NFF by service centers may be due to either hard or soft failures. The usage of the label NFF introduced by service centers hence is not very accountable for what it would mean currently from the deeper analytical point of view that should be adopted for developing insights about failures.

Despite its full coverage of field calls from the service perspective, the categorization proposed in Fig. 2. has an immediate drawback with respect to its practicability. This is brought about by the inclusion of "Error in service diagnosis[2]" under NFF. The dashed arrow suggests that some reported failures which may have been categorized as NFF may in reality be due to (possibly identifiable) hardware or software faults. This in turn suggests that these failures may in fact be hard failures. Therefore the two major categories of the figure are coupled, implying that they are not entirely differentiable. This coupling yields to a highly undesirable fuzziness when it comes to applying it in the field.

Service perspective is often not the most relevant one for researchers from academia in the field of quality and reliability engineering. In order to attain the essence of the problem (e.g. finding out about factors involved in causing these failures), they tend to adopt a more generic and

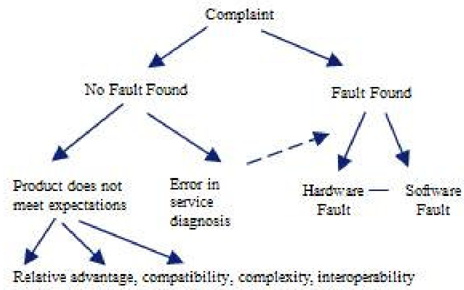

Fig. 2. Field Call Rate (FCR) categories from the service perspective [4]

modular approach. This approach takes the inherent nature of the failure as the most dominant distinction, which yields the failure categorization illustrated in Fig. 3. The reader is referred to [3] for a detailed discussion of this categorization. In terms of its applicability to real data, this categorization is also not the most feasible one. Real data usually misses out the level of detail necessary for differentiating between the types of soft reliability problems listed in Fig. 3. Furthermore, and more importantly, this categorization is not adequate for recognizing and classifying failures whose symptoms cannot readily be diagnosed and/or whose root causes cannot be readily identified: That is, failures which might eventually turn out to be hard or soft. This is what researchers provisionally name as the 'gray area,' which is missing from Fig. 3. as a third type of failure category. Although the inclusion of a 'gray area' in Fig. 3. would eliminate the model's inadequacy to cover all failures encountered in reality, it would nonetheless introduce a kind of coupling problem similar to that discussed with respect to the model in Fig. 2.

Prior to the relatively detailed kind of categorization shown in Fig. 3., a deeper understanding of hard and soft reliability problems, which incorporates the service point of view as well, should first be established. This is expected to be an essential springboard in making optimum use of real data, which will facilitate in building further on the theoretical grounds. Accordingly, our framework is intended to support the initial classification of real data with the underlying motivation to avoid any (potential) coupling among sub-/categories, hence imposing preciseness and modularity as opposed to fuzziness, as well as, making any further analysis of failure types -such as that for soft failures shown in Fig. 3.- more viable.

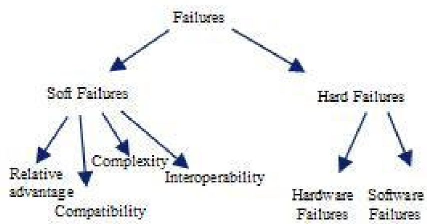

Fig. 3. Failure categories from the academic perspective [3]

[2] Ironically this label, in itself, acknowledges that this categorization is indeed prone to making erroneous diagnoses.

"No Fault Found" versus "Fault Not Found"

Since there has been no established uniformity as yet in using some terms to refer to types of failures in the outlined context, various expressions have so far been used somewhat imprudently. Here, we want to make a preliminary distinction between the two terms *no fault found* and *fault not found*, as they would be used within the practical context. The former implies the case where no fault yielding the (reported) failure or field call can be spotted since the product has never 'actually' ceased to function in accordance with its specifications, whereas the latter imposes the fact that there exists a fault which leads to a (technical) failure of the product under certain or all circumstances, however it cannot be readily identified due to its intricacy or other external factors. Consequently, *no fault found* has an apparent correlation with the existing definition of soft failures, while *fault not found* with that of hard failures.

III. DIMENSIONS OF FAILURES

The most encountered expressions in the so far used definitions of hard and soft failures are 'customer requirements', 'product specifications', and 'non-/technical nature' of the failure. In theory, these aspects are usually observed to be sufficient in distinguishing between failures of a hard- versus soft- nature. However they alone prove insufficient to distinctively categorize failures encountered by the industry: As pointed out in Section 2, available models of classification deploy fuzziness which makes their application infeasible in the industrial context, since they do not allow for systematic and modular classification. This suggests that the definitions need still to be expanded on, possibly by accounting for also other relevant aspects within quality and reliability. Full-fledged definitions of hard and soft failures will allow for further detailed analyses which will reveal other varieties of failures contained therein.

In an industrial context, failures usually concern Helpdesks and Service Centers at the low level (i.e. in trying to resolve them), and the quality department of the company at the high level (i.e. in trying to prevent them in the future). It appears that the three aspects currently involved in the definitions of hard and soft failures are decisive for the Helpdesk employee to evaluate whether a call s/he receives is due to a hard or soft problem, and hence whether s/he should forward the problem to the Service Center for repair of product. There are however other aspects, especially relevant for the Service Center and the quality department, presently being overlooked by the definitions: One main criterion from the Service Center point of view would be the recoverability from the failure of the product. The quality department, on the other hand, would be concerned with identifying root causes of failures and figuring out how it would be viable to prevent their occurrence in future generations of products. It is crucial that not part of but all of these aspects, or "dimensions" of failures in the broader sense, are accounted for in defining failures[3] so as to have an exhaustive means of doing systematic classification. These "dimensions" can be listed as follows:

1. Compliance with (explicit) customer requirements and (latent) expectations
2. Compliance with product specifications
3. (non-/technical) Nature of failure
4. Recovery
    a. By manufacturing company at Service Center, if failure is of a technical nature
    b. By consumer with help obtained from Helpdesk, if failure is of a non-technical nature
5. Root cause detection
6. Prevention

At this point, it is worthwhile to elaborate some on the correlation among the first three dimensions within the product development process [5] depicted in Fig. 4, which is simplified for our purposes. It is possible to view this process from when the customer requirements are gathered, until the product is made ready, as consisting of three main variables -namely Customer, Specifications, Product- and two main functions -namely Requirements Analysis[4], and Product Realization-. The two functions assume significant roles of first translating the customer requirements and wishes into product specifications, and then product specifications into a real product that will finally meet the expectations of the customer, hence closing the loop. Any deficiencies within the execution of these functions will result in cases where this loop remains ajar and so products exhibiting failures in the field. In relation to this, the first dashed box in Fig. 4. enclosing the customer and the requirements analysis phase, designates the area where soft failures will potentially be rooted, whereas the second dashed box designates that of hard failures. This is in line with the definitions of hard and soft failures. The incentive for including the 'customer' in the first dashed box is to point out its easily underestimated influence in the requirements analysis phase: It is not only the requirements of the customer that will eventually satisfy her, but also her

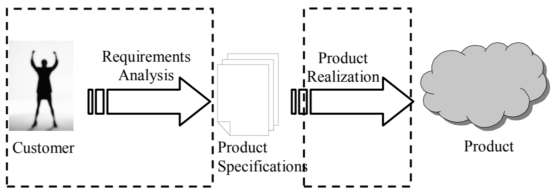

Fig. 4. (Simplified) product development process in relation to failures

[3] Every case where consumer has a problem with product is considered a *failure*, even if product is not returned.

[4] Requirements Analysis here is used in a broad sense involving the design steps/iterations that need to be walked through before specifications are finalized.

often latent wishes/expectations. Therefore the customer variable[5] should be well absorbed initially for maximizing the success of the Requirements Analysis function. Product Specifications does not have such influence on Product Realization since its contents tend to be rather explicit.

Theoretically, product specifications are compiled in a way that allows for as much coverage as possible of customer requirements and wishes. However reality challenges the ideal, posing an inherent problem from the reliability point of view: Backed by the market trends within strongly innovative product development as mentioned in Section 1, customer requirements/wishes/expectations dynamically change and increase, even after the specifications are finalized for a prospective product. This constantly fuels the conflicts encountered later on in the lifetime of the product, under the name of soft failures.

In summary, so as to cover all reliability problems identified in the field in an unambiguous manner, it is necessary to understand how failures relate to are captured in product development. The failure dimensions discussed in this section need to be taken into account in an improved failure classification framework.

V. CONCLUSION

In this paper, we first discussed the changing trends in the development of strongly innovative products, which lead to the emergence of new classes of reliability problems. We then analyzed the existing models for failure categorization of strongly innovative products, and delineated their limitations. Based on this analysis we identified a list of criteria (the so-called failure dimensions) that should be taken into account in an improved framework, specifically to overcome the fuzziness of the existing models that renders their application infeasible in the industrial context.

Our future work will focus on extensive evaluation of these criteria with regard to the four failure types: hard, soft, no fault found, fault not found. This evaluation should ultimately reveal a new improved model for failure categorization to enable systematic and exhaustive classification of the four failure types, as they are encountered in the field. The model will then need to be internally validated, by making use of ideas from set theory, and externally validated by experimental evaluation with real data. It is expected that once the internal validation is done, it will be possible to come up with formalized definitions of the four failure types mentioned earlier. Another future direction of this research would be to explore the field call management processes performed at Helpdesks and Service Centers. This might potentially alleviate the adoption of our classification model by the industry.

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[5] Customer is indeed a *variable* factor in the whole process: For each type of product manufactured by a company, there are many customers each having various expectations and usage profiles. This is already a challenge for companies in terms of achieving sizeable customer satisfaction.