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Managing product reliability in business processes 'under pressure'

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Abstract

Product reliability is often seen as a product attribute. Models with different degree of sophistication analyze and predict the reliability of a product as a function of the internal structure (such as components and their relation). The practical relevance of these models, in relation with the (business) processes in which the related products are actually used, is not often addressed. Different types of reliability issues, however, can be relevant for products in different industrial contexts. This paper will present a classification model to describe different business processes, based on the degree of product innovation. It will also propose a taxonomy that can be used to classify different types of reliability problems. As this paper will demonstrate, only certain combinations of reliability problems are relevant for certain business processes. It will also show that, given certain technology trends, some combinations will become more relevant in the future. The final part of this paper will demonstrate that especially for these combinations many of the existing reliability analysis and prediction methods can be considered inadequate.

Keywords: Product reliability management; Business processes; Reliability prediction and analysis

1. Introduction

In modern product development many companies struggle to maintain a balance between on the one hand performance and (technical) innovation (realizing a product that *does* what it *should do*) and on the other hand product quality and reliability (realizing a product that *does not* do what the product *should not do*). The use of new technology may be beneficial with respect to achieving certain advantages in terms of functionality and cost but (often unproven) new technology in combination with customers not familiar to this new technology may lead to all sorts of unanticipated quality and reliability problems. When, for a given business process, the learning time required to understand and manage these problems is longer than the pace in which innovation takes place, this can easily lead to business processes that are difficult to control. In literature this relation between product performance (in terms of quality and reliability) and execution of the primary business processes is often neglected. This leads at this moment, as this paper will demonstrate, in many companies to relatively large numbers of unpredicted and unmanaged problems. Also for problems where the cause is known, the time it requires to discover the (root-)cause is becoming for many companies unacceptably long. This paper will describe a number of trends currently dominating industrial business processes and the impact of these trends on product quality and reliability. It will address also some first ideas on how product quality and reliability could be managed in future business processes.

2. Different business processes and the impact on product development

In reliability literature the most common criteria to replace or repair a product is a technical product failure. In addition to these technical criteria, companies can have also other reasons to replace a product. One reason can be that a new, alternative, product becomes available that has

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certain advantages in terms of functionality or efficiency. In some of those cases it becomes economically justified to replace a still fully functional product by a new, 'better', product. In cases where the economic lifetime[1] is much shorter than the technical lifetime[2], companies will easily replace fully functional products; if the reverse is the case companies will seek ways to extend the technical life of a product by introducing different forms of maintenance and/or repair strategies. This process of optimizing the operational lifecycle costs of a product is a process of continuously evaluating the added value created by a product versus evaluating the possibilities to replace (or upgrade) a product. If the performance benefits[3] created by a introducing a new product outweigh the sum of the required investments (in this new product) and the existing performance benefits (created by the old product) it will be, in general terms, useful to replace a product. In order to make such a decision it will be necessary to have knowledge of two aspects: the operational lifecycle costs of both existing and future products and the rate in which products with a certain level of innovation are introduced into the market.

If the performance benefits of a product are constant in time the only criteria to replace a product will be innovation; the difference in performance benefits over time compared to the investments for the new product will determine the required pay-back time and therewith the decision for replacement.

For products that are subject to physical degradation the performance benefits will, however, not be constant. Either the performance may degrade or, due to effects such as wear-out, the likelihood of failure (and therefore the costs of maintenance and repair) may increase. Lifecycle strategies will therefore require both knowledge of the rate of innovation for certain products as well as the rate of degradation (and the impact on the performance benefits) for these products.

Which reliability problems are relevant for a product is strongly dependent on this lifecycle strategy; depending on developments in technology, the market, and the type of product that is being developed, companies will have different focus with respect to product reliability. In order to determine what reliability problems are relevant for what type of lifecycle strategy, this paper will use the innovation rate or the, closely related, ratio between technical and economical lifetime as factor to distinguish between different types of business processes. Although, the actual number of lifecycle strategies will be much larger (and the underlying decision processes far more complex) this paper will describe a number of 'generalized' business processes and will propose a set of relating lifecycle strategies with respect to product reliability. This paper will use the following business processes:

A. Business processes depending on products where the economical lifetime is much shorter than the technical lifetime. Especially thanks to recent developments in semiconductor industry and, related, developments in information technology it is for (fully functional) products in this category not uncommon to be discarded and to replaced by a product with more/better functionality. In this case the economical life (often 0–3 years) of a product is shorter than the technical life. Examples of products in this category are personal computers and other products with a strong IT content (e.g. mobile phones). Manufacturers of disposable products typically belong in this category, but also manufacturers of short cycle consumer products. Companies in this category will try to employ the latest technology in the shortest possible time in order to achieve (or maintain) a competitive advantage.
B. Business processes depending on products where the economical lifetime is comparable to the technical lifetime. This second category consists of the business processes that generate products with an extended (3–10 years) but still moderate lifecycle. Products like cars or more traditional consumer products have a modest degree of innovation (and the inherently related time pressure in their development process is also modest). Since in these business processes the emphasis is not, as in the previous process, on innovation but mainly on product costs this category will use different business processes and therefore different methods and tools to assure product performance, quality and reliability.
C. Business processes depending on products where the economical lifetime is much longer than the technical lifetime. The third category concerns business processes that are depending on systems with a long lifecycle (10 years and beyond). For example capital intense systems, like oil refineries, are such products or systems. The companies build, use, and maintain these systems to generate other types of products: mostly raw materials like chemicals or food. Here the degree of innovation is low due to considerations with respect to safety and the impact of failures when things go wrong. If a new technology becomes available it is rigorously tested before it is applied. In contrast with the earlier processes the emphasis will be on avoidance of (functional) risks, on system availability (uptime) and on the safety of the systems used.

Not all types of reliability problems will be relevant for all types of business processes. Research in the wear-out behavior of strongly innovative products such as hard disks, used in game controllers, may be interesting from an

[1] Economic lifetime is defined in this document as the average time where it is justified to replace a product for economic reasons.

[2] Technical lifetime is defined in this document as the average time that a product requires to reach end-of-life due to technical failures.

[3] Performance benefits are defined in this document as the added value created by a product minus the total costs of operating a product.

academic point of view, but once a manufacturer is able to ensure that the product lasts longer than the economical lifetime (the time where it is economically attractive to replace the product with a new product due to, for example, improved functionality) 'good is good enough'. Before it is possible to determine what kind of reliability problems are relevant for what kind of products (from a business context) it will be necessary to describe what types of reliability problems can exist.

3. Product reliability in relation with business processes

Since the different business processes will depend on different types of products each with different product reliability characteristics, it will be necessary to describe what kind of reliability issues are relevant in the context of which lifecycle strategy. Therefore this paragraph will introduce a model based on a set of common used reliability definitions and, from that, a taxonomy to describe different types of reliability problems.

3.1. Time dependent failures/time independent failures

From a customer perspective the main reason to report a (reliability related-) complaint is that, at a certain moment in time, there is a mismatch between customer requirements and the product performance. Although from a customer perspective all instances of such a mismatch will be grouped under the denominator 'reliability problem', there can be a large number of, fundamentally different, processes leading to such an event. The first process relevant to product reliability is the role that specifications play in the lifecycle of products. Companies rely on specifications[4] when they develop a product and these specifications are supposed to reflect (intended) product functionality in interaction with the user of the product. A common approach is to assume a product fails at the moment it does not meet its specifications. For such a failure there can be many reasons. One of the most common class of failures are the so-called physical failures. Many traditional reliability models assume that a product consists of components and that a failure happens when a (physical) gradual or instantaneous change occurs in a component. Such an event is called a (component) failure. If such a component fails and this failure is not covered by some form of redundancy, the entire product will fail [1,2]. Depending on the nature of the failure mechanism these failures can have a time-independent random character, or they can be, if mechanisms involve some form of wear, time or use dependent [2].

[4] The term 'specifications' is used in this paper to describe the set of documents that companies use to describe the intended functionality of a product.

A cause for products unable to meet with customer requirements only after a certain amount of time, could be the due to gradual change of behavior in time due to a gradual change in physical properties (drift or degradation). All these events can occur either systematically at all products due to inherent (structural or physical) product properties, can happen only at some products depending on individual products or users, and can be structurally present in a product or can manifest itself in a product only after a certain amount of time or product use. In other words: the fact that, at a given moment in time, a product is not able to meet with its users requirements can be due to a large number of different causes.

3.2. Hard/soft reliability problems

Next to these physical failures, a second group of failures consists of the so-called functional failures; there can be situations where there are no physical failures in a product but in spite of the absence of physical failures the product does not meet customer requirements. For problems in this class there can be, conceptually, two reasons. Either the product is, for other reasons other than physical failures, not able to meet specifications or there is a mismatch between specifications and customer requirements. This paper will distinguish between:

- Specification violations/hard reliability problems: Situations where the product is not able to meet both the explicit (technical) product specifications and customer requirements.
- Customer expectation deficiencies/soft reliability problems: Situations where in spite of meeting with the explicit product specifications, a customer explicitly complains on the (lack of) functionality of the product.

A special category in this context, is the situation where the product is only partially specified. With simple mono-functional products it can be assumed that a product can be (almost) fully specified. Both the functionality (does the product do what it should do) and the freedom from adverse effects (does the product not do what it should not do) can be written down in a set of explicit specifications.

Especially in the case where software is involved, due to the large state-space of software products, it can be very difficult to write a specification with a high coverage. Failures can be structurally present in the product but occurring only intermittently (due to the occurrence of so-called 'triggering events'). In other situations the product just may not be able to meet with the requirements of (some) customers. In order to keep a clear distinction between the different failures this paper will assume all failures (also software failures) that clearly violate specifications as hard reliability problems and all causes (hardware, software, user interface, etc.) for customer complaints that cannot be

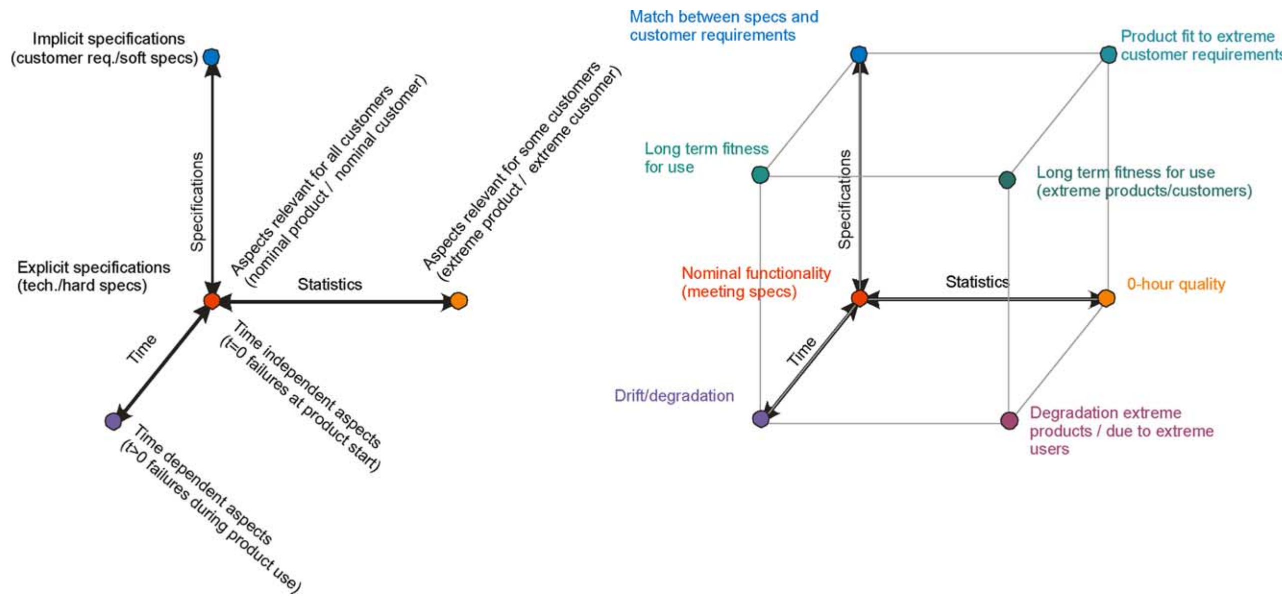

Fig. 1. Different types of reliability problems.

traced back to a violation of product specification as soft reliability problems.

3.3. The influence of product/customer statistics

One of the advantages of the old, component based, reliability approach was that product failure was due only to the (catastrophic) failure of components. Issues like hard/soft reliability and/or the influence of gradual failure mechanisms were not taken into account. The effect of taking a broader view, such as presented in the previous paragraphs, is that differences in products and differences in users must be taken into account. If, with respect to time related effects, user profiles influence the degradation rate some products will have different failure characteristics than others. Also product internal aspects, such as product tolerances, can play a role.

Especially with respect to soft reliability problems: since there are no clear-cut specifications that are violated the situation that causes a customer complaint may be different from product to product and from customer to customer.

3.4. A structure for mapping reliability problems

Based upon the aspects addressed above, it is possible to define different ‘dimensions’ or aspects of reliability problems in modern products. This paper will use three different ‘dimensions’ to explain a wide range of reliability problems (see Fig. 1 for a graphical representation):

- different failure classes (physical or functional failures)
- the relevance of statistics (failures happening only in certain (sub-)groups of products or in all products)
- the influence of time (random failures or failures due to cumulating of time or customer use of a product)

Fig. 1 gives a graphical representation of these three dimensions.

Using these three ‘dimensions’ it is possible to describe a number of issues that customers may experience as reliability problem, as a combination of one or more of these aspects (see Table 1).

This set of failures is much larger than the ‘random component failure’ related reliability models described in many reliability textbooks [3–6]. From a customer perspective however, it indicates in all cases a product not fulfilling the customers specifications at the required moment in time. This extended definition of reliability does not imply that all these failures are always relevant for all business processes. For single products (or products made in small series) product statistics will not be very relevant. For products made in large series the impact of statistics will be of crucial importance. For products with a high degree of innovation (A-type business processes) the focus will be especially to bring a product in time to the market within customer specifications; for products which require large capital investments (and therefore have often a lower rate of change) the main focus will be on the ability of this product to fulfill its requirements over a much longer period of time. Translating the failure causes back to products, and the underlying business processes, requires a systematic approach; different failure mechanisms may require different approaches in the product development process. To determine what reliability problems are relevant for what type of business process, a taxonomy will be introduced

Table 1
Different types of reliability problems

Description	Time dependency	Statistics	Failure class	Customer perspective
Nominal functionability	No	No	Soft	(Certain functions in) the product does not work
(Nominal) functional drift	Yes	No	Soft	After a while the product is no longer able to function
Functional yield	No	Yes	Soft	Some of the products do not work
Long term functional yield	Yes	Yes	Soft	After a while some products are no longer able to function
Nominal rated (over-)stress	No	No	Hard	The product is defective on arrival (DOA)
Nominal hardical degradation	Yes	No	Hard	After a while the product the product fails
0-h failure hard failure probability	No	Yes	Hard	Some of the products are defective on arrival
Long term hard failure probability	Yes	Yes	Hard	After a while some of the products fail

clustering the different, broadly defined, reliability problems into certain classes.

3.5. A taxonomy for performance, quality and reliability problems

In order to allow a better translation of product reliability (in the broad definition given above) to the underlying business processes, a taxonomy or classification system will be introduced. The taxonomy uses four different classes to classify problems with products.

1. *Hidden 0-h failures*: Products that arrive out-of-(customer[5])specification at the customer. Although, theoretically, these (often performance or quality related) failures should all be observed at the moment of commissioning of the product, complex functionality (software) or delay in customer reporting can cause delay in observing and reporting a failure. Possible explanations are that these products have either slipped through final tests, have been damaged during transport, or are used by (certain groups of-) customers in an unanticipated manner.
2. *Early wear-out*: In some cases situations are observed where a distinct sub-population of products, due to some discrete event during manufacturing or due to a discrete difference between users in product use, shows different quality and reliability behavior compared to the main population with respect to wear-out. Examples are products that are produced with internal flaws. In contrast with products of class 1 these products are able to function for a while but due to the extremes in the product (flaws) or the customers they show a different, faster, wear-out than the main population. These sub-populations are quite difficult to test during production because on the product level they initially perform according to specifications.
3. *Random failures*: Products are designed to be used against anticipated ('normal') user conditions. It is, however, difficult to anticipate and to design against all events to which a product can be subjected. External events with a strong 'random' character, such as lightning and mechanical shocks, can cause product failure at any moment in time.
4. *Systematic wear-out*: Many products, particularly mechanical products but also certain categories of electronic products, show some form of degradation over time. Well-known time effects are corrosion of metals and increased brittleness of plastics.

Although it is always a sound balance between the three business drivers, i.e. quality, time and costs, that is sought in a business process, differences in focus can be identified in the three classes of business processes. The class A business process, generating short lifecycle products, distinguishes itself by its focus on 'time'. Since new technology keeps becoming available at a continuing high speed companies will want to take maximum benefit from this technology. Therefore in order to maximally benefit from new technology companies will drive for the shortest possible 'time to market'. Business processes of type C, concerned with systems where high capital investments are required, will have a focus on maximizing the utilization of the investments made. The product has therefore to fulfill its function with a high efficiency during a long period of time. Safety, availability and reliability are important issues, requiring business processes that are quality-driven. Although a business process of class B can be seen as an 'in-between' type of process there are some remarkable differences. Often the main driver in B-type business processes will be on costs. People buying typical products generated by these business processes will not buy them for their innovative character or because of very high availability. Since business processes in this group do not share the innovative advantage of class A and do not have the requirements on capital investments of class C the competitive advantage will often be the price of the end-product.

[5] It can be argued that, in case of a design flaw, phase 1 failures are not to be considered as reliability problems since they are not technically defective products. This can be the case if a mismatch exists between the technical product specification and the (often implied) customer specification. From a customer's perspective, however, the product is not able to meet the customer requirements and are therefore included in this class.

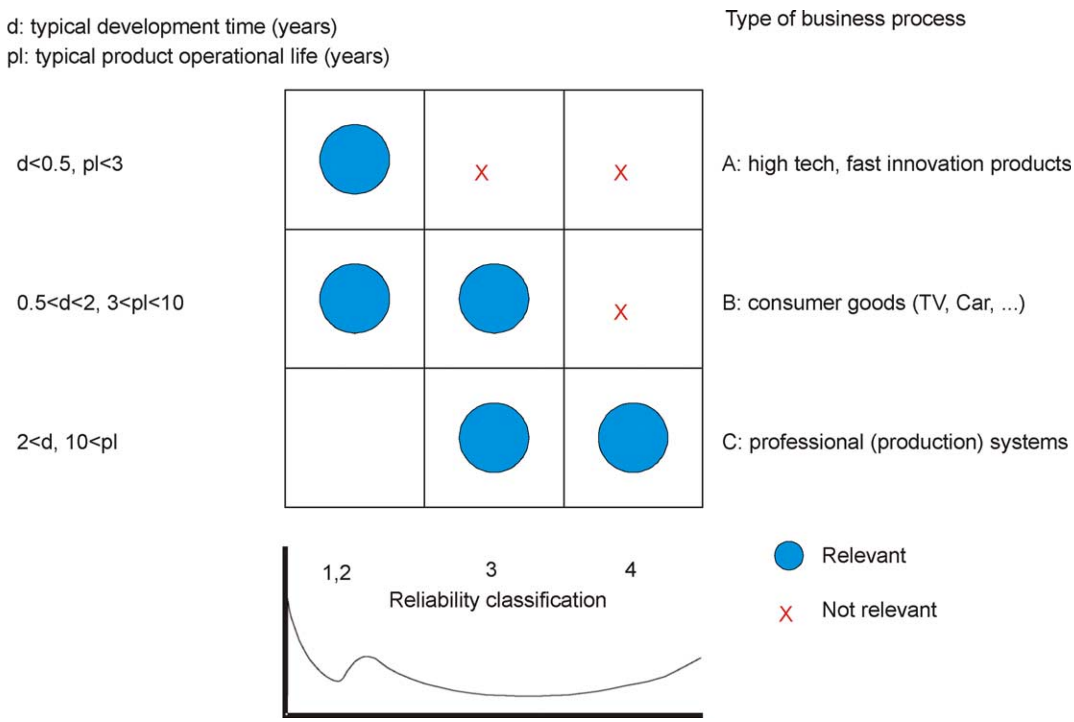

Fig. 2. The relevance of different classes of problems for different business processes.

3.6. The relevance of different failures for different business processes

All business processes try to meet their typical requirements as good as possible. An A-type business process tries to deliver their consecutive generations of products at the predefined moments of time, while a C-type of business process tries to meet its quality requirements agreed upon. Performance regarding the differently focused requirements, i.e. 'time' versus 'quality', requires different approaches and different operational structures.

The different operational structures of business processes will perform differently in terms of 'quality' and 'time', due to their performance capabilities. Combining the failure taxonomy presented earlier with the different types of business processes leads to a number of combinations that are interesting for further research (see Fig. 2).

A. *Business processes depending on products where the economical lifetime is considerably smaller than the technical lifetime*. Due to the short economical lifetime detailed considerations on phase 4 class of failures are not very relevant; at the moment it can be safely assumed that the onset of phase 4 is beyond the economical lifetime of the product. In some cases the economical benefit of applying new functionality can be such that a certain amount of phase 1 and/or phase 2 class reliability problems are accepted. The number of these failures should, however, not be such that the economical benefit of applying this new technology is endangered. Due to the constant evolution of new technology the related business processes show a very strong pressure on time to market and limited provisions to ensure flawless designs and will only to a certain extend use proven, mature, technology. Therefore the most relevant class of reliability problems for this type of business processes is phase 1 and 2. That failures in these categories exist is, generally speaking, not a problem but the number of failures should be limited in order to keep economic benefits.
B. *Business processes depending on products where the economical lifetime is comparable to the technical lifetime*. Because of the limited degree of innovation and modest time-pressure and the often large impact of especially class 1 failures, not too many risks are taken with the application of new technology[6]. Maintenance strategies to handle class 3 and 4 problems are, to a limited extent, accepted but, if possible, avoided by taking adequate measures in the design. Replacement strategies in this category resemble class A business processes but, due to the lower degree of innovation and the larger economical consequences of replacement, with a lower frequency.
C. *Business processes depending on products where the economical lifetime is much larger than the technical lifetime*. Many systems in this class of products (process industry, large infrastructure such as railroads) require very high investments. Therefore replacement of a total

[6] In car-industry, for example, a 'drive by wire' system is technically feasible and, economically speaking, very attractive but it is likely the application will wait until the technology has a proven maturity.

system due to some innovation is done only when this is economically justified. Class 1 an 2 failures are not common in these systems since due to the, on one side, limited time pressure and, on the other side, large consequences of failures, detailed test and verification programs are usually put in place. Class 3 and especially class 4 type of reliability problems can be expected here, due to the long lifecycle. Some parts of a system are susceptible to degradation and/or random failures and these failures are often accepted. Management of reliability for these products is therefore often concentrating on the selection of adequate redundancy or the application of adequate maintenance strategies to minimize the risk of an accident, within economic boundary conditions.

The fact that different business processes have different problems may not be entirely new. Product development processes, however, are by no means static; due to the influx of new technology it is possible that business models that where considered unacceptable for certain products in the past become, for competitive reasons, a necessity in the future.

3.7. The impact of trends on the development of future products

In the period 1999–2001 the Netherlands Study Centre for Technology Trends (an organization related to the Royal Dutch Society of Engineers) performed a study on how the trends mentioned affected the reliability of several larger industrial systems and products in- and around- the Netherlands [7]. When looking to the case studies presented in part two of this book, it is clear that quite a number of recent industrial reliability problems where directly due to one or more trends influencing the underlying business processes. The study identifies four different, but related, trends influencing product reliability:

- Increasing product complexity
- Increasing complexity of the underlying business processes
- A strong pressure on ‘time to market’
- Increasing customer demands on product quality and reliability.

The mechanisms through which these trends influence product reliability could be the following:

- The increasing complexity of products makes product (quality) validation and evaluation also increasingly complex and therefore also costly and time-consuming.
- The increasing complexity of (global) business processes, combined with problems with the supporting information flows, may mitigate knowledge accumulation with respect to quality and reliability.
- The strong pressure on ‘time to market’ requires, however, fast and efficient methods to ensure product reliability in the very early phases of product development.
- Since, especially with strongly innovative products used in complex field environments, there remains a strong likelihood that problems appear in the field (either due to flaws in the process and/or due to unexpected or even unintended use of the product) a strong feedback system is needed to learn fast and efficient especially from these unexpected failures.

Over the last decades business processes show a trend, for a given type of products, to shift from class C to class A (see Fig. 3). Due to the advantages of innovation

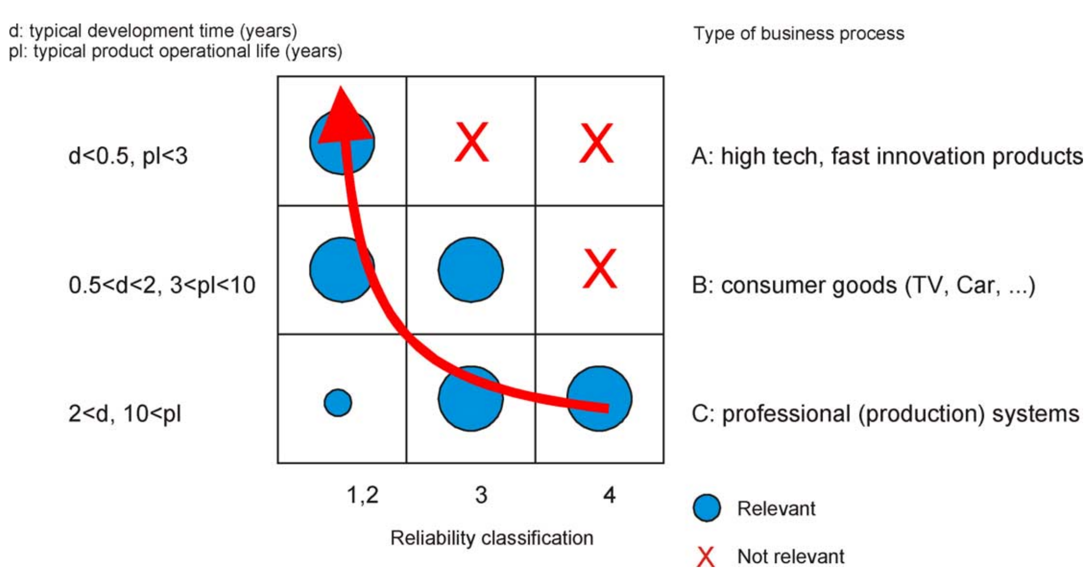

Fig. 3. Effect of business trends on product quality and reliability.

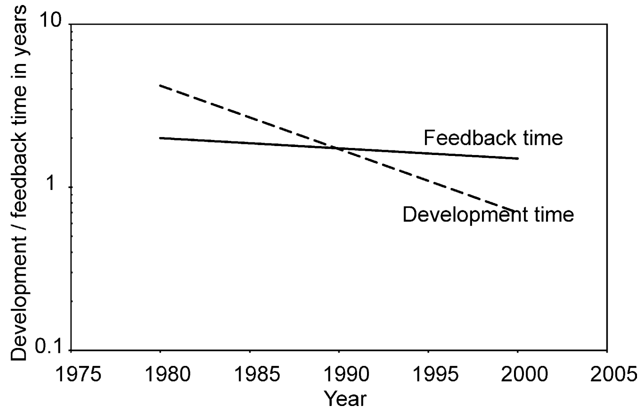

Fig. 4. Development time versus feedback time for high-volume consumer electronics [9].

(better functionality against lower costs) it becomes interesting for all types of business processes at least to consider the use of new, not yet fully proven and therefore often not quite mature technology. For example, in Military industry (originally a typical class C business processes) the functionality and costs of products generated with class A business processes are such that the use of commercially of the shelf (COTS) products is currently seriously being considered. As a consequence it can be expected that reliability problems will shift from B3/C4 type of problems to A1/B2 type of problems. It is the question whether the current industrial quality and reliability management methods are able handle this challenge.

To answer this question two parameters will be used: the speed[7] of the quality control loop and the granularity[8] of the quality control loop. Speed is used since for innovative products unexpected, new, reliability problems may appear. If the rate in which new technology is introduced is much faster than the time that is required to learn the actual field reliability performance of these products, companies will, sooner or later, have insufficient time to really understand the root causes of field problems. Due to the increasing product complexity it will be also necessary to have far more detailed field feedback; understanding failure mechanisms in complex products may require far better skills and analysis techniques than are currently available with the service people who act, for may companies, as the main source of product reliability data.

3.8. The increasing time gap (processing time and structure for data feedback)

One of the key-problems in fast, strongly innovative product development processes is the difference between the time that is required to develop a product and the time needed to learn about the actual product performance in the field. Applying new technology in new products and submitting them to, for this product, new customers will always involve a high degree of uncertainty; uncertainty about the performance of the new technology and uncertainty about the way customers will apply this new technology. Over the last decades the speed to bring new technology to the market has increased considerably. Unfortunately the time required to learn about the actual performance and perception of this new technology has not been reduced at equal pace (see Fig. 4).

Although currently many companies are able to develop products such as high-end consumer products and complex storage products (optical and magnetic) in timeframes of less than half a year the main paradigm used for feedback based on learning and managing quality and reliability is based on class 3 and class 4 failures. In order to manage random failures in components (class 3 failures) by metrics such as Mean Time To Failure, component failure or field call rate [8] are used. For class 4 failures metrics like average operating life (AOL) are very common. Not only it requires a comparatively long time to get this data, given a certain population of products and a corresponding market penetration rate, but these metrics are also fundamentally incompatible as a figure of merit for class 1 or 2 failures. Therefore substantial research will be required to develop metrics that are adequate for class 1 and 2 failures. A prerequisite for these metrics is also that the time to acquire these metrics should clearly fit within the timeframe of current and future product development processes. Research in this area will not only deal with the metrics themselves but also with methods to (fast and efficiently) generate reliability data (during the process and/or at the end of the process), gather reliability data, process reliability data

[7] In this document *speed* is defined as the time between the moment a product is released to the market and the moment adequate information is available to understand causes of reliability problems in this product to the level where they can be avoided in future products.

[8] In this document *granularity* of feedback is defined as the level of detail that is available on reliability problems. The level of details is defined as the amount of information required to determine the cause of a failures in terms of the earlier mentioned parameters failure type (what was the technical nature of the failure (physical, functional) and what was its cause), time (when did the failure happen) and statistics (at which customer(s) did the failure happen).

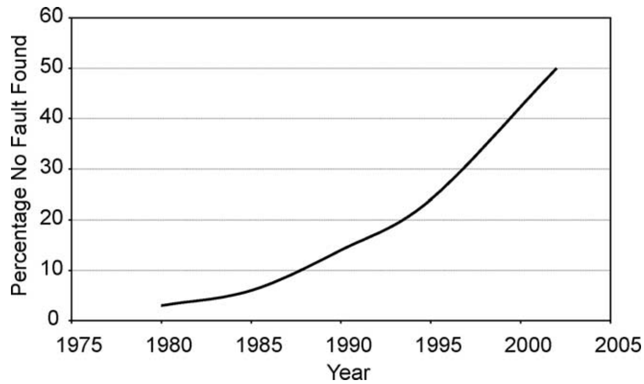

Fig. 5. Percentage no fault found in modern high-volume consumer electronics [9].

and deploy reliability data for use in current and future product development processes.

3.9. The increasing information gap (granularity of feedback)

One of the problems of strongly innovative products is that (explicit and implicit) specifications are often only partially known. This has serious impact on the performance, quality, and reliability studies that are usually performed in industry as part of the product development process. In those cases where the anticipated specifications, used during the product development process, do not meet with the real specifications during actual product use, this will result in unanticipated complaints with respect to either performance, quality, and/or reliability. Dealing with these issues in current or future products will not only require very fast (see also previous section) but also very flexible (because the nature of the mismatch may be unknown up to the moment where complaints are found) and very detailed (because a considerable information on the product, the user and the environment may be required) feedback systems. Perhaps due to the increasing information gap mentioned in the previous sections, current business processes are lagging behind in the amount of knowledge available on how new products are applied and what causes product complaints. Fig. 5 shows the development of the percentage of 'No Fault Found' (Failures where the cause of a complaint could not be determined) at a major manufacturer of high-tech, high volume consumer electronics over the last two decades[9].

It is evident that, especially for companies operating in the A1 area it becomes increasingly difficult to adequately manage product reliability. Apparently there is a considerable gap between current reliability analysis and prediction tools and methods and tools that are able to operate in an A1 context. Research to bridge this gap will therefore require methods to determine, already during the development process, a better understanding of the real specifications of a product from the perspective of the end-user of this product and to extract, very fast and efficient, information from very diverse sets of data in case still unexpected events happen in the field.

[9] Name and details of the manufacturer cannot be disclosed here due to reasons of confidentiality. Full details, however, are known to the authors.

4. Research challenges to manage reliability in future products

In order to bridge the gaps, mentioned in the previous paragraphs, for the selected industries a number of research lines can be developed. The first two lines are following directly from the gaps described above:

1. The development of fast feedback systems for use in the design process of strongly innovative products.
2. The development of dynamic high-resolution analysis systems for the root-cause identification of performance, quality and reliability problems.

A third method to bridge the gaps mentioned above could be in the selection of different design strategies where the emphasis is not on feeding back information faster and with a greater level of detail, but to obtain high quality information already earlier in the design process. Since it is not the intention of these alternative strategies to reduce the rate of innovation in product development, the alternative design strategies will have to rely on enabling earlier iterations in the process by confronting (potential or simulated) users earlier with (predicted or simulated) products. Therefore the third line of research becomes:

3. The development of design strategies that stimulate early product optimization by facilitating iterations with respect to performance, quality and reliability early in the design process.

5. Conclusions

Different business environments require different ways to manage product reliability. This paper introduces a way to classify both business processes and reliability problems and derives what are the most relevant reliability problems that are dominant in which case. The fact that different business processes generate, with a different business focus, different products with different requirements, means that it is not possible to identify one set of activities to solve all current performance, quality, and reliability issues. Issues that may be a major problem in one sector (operational availability of the product in type C business processes) can be only a nuisance in the other sector. Due a combination of trends, however, it can be expected that there will be an increase in type A business processes and, therefore, in type 1 and 2 reliability problems. Field data has shown that there are no methods and tools commonly available for this purpose; otherwise industry would not show the presented increasing gaps. Therefore a considerable research effort will be necessary in order to meet the required goals. This paper has outlined some elements of such a program.

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